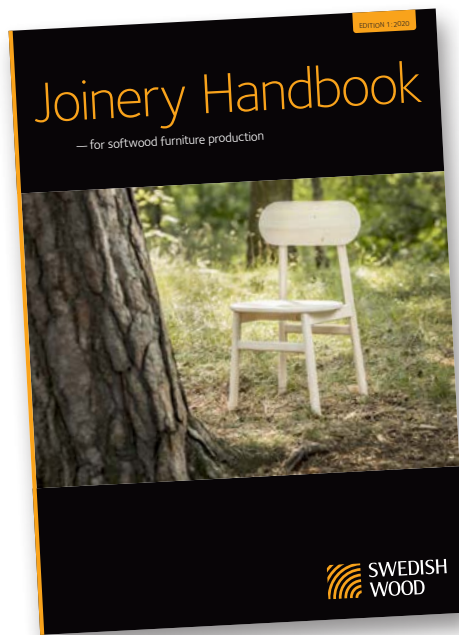


Joinery Handbook

— for softwood furniture production



SWEDISH
WOOD



The Joinery Handbook is the result of a collaboration between Swedish Wood, the Swedish Federation of Wood and Furniture Industry (TMF), universities and colleges.

The book is split into chapters that lead the reader through a process from initial concept to final product. Sustainability, particularly of the ecological kind, is a key factor to take into account in every stage of the process. However, the book also gives financial considerations plenty of attention, while also including a little about the historical and aesthetic dimensions. We have chosen to highlight these aspects as parts of a broader sustainability perspective. It is the artistically creative phase of the design process that establishes the form as something that not only stands up to practical use over time but also to repeated viewing. And it is in the history and the experience developed and tested over time that many of the solutions to our modern sustainability issues can be found. Embracing earlier advances and doing so with respect is not stealing as long as you are honest about your sources.

The content of this book is aimed at large companies, smaller joinery workshops and students who work in the design and production of furniture and fittings, predominantly in softwood. Each chapter opens with a general presentation of its content, along with a few perspectives on history and aesthetics.

Further information, inspiration and practical instructions regarding wood can be found on the Swedish Wood website, which is regularly updated with new knowledge and new projects, swedishwood.com.

Stockholm, January 2020

Björn Nordin
Swedish Wood

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Wood and the environment

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1.1 Environmentally efficient life and ecocycle of wood products

All construction and furniture materials except wood have a single ecocycle that involves reuse. For wood there are two ecocycles – a shorter one that reuses the component or material, and a longer one that is the natural ecocycle of which the wood is part, *see fig. 1.2, page 5*.

We see clear examples of the shorter ecocycle in both the furniture and joinery industries, where products such as windows, doors and joinery timber can be reused. In all cases, there is an organisation to deal with the products and find new users.

Once wood can no longer be reused or its material recovered, it can still generate energy through incineration. This energy is climate-neutral and is in fact stored solar energy.

To ensure optimum use of wood in climate terms, it should be carried out in a particular order that is illustrated by the environmental hierarchy for wood. When choosing between different usage options, step 2 in the environmental hierarchy should be applied where at all possible. Directly using felled forest for energy production is not optimal – although it is naturally still better for the environment than energy from finite fossil fuels. It is important to note that wood never needs to be sent to landfill.

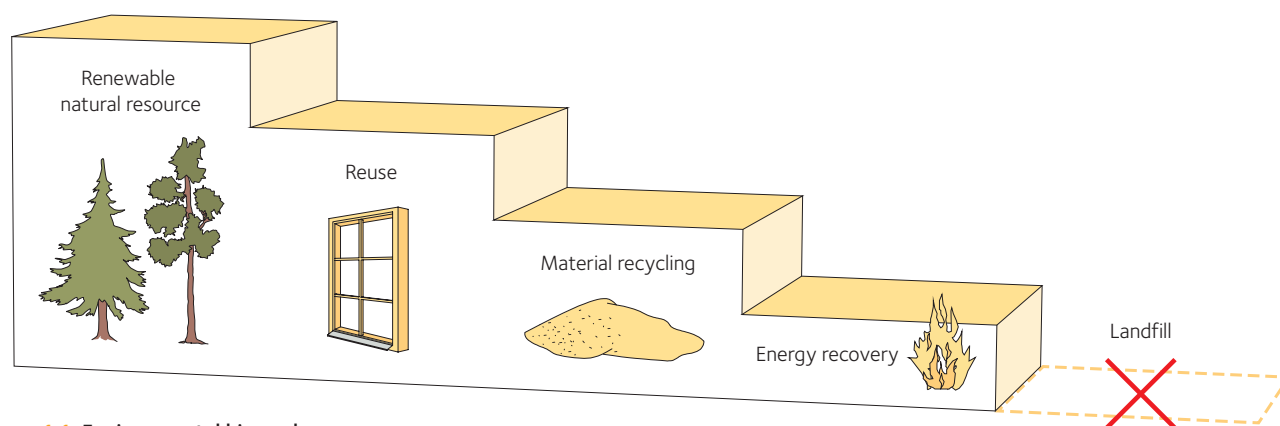


Figure 1.1 Environmental hierarchy

Wood material is never sent to landfill, instead providing energy at heating plants, for example.

1.2 Wood's natural ecocycle for interior products

The ecocycle comprises two parts. One relates to the forest and the other to the products. The forest gains its vitality from the sun. Through photosynthesis, solar energy is absorbed and reacts with carbon dioxide to produce nutrients for the growing trees. The forest's products contain carbon that has been absorbed by the trees in the form of carbon dioxide.

The ecocycle of the products includes restoration, repair and various forms of reuse. When these products reach the end of their life, the carbon dioxide is released into the atmosphere as the waste decays or is recycled as bioenergy. The carbon dioxide is then again captured by the trees and converted into nutrients and new building blocks for their growth.



Pine

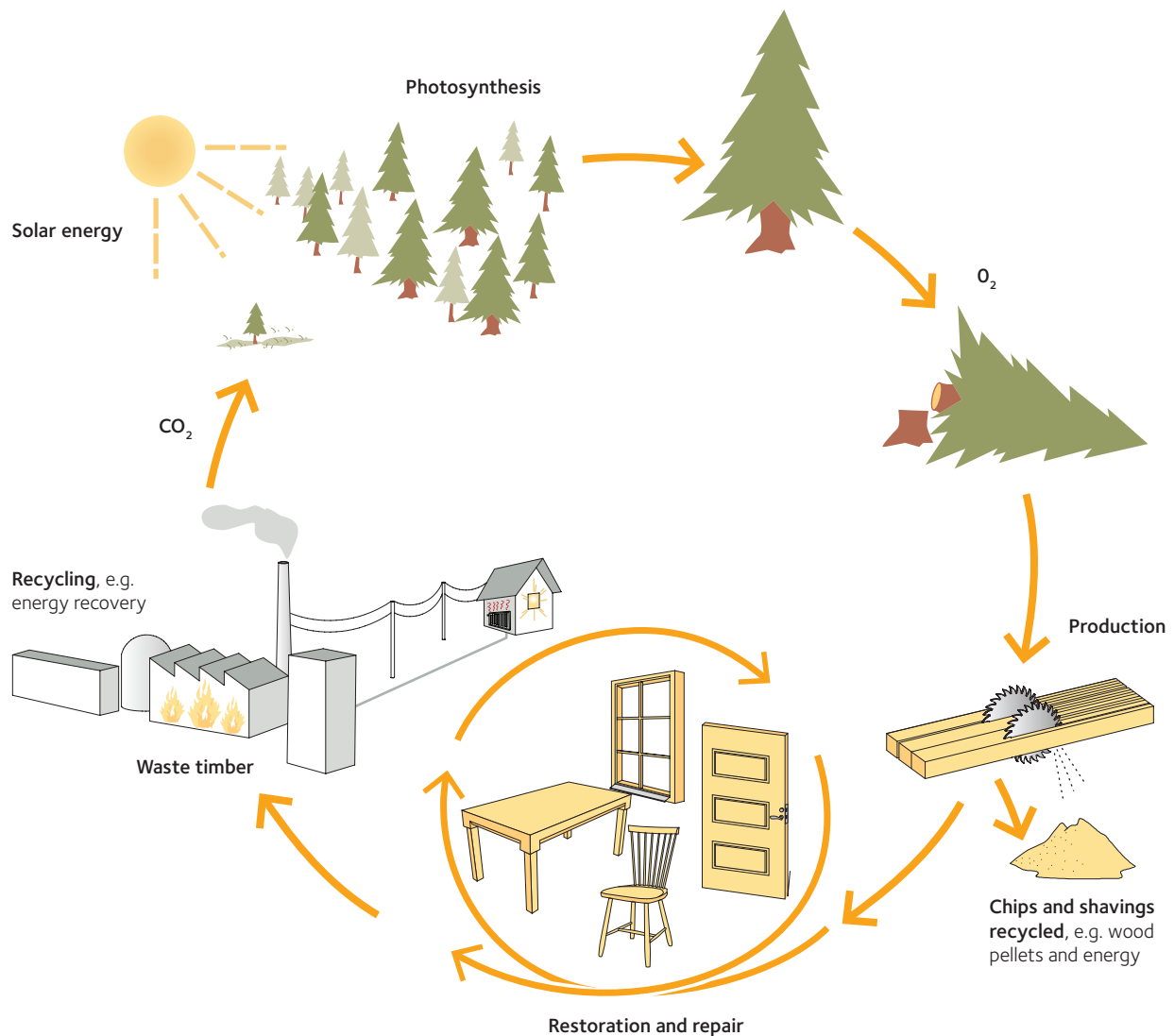


Figure 1.2 Wood's natural ecocycle for interior products

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It is possible to build houses, boats and furniture without drawings, as has been done throughout history. But for the customer or client to judge what is promised against what is finally delivered, a drawing has to be created in advance. A drawing is also required where the work will be carried out by someone other than the designer – when the designer and the craftsman are not the same person.

Drawings for individual furniture and prototypes are usually made by the designer or joiner and are called working or construction drawings. A different kind of design material is necessary for systematised series manufacture on a large scale. These are called production drawings and are part of the preparatory documentation. They must be adapted to standard dimensions that are prescribed in part by requirements concerning the function and ergonomics of the finished product and in part by the mechanical equipment used in the production process.

This chapter takes a deep dive into the different kinds of drawings that occur in modern manufacturing. This is followed by some general advice and recommendations about suitable dimensions for storage furniture, tables and chairs. The chapter concludes with a description and definition of the requirements that usually apply for the various parts of furniture in the large-scale manufacturing industry.

2.1 Drawing techniques

The process from concept to finished product requires drawings of various kinds, for which there are international standards. Knowing about these and all the technical terminology on the different parts of a drawing is important for communication with the client and everyone else involved.

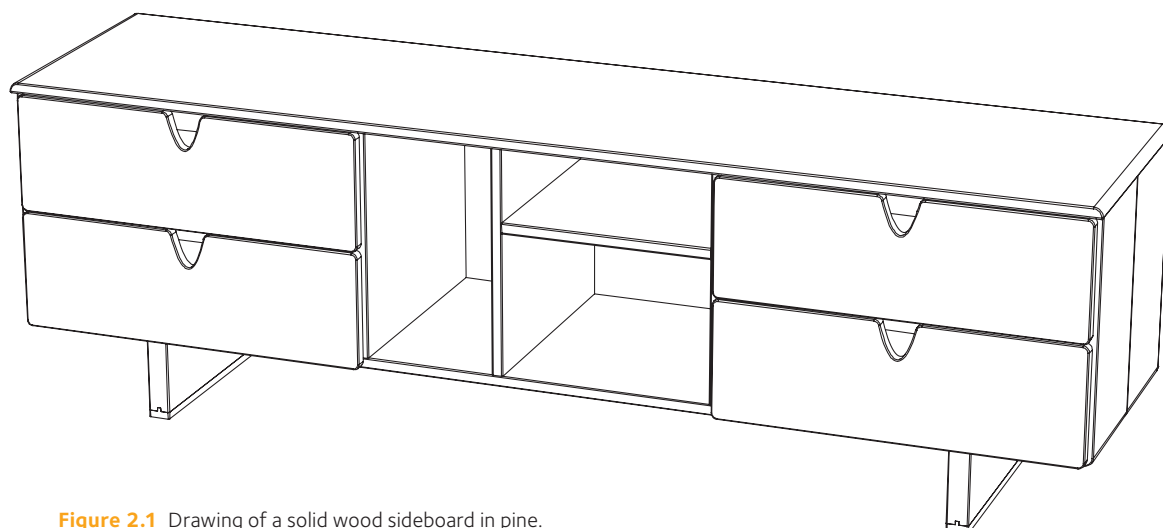


Figure 2.1 Drawing of a solid wood sideboard in pine.

2.1.1 Drawings

A picture says a thousand words. We can see this as soon as we try to describe an object just with words. A description can end up being extremely extensive and detailed. A drawing of the object, on the other hand, allows us to instantly understand what it looks like and how it is constructed. Simple sketches can, for example, describe details, joints, structures and more. Drawings are therefore an important operational part of a manufacturing company, not least in production. When we have an idea about what we want a product to be, we usually start with a sketch.

A sketch helps us to develop our idea

Detailed drawings are necessary for us to get the products that we really want. A company's customers have the right to receive the products they have been promised. It should also be possible to return with orders for the same product. The products therefore have to maintain the same quality and appearance from one time to the next. In other words, for the manufacturing to operate in a way that keeps the customers happy, we have to work from the same foundation every time we produce a new order. Drawings are therefore an important element of the company's quality system.

Fig. 2.1, page 6 shows a type of drawing that is common in the joinery industry. Architects often use this kind of drawing and it is therefore referred to as an architectural drawing. These drawings are life-size to a scale of 1:1. The disadvantage of a 1:1 scale drawing is that it takes up a lot of space and is hard to handle. There are, however, various methods for reducing the size of the drawing.



Furniture sketch, Malmstens, Linköping University.

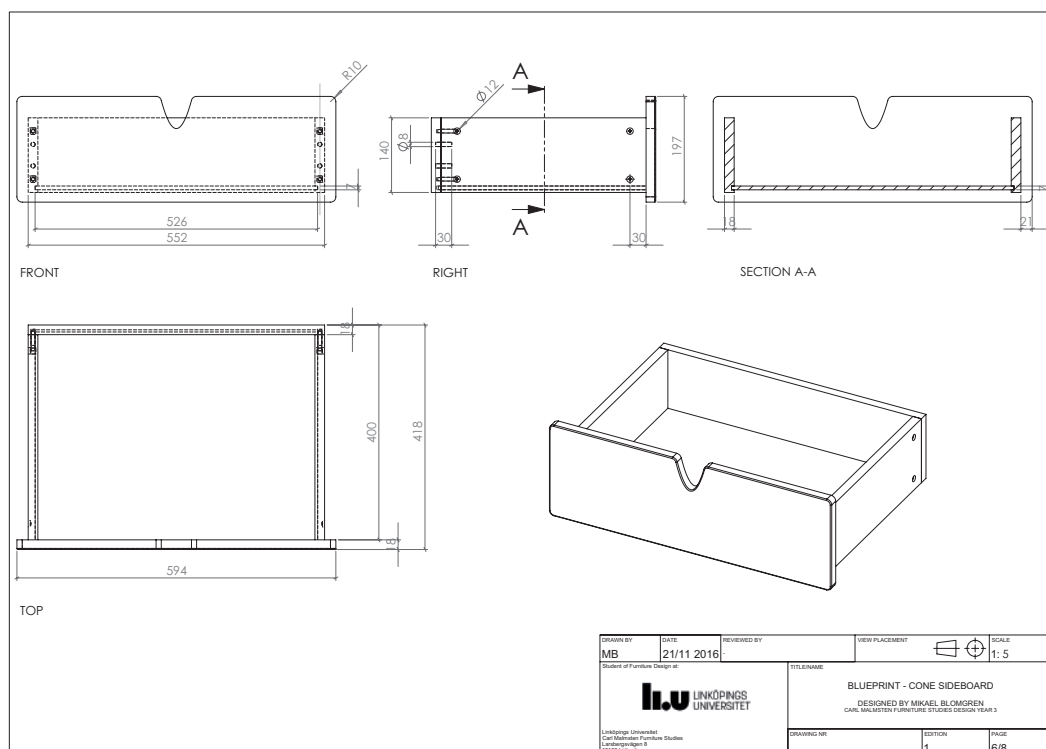


Figure 2.2 Drawing of a solid pine drawer.

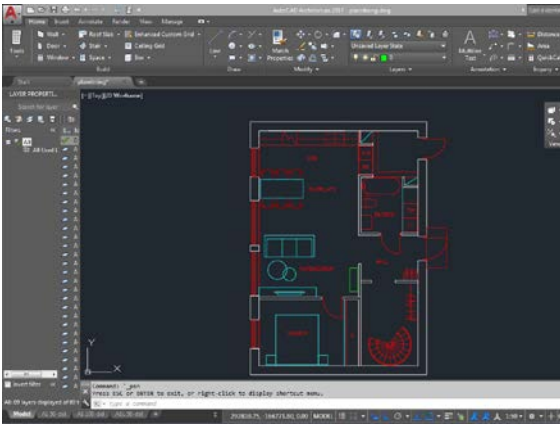


Figure 2.3 Screenshot from an AutoCAD program.

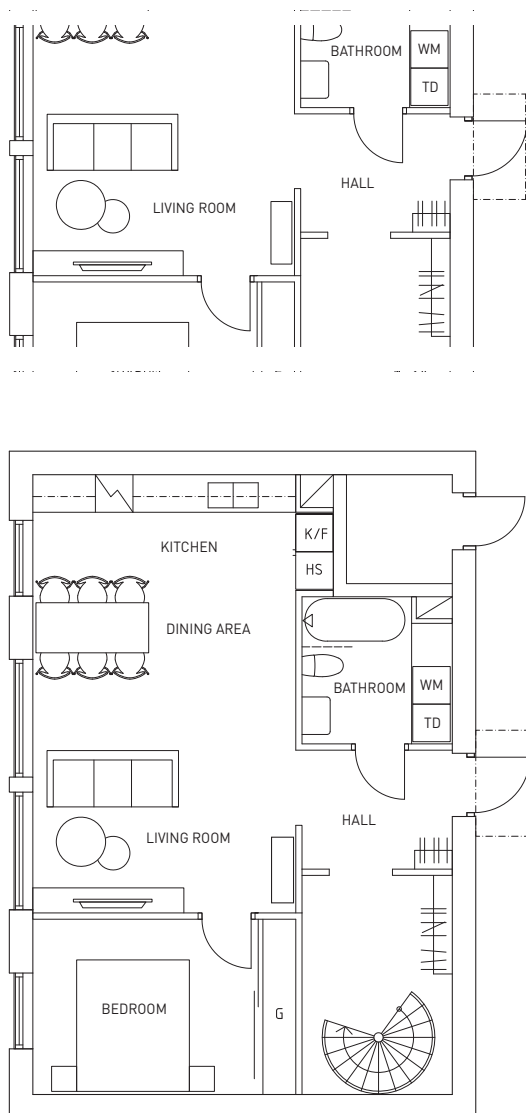


Figure 2.4 Example of a house designed in AutoCAD.

Drawings in the wood industry

On a full-scale drawing, all the dimensions can be roughly measured. Such drawings are therefore often used in the construction industry. Measuring the dimensions directly on the drawing is, however, not appropriate in the wood and joinery industry, since the measurements will not be exact. It is, for example, not possible to tell from the drawing how precisely tenons fit into mortices or how accurately a slot fits. Another difficulty is that the parts of an item of furniture are often made by several people, each of whom may read the measurements differently. In addition, furniture components may frequently be made at different times and in different factories. A drawer made at a certain point may, for example, have to fit into a carcass that was manufactured years before.

Precision is important

Precision is also crucial when manufacturing modular furniture, where you combine separate elements. Often, the furniture has new elements added after a few years. The need for precision in manufacturing in turn places high demands on the drawings. For the most part, you have to have a fully dimensioned drawing for every detail, i.e. a detail drawing. Precise drawings are thus a must for efficient production.

Fig. 2.2, page 7 shows a drawing of a solid pine drawer. Millimetres are the unit of measurement used on drawings in the furniture industry. In general terms, the following basic rules apply for drawings:

- A drawing must be accurate, which means that it describes all three dimensions of a detail and follows the applicable projection rules.
- A drawing must be complete, which means that it describes all the aspects of the product or detail in an unambiguous way. This includes dimensions, surfaces, materials and so on.
- A drawing must be clear, which means that it is easy to read and follows technical drawing standards. Under the technical drawing standards, the drawing must describe a whole product or a detail of a product in its finished state.

2.1.2 Preparing and planning for manufacture

CAD and CAM

CAD stands for Computer Aided Design. CAM stands for Computer Aided Manufacturing. A major benefit of CAD drawings is that they make production planning easier while also being a good resource during the actual production process. Furthermore, a CAD drawing is easy to change. The drawings are always on a 1:1 scale, which avoids complex recalculations. Printouts can then be produced in whatever scale you prefer.

There are various applications, such as MechSlide, MechCAD, Point and Genius, that have a library of symbols for screws, nuts, furniture, etc, that can be inserted into the drawing.

The construction industry has software libraries of interior design features that are depicted in both two and three dimensions. You can, for example, quickly build up a picture of a complete living room or kitchen.

A CAD drawing is highly detailed and well defined in terms of its geometry. This is useful when it comes to creating the programming for Computerised Numerical Control (CNC) machines, for example. These are numerically controlled devices for machining materials, see page 68, with their own computer that is capable of making calculations.

CNC machines can carry out numerous tasks, including drilling, milling and turning. With a CAD drawing as your starting point, you can use CAM software to create a finished program for manufacture in a CNC machine.

Standards

A standard is a set way of doing a specific task in a specific area. It may, for example, be that the fittings in a kitchen have to have certain common dimensions irrespective of the manufacturer, or that there are common requirements regarding product properties such as strength. Standardisation of certain products is incredibly significant. One of the first areas to be standardised was threads for various purposes, not least screws and nuts. It is easy to imagine the chaos that would ensue if all the manufacturers had different threads on their screws and nuts.

A standard sets out the norms that apply and so makes production cheaper and more uniform. Standards are set by dedicated standardisation bodies. There are a whole host of international, European and national standards in existence. Each standard has its own specific designation. Standards from the International Organization for Standardization are prefixed with ISO, while the Swedish Standards Institute (SIS) determines Swedish Standards – SS. Sometimes a standard may be prefixed with SS-ISO, which means that an international standard has been adopted as a Swedish standard.

Drawings must also be created in a standardised way. This is because:

- Drawings play an important role in communicating technical information between different departments and people in a company and between different companies before, during and after production. Drawings are also sent to the supplier and customers. Everyone who reads a standardised drawing will interpret it in the same way.
- Standards mean that everyone knows what norms and rules apply. This makes creating drawings faster and more reliable.

Each year SIS issues a list of current standards. If you want to stay informed, you can subscribe to your chosen subject areas. That way you will receive new standards and new versions when they are published.

2.1.3 Projection methods

A drawing describes a number of figures in three dimensions. In order for an object to be made according to the drawing, dimensions must be given for length, height, width and depth. The drawing also shows the object from at least three views.

SS-ISO 128 contains rules on how the views should be positioned. Three methods are described:

- the European method (method E)
- the American method (method A)
- method with directional arrows (the arrow method).

Swedish Standards prioritise the European method and it is also the method that dominates in Sweden.

In this material, we will only be talking about the European method. The other methods are described in SP Wood Technology's book *Ritsteknik för möbelindustrin* (Drawing technology for the furniture industry).



Pine cupboard, Mikael Blomgren, Malmstens, Linköping University.

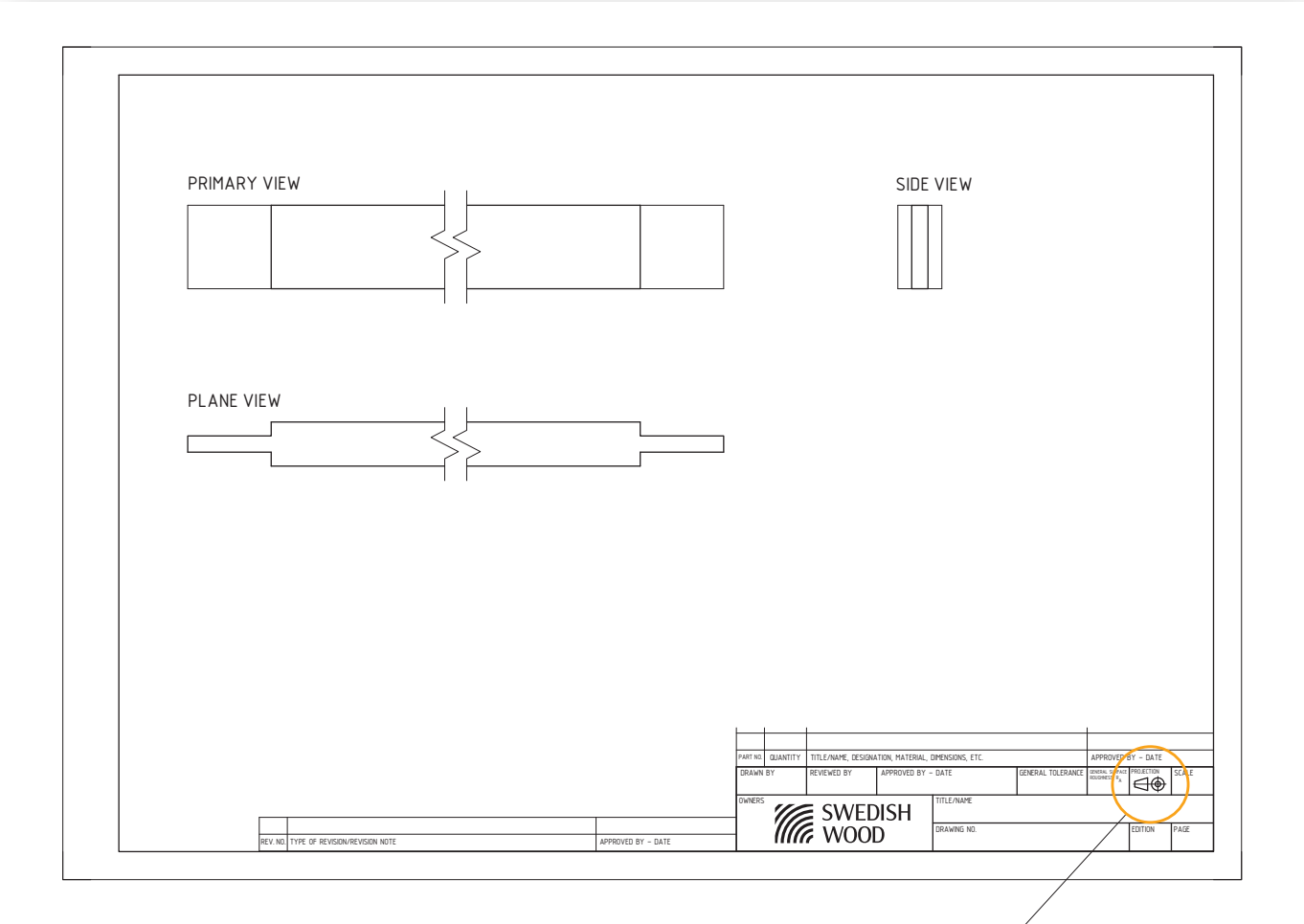


Figure 2.5 Drawing using the European projection method. The symbol, see figure 2.6, is placed in the title block.

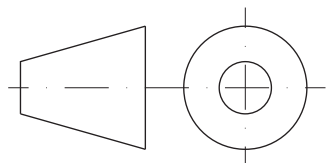


Figure 2.6 Symbol for European projection.

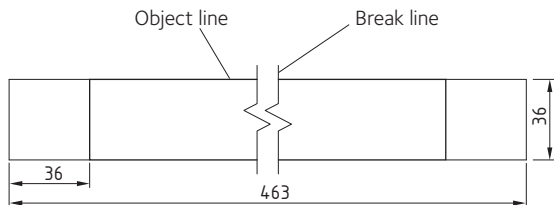


Figure 2.7 Object line and break line.

The European projection method

The European projection method (method E) is also called “the first angle projection” or “the tipping method”, as the figures are tipped over on their side. To achieve different views, an object can be tipped into different positions, see fig. 2.5. You begin by drawing the primary view (A), which is the “view from the front”. The primary view must be the side of the object that is usually considered the front or the side that best describes the appearance. The primary description does not provide sufficient description of the object. To make the drawing clear and usable, the view must be drawn from at least two sides. In addition to the primary view, there are further views to choose from when creating a full picture of the detail. The symbol for the European projection can be seen in fig. 2.6 and it is placed in the main field on the technical drawing template. There are other types of projection and these are shown using other symbols in the same field.

Object line

The line around the section is the thickest line on the drawing. The line around an object is the next thickest line on the drawing. According to SS-ISO 128, the line must have a thickness of 0.5 mm or 0.7 mm.

Break line

Break lines are used to show that parts of an object have been left out of the drawing. This is particularly useful for larger objects, as you can then draw the object on a larger scale and make any clarifications.

Hidden line

The outline of a detail that lies inside an object and therefore cannot be seen, is drawn with a thin dashed line measuring 0.18, 0.25 or 0.35 mm.

Centre line

A thin dotted line of 0.18, 0.25 or 0.35 mm is used to mark the centre of a hole, for example.

Fine line

When you want to show something in an object that is not an outline, use a fine line that measures 0.18, 0.25 or 0.35 mm.

Cutting plane line

Drawings are not only used to describe an object from different views. With the help of drawings, it is also possible to cut through the object to show what the structure looks like below the visible surface and to facilitate dimensioning. Cross-sections along a plane are the most common. The cross-section divides the object into two parts, each of which has a cut surface.

To be clear about which of the cut surfaces on the drawing is being referred to, the custom is to place arrows at the thicker ends of the cutting plane line. If there are several sections on the drawing, the section should be marked with a letter at each arrow, *see fig. 2.8*.

Fig. 2.8 shows that the section is drawn as in a regular projection. We have used the European method here. The section is viewed from the left and is drawn to the right of the primary view.

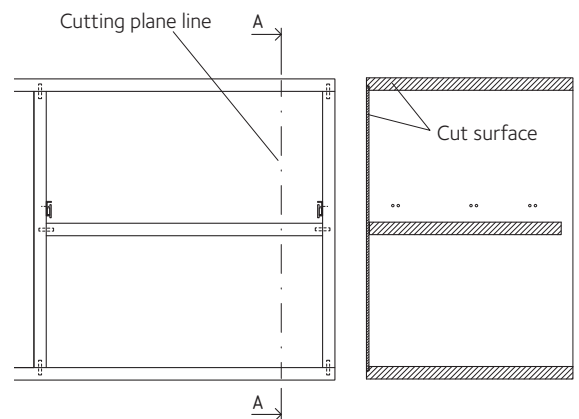


Figure 2.8
Cutting plane line

Figure 2.9
Cut surface

Section marks

Various structure and material marks are used to clarify drawings. It is important to learn the difference between these marks and section marks.

Fig. 2.9 shows how end wood can be marked. The marks should only be used to make the manufacturer aware of the structure.

There is no set standard for putting material marks on a drawing. It is therefore better to avoid using such marks. Note the material on the item list instead, *see fig. 2.19, page 15*.

Dimensioning

The rules for dimensioning can, at first sight, seem long-winded and rather complex. The purpose is to ensure clarity and uniformity on the production drawings/working drawings that form the basis for manufacture. Once you have procedures in place for dimensioning, you will realise the benefits of these rules. *Fig. 2.10* shows how the dimension line and dimension limit line are drawn. The dimension line should have an arrowhead at each end and the dimension limit line should be drawn around 2 mm beyond the dimension line. The distance between the outline and first dimension line, where you may sometimes wish to place text, should be 12 mm, if the text height is 3.5 mm. The distance between two dimension lines is 10 mm for the same text height of 3.5 mm.

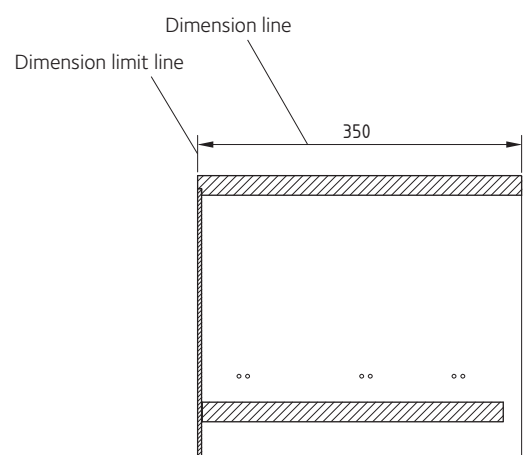


Figure 2.10 Dimensioning

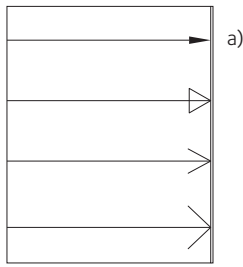


Figure 2.11 Dimension arrows.

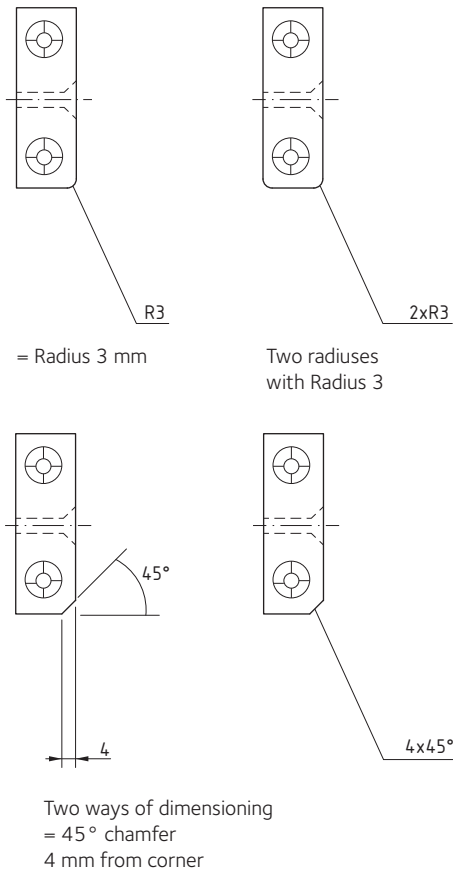


Figure 2.12 Dimensioning arc or chamfer.

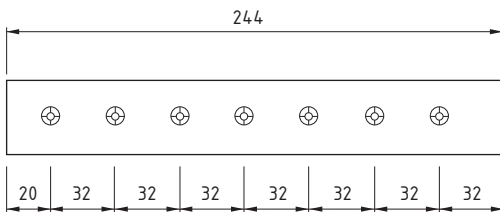


Figure 2.13 Baseline dimensioning.

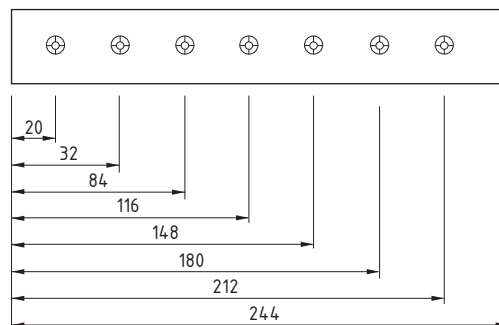


Figure 2.14 Simplified baseline dimensioning.

Dimension arrows according to Swedish Standards

Swedish Standards have four different variants of the arrowhead, see fig. 2.11. The angle of the point is between 15° and 90°. The furniture industry and furniture workshops mainly use the solid arrowhead, see fig. 2.11 a). As a rule, only one type of arrow should be used on the same drawing. The aim is always to make the drawing as consistent and uniform as possible. The dimension should be placed above the dimension line, preferably centred along the line. The dimension should be readable from the bottom or the right of the drawing. The dimension of an object must only be given in one view and should not be repeated if it occurs in multiple views on the drawing.

Dimensions that belong together, such as dimensions used for setting up an operation, should be as close as possible to each other on the drawing. They should not be spread across more views than is absolutely necessary.

Dimensioning arcs or chamfers

Fig. 2.12 demonstrates different ways of showing the dimensions of arcs and chamfers. The most common way to give the dimension of a radius is to write it in the text box. Example: Object lines should have a radius of approx. 2 mm.

Baseline dimensioning

Dimensioning from a zero point is called baseline dimensioning, and it is considered a more accurate method than chain dimensioning. The disadvantage of baseline dimensioning is that it takes up a lot of space on the drawing. Baseline dimensioning can be simplified to occupy less space, but that creates a greater risk of misunderstanding.

Simplified baseline dimensioning

The zero point is marked with a circle with a diameter of around 3 mm.

When dimensioning a hole or a chamfer, for example, there may not always be room between the dimension limit lines for a clear measurement. In this case measurements should be positioned as shown in fig. 2.15.

As a general rule, measurements should be placed outside the object. Dimension lines and dimension limit lines that cross each other or other lines should be avoided. However, if it makes the drawing clearer, measurements can be placed inside the diagram.

Outlines and centre lines must not be used as dimension lines. In exceptional cases, they may be used as dimension limit lines, but this should preferably be avoided.

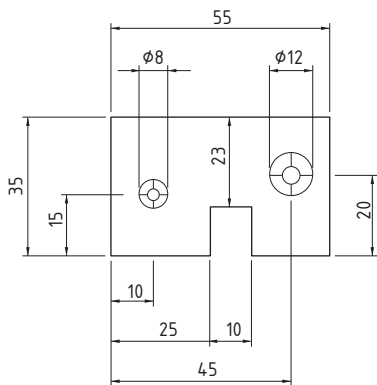


Figure 2.15 Simplified baseline dimensioning.

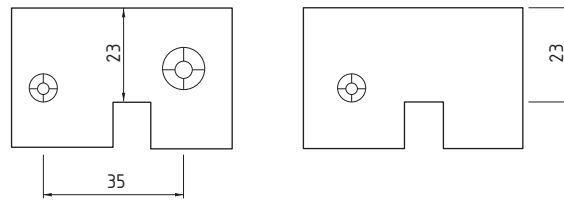


Figure 2.16 Positioning of measurements.

In fig. 2.16 the measurement is on the actual drawing, between the two holes where there is no other hole on the drawing. If there is a risk of the dimension limit line crossing other lines on the drawing, however, placing the measurement outside the diagram is correct.

2.1.4 Layout of the drawing sheet

To ensure that drawings are clear and easy to read, there is also a uniform layout for the information needed on drawings. The layout convention relates to the positioning of the title block, revision block and item list, plus the type of information that should be placed in these fields.

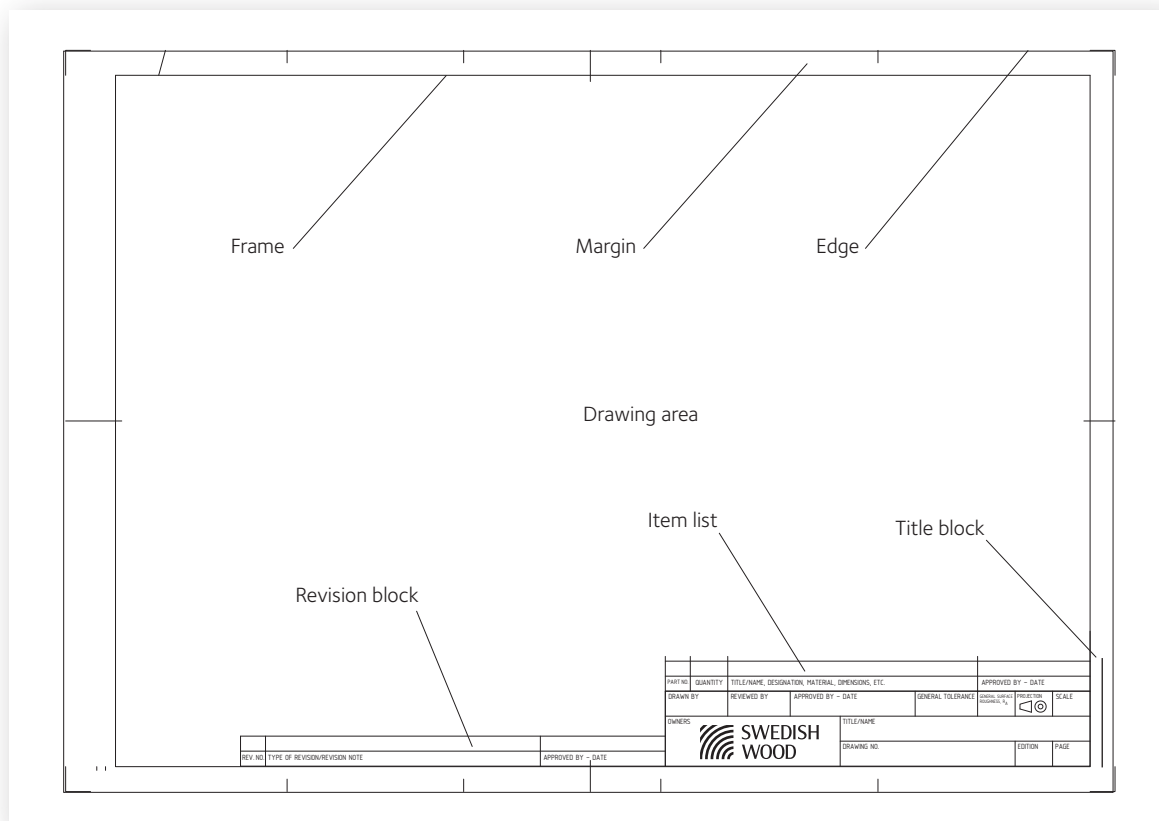


Figure 2.17 Layout of the drawing sheet.



Pine stool, Hemmo Honkonen, Malmstens, Linköping University.

Title block

The title block is always placed in the bottom right-hand corner of the drawing field, together with the item list and sometimes the revision block. This is true whether the drawing is in portrait or landscape format.

The title block contains the title and designation of the drawing plus a range of other information, such as the number and scale of the drawing, who made the drawing and the owner of the drawing. Fig. 2.18 below shows a title block that follows standard SS 3149, adapted for the wood industry.

The following details must be provided in the title block:

- Owner 1.
- The title is the name of the drawing (sub-assembly). The designation refers to what the drawing represents (carcass). If the drawn detail belongs to a larger part, you can also include the name of the larger part in the title 2.
- The number of the drawing according to the company’s procedures for documentation 3.
- Signatures of the people who drew/designed, reviewed and approved the drawing. The company’s procedures for documentation management state who is authorised to carry out these various tasks 4.
- The main scale of the drawing 5.
- Symbol showing which projection method has been used 6.
- General surface roughness. Other general dimensional tolerances are stated in plain text 7.
- Issue, expressed as a number 8.
- Where drawings have multiple sheets, both the sheet number and total number of sheets should be stated, for example 1/4 or 1(4) 9.

Revision block

Sometimes drawings need to be revised over the course of the job. All corrections to the drawing must be meticulously noted, giving details of what the change related to and when it was carried out. In A4 format, the revision block should be placed in the top right-hand corner of the drawing. In large formats, it should be placed to the left of the title block 10. When you make a change, you can sometimes create a new issue of the drawing at the same time. In this case, the designation used for the revision can also be used to name the new issue. On the drawing, the detail that has been changed is marked with a revision symbol in the form of a triangle.

There are two ways to list the changes in the revision block. You can either briefly describe the change in the revision block or state a memo number that refers to a revision memo. It is essential that everyone concerned — for example product developers and draftsmen — is informed about the changes that have been made over the course of the job. Deficiencies in the information can cost the company dearly. Everyone in the company should therefore regularly review their procedures regarding internal and external information.

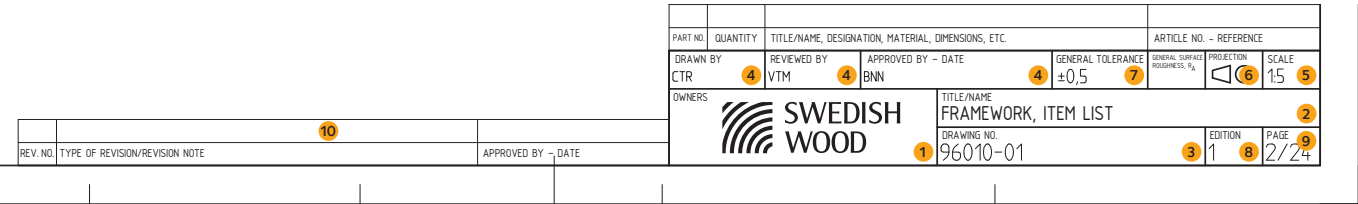


Figure 2.18 Title block and revision block.


7	1	BASE	96010-11
6	1	BACK	96010-10
5	2	TRACK	96010-09
4	1	SHELF	96010-08
3	2	SIDE	96010-07
2	1	PARTITION	96010-06
1	1	TOP	96010-05
PART NO.	QUANTITY	TITLE/NAME, DESIGNATION, MATERIAL, DIMENSIONS, ETC.	
DRAWN BY CTR	REVIEWED BY VTM	APPROVED BY - DATE BNN	GENERAL TOLERANCE ±0,5
OWNERS 		TITLE/NAME FRAMEWORK, ITEM LIST	
DRAWING NO. 96010-01		EDITION 1	PAGE 2/24

Figure 2.19 Item list.

Item list

On drawings of composite objects, additional information about details and materials is given in an item list. The item list is the same length as the drawing's title block and is placed above that field, see fig. 2.19.

Scales

The format of the drawing can be reduced using symmetry and break lines. You can also vary the size of the drawing by using different scales, usually as shown in table 2.1.

It is of course not always possible to use drawings in natural size, as they soon become too big and unwieldy. It is therefore useful to be able to create drawings on a reduced scale. This applies to both assembly drawings and detail drawings.

Sometimes it may be necessary to make the dimensioning clearer, to avoid misreadings. This can be achieved by enlarging a particular detail on part of the drawing, for example, see fig. 2.20. The part being enlarged should be circled with a solid line. Then you label the area with a capital A, B, C etc — above the circle.

The enlarged view of the part is positioned elsewhere on the drawing, where it is delimited with a circle or break line. State the scale in brackets next to the capital letter. A scale of 1:1 is often used for an enlarged view. Where there are multiple enlarged views, they are placed in alphabetical order.

Table 2.1 Scale table.

	Scale		
Enlarged	2:1	5:1	10:1
Full scale			1:1
Reduced	1:2	1:5	1:10

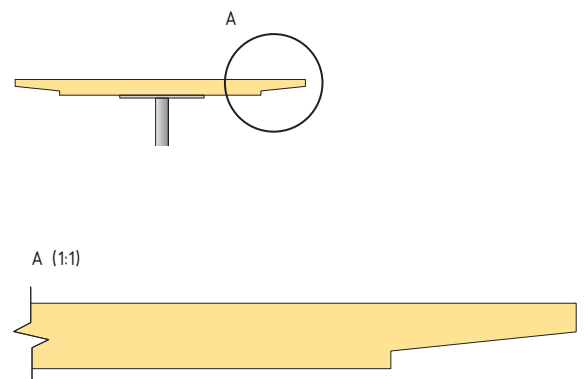


Figure 2.20 Part enlargement.

2.1.5 Drawing structure

In order to get a good overview of the project and the various drawings, you should settle on a drawing structure. Fig. 2.21 illustrates what a drawing structure might look like.

Sometimes, there may be no need to produce a sub-assembly drawing, in which case you can skip that step and go straight to the detail drawing.

General arrangement drawing

The general arrangement drawing describes what the finished product will look like and the overall dimensions. In order to refer to sub-assembly drawings or detail drawings, they must be given a number. The number is placed in a circle that is drawn with a fine solid line. A reference line is then drawn from the circle to the detail. If possible, the circles should be placed together, and arranged in a vertical

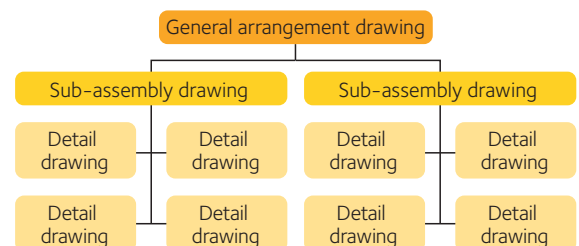


Figure 2.21 Drawing structure for preparatory documentation.

or horizontal line. The number should be entered in the item list and should refer to a drawing number:

- 100 general arrangement drawing
- 110 sub-assembly drawing
- 111 detail drawing.

Sub-assembly drawing

If it is not possible to describe the function of the product or the details in the GA drawing, the drawing will have to be divided up into sub-assembly drawings. If the function of the detail is described in the sub-assembly drawing, it is also drawn in a simplified form on the GA drawing.

Both the GA drawing and the sub-assembly drawings should feature references to detail drawings. These are noted in the item list as set out in *fig. 2.23, page 17*.

Detail drawing

As the name suggests, a detail drawing describes just one detail. The drawing should contain all the information required about the detail's function and its finished dimensions, *see fig. 2.24, page 17*. There is no requirement to be able to read the detail's placement in the product from the detail drawing. When creating a detail drawing, it is necessary to put yourself in the manufacturer's shoes and lay the drawing out in such a way that the manufacturer can easily read the clearance measurements and other information that is vital for the production. There is no room for misunderstandings.

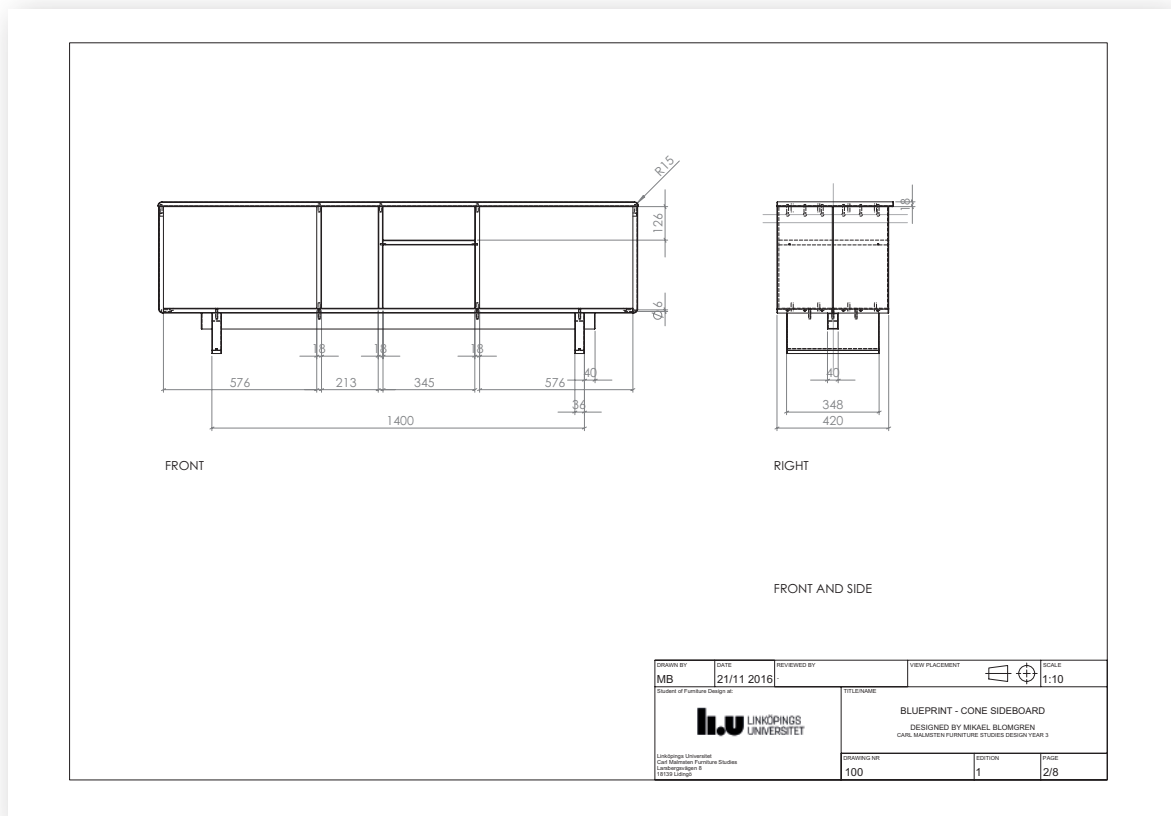
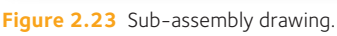


Figure 2.22 General arrangement drawing.



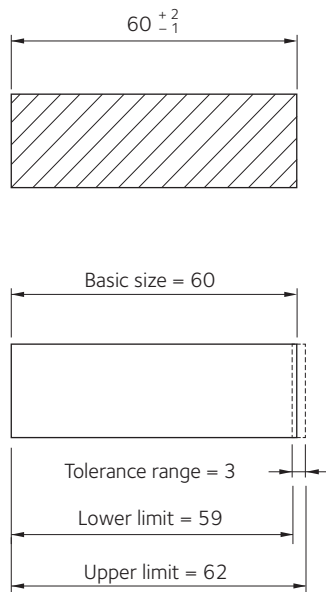


Figure 2.25 Examples of dimensional tolerances
If we have a measurement of 60, the basic size is 60 mm.
If the upper limit is 62 mm and the lower limit is 59 mm,
the tolerance range is 3 mm.

2.1.6 Tolerances

In technical terms a tolerance is the permissible limit of variation in a physical dimension, such as a length measurement. 10 ± 1 states that the permissible upper limit of the measurement is 11 mm and its lower limit is 9 mm. This means that all measurements from 9–11 mm are approved. A tolerance can also relate to requirements concerning straightness and levelness, for example.

Dimensional tolerances

However precise the measuring device you use, there is always a device that is even more precise and can show you another decimal place. The obvious conclusion is therefore that exact measurements do not exist. This makes it necessary to state the permissible values of a measurement by giving a dimensional tolerance. In the wood industry there are machines that are unable to work with exact measurements and that prefer tolerances. Another challenge is that wood is affected by the humidity of the air around it. Dimensional tolerances are also necessary to ensure that different parts fit together. For a drawer to fit in a sideboard, for example, the drawer mustn't be too large for the aperture in the sideboard. This is resolved by setting an upper and lower limit for the dimensions of the drawer and a lower limit for the hole. It is important not to stick to too fine a tolerance, as this can make production considerably more expensive due to the time spent keeping the measurements in check. When talking about tolerances, we use the following terms, *see fig. 2.25*:

- basic size
- upper and lower limit
- tolerance range.

2.1.7 Cutting list

A cutting list, *see table 2.2*, is used in order to gain a simple overview of the amount and type of material in the constituent parts. A scale drawing or a working/production drawing forms the basis for the cutting list, which in turn forms the basis for the material order. Unplaned timber is around 1 mm thicker and 3 mm wider than planed. State in the list whether the timber should be planed or unplaned. Write out the name of the parts and the number of parts of the same size in the order: length, width, thickness. If possible, include a cut margin for length and width. Specify the wood species and check that the total number of parts is correct.

Table 2.2 Example of a cutting list (cutting note).

Name	No.	Material	Length	Width	Thickness
Leg	4	Pine	735	70	30
Leg	4	Pine	735	50	30
End	2	Pine	1 052	100	20
End	2	Pine	440	100	20
Top	1	Pine	1 212	606	23
Top fixings	14	Pine	45	35	20
Dowels	14	Beech	40	11	(diam)
Corner brackets	4	6 mm bolts, washers and wing nuts			

All material is planed. All measurements are in mm.

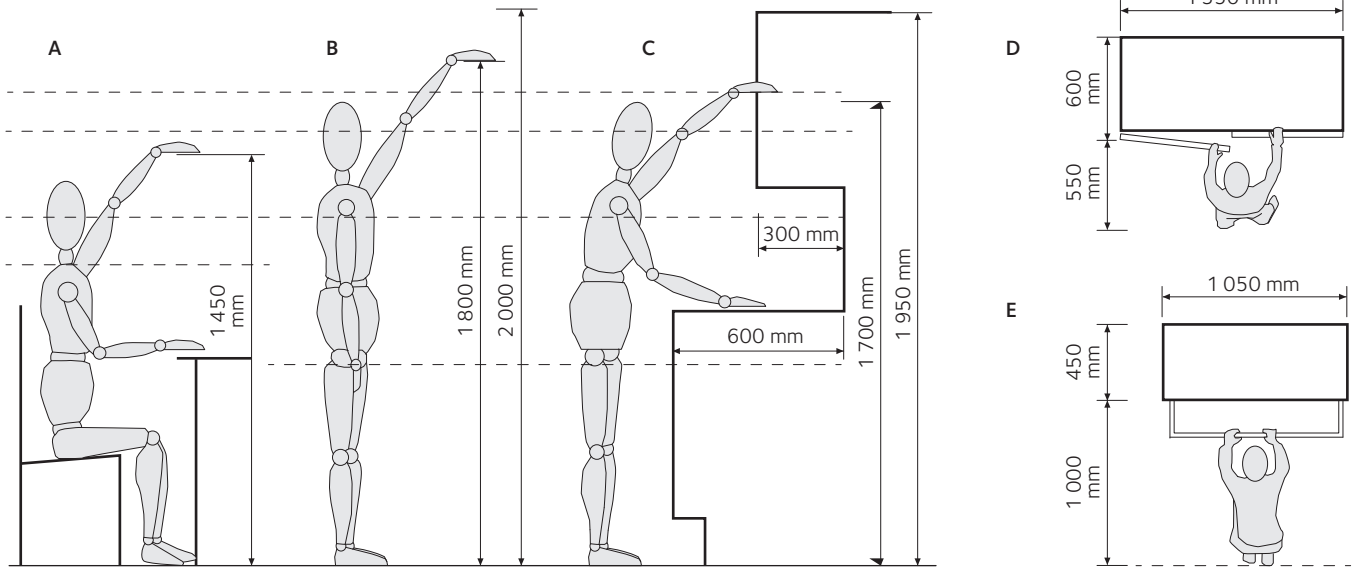


Figure 2.26 Universal measurements, storage furniture.

2.2 Interior products

The following recommendations should be seen as general guidelines only. They apply primarily to function, taking into account human measurements and posture. The real-world situation requires an analysis of any deviations from the norms described.

2.2.1 Storage furniture

The ideal storage furniture can be changed to meet particular preferences and needs. It should be flexible, easy to access, make good use of space and protect the contents. The functional design may be based around an analysis of the following parameters:

- what is going to be stored
- the space available
- how high or far you need to stretch to put in or take out objects.

You also need to think about how much space you require to get around other objects or workspaces and what the room is mostly used for. The items to be stored can be split into various groups:

- items that are used regularly, such as food, clothing and toys
- items that are only needed occasionally or seasonally, such as winter clothing and suitcases.

Items that are used frequently must be easy to access, while those that are rarely used should be well protected. Storage furniture can also be divided into freestanding and wall-mounted. Freestanding designs can be made in modules. Equal-sized elements can be put together to meet specific functions and can be added to, rearranged and combined with new elements as required. The modular system also works for wall-mounted storage furniture. Prefabricated uprights or frames that are fixed between the floor and ceiling become a fixing for shelves, cupboards or drawers. Fixed storage furniture can be built into or attached to a wall. For universal measurements *see* fig. 2.26.

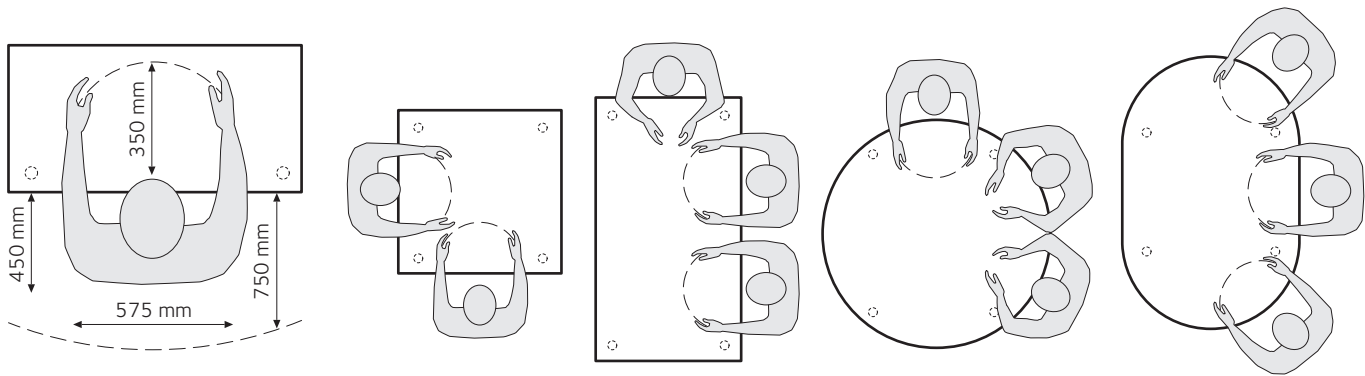


Figure 2.27 Universal measurements, table.

2.2.2 Tables

There are four basic table designs. Each type clearly shows what problems the designer is dealing with when answering the following questions:

- Will the table be used daily or less often?
- How large is the space in which the table will stand?
- How many people will be sitting at the table at the same time?

Table types

The first type is tables with a fixed top, such as regular dining tables or coffee tables. The second type is collapsible tables, for example tables on trestles. These are good for bringing out for particular occasions. The third and fourth types have a design that extends the table-top space. One has drop-leaves and gatelegs, the other has concealed extension arms for loose or fixed, insertable or pull-out leaves, or folding leaves.

Dimensioning

The height is important for all types of table. Tables that people sit at should have a height from the floor of 675–725 mm. Tables with the lowest height tend to be office desks, while the highest are dining tables. The height of tables that people stand and work at, in a kitchen or a workshop, should be around 900 mm, while a bar table can be up to 1,100 mm. The height of a side table should be between 300 and 550 mm. Table height is closely related to human anatomy, but may be determined by cultural differences. It is also important to think about what surface is required on the tables, see example in *fig. 2.27*.

2.2.3 Chairs

Designing and developing chairs requires a wide range of professional skills in a process that includes knowledge of the material's properties, ergonomics, culture, aesthetics and manufacture. Some modern furniture uses straight materials where possible, and then steamed or laminated wood is bent into shape for the curved details. Pine has limited properties when it comes to bending. The production process is one of the factors to consider when choosing the material.

Before beginning with the drawing, account must be taken of three crucial function-related factors:

- stability/safety
- strength/durability
- comfort/ergonomics.

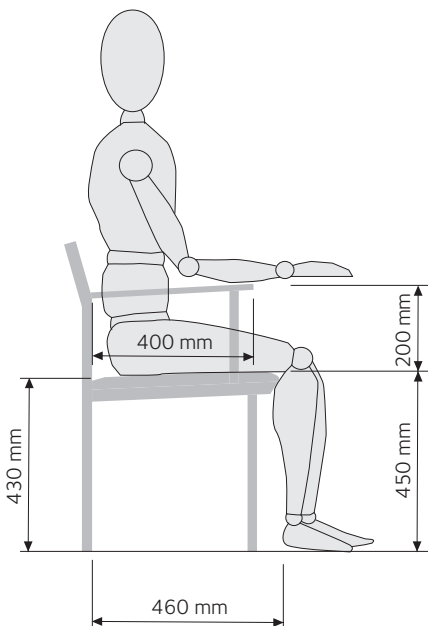


Figure 2.28 Universal measurements, chair.

Will the furniture survive many years of use? Are arms necessary? Are the upholstery and filling fit for purpose — practically and aesthetically? Will it fit in with the other furniture in the room?

Comfort cannot be measured or guaranteed by the amount of soft filling. The most important factor for comfort is the sitting angles, the placement of the individual parts and the support that the whole frame provides. If all this is right, the body's muscles shouldn't have to work to find a properly comfortable position and to maintain it.

The seat height at the front edge varies between 400 and 450 mm if you want your feet to touch the floor. The depth of the seat should not exceed 460 mm measured along the centre line of the seat. It is important that the front edge does not press into the back of the knees, which prevents blood flow to the legs. The seat should lean backwards about 5–8° in relation to the horizontal plane, which gives a height difference between the front legs and back legs of about 20 mm, *see fig. 2.28, page 20*. This incline allows you to maintain the proper position for your pelvis and the natural curve of your spine when seated. Around 150–200 mm above the seat, the chair back should have a lumbar support. The arms should be around 200 mm above the seat. You also need enough space between the underside of a table and the armrests to avoid crushing your fingers when you pull the chair under the table. Short arms are good for the same reason. In recent years, researchers have increasingly also pinpointed sitting as a health problem and proposed other features for improved relief and rest.

2.3 Classification

The various parts of a product may be treated differently when it comes to requirements for aesthetic quality and surface finish. The classes below may be used in procurement documents. *See fig. 2.29* for an example of furniture parts classification:

Exclusive and class A: Prominent parts, such as cupboard sides, outside of drawers and countertop.

Class B: Less prominent parts, e.g. inside of cupboard doors and upper face of shelves.

Class C: Partially seen parts, e.g. inside of cupboard walls and underside of shelves.

Class D: Unseen parts, e.g. sides facing wall, ceiling or floor.

Class E: Temporary fittings with low quality requirements.

Table for classification, requirements and tolerances
To make tolerance and requirement levels clear, taking account of the product's area of use, user environment and finish, below is a table created by Swedish woodworking industry body SNIRI's specialist furniture group. On inspection, it should be possible to place a finished item of furniture in one of the six classes shown in the table.

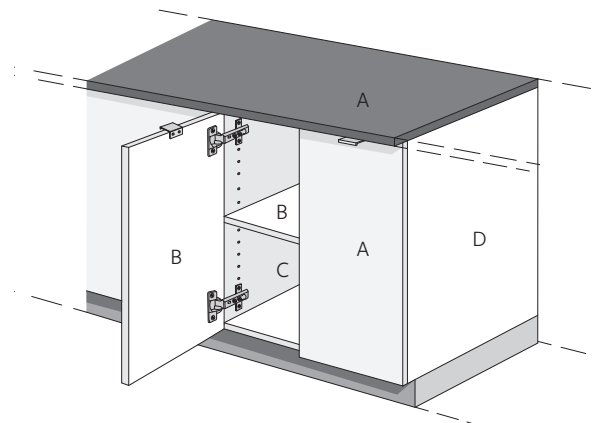


Figure 2.29 Item of furniture showing classification.

Facts Möbelfakta

Möbelfakta – a labelling scheme for furniture – is stronger, tougher and more complete than ever before. The aim is for Möbelfakta to be a useful tool for manufacturers, buyers, retailers and consumers. The criteria are based on three areas: quality, environment and social responsibility. There are two regular courses linked to Möbelfakta – a full-day course on assessing furniture for labelling and a half-day course focusing on risk assessment of suppliers. For more info go to mobelfakta.se.

2.3 Classification

Table 2.3 Classification.

Source: Guide to interior joinery, 2002, SNIRL.

	Exclusive	Class A	Class B	Class C	Class D	Class E
Design	Extraordinarily high requirements for professional and accurate execution down to the smallest detail. High quality surface finish. Exclusive materials. No cause for remarks is permitted.	High requirements for professional execution and detail work. No defects that affect usability and intended appearance are permitted.	No usability defects, barely noticeable defects that do not affect the intended appearance are permitted. Material choices take account of user environment and appearance.	No defects that affect usability are permitted. A few clearly noticeable defects in appearance are permitted. Material choices take account of strength and stability.	No defects that affect usability. Multiple defects in appearance are permitted. Materials chosen only on basis of function.	No usability defects or broken parts. Defects in appearance to almost unlimited extent. Major tolerance when assessing execution.
Area of use/ User environment	Exclusive user environments.	High-class user environments.	Fittings for normal use in public environments.	Simple furniture in harsh environments.	Simple fittings, e.g. of a temporary nature.	Temporary fittings with low quality requirements.
Precision in manufacture						
Angles						
a) Deviations from the stated measurements are permitted for a max length of 400 mm:	< 0,4 mm	< 0,4 mm	< 0,6 mm	< 0,8 mm	1 mm	IV
b) plus as percentage of whole length:	< 0,1 mm	0,15 percent	0,15 percent	0,3 percent	0,3 percent	IV
c) but max:	< 1 mm	1,5 mm	1,5 mm	3 mm	3 mm	IV
Smoothness						
a) Deviation:	0,2 percent	0,2 percent	0,4 percent	0,8 percent	IV	IV
b) but max:	< 1,5 mm	< 1,5 mm	3 mm	4 mm	–	–
c) Uneven fitting on level substrate:	I	I	II	III	III	IV
d) but distance leg–floor max:	–	–	1 mm	2 mm	3 mm	–
Straightness Crookedness of braces, rails, pegs meant to be straight, as % of length, max:	< 0,2 percent or I	0,2 percent or II	0,4 percent or II	0,6 percent or III	1 percent or IV	IV
Parallelism of gaps , e.g. between or around drawers or doors						
a) Deviation for gap length no more than 400 mm max:	< 0,5 mm	0,5 mm	1 mm	2 mm	3 mm	IV
b) Deviation as percentage of length, max:	< 0,15 percent	0,15 percent	0,25 percent	0,5 percent	0,75 percent	IV
c) but max:	< 1 mm	1,5 mm	2 mm	3 mm	5 mm	–
Gap width ¹⁾ Permissible difference max:	< 1 mm	1 mm	2 mm	3 mm	4 mm	IV
Alignment of drawers, doors, drop-leaves, extension leaves Deviation in edge or middle max:	1 mm	1 mm	1,5 mm	2 mm	3 mm	IV
Drawer action ²⁾ – Seizing						
a) Insertion force centric	< 30 N	< 30 N	< 30 N	< 40 N	< 50 N	< 100 N
b) Insertion force eccentric	< 40 N	< 40 N	< 70 N	< 100 N	< 150 N	< 150 N
c) Abrasion on adjacent drawer or carcass	I	I	I	II	II	III
Door action						
a) Seizing of doors or screen	I	I	I	II	III	IV
b) Abrasion against other door or carcass	I	I	I	II	III	–
Visible and accessible defects in:						
Composites						
a) Penetrating fixings that cause damage	I	I	I	I	I	IV
b) Checks	I	I	I	II	III	IV
c) Paint/material	I	I	I	II	III	IV
d) Irregular level differences	I	I	II	II	III	IV
e) Visible adhesive or adhesive discolouration	I	I	II	II	III	IV
f) Gaps	I	max 0,1 mm	II, width but max 0,2 mm	III, width but max 0,5 mm	III, width but max 0,8 mm	IV

Cont. >>>

Table 2.3 Cont. >>>

Source: Guide to interior joinery, 2002, SNIRI.

	Exclusive	Class A	Class B	Class C	Class D	Class E
Veneer, foil						
a) Blisters	I	I	I	I	I	IV
b) Filling	I	I	I	II	III	IV
c) Flaking	I	I	I	II	III	IV
d) Adhesive bleeding	I	I	I	II	III	IV
e) Adhesive in joint	I	I	I	II	III	IV
f) Loose joints	I	I	I	II	IV	IV
Edges						
a) Unchamfered leg	I	I	I	I	I	IV
b) Unprotected edge of sheet material	I	I	I	I	II	III
c) Unevenness edging strip or sheet	I	I	I	I	III	IV
d) Flaked edge	I	I	I	I	II	III
e) Colour deviation	I	I	I	II	II	IV
f) Irregular chamfer/arc	I	I	I	II	III	IV
g) Filling or adhesive between edging strip and sheet	I	I	I	II	III	IV
Bent and laminated parts						
a) Rupture	I	I	I	I	I	II
b) Delamination	I	I	I	I	II	III
c) Uneven bending	I	I	II	II	III	IV
d) Variation in bending between different edges	I	I	I	II	III	–
Fittings						
a) Sharp edges	I	II	II	II	II	II
b) Screws too large for countersinking	I	I	II	III	III	IV
c) Unevenly inset or not on plane	I	II	II	III	III	IV
d) Loose connections	I	II	II	III	III	IV
e) Screws skewed or head stripped	I	II	II	III	III	IV
Smoothness and polish						
a) Pencil marks not removed	I	I	I	I	II	IV
b) Unsmoothed or rough edges	I	I	II	II	III	IV
c) Marks or unevenness	I	I	I	II	III	IV
d) Cutter marks, roller marks	I	I	I	II	III	IV
e) Sand through surface layer or veneer	I	I	I	I	II	IV
f) Uneven polishing	I	II	II	III	III	IV
g) Lifting fibres	I	II	II	III	III	IV
h) Transverse polishing marks	I	II	II	III	IV	IV
Surface finish						
a) Smeary or sticky layer	I	I	I	I	I	I
b) Sand through	I	I	I	II	III	IV
c) Soiling	I	I	I	I	II	IV
d) Discolouration	I	I	II	II	III	IV
e) Runs	I	I	II	II	III	IV
f) Scratches	I	I	II	II	III	IV
g) Surface splits, crackling	I	I	I	II	III	IV
h) Whitening, impurities, blisters	I	I	I	II	III	IV
i) Visible thickness variations	I	II	II	III	III	IV
j) Shade or gloss variations	I	II	II	III	III	IV

¹⁾ The largest permissible difference, for example in the gaps along a row of drawers.

²⁾ The maximum perpendicular force that is needed to close the drawer with a load of 10 kg inside it.

I Stated defect not permitted.

II The defect is permitted in a few places and is either small in size or forms a barely noticeable contrast with the surrounding surface.

III The defect is permitted even if it is clearly visible. It may comprise a few large or several smaller defects.

IV The defect is permitted to an unlimited extent, as long as the function of the item is not greatly impaired.

Ordering wood

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Wood is a living material. The properties of different woods are influenced by the place where the tree grows and by the forces of nature that it is exposed to. Weight and fibre density vary, affecting the strength and functionality of the resulting product. Pine has historically been one of the materials most commonly used in Sweden for furniture production. It has been employed successfully for load-bearing, supported and filler elements, as well as decoratively cut pieces.

Whether the focus is on small-scale production, creation of unique, one-off designs or industrial-scale manufacture, the choice of material is a matter of sustainability — financial, aesthetic, ethical and ecological. Sustainability considerations begin with the first production concept and continue to be present in every stage of the process from the drawing board to the finished result.

Suppliers to the joinery industry tend to be small sawmills and wholesalers. The majority of sawmill production, around 70 percent, is exported.

The sawmills seek to obtain as high a financial return as possible from the raw material. This involves getting as high a yield of sawn timber as possible out of every log, as well as sawing a high volume per unit of time and producing high quality timber at the end.

This means that it can sometimes be difficult to buy small volumes of specialist grades from large sawmills. Furniture makers often use high quality pine as their raw material, preferably free from knots and with a vertical grain.

There are small sawmills that specialise in sawing large pine logs with a large proportion of knot-free wood. It is probably easier to buy small volumes of high quality pine direct from these sawmills, or from local or national wholesalers.

3.1 Wood as a material

3.1.1 Cutting patterns and character description

Common cutting patterns

Block-sawing was once the only method used in Sweden. This involves first sawing or milling away the sides of the log. Then it is placed on one of the four flat sides and cut into planks (thickness 35 mm or more) and boards (thickness below 35 mm).

Nowadays, the profiling method mills a multi-edged block from the log and then divides it into planks and boards. The milling tool is called a reducer. The wood that is milled away becomes wood chips.

The sawing is done with either band saws or circular saws. The plank can then be split into boards for later processing.

Since different types of machinery are used to divide the log up into planks, boards, chips and sawdust, the processes are often referred to as breakdown.

The wood from the central part of the log is called the main yield. The wood from the outer parts of the log is often referred to as the side yield.

In block-sawing, the inner parts of the log are usually sawn into planks. Depending on the number of planks sawn from the log, the cutting pattern is known as 2 ex-log, 3 ex-log, 4 ex-log and so on.

To achieve a high yield of sawn timber from the log, the usual aim is for a main yield that is as rectangular as possible, for example 2 ex 50 × 100 mm.

2 ex-log

The 2 ex-log cut is commonly taken from small-diameter logs with a top diameter of 110–180 mm. It may be the butt log from a tree that has been cleared during thinning or a top log from a fully mature tree. The knots are limited in size and are usually sound, so they remain firmly in place even after drying. The pith can be seen in one flat side. It is surrounded by what is known as juvenile wood – 15–20 growth rings closest to the pith – which exhibits somewhat larger moisture-related movements.

3 ex-log

The 3 ex-log cut is commonly taken from logs with a top diameter of 190 mm or more. They could be butt logs or middle logs. With spruce the knots tend to be sound, but with pine they can be dry, known as dead knots. The knots are larger than in 2 ex-log timber. Of the three planks, the centre plank has a vertical grain, which means it doesn't bow after drying and is suitable for use in furniture. The section around the pith is juvenile wood and contains heartwood. Side boards from 2 and 3 ex-logs are entirely sapwood. The side planks may have no heartwood in them.

4 ex-log

The 4 ex-log cut is usually taken from butt logs with a top diameter greater than 230 mm. The knots may be larger than in the 3 ex-log. The inner section of the log is partially made up of heartwood with limited knot size, and this makes up part of the two middle planks. When breaking down pine butt logs, the two outer planks are likely to contain knot-free sapwood, which is suitable for use in furniture. Knot-free wood is very uncommon in spruce.

The distance between the knot whorls varies, depending on the tree's growth conditions. Spruce commonly has small pin knots between the knot whorls.

3.1.2 Material description, pine

Knot condition and knot shape

When working with wood, account must be taken of the different types of knots in the timber. These will be sound, fixed knots of a light colour, dead knots that are not intergrown into the surrounding wood, whose colour can vary from light to dark, or unsound knots. In some cases, part of the knot's bark may also grow into the tree, creating an encased knot.

Knots are formed from the growth of the tree's branches and grow out from the pith. Knots always appear radially in a log. Small knots in the wood equate to thin branches on the tree. A young tree has thin branches that end up at the top of the growing tree.

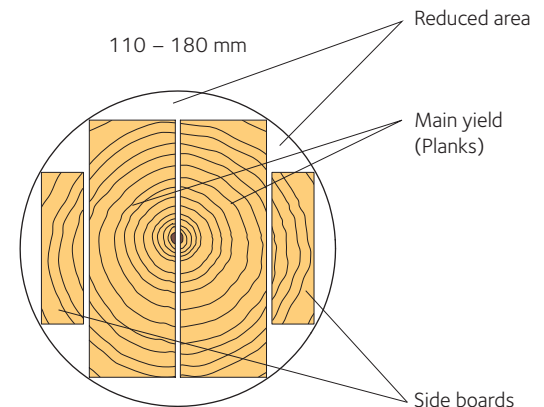


Figure 3.1 2 ex-log.

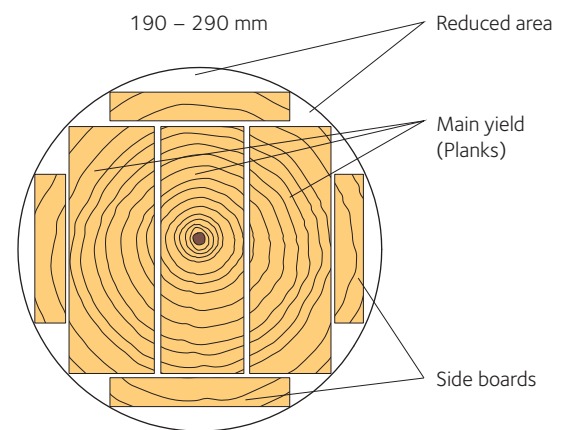


Figure 3.2 3 ex-log.

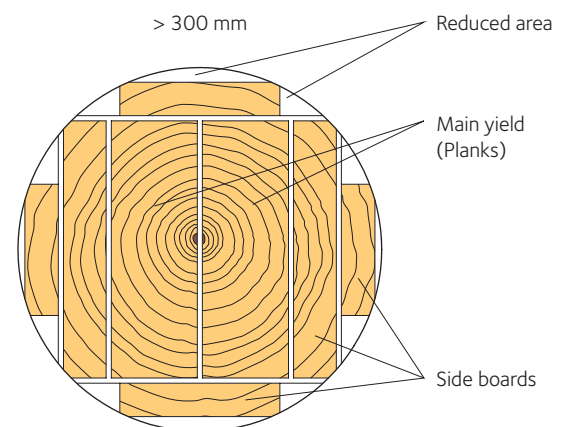


Figure 3.3 4 ex-log with centrecut.

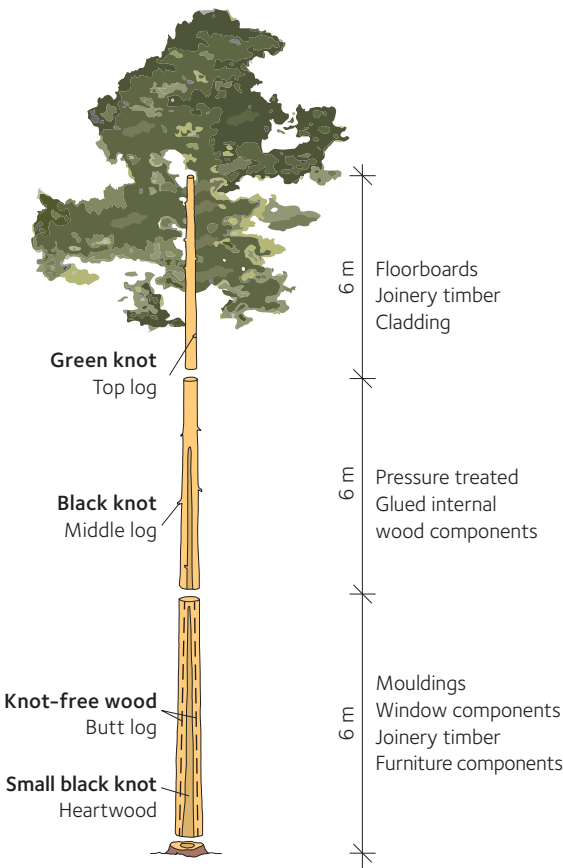


Figure 3.4 Parts of a tree

With pine, the knot pattern varies on different parts of the trunk. Generally speaking, the lower branches are the thickest and so this is where the largest knots appear on the log.

As a tree ages, the lower branches die and break off. The tree then forms new wood to seal up the wound left behind in a process known as occlusion.

In the top log most of the knots are sound. The knots are small to medium-sized, as the branches at the top of the tree are the thinnest. The yield of knot-free wood is limited. Wood from the top log is commonly used for the production of interior joinery and boards for flooring and cladding.

In the middle log, many knots will die and be grown over, but a small number of the knots may remain and they then appear as black knots. These run all the way from the core out through the sapwood. Wood from the middle log is usually used for pressure treated products such as decking, and for glued interior wood components such as edge-glued panels.

In the butt log, the inner parts always contain knots from branches on the young tree. These branches die and fall off as the tree grows. Wood then grows over the wound making this area knot-free. Wood from the butt log is used in applications such as mouldings, window components, joinery and furniture.

Knots

The way the log is sawn determines the condition and shape of the knots in the surface of the timber.

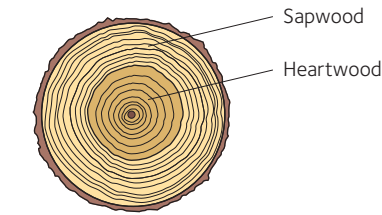


Figure 3.5 Pine

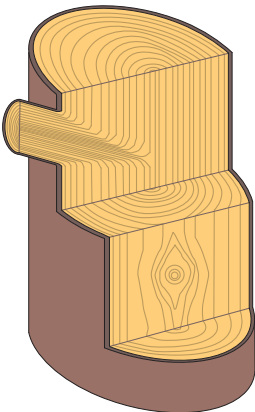
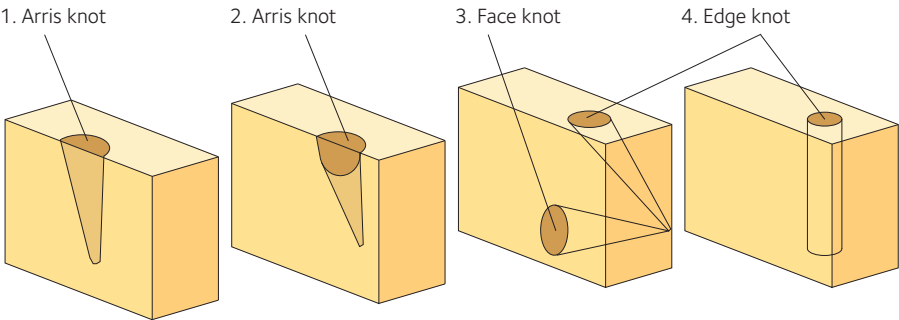


Figure 3.6 Log section.

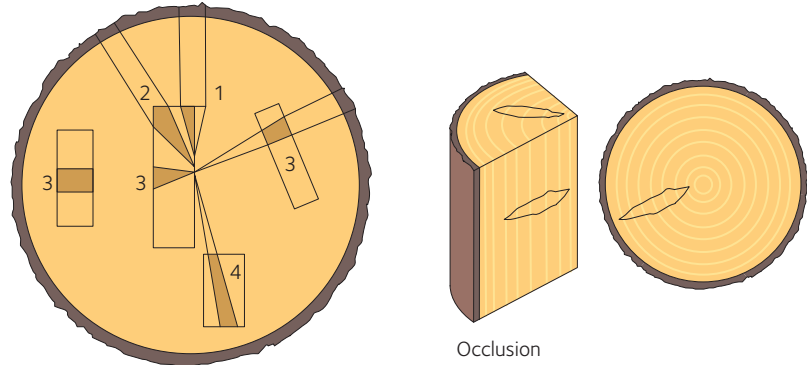


Figure 3.7 Position of timbers and knots in log cross-section

Wood with **small knots** can be obtained from a 2 ex cut of small diameter logs or the top log. Generally speaking, the smallest knots can be found in the main yield.

Large knots coupled with small ones can appear in side boards from the 3 ex or 4 ex cutting of a top log or middle log.

Almost entirely **knot-free** wood can be sourced from the side yield of a pine butt log.

Dark dead knots are most common in the middle log, where most branches have fallen off but the wood has not yet healed over.

3.1.3 Material properties of softwood

Wood is Sweden's most traditional building material. Since wood is used for a whole host of purposes — furniture, construction, exterior and interior wall cladding, fittings, floor coverings, and so on — it is important to understand how wood behaves under different conditions. Each type of wood has its typical areas of use, depending on availability and on its specific properties.

Spruce is the wood of choice for construction timber. Pine is commonly used for furniture, joinery, mouldings and internal cladding, although spruce may also be used in this context. Hardwoods such as oak and beech are used in flooring and furniture.

Material properties vary between the different wood species. Even within the same wood species, there are major variations between different locations, but also between different trees grown in the same location. There is, however, even greater variation within a single tree, for example between different heights in the tree, between wood that is close to the pith and to the bark, and between springwood and summerwood in the individual growth rings. Knots and other fibre distortions (peculiarities) also affect the wood's technical properties.

Normal variations for the properties of density, strength and stiffness (modulus of elasticity) within the same wood type with an undistorted fibre structure:

- Density ± 20 percent
- Strength ± 40 percent
- Modulus of elasticity ± 35 percent.

Due to the variation in the wood, the quotient is greater between, for example, the average material strength of wood and allowable working stress, in comparison with other construction materials.

3.2 Wood and moisture

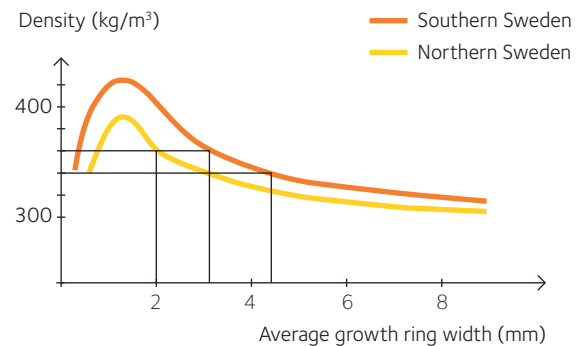
Wood is a hygroscopic material. This means that the material monitors the surrounding air humidity and temperature and constantly strives to remain in equilibrium with the local climate, i.e. the relative humidity (RH) and the temperature.

3.2.1 Moisture content

The moisture (water) content in the wood is defined as the weight of the water in damp material divided by the weight of the material in a dry state. To obtain a percentage, the result is multiplied by 100.

$$u = \frac{(\text{weight before} - \text{weight after})}{\text{weight after}} \times 100 = \text{moisture content in \%}$$

Figure 3.8 Influence of growth ring width and geographic location on basic density, in theoretical terms.



Wood from southern Sweden is generally denser, stronger and more durable than wood from northern Sweden. This is despite the fact that southern Swedish wood generally has broader growth rings than wood from northern Sweden. The reason for this is that the summerwood band, the dark part of the growth ring, is wider in southern Sweden. The summerwood, which weighs 900 kg/m³ torr ved, dry wood, is three times denser than springwood, which weighs 300 kg/m³ dry wood.

Facts Density and basic density

Density is a piece of wood's mass divided by its volume, expressed in kg/m³. This is usually stated as the basic density in the wood's dry state or for a particular moisture content, e.g. 12%.

Basic density is defined as the mass of a dry wood sample divided by the volume of the fully hydrated wood sample. The density varies from wood to wood, within the same type of wood and in different parts of the same tree.

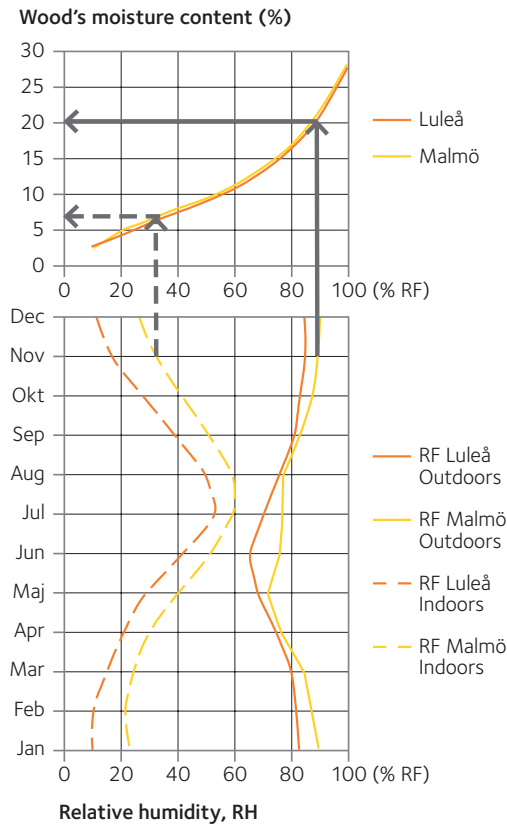


Figure 3.9 Wood's moisture content in relation to relative humidity, RH

The top section shows the correlation between ambient relative humidity (RH) and moisture content. The temperature also affects the correlation, but the effect is less than 1 % of the moisture content in the temperature range 0–20 °C.

The lower section shows the monthly average value for RH in the north of Sweden (Luleå) and the south (Malmö). The solid curves show RH outdoors and the dotted curves show RH indoors. The RH curves for indoors should be increased by around 18 % RH to account for the moisture added by a normal family (cooking, shower, laundry, breathing, perspiring and so on).

Example: What is the RH and average moisture content indoors in Malmö in November?

Following the black arrows, RH = 32 % and the moisture content = 7 %. (Outdoors, the corresponding figures are RH = 89 % and moisture content = 20 %). At an RH of around 32 %, the wood's moisture content is thus around 7 %.

The equilibrium moisture content is the moisture content that the wood has when it is in equilibrium with the local climate.

If the wood's moisture content is higher than the equilibrium moisture content, the wood will dry out and if it is lower the wood will take on moisture. When the moisture content changes, below the fibre saturation point, the wood will therefore change its volume, depending on whether moisture is being released or absorbed – the wood swells or shrinks accordingly.

Dimensions, strength and resistance to decay are examples of key properties of wood that are affected by the moisture content.

3.2.2 Relative humidity and vapour concentration

Relative humidity (RH) may also be referred to as “relative air humidity”.

The air's content of water vapour, its vapour concentration, is stated in grams water/cubic metre air and it varies over the year. Vapour concentration outdoors is at its highest in summer (9–11 g/m³) and lowest in winter (3–5 g/m³) – while RH and thus wood's equilibrium moisture content is lowest in summer (65–75 % and 11–15 % respectively) and highest in winter (90–95 % and 19–23 % respectively). Wood should have a surface moisture content of max 16 % if being given a surface treatment.

Physically, the RH figure lies between the water vapour's partial pressure and its saturation pressure at the temperature in question. The relative humidity of the air indoors in a heated room is therefore highest in summer (45–60 %) and lowest in winter (10–25 %). The colder it is outdoors, the drier the air indoors. The moisture content in wood, both indoors and out, adapts the RH and temperature of its surroundings. In heated homes in Mid Sweden, the moisture content in wood averages out the year at 7.5 %, with the highest figures in summer (7–12 %) and the lowest in winter (2–6 %). On average, it is drier in the north of Sweden than it is in the south, *see fig. 3.9*.

3.2.3 Target moisture content

Undried, newly sawn wood is usually dried to a particular target moisture content in the sawmills' drying chambers. Target moisture content describes the desired average moisture content for a batch of wood and the allowable moisture content of the individual pieces in the batch. It is defined in standard SS-EN 14298. Each piece of wood in a batch is unique and is affected differently by the drying, depending on its density, resins, storage time before drying, sawing pattern, green moisture content and so on. This means that the individual pieces in a batch of wood will have a certain range of moisture content figures, which are combined to form an average value – the average moisture content for the batch. When ordering wood with a target moisture content of 8 %, it would naturally be desirable for the average moisture content of the batch to be 8 % – and ideally for all the pieces in the batch to have a moisture content of 8 %. However, this is almost impossible. The average moisture content of a batch and the moisture content of the individual pieces are therefore allowed a certain range of variation for orders of a specific target moisture content in line with *table 3.1*, which is part of the standard SS-EN 14298.

3.2.4 Moisture content variation in the wood's cross-section

The moisture content doesn't just vary between individual pieces in a batch of wood — it also varies in the cross-section of a piece. When wood dries, it occurs from the outside in. If no special measures are taken, the inner part of the wood will therefore be much damper than its surface after drying at the sawmill. This difference in moisture content in the wood's cross-section is called the moisture gradient.

When wood has been dried down to 8% in a kiln, the surface of the wood becomes very dry, often 4–5% moisture content, while the moisture content in the middle of the wood may lie at around 10–12%. Depending on the time between drying and packaging, the outdoor temperature and relative humidity (RH), this difference in moisture content will remain in place to a greater or lesser degree.

Note that wood dried to a moisture content of 8% must be stored in a climate equivalent to the one we have in heated homes.

The evening out of the moisture gradient often takes a long time.

When a piece of wood has its moisture content measured, this is in fact a value for the average moisture content of the cross-section. The average moisture content of the wood can be measured in two ways. A very accurate way is to first weigh a piece of wood, then dry it in a kiln at 103 °C and weigh the fully dried wood again, in accordance with SS-EN 13183-1.

A more practical, but not as accurate, method is to use an electrical resistance moisture meter with insulated hammer electrodes, and to measure at a specific point and at a depth of 0.3 times the wood's thickness. This measurement is considered to be representative of the cross-section's average moisture content. *See section 3.2.6, page 30.*

A low moisture gradient is an important quality factor in preventing uneven shrinkage and bowing, for example.

3.2.5 Sawmill conditioned wood

Discrepancies between the average moisture content in a batch of wood and the target moisture content are difficult to reduce. Some improvement can be achieved by using good drying kilns and controlling them carefully, and by conditioning the wood after the drying process. It is easier to reduce the moisture content range via conditioning at a high temperature at the end of the drying process. The moisture gradient in the cross-section of the wood and the drying stresses in the wood can be reduced with correctly performed conditioning at the end of the drying process.

In addition, conditioning improves the wood's dimensional stability. Wood that is to be split at a later stage should therefore have the stresses and moisture content evened out in the cross-section. This also reduces the risk that a finished wood product will gradually distort after the drying process. Distortions caused by drying stresses can be measured in line with the standard SS-ENV 14464.

Driven by increasing customer demand for quality, the sawmill industry is now able to more clearly specify/state the wood's drying quality, not least with the help of the new standards. It is possible to specify the quality of a batch of wood in terms of:

- deviation from the target moisture content
- the moisture content range in the batch
- drying stresses (drying quality).

Table 3.1 Target moisture content.

Allowable variation for the average moisture content in line with SS-EN 14298.

Ordered moisture content (target moisture content)	Allowable variation in the timber batch's average moisture content		Allowable range for the moisture content in 93.5 % of the pieces in the timber batch	
	Lower limit (%)	Upper limit (%)	Lower limit (%)	Upper limit (%)
8	7	9	5.6	10.4
12	10.5	13.5	8.4	15.6
16	13.5	18	11.2	20.8

When measuring the moisture content of all the pieces in a batch with a target moisture content of 16%, the average value for the moisture content of the whole batch (average moisture content) is allowed to fall between 13.5% and 18% to be approved. As regards the individual pieces in a batch, the moisture content of 93.5% of these must fall between 11.2% and 20.8%.

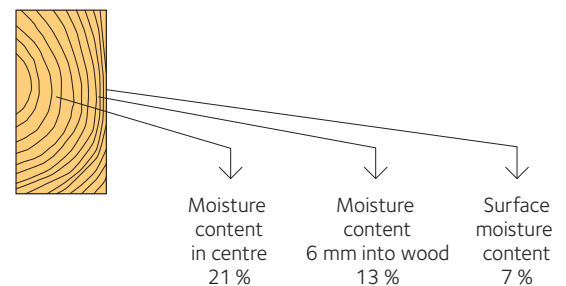


Figure 3.10 Moisture content in a length of wood after drying

The variation in the moisture content of a piece of wood at the sawmill after drying. An electrical resistance moisture meter with insulated hammer electrodes measures 16% in line with SS-EN 13183-2. The wood may be included in a batch with a target moisture content of 16%.

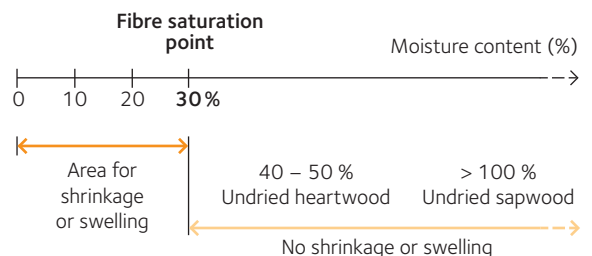


Figure 3.11 Movement in wood at different moisture contents

A rule of thumb is that if the wood has low drying stresses, the moisture content range also tends to be low.

For the joinery industry, for example, conditioned wood products are necessary in order to achieve high quality joinery products (fewer gradual deformations).

In addition to having the right target moisture content, joinery timber is also improved if the above quality parameters are used.

When buying a batch of wood, a narrow variation in the moisture content range is just as important as the batch's average moisture content being close to the target moisture content. A reduced variation in the moisture content, by conditioning the wood at high temperature at the end of the drying process, also means that the stresses in the wood will be evened out. This makes the wood more dimensionally stable and makes certain joinery products easier to manufacture.

3.2.6 Measuring average moisture content and surface moisture content

Checking the moisture content in wood involves measuring the level at different points in the structure in question. The measuring points are determined by conditions on site. Seek out the place where the risk of damp is greatest and drying conditions poorest.

Average moisture content

To measure the average moisture content in wood, random tests on a number of pieces should be conducted with an electrical resistance moisture meter with insulated hammer electrodes, to gain an indication as to whether the right moisture content has been delivered. The average moisture content of wood is measured in line with SS-EN 13183-2 as follows: measure at least 300 mm from the end. Insert the insulated hammer electrodes into the face of the wood, in the direction of the fibres, and along an imaginary line running 0.3 times the width of the wood in from the edge. The measurement depth should be 0.3 times the thickness of the wood.

It should be noted that measuring the moisture content with an electrical resistance moisture meter with insulated hammer electrodes is not an exact method, and comes with a degree of uncertainty, depending on the measuring instrument's quality and calibration. The method is, however, an effective way to get an idea of any deviations if correctly used. Regularly calibrate the moisture meter using a calibration block.

A more precise method is the aforementioned dry weight method, which can be useful for production and delivery controls, but it is not a practical method of measurement at a joinery workshop, for example.

To ensure that everyone measures moisture content and drying stresses in wood in the same way, there are now four standards:

SS-EN 13183-1 Moisture content of a piece of sawn timber. Determination by oven dry method,

SS-EN 13183-2 Moisture content of a piece of sawn timber. Estimation by electrical resistance method,

SS-EN 13183-3 Moisture content of a piece of sawn timber. Estimation by capacitance method,

and SS-ENV 14464 Sawn timber. Method for assessment of case-hardening.

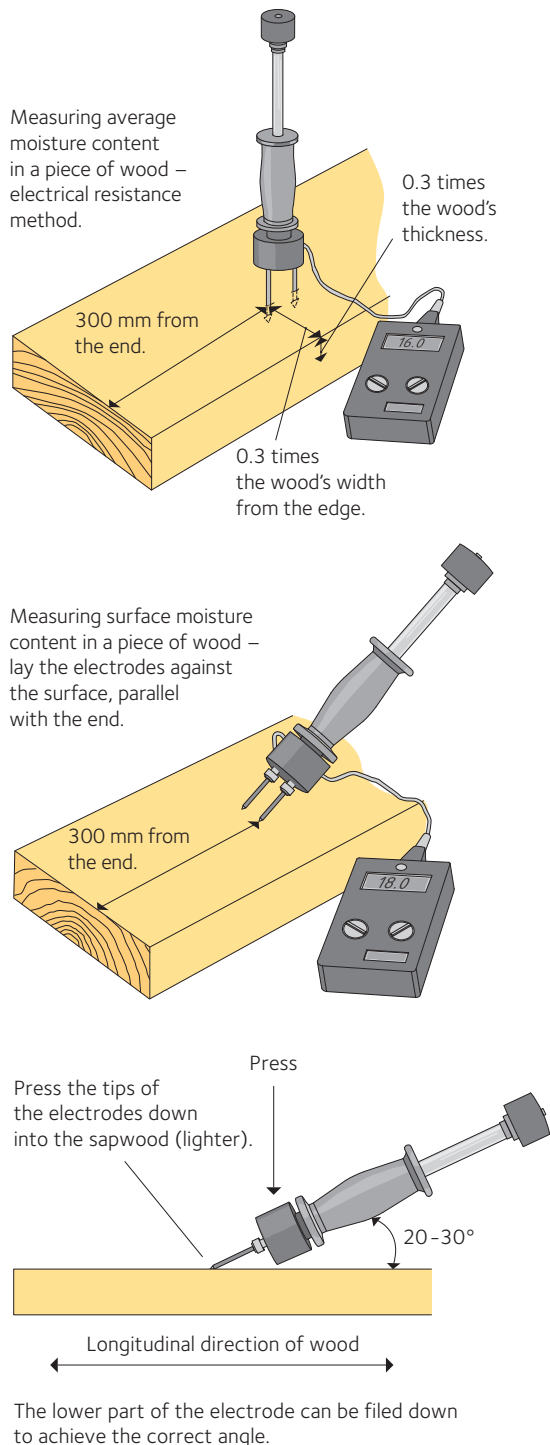


Figure 3.12 Measuring moisture content.

Surface moisture content

Measure the surface moisture content with an electrical resistance moisture meter by pressing the conical jacket of the insulated hammer electrode tips down into the springwood of the surface by hand, so that half the jacket of the electrode tips makes an impression in the wood, going across the grain. Always take three measurements close to each other at the measuring point and then work out an average. The average can then be checked against the relevant requirement.

It is important to check the surface moisture content before coating the wood, since it is crucial in determining the risk of microbial growth. It also has an impact on the adhesion of paint.

The wood may have become damp due to rain, incorrect storage or the wood being placed in contact with damp concrete, giving it an elevated surface moisture content. The moisture content in the inner part of the wood will not normally be affected by short-term exposure to damp. Wood that has become damp must be dried – naturally, with a dehumidifier or with a construction fan.

Note

There is no standard for measuring the surface moisture content of wood.

Acceptance check of drying quality

Acceptance checks have also been standardised. Two standards are used for this purpose:

SIS-CEN TS 12169 Criteria for the assessment of conformity of a lot of sawn timber.

SS-EN 14298 Sawn timber. Assessment of drying quality.

SIS-CEN TS 12169 describes how samples from a batch of wood are to be selected to check whether the ordered drying quality (average moisture content in a batch, moisture content range and drying stresses) has been delivered as per the contract or building specification. The method is based around the use of the most common control method for all industries, Acceptable Quality Level (AQL). An acceptance check involves randomly selecting a set number of sample boards or planks, depending on how many boards or planks are contained in the batch. The standard sets out what deviations are allowable, depending on the chosen quality level.

Note

The whole package must be made available for inspection in the event of a complaint.

3.2.7 Moisture-related wood movement

For floorboards and internal cladding, the target moisture content should be 8% and 12% respectively to minimise swelling or shrinkage, see fig. 3.9, page 28 and the relevant product standard.

The moisture content of undried softwood is up to 160% in the sapwood and up to 50% in the heartwood. During drying, the first water to disperse is the unbound water in the gaps in the fibres' cells. When the moisture content then reaches fibre saturation, at around 30% moisture content, the moisture in the cell walls begins to leave the wood, and this contributes to the wood beginning to shrink. The wood begins to shrink in its outer parts, before later shrinking further in. This creates seasoning checks (cracks) if the drying

Facts Moisture content, dry basis and wet basis

Moisture content (dry basis) is defined as the mass of the water in damp material divided by the mass of the material in a dry state. It is usually expressed as a percentage (%).

Moisture content (wet basis) is used in certain wood technology contexts, such as wood fuels, and is defined as the mass of the water in damp material divided by the mass of the damp material.

Around 95% of sawn wood products are now dried in kilns. Only 2% is dried in stacks at the sawmill during the summer, known as timberyard seasoning, while 3% is delivered from the sawmills undried, primarily to the furniture and joinery industry, which dries the wood itself.

The drying of newly sawn wood is the most energy-intensive step in the sawmill process. The kilns are heated primarily by burning bark and possibly shavings, while the fans run on electricity.

Table 3.2 Examples of suitable moisture contents.

Application	Moisture content
Furniture and fittings for regular heated rooms	8 %
Dowels	6 %
Windows, external doors, furniture and fittings for rooms that are rarely heated	12 %
Objects that stand outdoors under a roof	15 %

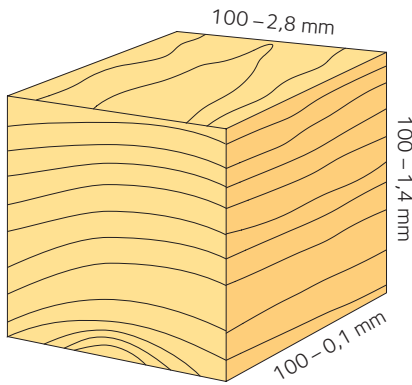


Figure 3.13 Shrinkage or swelling. Shrinkage in a cube of softwood with 100 mm sides during drying from 20% to 10% moisture content. The greatest movement is tangential to the fibres, and the least occurs parallel with the fibres..

temperature is too low or the drying happens too quickly. The shrinkage in the outer parts of the wood also causes high drying stresses, which can be reduced by introducing a conditioning phase at the end of the drying process. See section 3.2.5, page 29.

In a board or plank the growth rings are usually curved, which is why there is rarely purely tangential or radial shrinkage. A rule of thumb is therefore that the average movement (shrinkage or swelling) for pine and spruce in both a radial and tangential direction is around 0.26% per percentage point of change in the moisture content. See table 3.3, page 33 for the percentage of shrinkage per 1 percentage point moisture content change for other woods.

Example: A 95 mm wide floorboard with a moisture content of 12% is laid in a room with a climate equating to the wood's equilibrium moisture content of 8%. The change in moisture content $12 - 8 = 4$ percentage points. The board shrinks $4 \times 0.0026 \times 95 \text{ mm} = \text{approx. } 1 \text{ mm}$ in width.

The shrinkage will be half that size if the board is sawn in a radial direction rather than in a tangential direction, i.e. with vertical growth rings. Floorboard gaps will be half the size.

The delivery moisture content for the wood from the sawmill was previously around 20% for planks and around 16% for boards. This was called "shipping dry". Now the wood's moisture content is adapted more to the product or application. Since wood strives to achieve equilibrium with the air's temperature and relative humidity, the moisture content will move towards the equilibrium moisture content. This takes quite a long time.

The capacity to absorb water is different for spruce and pine. Spruce absorbs water slowly in both the heartwood and the sapwood. The absorption capacity of pine varies greatly between the heartwood and the sapwood. The heartwood of pine has around the same capacity to absorb water as spruce, while pine sapwood absorbs water many times faster. A window should therefore be made from pine heartwood. This keeps the risk of rot very low.

Shrinkage or swelling between absolute dry state and fibre saturation point (%).

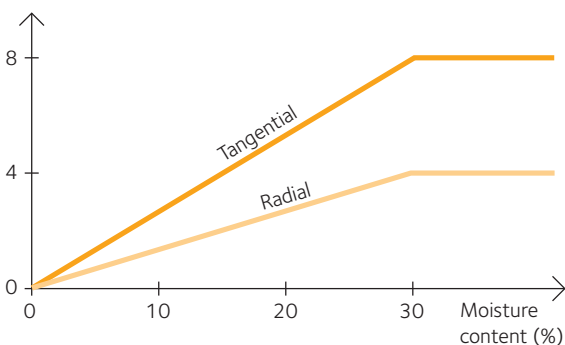


Figure 3.14 Wood movement between zero and the fibre saturation point. The movement is similar in pine and spruce when the wood swells from an absolute dry state to the fibre saturation point, approx. 30% moisture content.

Shrinkage or swelling (%).

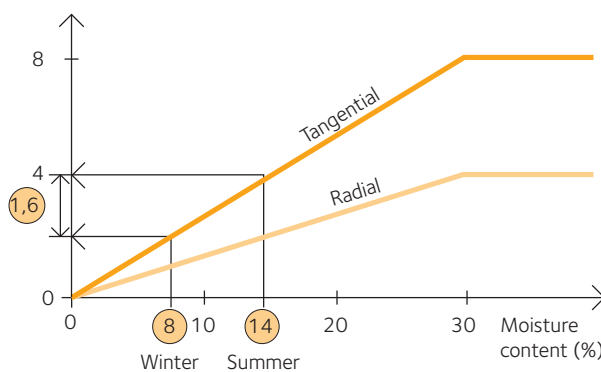


Figure 3.15 Shrinkage or swelling between winter and summer indoors.

Example: The wood's movement indoors over the year, from summer to winter, is 1.6% on average. The moisture content in the wood changes by around 6% from summer to winter, which can give a maximum movement of 16 mm/metre in a tangential direction..



These pine logs were recently felled. The left image shows the root end and the extent of the pine heartwood. The right image shows the top end and how the transport of nutrients, in the fluid which runs through the sapwood in the log, has not yet stopped.

Table 3.3 Average values for shrinkage in various wood types during drying, from fibre saturation to absolutely dry wood.

Wood type	Shrinkage				Shrinkage in percent per 1 percentage point change in the moisture content
	Fibre direction, along length of stem, axial β_a (%)	Radial direction, across the growth rings, radial β_r (%)	Tangential direction, along the growth rings, β_t (%)	Volume change β_v (%)	
Alder	0,5	4,4	9,3	14,2	0,31
Ash	0,2	5	8	13,2	0,27
Aspen	0,2	3,8	8,7	12,7	0,29
Birch	0,3	6,7	10,4	17,4	0,35
Beech	0,3	5,8	11,8	17,9	0,39
Oak	0,4	4	7,8	12,2	0,26
Pine	0,4	4	7,7	12,1	0,26
Spruce	0,3	3,6	7,8	11,7	0,26

For practical calculations, 7 % can be used as the average figure for movement in sawn pine and spruce timber, which corresponds to 0.24 % per 1 percentage point change in the moisture content.

Figure 3.16 Shrinkage or swelling in a softwood log

Shrinkage or swelling in a piece of timber varies depending on how the growth rings are positioned in the wood. The smallest dimensional changes occur in wood where the growth rings are perpendicular with the face, known as vertical grain.

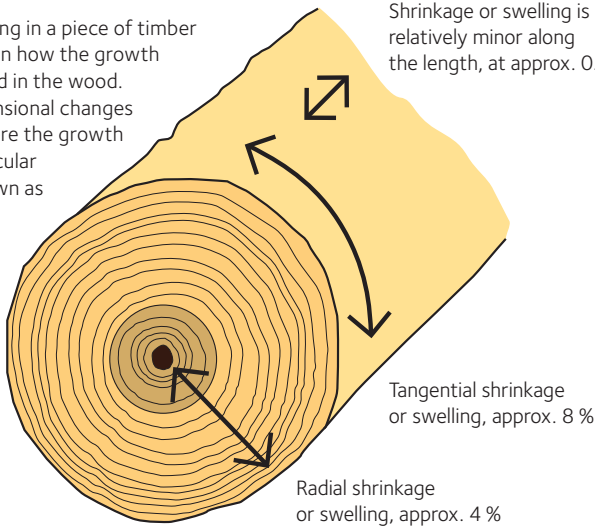
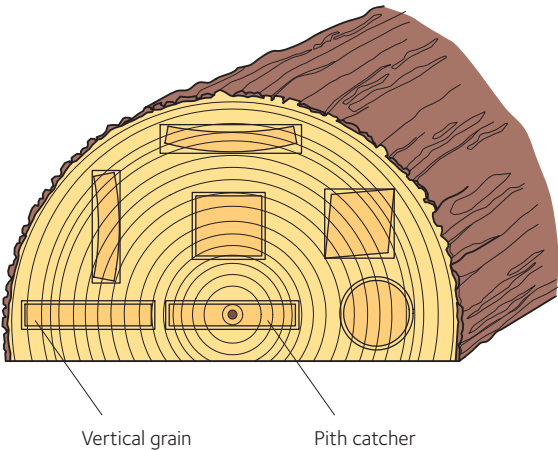


Figure 3.17 Growth ring orientation in a piece of wood





Pine edge-glued panels.

3.3 Quality and range

Some woodworkers and artisans gather their wood from the forest and work on the material in its fresh state. However, most producers and designers of products in wood choose from the range of wood offered by their supplier.

3.3.1 Wood grades, appearance grading

The grade of wood can be specified using a number of parameters, including:

Knots	Cross grain	Deformation
Checks	Top rupture	Insect damage
Wane	Compression wood	Discolouration
Pitch pockets	Wavy grain	Handling damage
Bark-encased scar	Pitchwood	Dimension
Open scars	Fungal attack	deviations.

The parameters are assessed in visual sorting, known as appearance grading. In Sweden this is usually done at the sawmill, following the guidelines in the document *Grading of sawn timber, 2019 version 1*. Builders’ merchants use the grading standard SS-EN 1611-1.

The sawmill will commonly stamp each piece of wood on the end with a shipping mark. This allows the graded quality to be checked along the chain from the sawmill to the joinery workshop. After processing, e.g. planing or splitting, these marks may be cut away or hard to identify. The grade is then marked on the packaging.

The grading of wood is a general process based on appearance. It is thus not designed to take account of the wood’s use, for example in joinery, construction or packaging.

Examples of knot types



Sound knot



Dead knot



Unsound knot



Leaf knot



Horn knot



Pin knot



Encased knot



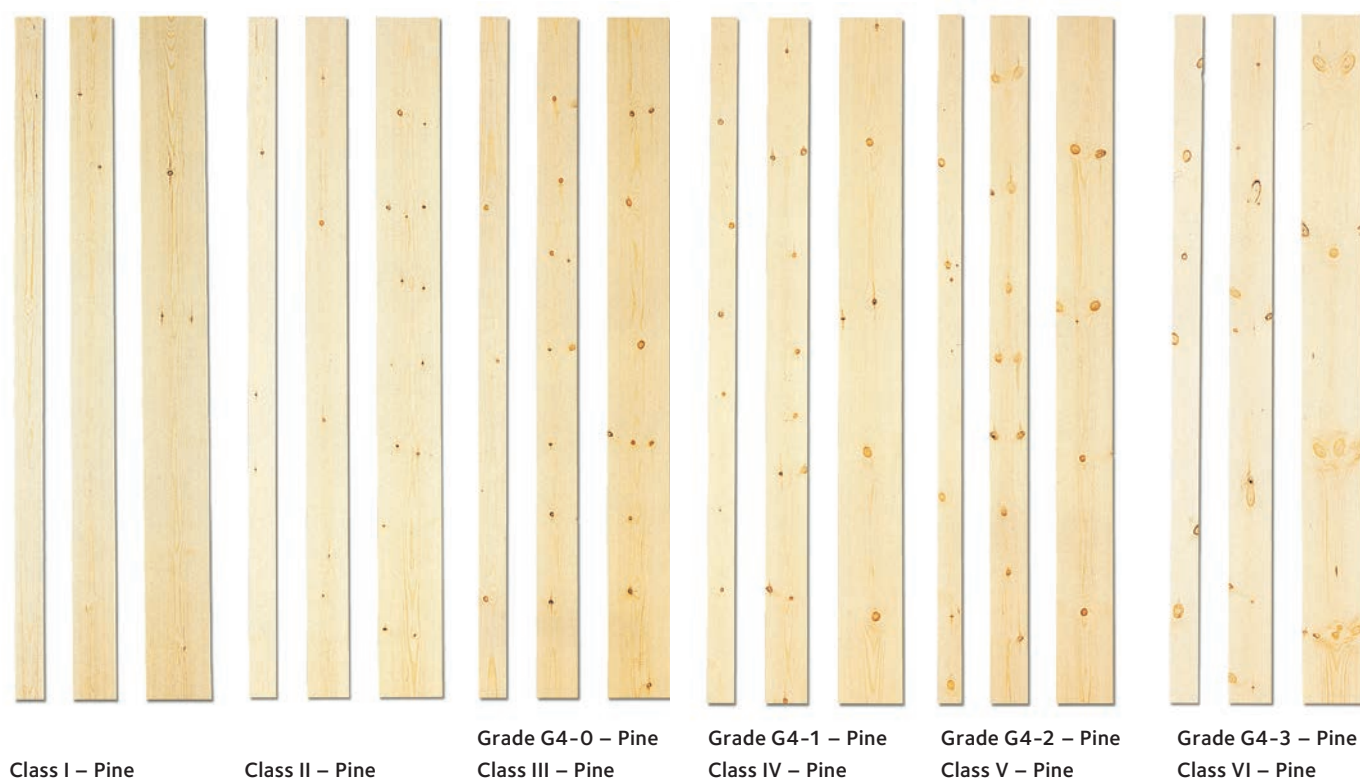
Arris knot



Knot cluster

Appearance grades – Quality classes

The wood is shown in the dimensions: 25 × 100, 50 × 150 and 75 × 200 mm



3.3.2 Regulations for appearance grading

Grading of sawn timber

Under the rules in the document “Grading of sawn timber”, wood is sorted into seven classes, with Class I representing the highest quality. Classes I–IV are usually grouped under the designation U/S, unsorted. Class V is generally referred to as fifths and Class VI is named sixths.

Facts Specialist grades

Swedish sawmills may in some cases also supply specialist grades for specific purposes. Specialist grades may include custom dimensions, moisture content and sorting parameters.

Standard SS-EN 1611-1

According to the standard for appearance grading of softwoods, SS-EN 1611-1, the grading may be performed on the faces and the edges or only on the faces. In these cases, the grades are called G4 and G2 respectively. The grading designations are followed by a number from 0–4 stating the quality of the wood, with 0 as the highest quality. A grade can thus have the designation G4-2, which means a 4-sided visual sorting of typical construction timber, corresponding to the fifth grade, V. An approximate comparison between the two sorting systems is given in table 3.5. G2 is a grade that is rarely used in Sweden.

Table 3.4 Wood grades. Common wood products with appropriate appearance grades and wood types.

Type of wood product	Grade, class	Wood type
Interior cladding	G4-1, Class IV or better	Pine and spruce
Planed wood for interior joinery	G4-1, Class IV or better	Pine
Floorboards	G4-2, Class V or better	Pine and spruce
Mouldings	A – B	Pine as per SS 232811

See also table 3.5.

Table 3.5 Wood grades. Approximate relationship between the different appearance grades – quality classes.

Grading rules	Grades – quality classes						
	U/S				Fifths	Sixths	
	I	II	III	IV	V ²⁾	VI	VII
SS-EN 1611-1							
4-sided grading			G4-0	G4-1	G4-2 ²⁾	G4-3	G4-4
2-sided grading ¹⁾			G2-0	G2-1	G2-2	G2-3	G2-4

¹⁾ 2-sided grading, G2, seldom used in Sweden.

²⁾ Most common for construction timber.

3.4 Handling and storage

Wood offers good durability — as long as it is handled correctly. To preserve the high quality of the wood until it is processed, it should be protected from precipitation, condensation, sun, dirt and ground moisture.

3.4.1 Planning and preparation

Plan deliveries to match the pace of production, order materials in batches and prepare for their delivery and storage. If the wood is stored, transported and handled so that it is not exposed to precipitation, dirt or strong sunlight, it can be supplied without packaging. If this is not the case, ensure that the wood is delivered in packaging which is not transparent.

Wood to be used in interior applications where it will be seen, such as mouldings, cladding and floorboards, must be stored in a well ventilated space with a typical indoor climate.

Choose a storage place where water will not pool under the wood. Asphalt or coarse macadam is a good underlay, as there is minimal risk of soil and dirt splashing up.

The ground should be cleared of snow. Do not place the wood where there is a risk of soiling and splashing from guttering or traffic, for example.

3.4.2 Receipt and inspection

Inspect the wood on receipt of the delivery.

- Packaging: check that any packaging is intact.
- Quantity: make a rough estimate of the quantity.
- Dimensions: check that they match the order and the delivery note.
- Quality: check the delivery and note any visible damage. Check the type and labelling against the order and the delivery note.
- Check that the wood is free from soil and dirt.
- Moisture content: check a number of pieces with a moisture meter to get an indication that the moisture content matches the order.

See also section 3.2.6, page 30.

Put in a complaint about the wood immediately if, on delivery, it has a moisture content or grade that does not match the order.

If a complaint is not registered on receipt of the goods, it can be difficult to resolve a dispute at a later date. In the event of a dispute, sampling is to be performed in line with the prevailing SIS-CEN/TS 12169, with the moisture content requirements set out in SS-EN 14298.

Note

The whole content of the wood package must be available for inspection in the event of a complaint.

3.4.3 Waste

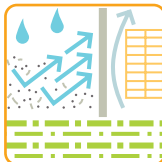
Sort wood waste as a separate category that can then be chipped and burned for energy recovery. Waste from treated wood should be handled in line with instructions from the municipal environmental office.



Protect from precipitation



Protect from sun



Protect from dirt



Check that the packaging is intact



Check the quality



Check the moisture content



Moisture meter

Table 3.6 Weight figures for handling.
Use the following weight figures when handling solid wood and glulam:

Material	Weight (kg/m³)
Spruce	approx. 470
Pine	approx. 500



Six-sided packaging



Wood for indoor use should be stored indoors



Waste

Woodworking

Woodworking involves processing wood into dimensioned pieces and production elements through sawing and planing. There are many ways of working on wood — manual and individual or large-scale and industrial. Whichever approach is taken, however, there are some features of wood that are always the same and that people have had to deal with and have explored through tried and tested experience over millennia. Even the operator of a CNC milling machine has to be aware of the material's properties.

There are machines that require manual and individual calibration and handling. Other machines are designed for large-scale and high-capacity production, and here the requirements for individual and manual assistance differ. *Sections 4.1.1, page 38, and 4.1.2, page 39*, relate to general woodworking, whether the manufacture relies on hand tools or machinery, on a small or large scale. From *section 4.1.3, page 40*, the text focuses on manufacture in machines, i.e. manufacturing processes where the principle is that the workpiece moves in relation to the tool. The different machines are presented by category: saws, planes, milling machines, drills and sanders, and within each group there is a specification of the various machines that are available for a range of specialist purposes.

4.1 Basic cutting

Whether the work involves sawing, planing, sanding or some other action, and whether the processing is manual on a small scale with hand tools or on an industrial scale, fibre density and fibre direction must be taken into account.

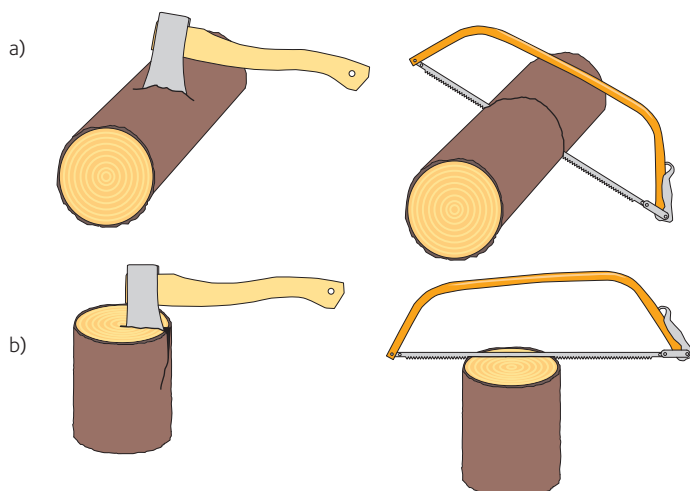


Figure 4.1 It is important to use the right tools, depending on the direction of the grain.

- a) Across the grain.
b) Along the grain.

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Knot-free pine.

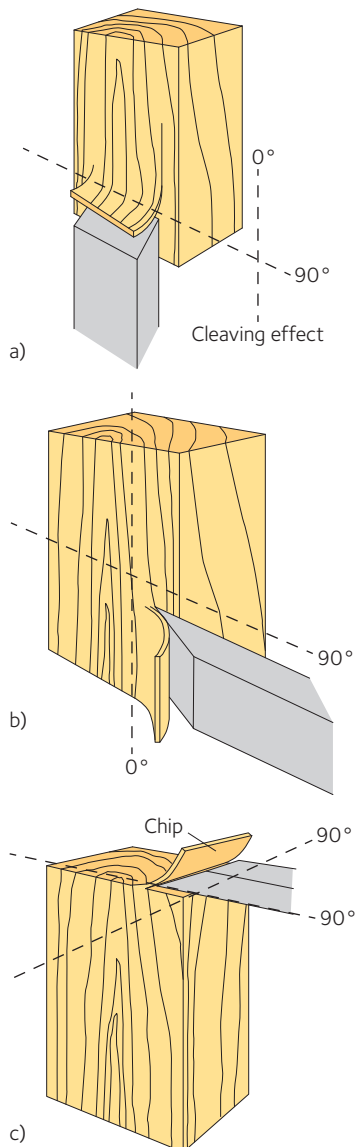


Figure 4.2 a) Cutting along the grain.
b) Cutting across the grain.
c) Cutting the end wood. No cleaving effect.

4.1.1 Different cutting directions

As we have seen previously, a piece of wood can be worked either with a rotary tool or a non-rotary tool. When cutting, it is important to take account of the angle between the cutting edge of the tool and the grain, the angle between the blade's direction of travel and the grain and the choice of material in terms of wood type. This becomes abundantly clear when you try to cut up firewood crossways with an axe, see *fig. 4.1 a)*. It is much easier with a saw.

Splitting along the grain is easy with an axe, see *fig. 4.1 b)*, and significantly harder with a saw. This is because the strength of wood varies in different directions. The growth rings also have an impact on cutting. There are basically three groups of cutting directions.

When working along the grain the tool acts as a chisel, with the wood fibres parting just ahead of the sharp edge of the tool's blade. This is called the cleaving effect. The force required to push the tool forward, the cutting force, is moderate. If the cleaving effect becomes too great, the fibres will split in the direction of the wood's growth rather than the working direction. This then gives an uneven surface with chipping. To combat chipping, fit the tool with a chip breaker to reduce the cleaving effect. If the wood grain is not parallel with the surface being worked on, it is important that the piece is fed in the direction where the grain forms an acute angle in the cutting direction, see *fig. 4.2 a)*.

When working across the grain the tool acts in more or less the same way as when working with the grain. The cutting force is lower because of wood's low strength across the grain. The cleaving effect is less, but the fibres tear at the edge of the tool. To prevent this, tools intended for working across the grain are fitted with a side cutter. The side cutter cuts the fibres at the edges of the tool a little deeper than the leading edge of the tool does. Wood with an irregular structure where the direction of growth varies is usually easier to work across the grain. This approach always produces a poorer surface, however, see *fig. 4.2 b)*.

Working across end wood requires a tool in top condition, as there is no cleaving effect to help split the fibres. The cutting forces therefore have to be stronger and the tool is subjected to harder wear. Cases where you might work end wood with a cutting tool include milling mortises and tenons for doors and windows and chiselling operations of various kinds, see *fig. 4.2 c)*.

Summary – cleaving effect

Note that:

- working with the grain requires less cleaving force and produces a smoother surface and clean end wood.
- working across the grain increases the cleaving force required and produces an uneven surface and chipped end wood.
- working across end wood does not produce a cleaving effect, a smooth surface or chipped end wood.

4.1.2 Chip breaking

The wood grain will often be distorted at least to some extent and can become twisted around knots. The result is an alternating grain direction, with the risk of tearing out fibres when working against the grain. This makes it more difficult to achieve a good cut surface. With a chip breaker, you can achieve a smooth surface even against the grain.

The same chip breaking principle that applies to hand tools can be used on machine tools, but it is more difficult to achieve small-scale chip breaking. For the shavings to be carried away on a large scale, the chip breaking needs to be bigger. The chip breaker has to fit tightly against the blade. The smallest gap between the chip breaker and the tool's cutting face will allow shavings to get caught and impede the cutting work.

Key terms

As we continue, we will be using a number of words and terms that are explained in *fig. 4.4*.

Chip cutting

For the machine tool to cut freely when forming grooves and rebates, another two clearance angles are required. This makes a total of three clearance angles. To differentiate between them, they have different names:

- radial clearance angle, *see fig. 4.5*
- side clearance
- tangential side clearance.

Another angle which may occur is the helix angle, also known as the spiral angle. This is the angle of the tracks in the groove cutters. The most important tool angles are the clearance angle, the wedge angle and the rake angle, where:

- α is the clearance angle = the angle between the flank and the cut surface.
- β is the wedge angle = the angle between the cutting face and the flank.
- γ is the rake angle = the angle between the cutting face and the normal to the cut surface.

The normal is an imagined line that forms a right-angle with the cut surface and touches the tip of the tool. It thus follows that:

$$\alpha + \beta + \gamma = 90^\circ.$$

On machine tools that rotate, the normal goes from the tip of the tool to the centre of the tool.

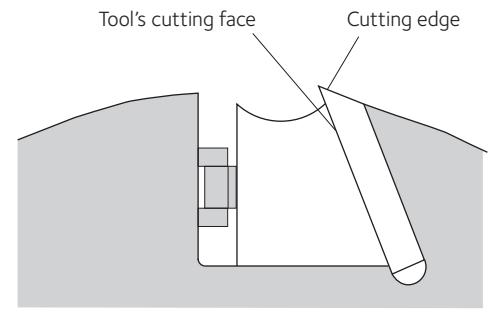


Figure 4.3 Chip breaker.

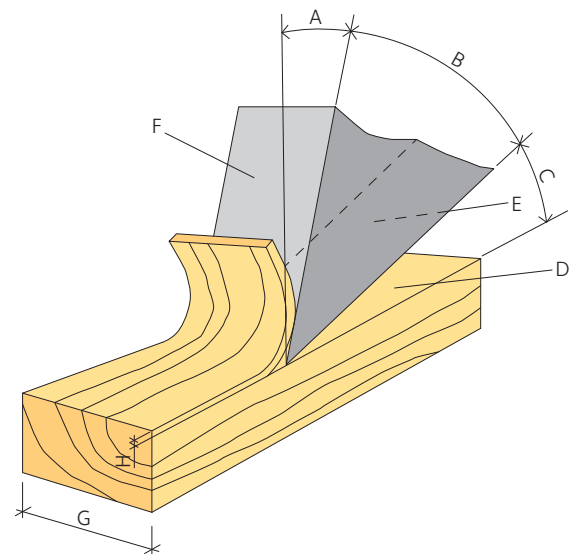


Figure 4.4 Key terms for chip-forming cutting

- A = rake angle
- B = wedge angle
- C = clearance angle
- D = cut surface
- E = flank
- F = cutting face
- G = chip width
- H = chip thickness.

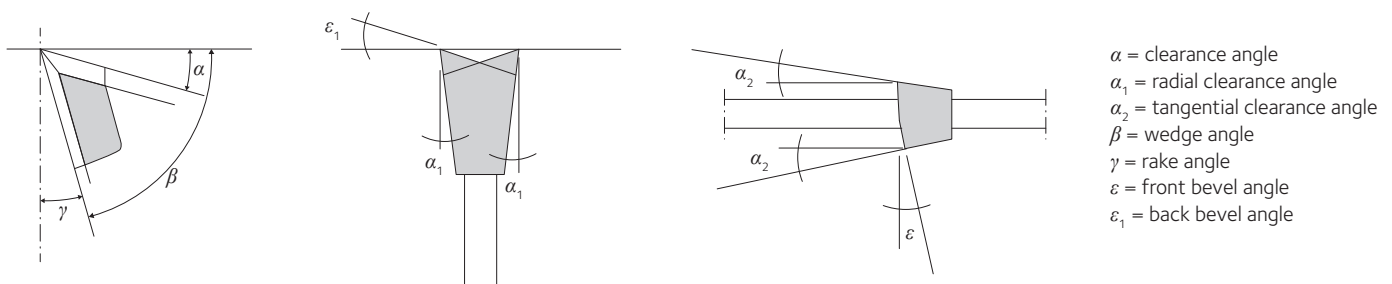


Figure 4.5 Definition of a sawtooth's cutting angles. The example shows a tooth with a soldered tip.

- α = clearance angle
- α_1 = radial clearance angle
- α_2 = tangential clearance angle
- β = wedge angle
- γ = rake angle
- ϵ = front bevel angle
- ϵ_1 = back bevel angle

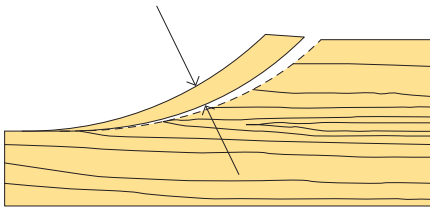
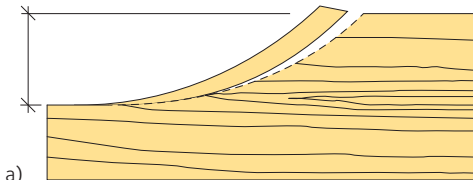
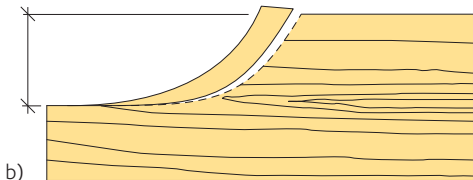


Figure 4.6 Average chip thickness.



Tool diameter = 150 mm
Cutting depth = 1 mm
Chip length approx. 41 mm



Tool diameter = 75 mm
Cutting depth = 12 mm
Chip length approx. 27 mm

Figure 4.7 Friction and wear

- a) Long chips mean that the cutting edge moves a long way through the material. This causes greater friction and greater wear on the cutting edge.
- b) A tool with a smaller diameter produces shorter chips, which is preferable if all the other cutting data is the same.

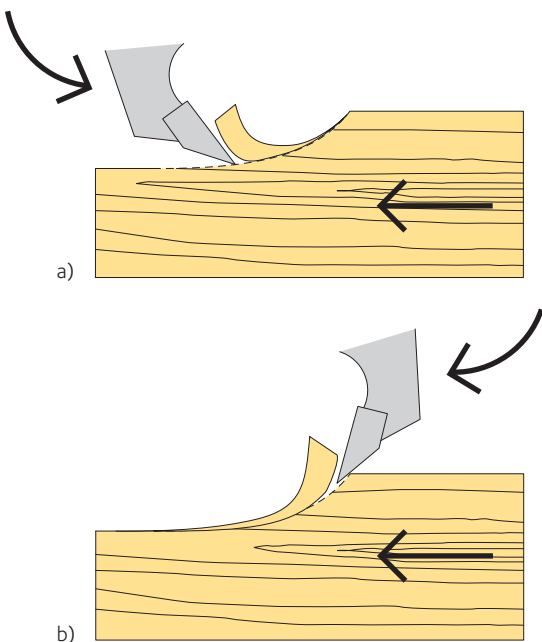


Figure 4.8 a) Counter-climb cutting, b) climb cutting.

Radial side clearance

This angle should fall in the range $0.5^\circ - 1^\circ$. Some milling bits are made without radial side clearance so that the cutting width does not change during sanding. Such a milling bit will burn easily. To avoid burning, the tangential side clearance should be slightly increased.

Tangential side clearance

The tangential side clearance is usually $4^\circ - 6^\circ$. If there is no radial side clearance, it is $5^\circ - 7^\circ$.

Average chip thickness

When a machine tool cuts a chip, it is initially thin. The thickness then increases once the cutting has properly started.

Since the chip theoretically has a wedge shape, the thickness is calculated at the middle. When we talk about chip thickness in this handbook, we mean an average value — the average chip thickness, see fig. 4.6.

Studies have concluded that the average chip thickness should not fall below 0.1 mm. If the tool cuts thinner chips, the wood will push up for much of the cutting work and create considerable friction. This will blunt the tool more quickly, as well as causing a poor cut surface and sometimes burning.

The diameter of the tool also affects the cutting work. A large diameter produces long chips and a small diameter gives short chips.

4.1.3 Feed

Feed is the speed at which the workpiece is fed past the tool. Feed is measured in m/min. A distinction is drawn between feeding by hand and machine feeding. Machine feeding usually makes use of rollers and feed mats. Obviously, machine feeding provides the smoothest and best feed, plus it is preferable for safety reasons. The feeding usually goes against the direction of the cutting edge, which is called counter-climb cutting. In rare cases, feeding with the direction of the cutting edge, climb cutting, may occur. The advantage of climb cutting is that you get fine cut surfaces, particularly when milling profiles from cross-grained wood types. The tool is keen to dig in, which causes the workpiece to buck rapidly. This entails an increased risk of accidents and so climb cutting is best avoided. In principle, you want to feed as quickly as possible. If the cutting speed and the number of cuts are increased, the feed rate can also be increased. The speed depends on how fine a surface you require. When high standards of surface quality are required, it does not make financial sense to have such a high feed rate that the wood requires extensive finishing work.

4.1.4 Cutting circle

The cutting circle is the path described by the edge of a rotating tool.

4.1.5 Cutting speed

The cutting speed is the speed that the cutting edge runs at through the tool's rotation. The cutting speed is measured in metres per second (m/s) and is dependent on the rotational speed and diameter of the tool.

The cutting speed can be calculated using the formula:

$$v = \frac{d \cdot \pi \cdot n}{60} \text{ m/s}$$

where:

- v is the cutting speed in m/s.
- d is the tool's diameter in m.
- n is the revolutions per minute (rpm).
- π is 3.14.

Example:

What is the cutting speed if the tool has a diameter of 110 mm and runs at 6,000 rpm?

$$\frac{0.110 \cdot \pi \cdot 6000}{60} \approx 34.5 \text{ m/s}$$

Large-scale production requires high cutting speeds. The focus is therefore on maintaining as high a speed as possible, while also having to take account of what the tools and machines can handle in terms of strength, stability, concentricity and safety.

It is essential to always use sharpened tools. A sharp tool:

- always gives a perfect cut surface
- in most cases ensures no tear-out
- reduces or in many cases eradicates the need for extra finishing
- makes the feed easier and less labour-intensive
- cuts the noise level
- reduces wear on all the machine's functions
- saves the company money.

Note that:

- a clean tool stays sharp for longer
- resins create a hard coating on tools, which generates high heat
- the temperature can get so high that the steel deforms in the cutting zone.

Cutter marks

All machining with rotating tools causes cutter marks. The length of the cutter marks relates to the feed per tooth and is called cutter mark distribution. You can make the cutter marks more or less visible to the eye. There are differing opinions on suitable cutter mark distribution. A smooth surface, for example, can have 0.3–0.8 mm distribution, while a distribution of 2.6–5.0 mm may be called a rough planed surface. It is naturally best if the cutter marks have a regular distribution. All the cuts should thus leave the same mark on the wood, although this is very difficult in practice. It requires the cutters to have precise rotation.

The depth of the wave depends on the diameter of the cutting circle. A smaller diameter gives a greater wave depth. If you want good surface smoothness with small cutting circle diameters, you need to reduce the cutter mark distribution.

Calculation formulae:

$$\text{Cutter mark distribution} = \frac{\text{feed [m/min]} \cdot 1,000}{\text{rpm} \cdot \text{no. of cuts}}$$

$$\text{Average chip thickness} = \sqrt{\frac{\text{cutting depth [mm]}}{\text{cutting circle diameter [mm]}}} \cdot \text{cutter mark distribution [mm]}$$



4.1 Basic cutting

Table 4.1 Guidelines for cutting speed (m/s).

Tool diameter (mm)	Revolutions (rpm)																
	1500	2000	2500	3000	3500	4000	4500	5000	6000	7000	8000	9000	10000	12000	14000	16000	18000
5	0,4	0,5	0,7	0,8	0,9	1,1	1,2	1,3	1,6	1,8	2,1	2,4	2,6	3,1	3,7	4,2	4,7
10	0,8	1,0	1,3	1,6	1,8	2,1	2,4	2,6	3,1	3,7	4,2	4,7	5,2	6,3	7,3	8,4	9,4
15	1,2	1,6	2,0	2,4	2,7	3,1	3,5	3,9	4,7	5,5	6,3	7,1	7,9	9,4	11	13	14
20	1,6	2,1	2,6	3,1	3,7	4,2	4,7	5,2	6,3	7,3	8,4	9,4	10	13	15	17	19
25	2,0	2,6	3,3	3,9	4,6	5,2	5,9	6,5	7,9	9,2	10	12	13	16	18	21	24
30	2,4	3,1	3,9	4,7	5,5	6,3	7,1	7,9	9,4	11	13	14	16	19	22	25	28
35	2,7	3,7	4,6	5,5	6,4	7,3	8,2	9,2	11	13	15	16	18	22	26	29	33
40	3,1	4,2	5,2	6,3	7,3	8,4	9,4	10	13	15	17	19	21	25	29	34	38
45	3,5	4,7	5,9	7,1	8,2	9,4	11	12	14	16	19	21	24	28	33	38	42
50	3,9	5,2	6,5	7,9	9,2	10	12	13	16	18	21	24	26	31	37	42	47
55	4,3	5,8	7,2	8,6	10,1	12	13	14	17	20	23	26	29	35	40	46	52
60	4,7	6,3	7,9	9,4	11	13	14	16	19	22	25	28	31	38	44	50	57
65	5,1	6,8	8,5	10	12	14	15	17	20	24	27	31	34	41	48	54	61
70	5,5	7,3	9,2	11	13	15	16	18	22	26	29	33	37	44	51	59	66
75	5,9	7,9	10	12	14	16	18	20	24	27	31	35	39	47	55	63	71
80	6,3	8,4	10	13	15	17	19	21	25	29	34	38	42	50	59	67	75
85	6,7	8,9	11	13	16	18	20	22	27	31	36	40	45	53	62	71	80
90	7,1	9,4	12	14	16	19	21	24	28	33	38	42	47	57	66	75	85
95	7,5	10	12	15	17	20	22	25	30	35	40	45	50	60	70	80	90
100	7,9	10	13	16	18	21	24	26	31	37	42	47	52	63	73	84	94
110	8,6	12	14	17	20	23	26	29	35	40	46	52	58	69	81	92	104
120	9,4	13	16	19	22	25	28	31	38	44	50	57	63	75	88	101	113
130	10	14	17	20	24	27	31	34	41	48	54	61	68	82	95	109	123
140	11	15	18	22	26	29	33	37	44	51	59	66	73	88	103	117	132
150	12	16	20	24	27	31	35	39	47	55	63	71	79	94	110	126	141
160	13	17	21	25	29	34	38	42	50	59	67	75	84	101	117	134	151
170	13	18	22	27	31	36	40	45	53	62	71	80	89	107	125	142	160
180	14	19	24	28	33	38	42	47	57	66	75	85	94	113	132	151	170
190	15	20	25	30	35	40	45	50	60	70	80	90	99	119	139	159	179
200	16	21	26	31	37	42	47	52	63	73	84	94	105	126	147	168	188
210	16	22	27	33	38	44	49	55	66	77	88	99	110	132	154	176	198
220	17	23	29	35	40	46	52	58	69	81	92	104	115	138	161	184	207
230	18	24	30	36	42	48	54	60	72	84	96	108	120	145	169	193	217
240	19	25	31	38	44	50	57	63	75	88	101	113	126	151	176	201	226
250	20	26	33	39	46	52	59	65	79	92	105	118	131	157	183	209	236
260	20	27	34	41	48	54	61	68	82	95	109	123	136	163	191	218	245
270	21	28	35	42	49	57	64	71	85	99	113	127	141	170	198	226	254
280	22	29	37	44	51	59	66	73	88	103	117	132	147	176	205	235	264
290	23	30	38	46	53	61	68	76	91	106	121	137	152	182	213	243	273

Cont. >>>

Table 4.1 Cont. >>>

Tool diameter (mm)	Revolutions (rpm)																
	1500	2000	2500	3000	3500	4000	4500	5000	6000	7000	8000	9000	10000	12000	14000	16000	18000
300	24	31	39	47	55	63	71	79	94	110	126	141	157	188	220	251	283
310	24	32	41	49	57	65	73	81	97	114	130	146	162	195	227	260	292
320	25	34	42	50	59	67	75	84	101	117	134	151	168	201	235	268	302
330	26	35	43	52	60	69	78	86	104	121	138	156	173	207	242	276	311
340	27	36	45	53	62	71	80	89	107	125	142	160	178	214	249	285	320
350	27	37	46	55	64	73	82	92	110	128	147	165	183	220	257	293	330
360	28	38	47	57	66	75	85	94	113	132	151	170	188	226	264	302	339
370	29	39	48	58	68	77	87	97	116	136	155	174	194	232	271	310	349
380	30	40	50	60	70	80	90	99	119	139	159	179	199	239	279	318	358
390	31	41	51	61	71	82	92	102	123	143	163	184	204	245	286	327	368
400	31	42	52	63	73	84	94	105	126	147	168	188	209	251	293	335	377
410	32	43	54	64	75	86	97	107	129	150	172	193	215	258	301	343	386
420	33	44	55	66	77	88	99	110	132	154	176	198	220	264	308	352	396
430	34	45	56	68	79	90	101	113	135	158	180	203	225	270	315	360	405
440	35	46	58	69	81	92	104	115	138	161	184	207	230	276	323	369	415
450	35	47	59	71	82	94	106	118	141	165	188	212	236	283	330	377	424
460	36	48	60	72	84	96	108	120	145	169	193	217	241	289	337	385	434
470	37	49	62	74	86	98	111	123	148	172	197	221	246	295	345	394	443
480	38	50	63	75	88	101	113	126	151	176	201	226	251	302	352	402	452
490	38	51	64	77	90	103	115	128	154	180	205	231	257	308	359	410	462
500	39	52	65	79	92	105	118	131	157	183	209	236	262	314	367	419	471

4.2 Mechanical processing

Work in the wood industry is always affected to a large degree by the properties of the wood. Wood is not homogeneous, so its properties can vary greatly within the same piece. The material that is processed in the wood industry therefore demands the right tool for the job.

Technical advances in the wood industry have taken us from universal machines with various additions and aids to more specialised machines for each stage or type of production. As the use of various sheet materials, particularly MDF and particleboard, became more common in the furniture industry, new techniques for construction and assembly were developed and so the era of flat pack furniture was born. New types of machine lines for manufacturing large series meant long retooling times and low flexibility. A common approach was therefore to produce large volumes in different dimensions and variants at the factory to be held in stock.

The cost of stockpiling gets very high, however, if you count the interest on the money tied up in materials. And then there are the considerable costs of large warehouses and material handling. To cut these costs, the trend in the industry has been towards production that is led more by actual customer orders. Under this system, small series are manufactured based on immediate market demand and the products are sent directly to the customer instead of being stored by the company.

With the rapid technical advances of recent years, the wood industry has gained tools for cutting down setup times and facilitating more flexible production.

Products with different properties are manufactured at the same time on the same production line. Computerised and automated retooling systems reset the line for the specific components to be manufactured. CNC technology and more advanced machines have also provided even better opportunities for order-led production.

The material that is processed in the wood industry demands the right tool for the job. This is as true for solid wood with its varying properties, such as hardness and resin content, as it is for sheet materials such as particleboard, MDF, plywood and surface materials such as laminate and plastic foil. The machining of wood uses various methods to separate chips from a piece of wood, which always involves a break in the material between the workpiece and the chip, whatever type of wood the workpiece might be made of.

As a heterogeneous, anisotropic material, wood differs from most other materials when it comes to machining. What this means is that the structure and strength properties of the material in different directions have a considerable impact on the cutting process and the results of machining. Different types of variations and nonconformities such as knots, splits and major differences between heartwood and sapwood also have to be factored in.

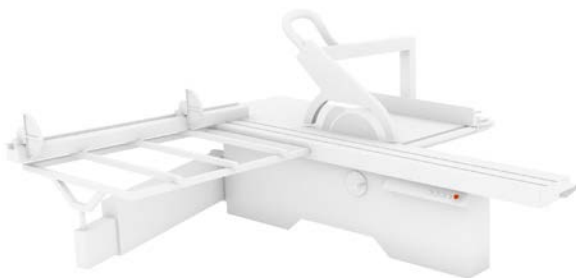
Wood can be machined in various ways, including chopping, milling, chiselling, sanding, sawing, planing, drilling, turning and cutting. This can be done using rotary tools, as is the case with machine planing, milling and circular sawing, and with non-rotary tools such as a hand tool, band saw or veneer lathe.

We have chosen to divide the stationary woodworking machines into the following main categories:

- saws
- planes
- milling machines
- drills
- sanding machines
- other machines.

Examples of saws

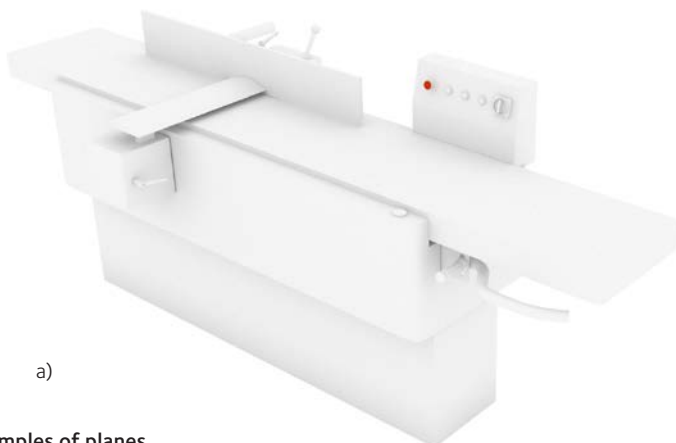
- a) Panel saw
b) Band saw



a)



b)



a)



b)

Examples of planes

- a) Jointer
b) Thicknesser



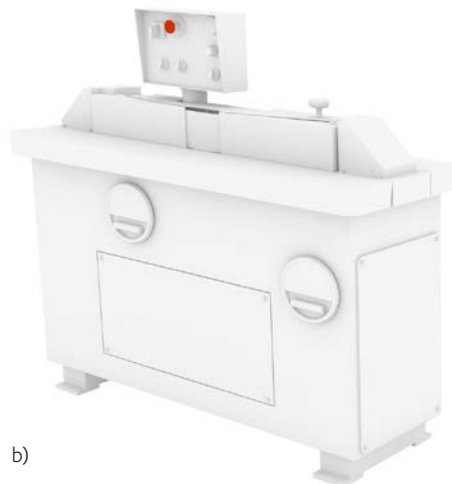
Example of a milling machine.



Example of a drill.



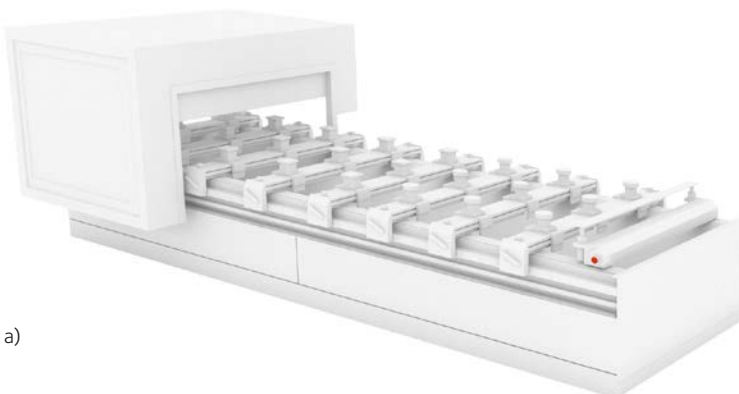
a)



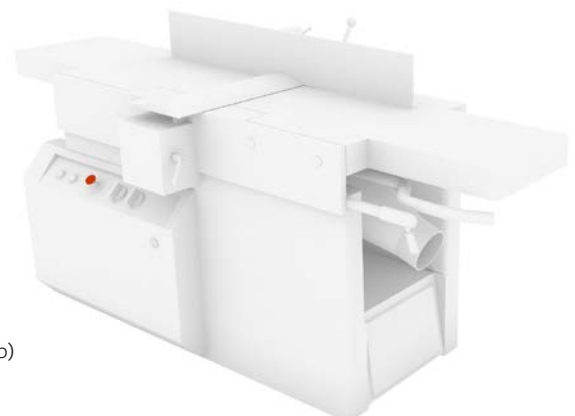
b)

Examples of sanders

- a) Wide belt sander
- b) Vertical belt sander



a)



b)

Examples of other machines

- a) 5-axis CNC machining centre
- b) Combination planing-thicknessing machine

4.3 Saws

4.3.1 General information

As a rule, sawing is the first type of machining when producing pieces for joinery production. The wood is delivered to the joinery workshop in the form of planks that are crosscut and rip sawn to the required length, width and thickness for further processing. Saws used in the joinery industry include circular saws and band saws.

A huge variety of saw blades are available for these saws, depending on the material and the nature of the required machining.

Saws for rough machining of wood:

- crosscut saw
- rip saw.

Saws for fine and precision machining:

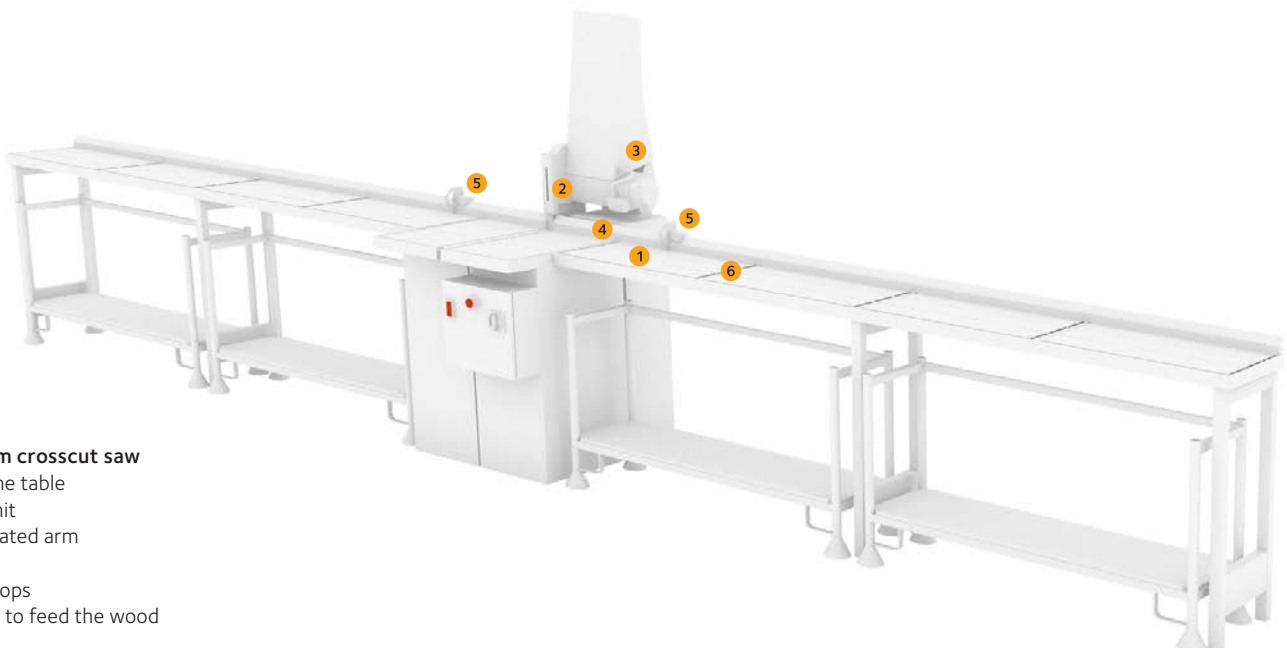
- panel saw
- mitre saw
- band saw, manual feed carpenter's band saw.

4.3.2 Crosscutting

The way the material is cut into pieces affects factors such as quality and cost in manufacturing. It is therefore important that machines and methods are tailored to the nature of the production in question.

There are different kinds of crosscut saws:

- pendulum crosscut saw
- radial arm crosscut saw
- semi-automatic crosscut saw
- mitre saw.



Pendulum crosscut saw

1. Machine table
2. Saw unit
3. Articulated arm
4. Fence
5. Side stops
6. Rollers to feed the wood

4.3.3 Pendulum crosscut saw

The pendulum crosscut saw is among the most widely used crosscut saws. The saw unit is pulled across the workpiece and towards the operator. It is designed to cut timber up to 900 mm wide. The ideal diameter of the saw blade is 400–450 mm. The blade's cutting speed is 50–60 m/s.

The pendulum crosscut saw should be fitted with the following safety features:

- fixed cover for the actual blade
- blade guard that covers the exposed part of the blade
- limiter to prevent the saw blade moving beyond the table
- noise-damped saw blade that limits the vibrations in the saw unit.

The pendulum crosscut saw may have a device that automatically returns the saw unit to the starting position once the workpiece has been sawn through.

The pendulum crosscut saw is used as a universal crosscut saw, where the demand for high capacity is not too great and the batch sizes are small. The saw may be fitted with a button-controlled compressed air cylinder that pushes the saw unit across the workpiece. This pneumatic feed makes the machine safer, easier and quicker to work with.

4.3.4 Radial arm crosscut saw

The radial arm saw is used to make long crosscuts, mitre cuts and notches in joists, for example. The saw unit can be moved over the table on an arm. In addition, the whole arm can be angled for making mitre cuts. Since the saw unit can also be adjusted in relation to the arm, there is considerable flexibility in setting cutting angles. Some radial arm crosscut saws are designed so that the saw unit goes through the kerf board at the same point, whatever the mitre angle.

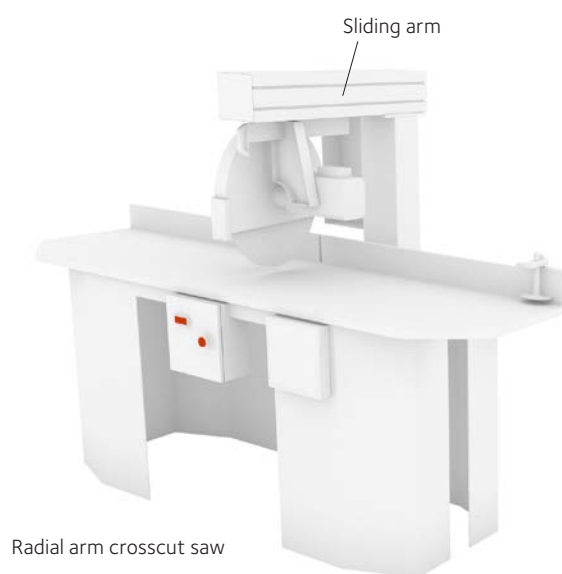
Radial arm saws come in many different variations, from small machines in bench form with a reach of 250 mm and a 70 mm cut depth to large models with multiple saw units that are sometimes combined with milling units. The largest machines have a reach of 1,500 mm and a cut depth of around 300 mm.

Radial arm saws are used for both solid wood and sheet material.

Safety

There are two major risks when working with a manual feed pendulum crosscut saw or radial arm saw: coming into contact with the saw blade and getting your hand caught between the fence and the timber. The direction of rotation of the blade is always down toward the table and in towards the fence.

Take extra care with bent timber because there is a risk of the wood binding the blade, causing the saw unit to jump towards you with force. That is why you should never stand directly in front of the blade guard on the saw unit, as that is the part of the saw unit that sticks out the most. Cupped wood is also a risk because it may be unstable. Place the wood with the convex side up so there is as much support as possible.



Radial arm crosscut saw

4.3.5 Semi-automatic crosscut saw

The design of the semi-automatic crosscut saw makes it one of the fastest and safest crosscut saws. It has a high capacity and is therefore good for cutting large amounts of wood. The wood is fed onto the saw table and automatically cut to set lengths. First clamping pistons clamp the workpiece into place on the saw table. The saw unit, which is mounted underneath the table, then moves up and cuts through the workpiece. The entire sequence of clamping and cutting is controlled automatically and manoeuvred pneumatically. Thanks to the secure clamping, a two-handed manoeuvring option is also easily installed.

Below is an example of the capacity of a semi-automatic crosscut saw with installed power of 5.5 kW:

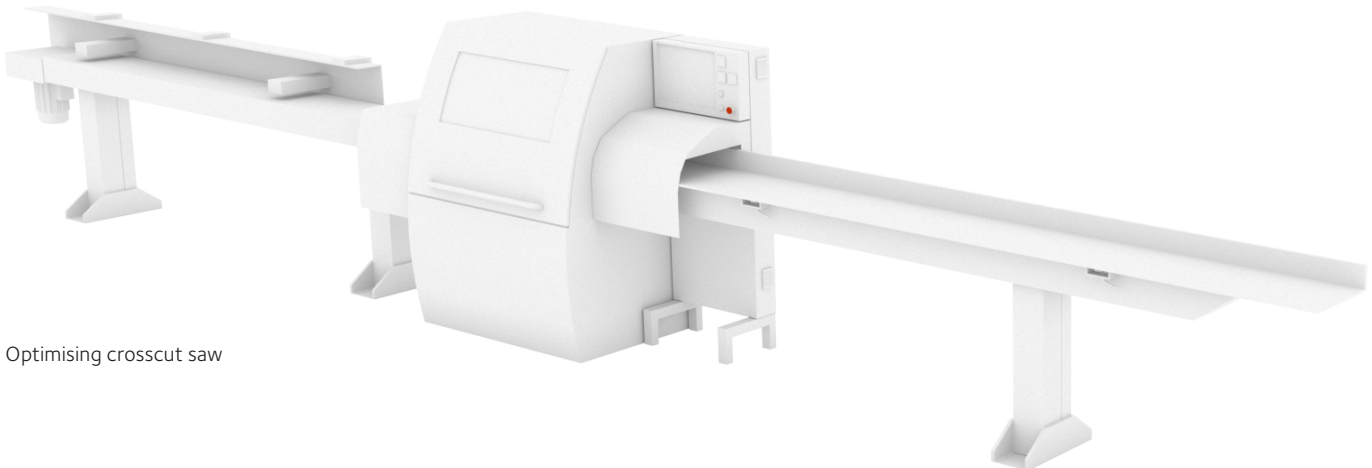
- 50 cuts/min
- maximum wood dimensions 100 × 250 mm.

Semi-automatic crosscut saws are often used on cutting lines where the cutting is controlled by a computer. It is in these setups that the high capacity of the semi-automatic crosscut saw comes into its own. Large operations use special semi-automatic crosscut saws. For manual systems, the semi-automatic crosscut saw can be equipped with efficiency aids such as pneumatic stoppers and length adjustment devices.

4.3.6 Optimising crosscut saw

Crosscutting work involves extensive calculations, which place a heavy burden on the operator. The length of each ingoing piece must be checked, the quality assessed and then the yield in each length calculated and compared with the cutting list, i.e. the wood requirement as set out in the preparatory document.

All this calculation work is built into a more advanced type of semi-automatic crosscut saw called an optimising crosscut saw. A computer takes care of all the calculations, so the operator can concentrate on the visual assessment of the input material. The operator is able to state the location of the defects in the workpiece. If there are defects that are not permitted in the product, the computer is given instructions to cut the offending section out of the length of wood.



Optimising crosscut saw

On this basis, the machine automatically measures the length of the wood, works out the optimum yield and controls the automated crosscutting.

Computerised crosscut saws generally only begin to pay their way with medium and large volumes of wood. This is particularly true where the cutting list comprises many variations and numerous short lengths.

4.3.7 Ripping

Rip saws can be roughly divided into three categories:

- rip saw
- circular rip saw (for larger dimensions)
- multi-blade circular saw.

The choice of machine is determined in part by the wood raw material and in part by capacity requirements. The wood raw material varies in dimension and quality and may be edged or unedged. You also need to take account of whether wider material will need to be ripped, since planks, for example, may be cupped and sometimes also twisted after drying. This applies in particular to hardwood grades. The wood material may also be bowed and have to be aligned to achieve the right tolerances in the end product. Another problem with ripping wood material is that it may have internal tensions. A piece of wood that initially appears straight may bow significantly after ripping.

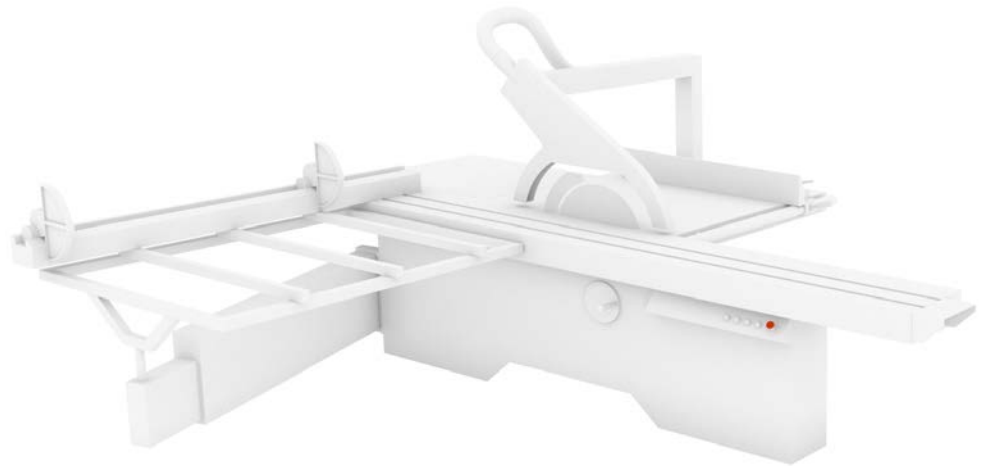
4.3.8 Rip saw

There is a rip saw in most woodworking and furniture workshops, where it is used for ripping and edging wood. Rip saws are usually hand fed or have an assisted feed function built into the table. The assisted feed function may take the form of a toothed feed chain aligned with the rip saw. When sawing edged timber, a fence is used to control the width of the piece. Part of the table can generally be moved in the feed direction. This sliding table is used for edging planks. Rip sawing solid wood can cause serious accidents if the machine is not equipped with statutory safety functions. This is because of solid wood's inclination to clamp around the saw blade, which lifts the workpiece and throws it back at high speed.

Safety

The rip saw should be fitted with the following safety features and aids:

- Upper blade guard that protects the blade above the table.
- Lower blade guard that protects the blade below the table.
- Riving knife that prevents the operator from coming into contact with the blade from behind and prevents the timber from closing onto the blade and being thrown backwards.
- A push stick is used to feed the workpiece past the blade if the operator's hands risk getting too close to the blade.
- A low fence, which is useful when handling thin mouldings, as it means the upper blade guard can be fully lowered without hitting the fence.
- Extractor to carry chips and dust away.



Panel saw

4.3.9 Panel saw

A panel saw has the same basic design as a circular saw, where the material can be controlled either by an adjustable side fence or via a sliding table. The panel saw is used to finely trim workpieces to the right length and width. The blade is height adjustable and can be tilted from 0–45°. The fence on the sliding table can be set at an angle so you can cut different angles along the length of the workpiece. To prevent tear-out on the underside of the workpiece, some panel saws are fitted with a scoring blade. This is mainly used for veneered MDF sheets, not solid wood. The blade has a small diameter and is the same thickness as the panel saw blade. The scoring blade is situated in front of the saw blade, cutting a shallow groove into the underside of the workpiece to prevent tear-out. The simple panel saw is a very universal saw and one of the basic workhorses in machining wood in small and medium-sized joinery workshops.

The panel saw is similar to a rip saw and is fitted with the same type of safety features:

- Upper blade guard that protects the blade above the table.
- Lower blade guard that protects the blade below the table.
- Riving knife that protects the rear of the blade and prevents the wood from binding the blade and kicking backwards.
- Push stick to push the wood past the blade.
- A low fence, which is useful when sawing thin mouldings, as the upper blade guard can be fully lowered.

4.3.10 Band saw

The band saw is used in small and medium-sized joinery workshops to rip and crosscut solid wood and to saw curved contours in a workpiece. There are heavy-duty band saws for rip cutting, such as industrial band saws for sawmills with a feed system.

A band saw comprises a stand that holds two wheels, over which the saw blade runs, a motor unit, blade supports, blade guides, plus a table with fences for the workpiece. The diameter of the wheels tends to be around 600–900 mm. Depending on the size of the saw and the type of sawing, a saw blade with a width of 6–200 mm may be used. Band saw blades can be made quite thin, which creates less loss of material than with circular saws of equivalent capacity. Another key property of band saws is the considerable saw depth, which means you can cut large timbers. Mobile band saws are available for sawing logs. The band saw should be fitted with the following safety features:

- wheel guards above and below the table
- a guard by the upper blade guide to prevent contact with the saw blade
- push stick
- low fence.

4.3.11 Saws combined with other machine groups

The sawing process is also included in most other machine groups, such as:

- Spindle moulder, for cutting grooves.
- Planing machines, for sawing laminates or glazing bars.
- Tenon machines, for cutting tenons to length.
- Edgebanders, for cutting edging strips.
- CNC milling and drilling machines, for cutting grooves.

Saw units can also be purchased separately for fitting to other machines.



Band saw

4.4 Planes

Machine planing involves machining with rotary tools. The tools rotate at high speed and each cutting edge removes chips from the wood at every pass. The tools in machine planes are called cutter heads. The most common types of cutter heads have four interchangeable cutter bits that do not need adjusting when changed. The bits are discarded when they wear out, rather than being resharpened.

4.4.1 General information

The wood is planed into standardised measurements. The dimension planed wood has a quadratic or rectangular cross-section.

There are a wide variety of machines for planing. Many machines are pure specialists that are tailored to a particular product. Others are standard machines that can be used for many different products. Below are a few examples of common planing machines:

- jointer
- thicknesser
- planer moulder.

4.4.2 Power consumption and surface quality

The following factors affect power consumption and surface quality when planing and milling:

Properties of the workpiece

Wood type and density

Power consumption when machining different types of wood largely depends on the material's density. High-density wood is strong. The chips are heavy and it takes a lot of force to accelerate up to the cutting speed. The power demand increases with the density.

Moisture content

At “normal” rake angles, it takes more power to machine green wood than dry wood. This is because it takes more power to accelerate through green chips than dry chips, despite the lower cutting speed for green wood. If the rake angle is very small or negative, on the other hand, dry wood requires more power than green wood.

Direction of the grain

The direction of the grain has only a small impact on cutting force and power needs.

Properties of the cutting tool

Cutting speed and cutting circle diameter

The main cutting force is constant at cutting speeds of 2 – 50 m/s. The power demand rises, however, with a higher spindle speed and larger cutting circle diameter.

No. of blades

The total power demand increases with the number of blades. The power required per planed metre depends on the feed rate per blade.

A study conducted at a feed rate of 150 m/min showed that the power demand falls when the number of blades rises from 2 to 6. The power demand then rises when the number is doubled from 6 to 12 blades. The reason for this is that if the feed rate is too small, the chip thickness becomes too small and the tool's cutting edges begin to pull towards the workpiece.

Rake angle

The power demand drops significantly when the rake angle rises from 5° up to around 20°. Beyond that, the power demand drops off slightly.

Clearance angle

The power demand falls as the clearance angle rises.

Edge sharpness

The power demand rises as the cutting edge becomes less sharp.

Width of honing plate

Try to keep the honing plate as small as possible. Otherwise the service life of the cutting edge can be drastically reduced. The true rake angle is smaller with a honing plate than without. The true clearance angle will, in principle, be 0°. The power demand thus increases with the width of the honing plate.

Blade position

The way the blade and chip breaker are positioned has a critical impact on the power demand. If a transverse chip breaker is too close to the cutting-edge, chip formation will be disrupted and the power demand will rise.

Chip breaker design

It is important that the chip breaker is correctly designed and that there is enough space for the chips. A transverse chip breaker requires more power than a concave chip breaker. The concave chip breaker sits very gently alongside the cutting edge. The design of the chip breaker and chip space becomes more important, the more chips are machined away per blade. If too many chips collect at the cutting edge, chip formation will be disrupted and the power demand will rise.

Better concentricity

A good way to achieve better concentricity, and achieve as many cuts as possible, is to have hydraulic tool tensioning. This can be achieved using either hydrocutters or loose sleeves that are fitted between the cutting tool and the spindle. Pumping in lubricant makes these sleeves expand against the spindle, removing any spin or gap.

Properties of the machine

Feed rate

If, within a range of 30–300 m/min, you increase the feed rate without increasing the feed per cut, the power demand per blade remains fairly constant. This can be achieved by doubling the number of blades every time you double the feed rate, for example. The power demand per blade rises at feed rates above 300 m/min due to the high kinetic energy in the chips.

Cutting depth

The power demand per blade increases as the cutting depth increases.

Counter-climb cutting or climb cutting

Counter-climb cutting is most common. The tool makes a longer cut with counter-climb cutting than with climb cutting.

The cutter mark depth is also less with counter-climb cutting. Climb cutting requires around 25% more power, possibly because of the thicker chips. With counter-climb cutting, the tool will often lift the workpiece off the machine table. With climb cutting, the tool presses the workpiece down onto the table. You therefore need less holding force with climb cutting.

With climb cutting, it is important that the feed system is able to brake the workpiece to prevent self-feeding. Planers and milling machines that are hand-fed should therefore apply counter-climb cutting.

It is more difficult to ensure good chip extraction with climb cutting than with counter-climb cutting.

The risk of chip marking is very small with climb cutting.

4.4.3 Jointer

The jointer is used in the joinery industry to joint and plane wood. This means planing one or two adjacent surfaces so that they are absolutely smooth and usually also at a 90° angle to each other. The process planes away cupping, warping and other defects.

Jointers mostly have cast iron stands and tables to give the machine weight and vibration-free operation.

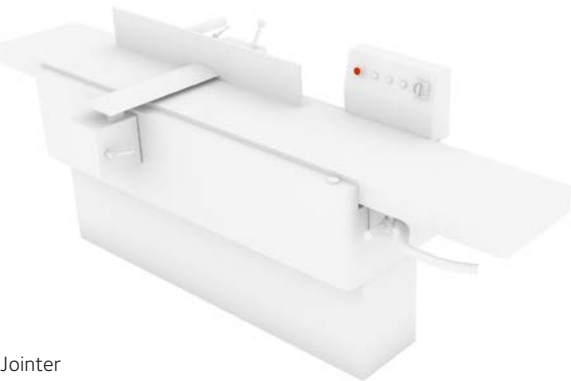
The jointer normally has a working width of 300–600 mm. The feeding table is height adjustable to set the reduction level. The simplest of all the planing machines, the jointer is made up of the following main parts:

- stand
- infeed and outfeed table
- fence and cutter.

The outfeed table must be set so that it is exactly level with the cutting circle of the cutter head. The cutting depth is controlled by raising and lowering the infeed table. On older machines, this is done by hand using a lever or foot pedal, with the setting locked manually. Newer machines have a digital display for the cutting depth or electronic settings, where you enter the value and the machine then automatically sets and locks the infeed table. It is also possible to use a special setting to prepare material that is to be glued together into edge-glued panels.

The jointer has a fence that can be adjusted from side to side so you can use the full width of the cutter head. The fence can also be adjusted to plane angles other than 90°. The jointers used in small or medium-sized workshops are often fed by hand. If planing large batches, the machine can be fitted with a feed system.

It is important to be aware that a jointer must not be operated without a SUVA type guard. Table 4.2 shows the typical machine data that applies for a normal jointer.



Jointer

Table 4.2 Typical machine data for a normal jointer.

Machine data	
Total table length	2.2 – 3.0 m
Working width = cutter width	400 – 600 mm
Cutter diameter	approx. 100 mm
Cutter speed	4,000 – 5,000 rpm
Number of blades in cutter head	2 – 4
Motor power	3 – 4 kW

4.4.4 Thicknesser

The thicknesser has a cutter mounted above the table and the distance between table and cutter determines the thickness of the workpiece. The workpiece is fed past the cutter by two rollers, an infeed roller before the cutter and an outfeed roller after the cutter. The infeed roller is often split into sections with sprung rings in order to be able to feed workpieces of slightly varied input dimensions. Two pressure plates sit on each side near the cutter. The front plate holds the workpiece down against the table and also channels the chips away. The rear plate prevents the ends of the workpiece from being kicked back into the cutter before the outfeed roller engages. If the front pressure plate is correctly designed, it can prevent the wood from splitting in front of the cutter.

The table is fitted with freewheeling rollers that reduce the friction between table and workpiece.

A thicknesser generally has a range of feed rates for mechanical feeding through the machine. Most modern machines are built for a working width of 630 mm.

A thicknesser is used to plane a workpiece to particular thicknesses or dimensions. The input workpiece should have a flattened side, which is placed face down so that the cutter planes the upper face of the wood. The thickness is controlled by raising or lowering the infeed table.

It is important to check the dimensions of the workpiece before planing, so that the cutter does not cut too deeply into the wood. Otherwise there is a risk of the workpiece sticking in the machine. The maximum cutting depth usually falls within the range of 5–9 mm.

An anti-kickback mechanism is an essential safety feature on all thicknessers, preventing the cutter from forcing the workpiece backwards in the machine.

Newer machines often have mechanical thickness adjustment, where the value is programmed in and then the machine locks to that setting automatically.

Another option on the market has a fixed infeed and outfeed table. The cutter then works from above and is height adjustable on a four-column cranking system. A constant table height makes it possible to fit infeed and outfeed tables to the planer. Listed in *table 4.3* is the typical machine data for a normal thicknesser.

4.4.5 Planer moulder

The machine is used by planing and joinery workshops, timber yards, house fabricators and builders' merchants, primarily to produce interior and exterior cladding, as well as windows, doors, mouldings and construction timber such as beams and joists. The machine is mainly used where it is necessary to produce large volumes.

The planer moulder can be described as a planer-thicknesser and spindle moulder in one. Built up in modules, it has cutter heads on the top and bottom, and profiling tools on the sides. The usual configuration is to have two or three different parts, with a total of 4–9 spindles, for example in a 3 + 2 + 2 formation, which achieves planing on both faces and sides, after which come 1–3 profile millings.



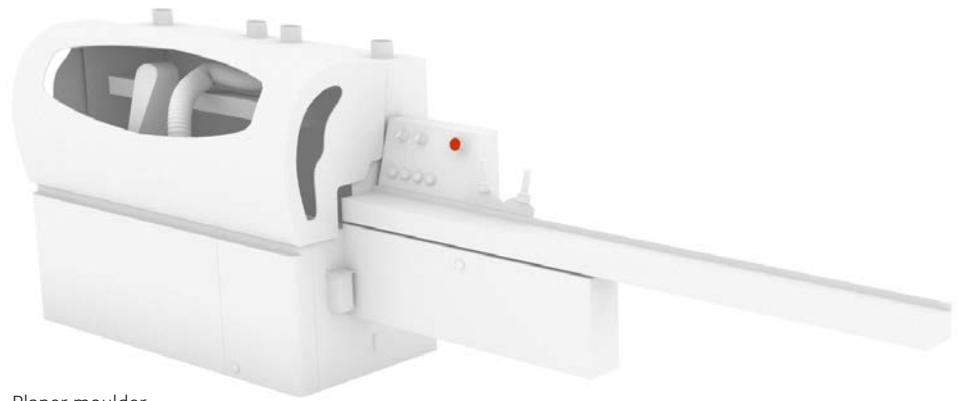
Thicknesser

Table 4.3 Typical machine data for a normal thicknesser.

Machine data	
Planing width (some machines have planing widths of up to 1.5 m)	500 – 800 mm
Maximum thickness of workpiece	200 – 300 mm
Minimum thickness of workpiece	1 – 3 mm
Table length	1,000 mm
Cutter diameter	120 mm
Cutter speed	4,000 – 6,000 rpm
No. of blades	2 – 4
Feed rate	6 – 20 m/min
Motor power	3 – 4 kW

Normal $\alpha + \beta + \gamma = 90^\circ$.

Cutting speed $v = \frac{d \cdot \pi \cdot n}{60}$ m/s



Planer moulder

A planer moulder has an infeed mechanism with different speeds, depending on the type of wood to be planed and the quality requirements. The speed of the machine's infeed varies from 6 – 150 m/min, depending on the quality requirements, from lower speeds for furniture details to higher speeds if you are planing joists, for example. Lower infeed speeds give a smoother surface.

The speed is measured in metres per minute. High-speed planers run at around 300 m/min and some specialist planers can get as fast as 1,000 m/min. The limit is set by the peripheral equipment. A machine that pumps out 1,000 m timber per minute will mostly be producing rectangular lengths.

The working width refers to the width of the processed wood when it comes out of the machine. There are larger machines that plane sheet material and glulam. These machines have a working width of 200 – 600 mm.

The planer moulder is often placed together with an infeed table that carries the raw material into the machine.

The machine is encased to prevent contact with moving parts and to reduce noise levels. If any part of the case is opened during operation, the machine is designed to stop.

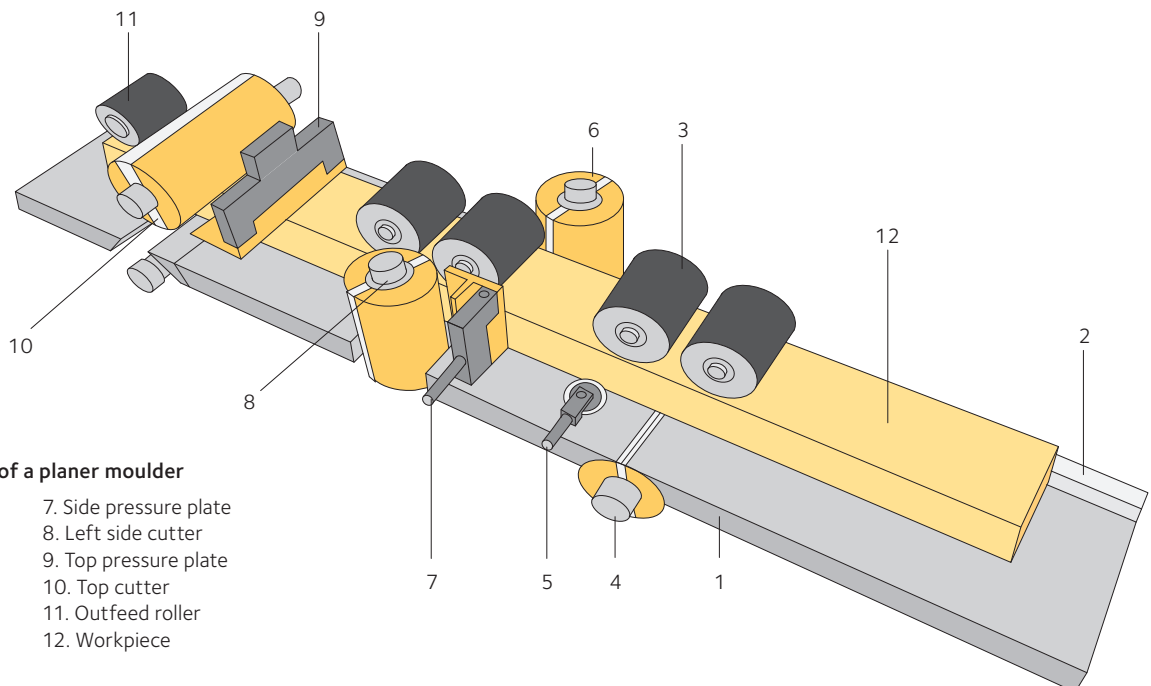


Figure 4.9 Key parts of a planer moulder

- | | |
|----------------------|------------------------|
| 1. Infeed table | 7. Side pressure plate |
| 2. Fence | 8. Left side cutter |
| 3. Infeed roller | 9. Top pressure plate |
| 4. Bottom cutter | 10. Top cutter |
| 5. Pressure roller | 11. Outfeed roller |
| 6. Right side cutter | 12. Workpiece |

4.5 Milling machines

The milling task is often included in other machines, such as edge-banders, edging lines, planers and CNC drilling machines. There are also milling units of various kinds that can be added to other machines or built into specialist machines.

4.5.1 Basic types and designs

Milling is a broad term for a range of actions, which can be split into several areas and different types of machine. The most common milling machines divide into the following groups:

- spindle moulders
- CNC machines.

Many factors come into play when choosing the type of machine. It roughly comes down to the size of the series being produced and the total volumes. Simple “straight” milling operations can often be carried out directly in a planer moulder at the same time as the dimension planing, saving on a whole milling stage. It is important to make the most of such a simple saving on the machining process. To help with finding shortcuts to savings, an operational schedule can be drawn up to show which tasks are to be performed.

Tools

The tools for milling may be fixed or adjustable cutter heads, discs for milling deep slots, saw blades and router bits of various designs. Fixed cutter heads are available with fixed or interchangeable blades that either make straight cuts or all sorts of different profiles. Adjustable cutter heads can be used to mill chamfers at various angles, but also come in straight form to cut grooves. Several cutting discs can be used on the same spindle, separated by spacers, to mill box joints with multiple profiles. Saw blades can be used to mill narrow grooves or slots.

Some milling machines come with a set of tools designed for a specific purpose, such as window manufacture.

Router bits are used primarily for milling in CNC machines and when high speeds of 12,000 rpm or more are involved. Some spindle moulders have the option of mounting a high-speed router spindle with a collet chuck for router bits.

4.5.2 Spindle moulder

The spindle moulder has the widest range of applications of all the woodworking machines. It can be used for many different tasks, including milling all sorts of profiles on straight and curved workpieces. The spindle moulder can carry out practically every kind of milling, if you use the extensive selection of accessories for the machines. The spindle moulder is used in both the furniture and the joinery industries.

Table 4.4, page 58 shows the typical machine data that applies for a normal spindle moulder. The most common machine type has a vertical height adjustable working spindle. Some spindle moulders have a spindle that can be tilted to angles of $+45^\circ - 10^\circ$, for example. One advantage of the tilted spindle is that you can use simple standard cutting tools to mill complicated profiles or to achieve better cutting conditions when producing chamfers and so on.



Spindle moulder

Table 4.4 Typical machine data for a normal spindle moulder.

Machine data	
Table size	1,000 × 1,000 mm
Spindle diameter	30 – 35 mm
Height range of spindle	approx. 120 mm
Tilt	0 – 45°
Spindle speed	2,500 – 10,000 rpm, 4 – 5 steps
Motor power	3 – 10 kW

Many special versions of the machine have been developed over the years, such as spindle moulders with two working spindles for up milling and down milling or to carry out two tasks in a row.

There are spindle moulders with four or six spindles in one tool changer for quick tool replacement. It is faster to change the whole spindle than to change the actual tool and it makes for greater precision.

A spindle moulder with a height adjustable spindle can have space for up to eight tools, which are mounted above each other on a tall spindle. The fence is positioned at the same time as the tool, when the programmed tool setup is engaged. The main parts of the spindle are:

- cast iron stand
- cast iron table
- rear and front fence, individually adjustable
- spindle whose speed can be varied and direction of rotation changed.

It is important that the machine is fitted with full guards that don't get in the way of the work, as many hand injuries have occurred on spindle moulders. To reduce the risk of accidents and increase the quality of the milling work, a feed system should be used wherever possible.

The development of CNC technology and shorter retooling times have also been good for the traditional spindle moulder. There are machines with up to around 1,000 programmable positions and automatic settings that make the spindle moulder a highly efficient machine in smaller companies and at specialist joinery workshops.

4.6 Drills

Drilling holes is a common operation in the wood industry. Drilled holes are needed for various joining methods, such as tenon, screw and bolt joints and for fittings.

4.6.1 Basic types

In the window and door industry, the various components are assembled with the help of tenons that are produced using a tenon milling machine or tenon cutter. The tenons are designed to fit into long holes that are cut using a slot mortising machine or mortise drilling machine. Loose tenons, known as dowels, are also used.

Another common drilling operation is drilling out defects such as knots. This task is usually performed using a regular drill or a special knot repair machine. You drill out the bad knot using a special knot remover and then you glue in a wooden dowel that you cut out of the same wood with a tenon milling machine.

Long rectangular holes are produced using a mortiser. In this case you talk about mortising a hole rather than drilling it. With large production volumes, special machines are used to drill and create rounded and rectangular holes for fittings. Sometimes mortise drilling or milling and drilling operations are carried out at the same time in a CNC drilling and milling machine.

4.6.2 Drill press

The drill press is the simplest and most basic drilling machine and its versatility makes it a feature of practically every joinery workshop. The machine, which comes in floorstanding and bench versions, can also be used to drill into steel and other metals and into various plastics. The drill press usually operates at speeds of 100–3,000 rpm, powered by a 0.5–1 kW motor. Stepless control is sometimes used for the drill speed, but it is more common to have gears that can be changed via the gearbox. The drill press usually has a manual feed, plus an adjustable stop that controls the drilling depth. It may also be fitted with a pneumatic feed, which makes the machine significantly faster. The table is vertically and horizontally adjustable, and sometimes also tiltable for drilling at an angle. Some professional drills, radial arm drill presses, have a particularly large distance between pillar and chuck to allow large workpieces to be machined.



Drill press

4.6.3 Knot remover

The knot remover is a kind of drill press that is used to repair defects in wood by drilling out bad knots with a special bit (15–40 mm). The drill hole is then plugged with glue and wooden dowels produced using a plug cutter. The knot remover differs from the drill press in that it has multiple spindles of varying drilling diameters to match the dimensions of the knots. There are also large automated knot repair machines on the market that carry out the entire repair process in sequence.

4.6.4 Dowel drill

Dowels are the dominant method of joining pieces of wood when manufacturing storage furniture. Dowels are loose round tenons made of wood, usually birch, that have a lower moisture content to facilitate their expansion. The dowels are compressed and given a ribbed surface to more easily carry the glue all the way into the drilled hole. The glue in turn makes the dowels swell once they have been pushed into the dowel hole. The dowels are chamfered at the ends for ease of insertion, and they are commonly made in diameters of 6, 8, 10 and 12 mm and lengths ranging from 25–50 mm.

As joining components, dowels are used in practically all furniture types, from cupboards to tables and chairs, in both small workshops and large factories. Specialist machines have therefore been designed to handle both drilling the holes and gluing the dowels. The most common drilling machine is the one with a drilling unit that drills a large number of holes in a single operation.

A dowel drill generally has a drilling head that can be moved from a vertical to a horizontal position. The drilling head normally comprises 18–29 spindles. The centre spacing between each spindle is 32 mm and this standard measurement should be used as far as possible when designing products. This type of drill is also used to drill holes for fittings.

The machine is fully automated. After setting it up, all the machine operator has to do is move the workpieces onto and off the table, as well as pressing a foot pedal to launch the following sequence:

1. The two clamps hold the workpiece in place.
2. The drilling head begins.
3. The drilling head returns to the start position.
4. The clamps release the workpiece.



Dowel drill

The drilling head's movement in and out is aided by a pneumatic cylinder, but to keep the movement smooth, there is also a hydraulic brake cylinder. This can be adjusted to the required speed in and out. The clamps are also pneumatic.

Different drilling methods:

- The dowel drill can perform vertical drilling, which means that the drilling head is dropped down and works from below.
- With horizontal drilling, the drilling head is fully extended and works from the side.
- When drilling at an angle, the head is tilted down, for example at 45°.

4.6.5 Mortise drill

The mortise drill is used primarily to drill long mortises for joints in furniture and fittings.

The machine has a horizontal rotating spindle that moves sideways, either manually or automatically with a forward and return movement. The tool, which is fitted with side-cutting bits, is fixed onto the end of the spindle with a chuck or clamping sleeve. The spindle is fed into the workpiece to the desired depth, manually or in a continuous work cycle. The dimensions of the drilled hole are determined by: width — the radius of the tool, length — the sideways movement, depth — the spindle feed. The workpiece is fixed in place on a table fitted with stops, so that the piece is always placed in the same position.

Depending on the design of the machine, the feeding movement in different directions may be performed by moving either the table or the spindle. The same is true for the settings for the positioning of the hole on the workpiece.

Mortisers

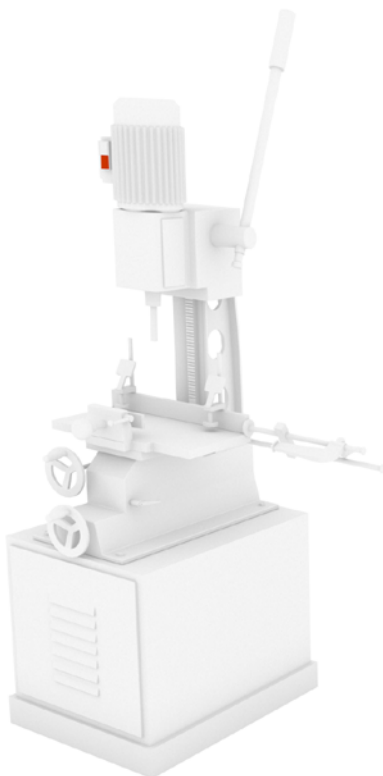
Mortises are square or rectangular holes cut out of the wood for a tenon or to take fittings, lock cases and so on. There are different kinds of mortisers.

The machines are used in more or less the same way, but the capacity of the different machines and the quality of the result vary.

4.6.6 Hollow chisel mortiser

The hollow chisel mortiser is the oldest kind of mortising machine. It does not have a very high capacity and is therefore mostly used in artisan production. The machine is basically like a powerful drill press with a special drill bit enclosed within a square chisel that drills a quadratic hole. A rectangular hole of the required dimensions can be obtained by drilling several square holes in a row.

The width of the hole is determined by the dimensions of the hollow chisel, which is usually measured in inches from 1/4" — 1", or around 6—25 mm. The length of the hole is determined by setting the stops that control the machine table's sideways movement. A lever controls the drill and the table is manoeuvred from the side with a wheel. The disadvantage of this method is that the hole's sides and particularly its base have a poor surface finish. The reason for this is partly that the chisel's cutting edges are pushed slowly at a right angle to the grain and into end wood, and partly that the drill goes a little deeper than the hollow chisel at the bottom of the mortise.



Hollow chisel mortiser

4.6.7 Chain mortiser

The chain mortiser is used to produce large-scale mortises. It differs from a hollow chisel mortiser only in the design of the cutting tool. This comprises an endless, toothed steel chain that runs over and is controlled by a chain tensioner. The machine is used to cut long, deep notches and is used primarily in industries that focus on timber framed buildings.

To make the cut, the tool support lowers the rotating chain down into the workpiece, which is clamped in place on the work table. The table can be adjusted vertically and horizontally, and can also be tilted.

An important feature of a chain mortise is the foot that pushes down on the workpiece at the edge of the notch, on the side of the hole where the chain lifts up from contact with the workpiece. The task of the foot is to prevent the wood from splitting at the edge of the notch. A chain mortiser will normally have a power rating of 1.5–4 kW and operate at around 2,800 rpm.



Chain mortiser

4.7 Sanders

All flexible sanding materials are made up of three components — abrasive, backing and binder. All three components can be varied and combined to give each product its specific characteristics to suit different sanding operations and machines.

4.7.1 Cutting process when sanding wood

The cutting process for most sanding operations involves working parallel with the grain, as this is the easiest way to achieve a fine surface. Flexible sanding materials is the collective name for sandpapers or sanding sheets that are used by hand, in handheld machines or in stationary machines.

4.7.2 Sanding materials

Backing

The backing is paper, cloth or a combination of the two. Different paper thicknesses are identified with letters from A to F, where A is the thinnest type. The combination is used when a strong and non-elastic material is required. Cloth provides good strength and bending properties. The binder comprises animal-based glue and plastic glue. The grit is mainly aluminium oxide and silicon carbide, both of which are synthetic and extremely hard materials. Silicon carbide is almost as hard as diamond.

Grit size

The grit is sifted into set grit sizes, which are described by a grit designation. These grit designations are internationally standardised. Each number represents a set number of holes per inch in the sieve. The higher the grit designation, the finer the grit, as shown in *table 4.5*.

In normal cases, you would choose two grit size intervals, such as 80 and 120, between sanding operations. That way the finer sanding belt will be able to remove the scratches from the previous process.



Sanding belt

Table 4.5 Grit size.

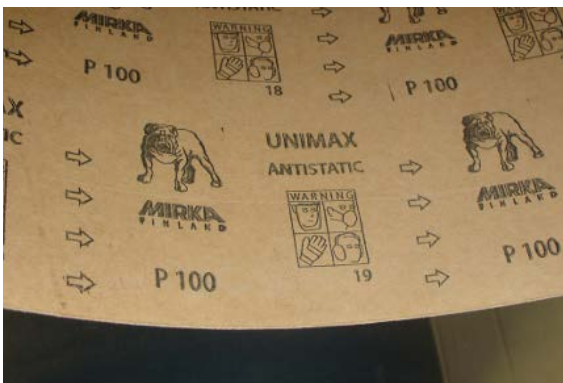
Type of sanding	Grit
Coarse sanding	24 – 80
Medium sanding	80 – 120
Fine sanding	120 – 220
Very fine sanding	180 – 600



Suitable storage of sanding belts for vertical belt sanders.



When the grit loses its sharp edges, heat builds up during machining, which causes sanding dust to adhere to the belt's surface and leave marks on the sanded surface. A worn belt can break and damage both the machine and the workpiece.



Inside of a sanding belt with arrows showing the direction of travel. Note the join that is visible in the bottom left of the picture. The grain size P 100 is also displayed.

Grit density

Varying the density of the grit distribution produces different results from the sanding belt. In terms of density, sanding belts fall into two camps:

- The most widely used is densely coated.
- A sparse coating gives better sanding results when sanding soft and resin-rich woods that are inclined to clog up the belt.

A few basic tips for choosing your sanding belt

- Start with as fine a grit size as possible, since the initial scratches are the most difficult to rub away during the finish sanding.
- Sanding hard and tough materials — wood, steel and other metals — is most effective with a belt that is coated with aluminium oxide on a cloth or paper backing.
- Sanding hard and brittle materials — lacquer, filler and plastics — is most effective with a belt coated in silicon carbide on a cloth or paper backing.
- You should choose as stiff a sanding belt as possible, taking account of the shape of the workpiece. Stiff belts have a longer service life. Flexible belts follow the shape of the workpiece better. When wet sanding, you should use a fully plastic bonded sanding belt.
- When sanding clogging materials, such as pine, a sparsely coated sanding belt is recommended for more economical sanding.

Sanding tips

- Use the lowest possible sanding pressure. This preserves the sharp points of the grit and achieves a better surface, while also increasing the service life of the sanding material.
- Check the machine's power consumption. A machine correctly set for low sanding pressure saves energy.
- Use an elastic sanding pad as it keeps the grit sharp.
- Use graphite cloth on fences and sanding pads.
- Coarse sand until the surface of the wood is entirely free from adhesive tape, glue and so on. When sanding a surface, it is important that the distribution of the work between coarse and fine sanding is correctly balanced.
- Only fine sand until the scratches from the coarse sanding disappear. This will give the best surface.
- Choose the right belt speed. When sanding wood, the speed should be 25–30 m/s for the best effect and finish. A suitable belt speed for lacquer and profile sanding is 12–15 m/s.
- Regularly check that the devices for dust extraction are in the best condition to keep the sanding machine and workpieces as clean as possible.

Storage

Belts should be stored for as long as possible in their unopened original packaging and then on special hangers made from wood or metal. The hangers must be horizontal, generously proportioned and have a rounded surface so the belt does not break. Sleeves, cartridges and other forms of sanding material should be stored in drawers or boxes.

Flexible sanding materials are sensitive to variations in temperature and air humidity. Because they are made up of layers with different properties, tensions and deformations can easily occur if the temperature and humidity are wrong. A suitable temperature for storage is around 20 °C and the relative humidity should be 50–60 %.

If the sanding material is stored and treated correctly, it will retain its shape and cutting ability for a long time.

When storing, the following should also be kept in mind:

- Do not store sanding material near heat sources or windows.
- Do not place sanding material directly on a concrete floor or against an external wall.
- Be careful to avoid temporary sudden temperature fluctuations in the premises.
- Use the oldest material first.

Risks of dust

Wood dust can cause various types of allergies as well as harmful changes in the upper airways, for example. The limit value for dust is 2 mg/m³ where dust in the air may give rise to dust explosions and fire. If the dust is not removed from the workplace, it can cause disruptions to production at a later stage of manufacture. All sanding and polishing machines must therefore be connected to an effective extraction system.

4.7.3 Long belt sander

The long belt sander used to be the most common sanding machine for wood. It is mainly designed to sand flat surfaces but can be used for slightly bent workpieces. The table slides in and out and can also be height adjusted with a wheel. The belt sander can also be equipped with motorised table height adjustment and two belt speeds. To begin the process, the workpiece is placed on the table, which is first set vertically. During sanding, the sanding belt, which runs between two short rollers, is pressed down against the workpiece. This is done either with a controlled block or a loose block that you hold in your hand. The block is run along the belt in even strokes. When the block comes to the edge of the workpiece, the workpiece is gradually fed along the table under the belt. This continues until the whole surface of the workpiece has been sanded. A versatile small model of belt sander may be a combined surface and edge sander that is fitted to a fully welded steel stand. The feed table runs on steel tubes and guide rods on bearings. The table has adjustable fences. The sanding unit is equipped with extraction hoods at both ends. The machine is open at the side, which means that you can sand workpieces that are almost twice as wide as the table. The top of the sanding unit can also be used for sanding.

4.7.4 Vertical belt sander

The machine is so-called because the sanding belt is arranged vertically in the machine. The endless belt runs over two vertical, rubber-clad rollers, one of which drives the belt. The machine has a horizontal table that supports the workpiece. The table can be set at various angles to the plane of the sanding belt. The sanding belt usually oscillates, in which case it may be referred to as an oscillating belt sander. In this case, as well as rotating, the belt has an up-and-down motion.

The benefits of this are:

- the surface is sanded more evenly
- the belt wears less and does not burn the wood.



Vertical belt sander

The machine is also known as an edge sander, as it is mostly used to sand straight edges. Since the belt rollers are rubber-clad and have different diameters, the machine can be used to sand curved edges of various radii as well. When sanding straight edges in large series, the vertical belt sander can be fitted with a feed system of a similar type to the one used on spindle moulders. Vertical belt sanders without the oscillation can be used to sand profiled edges. In this case you have a short sanding fence that is shaped to the same profile as the piece to be sanded. The sanding belt should have a soft and flexible backing to avoid the higher parts of the profile being sanded too much. On some models, separate sanding rollers with a diameter of down to 30 mm can be fitted onto the driving belt roller. This, combined with an adjustable table, enables sanding of small radii. Rollers with a diameter of 30–60 mm and a height of 150 mm are available as accessories.

4.7.5 Wide belt sander

The wide belt sander is designed to sand flat material in large series. In its simplest form, the machine is constructed so that a wide sanding belt rotates between two rollers, one above the other – the contact roller and the tensioning roller. The contact roller is coated with profiled rubber whose hardness is tailored to the nature of the work. Hard rubber is used for coarse sanding and a softer rubber is employed for finer sanding operations. The workpiece is fed in by a rotating feed mat on the table. The height of the table controls the thickness of the workpiece. Large wide belt sanders have two or more sanding heads, with different grades and types of sandpaper, lined up one after the other.

Wide belt sanding mainly takes the form of:

- surface sanding
- equalising.

With surface sanding, a consistently thick layer is sanded off the whole surface of the workpiece, regardless of whether the piece varies in thickness at all. This can be achieved by having the sanding head's sanding pad vertically sprung.

With equalising, the workpiece is sanded to an even thickness in the same way that you plane a workpiece to an even thickness in a thicknesser.

Wide belt sanders with two sanding belts give a more precise thickness and a finer surface. The machines are generally fitted with a contact roller and a sanding pad. In this way, the first roller head can be fitted with a coarser sanding belt and take care of the actual wood removal. However, the roller does not provide a fine surface, as the slightest unevenness in the roller leaves “cutter marks” in the workpiece. The sanding pad is used for fine finishing work, and this unit is fitted with a finer sanding belt. Since the sanding pad does not rotate, and instead remains fixed in its position, there are no cutter marks on the workpieces, as long as the sanding belt joint is properly made. The pressure on the sanding pad is often pneumatically controlled, although electronic controls also exist.

The most advanced wide belt sander is the dedicated CNC sanding machine, which can detect thickness variations in the material fed into it. The pressure bars can handle variations of 2 mm or more with a good sanding result.

To increase capacity and reduce the workload, two wide belt sanders can be connected together, with one sanding the upper face and



Wide belt sander

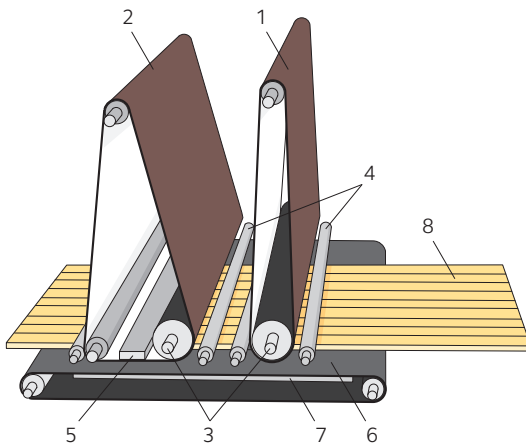


Figure 4.10 Diagram of a typical wide belt sander

1. First sanding head with sanding belt
2. Second sanding head with sanding belt
3. Drive rollers
4. Pressure rollers
5. Pressure plate for fine sanding
6. Feed mat
7. Table
8. Workpiece

the other taking care of the lower face. The same technique applies when setting up wide belt sanders as for the setup of planers. The top sander is set like a thicknesser and the bottom sander is set up like a jointer.

Machines that are designed to be installed on machining lines have a movable top section and a constant table height in order to fit in with the conveyors. Wide belt sanders are manufactured in widths from around 300 mm up to approximately 1,400 mm and are designed for sanding interior furnishings. Wider widths are available for sanding particleboard. The feed rate for a modern machine can be seamlessly adjusted from around 5 m/min to around 25 m/min. The cutting speed ranges from approx. 15–25 m/s. The power of the motor installed on a 1,300 mm wide belt is 15–20 kW.

4.7.6 Profile sander

Profile sanders come in various guises, from the simple manual profile sander with air-filled rubber rollers and sanding belt to edge and profile sanding machines for high-capacity series production. By varying the air pressure in the rubber expander, the sanding belt grade and the peripheral speed, you can adapt the flexibility and wood removal to the current workpiece. It is important to avoid too high a cutting speed. A speed of between 15 and 25 m/s is ideal in most cases. The machine can also be fitted with brushing heads or sanding discs.

Profile sander for mouldings

Another type of profile sander for mouldings feeds the moulding through the machine and sands it with profiled sanding discs. The machine can be equipped with two sanding heads and the feed rate is 8–40 m/min.

The sanding discs can vary according to the purpose, for example:

- Polyurethane profile sanding discs, which are very easy to work with. The sanding sheet is attached with Velcro for quick and simple replacement.
- Homogeneous profile sanding disc, where the disc itself sands the profile. As the plate wears, the diameter reduces. The pre-milled profiles can be sanded to a high finish and complex profiles can be worked on.
- Profile sanding disc for MDF, which has a homogeneous sanding body and is made up of grit in an elastic foam binder. This gives the grit a sprung bed and combats clogging. This type of profile sander is used for fine sanding of MDF panels before finishing in order to reduce lifting fibres. The profile discs used here can also be used on edge sanding machines.

4.8 Other machinery

4.8.1 Single end tenon machine

The single end tenon machine is designed to machine the ends of a workpiece. The name reflects the fact that the ends are worked on one at a time. It is also simply referred to as a tenoner. The machine is used primarily to machine solid wood, for example in window and door manufacture (panelled doors), but also for other frame structures or joints, for example in the furniture industry. The most common operations for which the machine is used are end cutting, tenoning and mortising, and profiling.

When manufacturing panelled doors and solid wood cupboard doors, for example, counter profiles are cut into the frame components where these products are to be joined together. The machine is therefore used for much more than just machining end wood. Single end tenon machines are best suited to making individual pieces or small series. That might include special orders for windows, where there is little demand for high production capacity but flexibility of production is highly prized.

The machines come in many different sizes and designs. The simplest have one cutting spindle and one sanding spindle. A typical machine for Swedish conditions might have five working spindles:

- tenon cutter
- bottom tenon cutter
- top mortise cutter
- bottom mortise cutter
- saw unit for length adjustment.

When making tenons with a tenon cutter, it is important to have tools with side cutters to prevent tear-out at the shoulder of the tenon. Many modern machines have no horizontally mounted tenon cutters, with all the operations performed by vertically mounted spindles. Machines are available with 2–10 spindles, which are often height adjustable and sometimes also tiltable. Larger tenon machines may be fitted with one long spindle (maximum approx. 600 mm) with support bearings at the top end. This spindle can be fitted with 3, and sometimes up to 6–8 tool sets. The spindle is then raised or lowered to achieve the required combination of tools. The adjustment is made automatically by selecting a program. The machines may have several such adjustable spindles, including a programmable saw spindle. The work table feed is manual on the smaller machines, while the larger ones are driven by motor or hydro pneumatics. On the simpler machines, the workpiece is clamped in place manually with an eccentric disk or automatically with a pneumatic piston. Larger machines always have automatic clamping and sometimes the option of running many workpieces at the same time. The fence can often be set to $\pm 45^\circ$ and it is also common for the table to be tiltable to 30° .

4.8.2 Round end tenon machine

In contrast to the single end tenoner, a round end tenon machine creates tenons with rounded edges that fit into mortises made using a mortise drilling machine. Production, cutting to the right length and end chamfering all happen in one operation. The machine can also be set to create entirely round tenons or tenons with straight corners. The round end tenon machine is often fully automated, with pneumatic clamping of the workpiece and speed adjustment for the table movement. Large machines can be made with two consecutive tables that can be tilted upwards, downwards and sideways. The fences are also adjustable from $0-45^\circ$. With double tables, you can machine both right-hand and left-hand details at the same time. The tenon cutter is fitted with a saw blade that is set for the required tenon length and with side cutters in order to machine across the grain without splitting it. The machine is also fitted with a chamfering tool that chamfers the end of the tenon for easier assembly. The cutter can also be ordered with a hogger that shreds up the waste and carries it away via the chip extractor. Side stops control the rotating cutter so that it runs a half turn on the forward feed and a half turn on the return feed.

The round end tenon machine has largely been replaced by the dowel drill for manufacturing joints in the furniture industry. There is also a double round end tenon machine with much higher capacity, up to 2,700 tenons per hour, and setting systems that make the retooling times considerably shorter.

4.8.3 Drill and insertion machines

There have been rapid advances in the development of new hinges and fittings in the joinery and furniture industry in recent years. Requirements for rational production methods and being able to deliver the products, particular furniture, flat packed to the customer have driven this development, as have the requirements for disassembly. The aim is that it should be possible to disassemble the products at the end of their life, so that the constituent components and materials can be reused or recycled in an eco-friendly way. The natural consequence of these advances is that machines for drilling and inserting hinges and fittings have also been developed at an ever-increasing pace. These machines come in many different variations, often specifically designed for a particular fitting, such as a butt hinge or fixing plate, or for a certain product such as windows or doors. The machines range from simple bench models for cabinet hinges to advanced and automated CNC drill and insertion machines that can handle several types of fitting. Smaller machines are often tied to a particular fitting manufacturer for which they are specially designed. The machining operations may include drilling, milling, chain mortising, chisel mortising, pressing and screwing.

4.8.4 Woodturning lathes

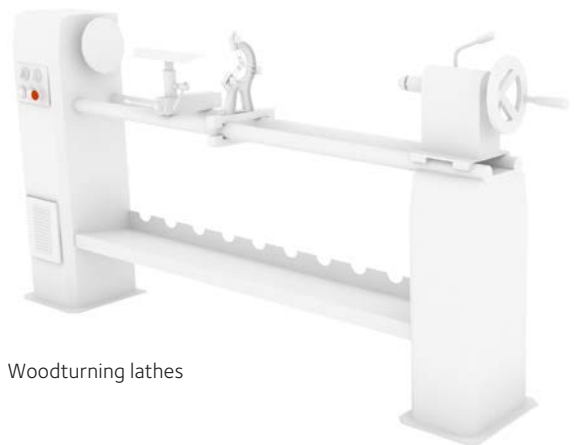
When turning wood, it is usually the workpiece that rotates and the tool that stands still during the machining operation. With form milling cutters and copy milling cutters, both the workpiece and the tool mounted on a milling spindle rotate. These machines are often counted as lathes. The regular, fully manual hand lathe is no longer used to any great extent in the wood industry, although it still has a place among artisan joiners and certain specialist joiners.

Semi-automated lathes that are controlled by a template or copy a finished object are sometimes used to manufacture posts, chair legs and so on. The machines used for larger volumes are fully automated electro-hydraulic lathes that either work using copying technology or have electronic control systems. Due to their high capacity, these machines are mostly found in specialist woodturning workshops. It is rarely worth an individual joinery workshop having its own automated lathes. Instead they buy material from the woodturners.

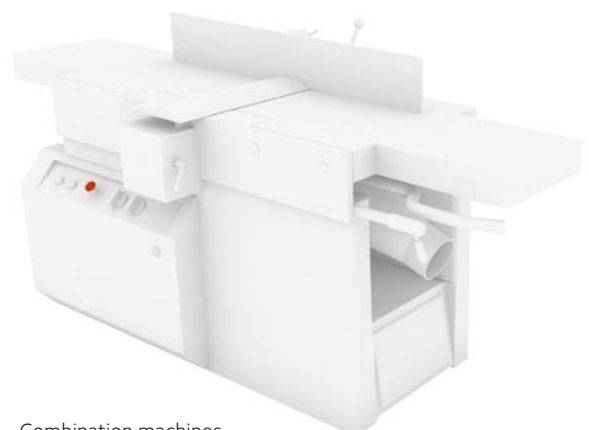
4.8.5 Combination machines

Combination machines can be an excellent solution for artisan joiners, construction firms or construction material suppliers that are not required to produce large series of products. The machines usually comprise:

- planer-thicknesser
- circular saw with sliding table
- vertical milling unit (spindle moulder)
- mortise drill.



Woodturning lathes



Combination machines

Larger machines can be supplied with a tiltable milling spindle and saw blade and with a tenoning carriage. Separate motors are now standard, but there are many second-hand machines on the market with just one motor, where you have to realign belts for the required function.

The combination machines are available with both cast stands and welded steel bodies. They have the following advantages:

- they take up little space
- they are a small investment considering the number of functions.

On the other hand, they have the following disadvantages:

- they take longer to set up
- usually only one function can be used at a time
- there are limitations regarding the table, planing width and so on.

The practicality of and demand for combination machines is reflected in the high prices for second-hand machines. A 50 year-old cast-iron machine can, for example, cost more than a newly produced machine in welded steel.

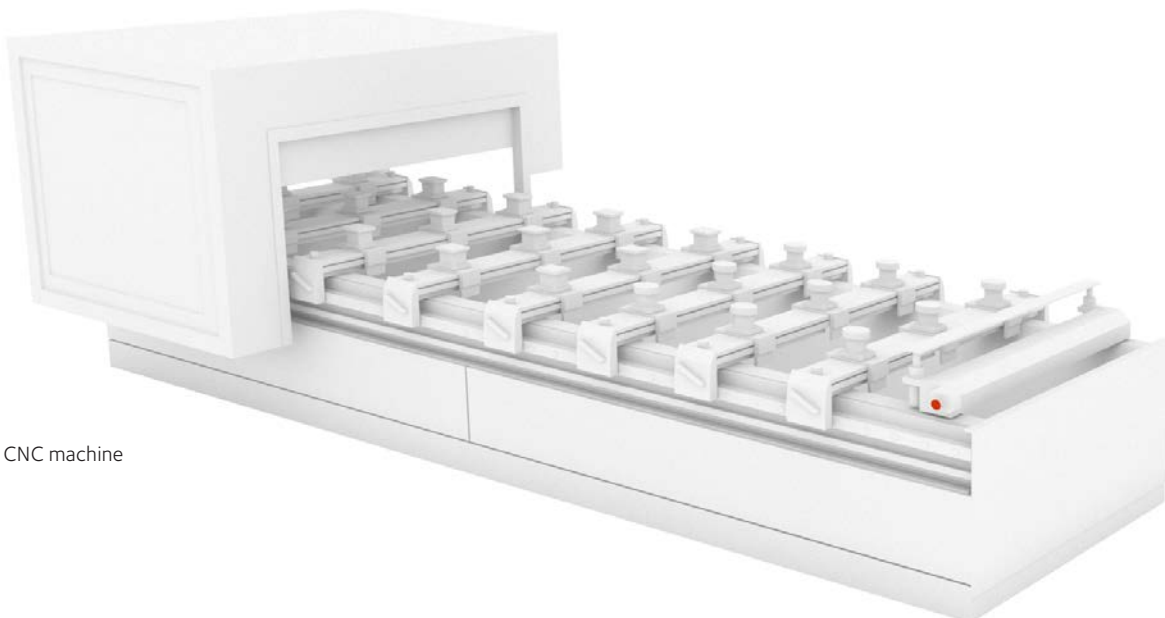
4.8.6 CNC

CNC (Computer Numerical Control) is a method of controlling wood-working machines by computer. The machine operates to a series of instructions in a data file, a program, that can easily be replaced or changed. The starting point for the program is usually a Computer Aided Design (CAD) drawing of the part to be manufactured.

The drawing is converted into machining data that may include:

- dimensions
- machining direction
- feed rates
- tool selection.

Some of this work is done with the help of tailored Computer Aided Manufacturing (CAM) programs, but also based on practical experience of the machining properties of different woods.



CNC machine

The CNC machine is made up of one or more mobile tool spindles that can be moved in different directions by servo motors. The servo motors are managed by the machine's control system, which in turn gets its instructions from the current machining programme.

The machine is built around a stand that may include devices for clamping and replacing workpieces, tool magazines for automatic retooling, chip extraction and various safety guards.

CNC machines operate in both two and three dimensions using a coordinate system. The machine works on at least three axes — X, Y and Z — but machines with four or five axes also exist. The most common configuration is to have three axes. When a machine has four or five axes, it is possible to twist and rotate the table or turn or angle the tool.

The CNC milling machine is able to perform most of the operations carried out by conventional woodworking machines, such as milling, drilling and sawing. Since it is easy to switch between machining programs, different products can be manufactured as short or long series, with very little resetting of the actual machine.

There are also specialist CNC machines for one type of machining, such as sawing or drilling.

The operation of the CNC machine differs depending on the manufacturer and usually operator training is included with the purchase of the machine.



Start button



Emergency stop



Safety switch stops dangerous moving parts when you open hatches.

4.9 Machine safety

4.9.1 General information

The machines must be equipped with protective devices that make the work safer. Covers, brakes, an emergency stop function and feed assistance help to protect you as the user. Even if you are working on a CE marked machine, there may still be risks. You must always make sure you are given clear instructions on how to use each machine safely.

Some of the common risks when working with woodworking machines include:

- cutting tools
- moving machine parts
- material flying out
- blades that come loose and fly out
- falling material
- losing balance by the machine
- pinch injuries and eye damage (shavings, chips in the eye, etc).

Remember

In order to be able to handle machines safely, it is important that:

- you know how it works
- all the protective features and covers are in the right position
- you use the right machine for the task
- you use personal protective equipment such as safety goggles and hearing protection.

4.9.2 Emergency stop devices

There are rules on how to make starting and stopping machines safe. Here are some examples:

The start button on all machines must operate in a way that prevents the possibility of starting the machine by mistake, for example by having the start button recessed, covered or fitted with a collar.

There must be an emergency stop button within reach of the operator's workstation.

Machines must have undervoltage protection so they cannot start by themselves after a drop in voltage or a power cut.

Emergency stop

The emergency stop device must always be red, with a yellow plate behind it. The text EMERGENCY STOP, must appear on or next to the switch, if the switch is not mushroom-shaped, with a yellow base-plate that has double the diameter of the button. If the emergency stop device is a wire, the wire must be red and have a sign with the words EMERGENCY STOP.

The emergency stop device must stop the machine immediately. It is well worth testing the emergency stop function regularly to check that it works. After an emergency stop, you must reset the emergency stop switch.

Remember

Do not use the emergency stop function to switch off the machine when you are finished with it – it may be fitted with emergency brakes that should not be subjected to unnecessary wear.

Safety stop

Many machines have safety switches that stop the machine if someone enters a risk area, for example by opening a hatch or coming too close to a tool. There are several types of safety stop, including beams of light that stop the machine when broken, contact pads and mechanical stop devices such as a touch strip.

Remember

- Not all machines have safety stop functions. Make sure you know which stop functions the machines at your workplace have.
- Check that the safety stop functions are located so that it is impossible to bypass them and enter the risk area.
- Regularly check that the safety stop functions work.

Brakes

All machines should be equipped with manual or automatic brakes that can bring the machine to a complete stop within 10 seconds. Automatic brakes engage when you switch off the machine. Older machines may have pedals or buttons for braking. These should be clearly marked with a sign, *see example to the right*.

Remember

Regularly check that the brakes work.

4.9.3 Machine guards

The covers on machines should be designed so that it is not possible to enter the machine's risk areas, and they should protect you from material and tools that might otherwise fly out. It should only be possible to open hatches and other openable covers when the machine is at a complete standstill, or the machine should also stop when you open the hatch. In addition, it should be impossible to start a machine until all hatches are fully closed.

There are three types of covers:

- Fixed covers that stop a saw blade from moving beyond the machine table. These covers should sit firmly in place and only be openable or removable with a tool.
- Moving covers that protect against cutting tools and other moving parts in the machine. These covers should stop the machine if they are opened or removed, or the guard should only be openable or removable if the machine is at a complete standstill.
- Adjustable covers are self-adjusting and prevent contact with the machine's moving parts. These covers should sit firmly in place and be easy to adjust. They should only be removable with a tool.

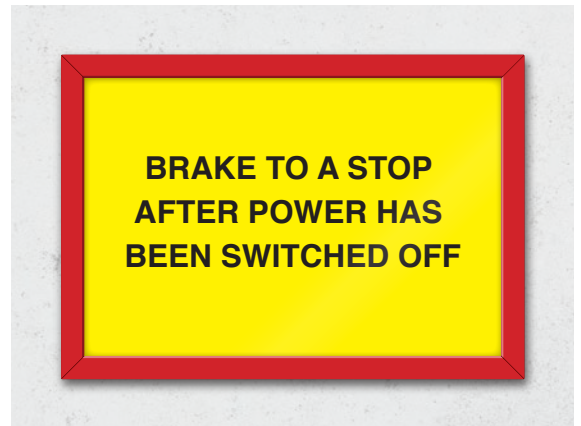
Remember

Jobs that require the covers to be opened to any great extent, such as ripping large pieces of wood, involve an increased risk of coming into contact with the machine's moving parts, in this case the saw blade.

Further reading

Go to the Swedish Work Environment Authority's website www.av.se and search on woodworking.

The Swedish Work Environment Authority's checklist for woodworking rooms in schools contains information on how to manage the risks of woodworking machines in both schools and businesses.



Example of a safety sign.



Covers on a crosscut saw. The fixed cover (1) always protects the upper part of the saw blade. The moving cover (2) follows the thickness of the wood as it runs over it. You set the adjustable cover (3) according to the thickness of the wood.

Connections

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There are some connections and designs that are proven through history to be particularly crucial and fundamental for the manufacture of furniture and interior fittings in wood: tenons in mortises, tongues in grooves, dovetail joints and rabbet joints, sliding dovetails and frames filled with a panel.

All these connections have been specifically developed for wood, taking into account its status as a living material. Many of them are best suited to small-scale production, among them mortise and tenon joints and dovetail joints. There are other methods that are tailored to large-scale production. Dowel joints are one, finger joints and box joints are another, not to mention metal fittings to tie together connecting parts.

Gluing joints and connections is a relatively late historical development. Glue-free structures remained common for a long time in more rustic carpentry. Today, glued joints are a common feature in both small-scale workshops and larger production facilities. There is a wealth of different adhesives, advice, instructions and factors to take into account, depending on the scale of the production. Whatever the case, movements in the wood and the direction and density of the fibres must always be considered in order to tailor the production method and guaranteed the fit and strength of the connections.

5.1 Joints

Most joints have been developed over centuries, many of them over millennia, as solutions to the particular problems that arise when building structures in wood. Here, we look at the joints that are best suited to solid wood. Few of these options work well on fabricated materials such as plywood, particleboard and so on. Unless they have to be moving or demountable, joints are usually glued. Large glued surfaces make joints stronger. End wood readily absorbs adhesive and therefore does not create a very strong bond.

5.1.1 Care and sensitivity

When producing small series of products, higher standards can be set concerning manual and individual care throughout the process. Study the grain of the wood carefully before you make any joints and make sure there are no knots involved. Decide how the materials will be joined. Choose the best side of the board (the good side) for the outer or front face and the best edge for the outer or front edge. First saw and plane the workpieces to the correct dimensions. Mark the precise shape on the good side and saw out the joint. The sawn surfaces will be coarse, but this is positive as it will give the adhesive a better grip. Smooth off chipped and rough edges, and plane and sand the sides you will not be able to access once the workpieces have been joined together. Leave in place the pencil markings showing the placement

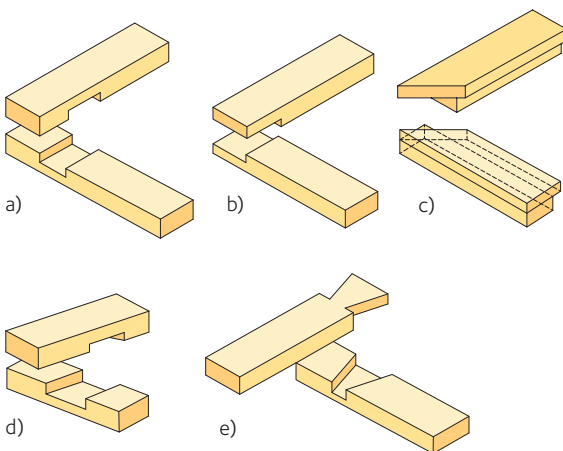


Figure 5.1 Halving joints

- a) Cross-lap joint.
- b) End-lap joint.
- c) Mitred halving joint.
- d) Oblique halving joint.
- e) Dovetail halving joint.

of the parts until the whole structure has been glued. Put the parts together to check that they fit, before you glue them in place. This is called dry fitting. A well-made joint should have a tight fit, but it should be possible to put it together and pull it apart by hand. Apply adhesive to all the internal surfaces on both parts. Take care not to exceed the adhesive's assembly time, i.e. the time between applying the adhesive and assembling the pieces. Tap them together with a hammer or wooden mallet, using a protective piece of wood between mallet and workpiece. Remove any surplus adhesive before it sets too hard.

5.1.2 Halving joints

Halving joints, where notches are cut halfway through each connecting piece, are used where two pieces cross each other or meet in a T- or L-shape. They are used in simple framing structures and in cupboard carcasses with a framed design. They are not as strong and stable as, for example, mortise and tenon or dovetail joints. Cross-lap joints, *see fig. 5.1 a)*, can also be used in industrial production, where crossed joints are made with large glued surfaces. They are suitable for internal dividers in boxes, drawers and furniture frames. End-lap joints, *see fig. 5.1 b)*, should be reinforced from the back with wood screws or nails, or with bolts. A variation on halving joints is mitred halving, *see fig. 5.1 c)*, which is ideal for mirror and picture frames. These should be secured with nails or screws on the reverse. The straight end-wood edges in an oblique halving joint, *see fig. 5.1 d)*, give the joint torsional rigidity.

In a dovetail halving joint, *see fig. 5.1 e)*, or double-dovetailed T-halving, the tensile strength in the dovetail combines with the large glued surface of the halving joint.

5.1.3 Mortise and tenon

Pieces of wood can be joined at an angle to each other using a mortise and tenon. This type of joint is used in artisan furniture workshops and when manufacturing strong frames. *Fig. 5.2* shows the basic form of these joints. The hole is drilled all the way through the workpiece. This means that the end wood of the tenon will be visible after assembly. The shoulders of the tenon serve as a stop and give the joint side-ward torsional rigidity. It is also possible to insert small wedges into the end wood of the tenon to strengthen the joint. In a blind joint, *see fig. 5.3 b)*, the tenon is shortened so that it does not pass all the way through. Loose tenons can also be used to form a joint. A half shoulder tenon, *see fig. 5.3 c)*, only has a shoulder on one side. This can be useful, for example, where a thin stretcher is being joined to a thicker chair leg and the face needs to be on one plane. This way, the mortise can be positioned with sufficient thickness of material on both sides, at a suitable distance from the outer edge of the leg.

The most common type of dovetail is traditionally used in joining the corners of door and window frames and casements.

A plain bridle joint, *see fig. 5.3 d)*, can be used at the junction of two members of equal or different size at an angle of 45–90°. A haunched tenon, *see fig. 5.3 e)*, has been made narrower to maintain the integrity of the mortise and so that the tenon cannot be pushed upward. A small haunch remains at the shoulder, giving the joint greater torsional rigidity. As always, a good fit is essential. A tenon or dovetail with asymmetric shoulders, *see fig. 5.3 f)*, is used in the assembly of a rebated frame. A corner mitred bridle joint, *see fig. 5.3 g)*,

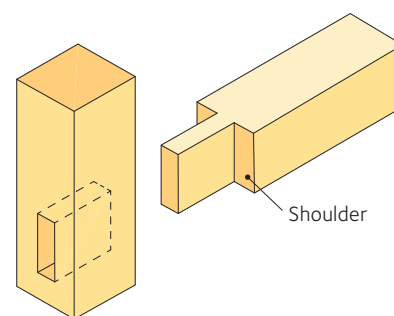


Figure 5.2 Basic form of mortise and tenon joint.

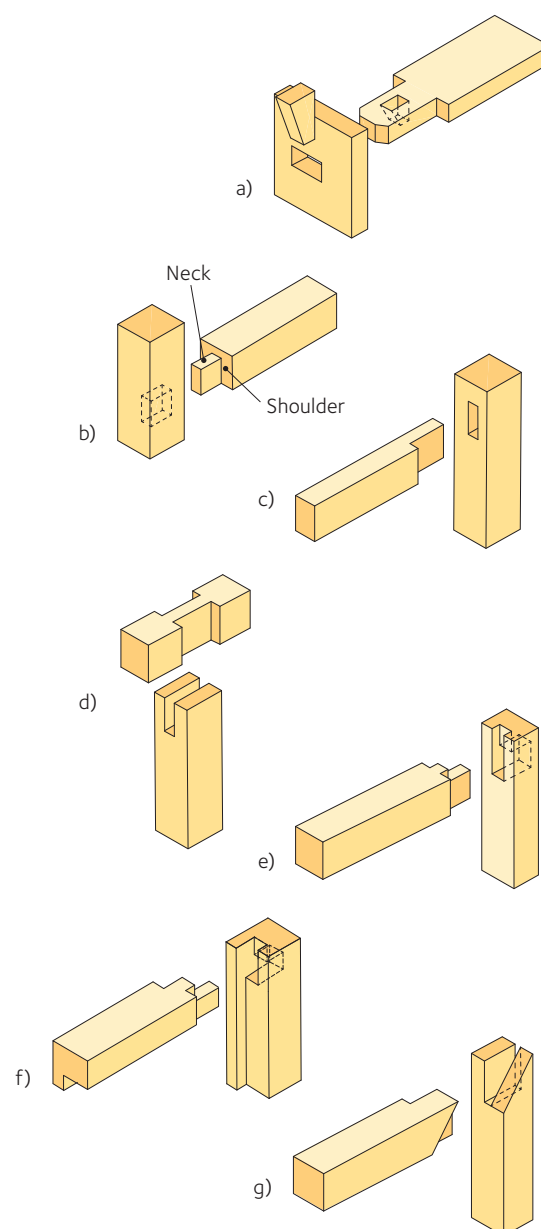


Figure 5.3 Mortise and tenon

- a) Keyed mortise and tenon joint.
- b) Blind joint.
- c) Half shoulder tenon.
- d) Bridle joint.
- e) Haunched tenon.
- f) Long and short shoulder mortise and tenon.
- g) Corner mitred bridle joint.



A keyed mortise and tenon joint is good for easy assembly. In this case the tenon goes through the leg and is wedged on the outside.

creates a tidy corner joint where you have a profiled or rebated inner edge. Tenons and mortises create a very strong joint, with a large glued surface and resistance to compression and torsion.

Making tenons and mortises

When making tenons and mortises, you should consider that the width of the mortise is determined by the size of the tool. You cannot therefore vary the width however you want. This means that you must cut out the mortise first and make the tenon afterwards. The thickness of the tenon should be around $\frac{1}{3}$ the thickness of the workpiece, but deviations may occur. To make the joint as strong as possible, the length of the tenon should be no more than four times its thickness. The thickness of the tenon is an appropriate size for the shoulder, although the minimum should be approx. 8 mm. The strength of the joint relies heavily on having as close a fit as possible. As a general rule, the fit should be so tight that the joint is difficult to push together. When making tenons and mortises, the wood should be well dried and acclimatised, so that it has achieved an equilibrium moisture content of 8–12%. Otherwise, the joint may be loose, leading to poor strength, or difficult to push together, causing splitting.

Bear in mind that moisture-related wood movement is twice as great in the tangential direction as it is in the radial direction, *see page 33*.

5.1.4 Dovetail joint

Dovetails are an extremely old form of joint. They used to be made on a workbench using a saw, chisel and mallet. Being able to produce a quick and precise dovetail by hand was a mark of a craftsman's skill and remains one of the criteria assessed in an apprenticeship. Dovetails can also be created by machine and may be described as through, half-blind or secret. A through dovetail is visible on both sides of a corner joint, while a half-blind dovetail can be seen from one side and a secret one cannot be seen at all. Dovetails create a very strong joint but are time-consuming to make. They therefore feature mainly in artisan production. Dovetails are usually used to produce various forms of corner joint, for example when joining a drawer box to a drawer face. Wooden boxes and crates also make use of box joints.

Box joint

A box joint, *see fig. 5.4 a)*, is a method of quickly producing strong corner joints in solid wood. It is also known as a comb joint.

A box joint has straight pins that create a large glued area. The joint is used in boxes and drawers and in furniture, particularly in serial production, but there are also specialist machines for making box joints. The joints can be cut using a circular saw or a spindle moulder.

Dovetail joint

This joint, *see fig. 5.4 b)*, is the strongest corner joint in a master joiner's armoury. Dovetail joints are used in cupboard carcasses that need to be fully stable and in drawers and boxes. The relatively large glued surface of this corner joint makes it very strong. Some woodworking styles make the tails wider than the pins.

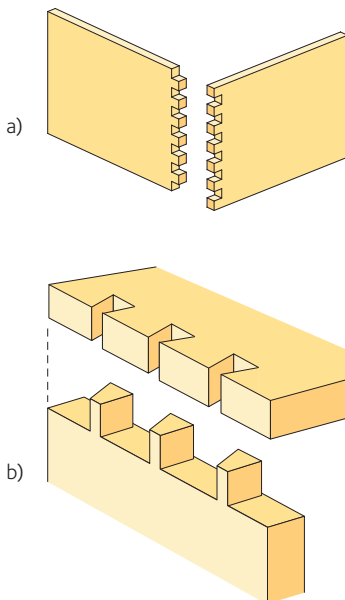


Figure 5.4 Dovetail joint

- a) Box joint.
- b) Classic dovetail joint.

5.1.5 Housing joint

A through housing joint, where the straight groove runs across the whole face and is the thickness of the joining member, *see fig. 5.5 a)*, is used for cupboard shelves and internal mouldings in cupboard carcasses. It is also possible to cut such grooves in bookshelves, so the shelves can be freely slid into place. Barefaced housing joints as shown in *fig. 5.5 b)* are used to join a top shelf to the sides. A tongue like a kind of long tenon is cut in the horizontal shelf, and then a corresponding groove is milled/sawn into the side board.

Tongues and grooves can be produced on a spindle moulder or a moulder.

5.1.6 Sliding dovetail joint

One means of executing a T-connection is to use a sliding dovetail joint. The dovetailing can be single or double-sided. The pin is made using a spindle moulder, *see section 4.5.2*. The tail is produced using a dovetailing machine, a router or a spindle moulder with a top spindle. This joint is excellent for attaching a crosspiece to a solid end-panel if the grain of the member does not match the direction of the grain in the panel. The crosspiece is only glued at one end, to allow the end-panel to expand and contract. With a sliding dovetail joint, *see fig. 5.6*, the pin and tail extend across the whole width of the board. This joint is designed so that the groove is slightly tapered for ease of assembly and a better fit. This is a very strong joint that can be used, for example, to attach shelves between two side boards.

5.1.7 Dowel joint

Dowels are used when two parts need to be glued together edge-to-edge, *see fig. 5.7 a)*, or at right-angles, *see fig. 5.7 b)*. They can also be used in mitred joints for frames, *see fig. 5.7 c)*, in the corner joints of solid wood cupboard carcasses or to attach shelves between two side boards. The joint is usually created using a dowel drill with fixed spindles. Dowel joints are used instead of traditional mortise and tenon joints. They are easier to manufacture and are almost as strong, not least because of significant advances in adhesive technology. Dowels are particularly good for gluing together more complex shapes.

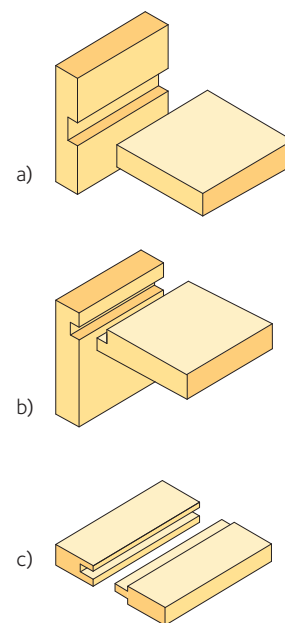


Figure 5.5 Housing joint

- a) Through housing joint.
- b) Barefaced housing joint.
- c) Tongue and groove.

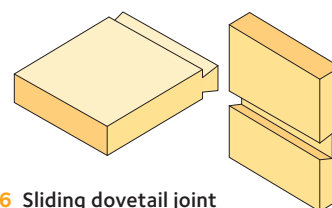


Figure 5.6 Sliding dovetail joint

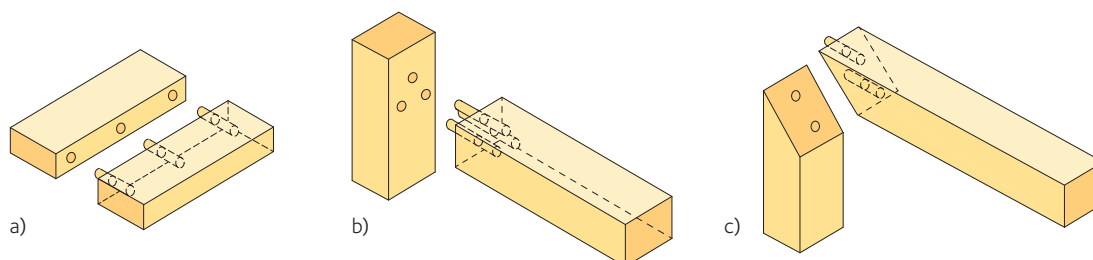


Figure 5.7 Dowel joint

- a) Edge-to-edge.
- b) Right-angled.
- c) Mitred.

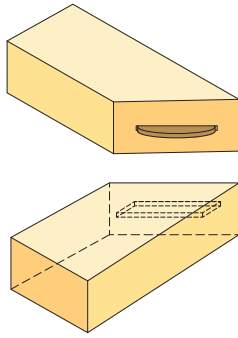


Figure 5.8 Biscuit with 45° mitre.

5.1.8 Biscuit joint

Biscuits may be made of wood, plastic or aluminium and are used primarily when making a small run of products or for specialist joinery and interior fittings. Biscuits can be used to join along flat edges, at a 90° angle or in mitres, *see fig. 5.8*. It is also an excellent way to keep pieces aligned during assembly. This form of joint can be made quickly using a special hand tool known as a biscuit joiner, which mills recesses into both the pieces to be joined. Biscuits can be purchased in a range of sizes. The sizing system includes sizes of 0, 10 and 20.

Domino

Nowadays, domino joiners are also popular tools for creating joints at joinery workshops. The domino joiner replaces the biscuit joiner and dowel drill all in one go.

5.1.9 Edge jointing

A sheet of solid wood is formed by gluing several narrow pieces of wood edge-to-edge. The most common method of joining is the butt joint, which forms a strong connection if the edges are planed and glued carefully. Tongue and groove makes the gluing easier as the parts fit together precisely. This joint is used without glue in cladding and floors. If both pieces have grooves, they can be joined with a loose tongue. A mitred corner joint can be reinforced with a loose tongue that is glued into a groove, or with small pieces of strong timber that are glued on once the corner joint is complete.

5.1.10 Rebates

Rebates can be used for inserting cupboard backs or glass, amongst other things. The method can also be used to improve the strength of a corner joint in combination with dovetails. When joining using adhesive alone, the direction of the grain must be the same on both the pieces being joined. A rebate is best milled using a spindle moulder that has a mitre cutter fitted with side cutters. Otherwise there is a risk of chipping. Rebates can be made quickly and efficiently in a moulder. Rebates are used, for example, when making recessed windows and doors, *see fig. 5.4 b), page 74*.

5.1.11 Mitres

Mitre joints are a type of corner joint that is often used where appearance is the key factor, for example when making doors and furniture. Mitres are usually cut at a 45° angle, but other angles are also possible. Dowels, *see fig. 5.7 c), page 75*, mortises, *see fig. 5.3 g), page 73*, biscuits, *see fig. 5.8*, and dovetails, *see fig. 5.1 c), page 72*, may be suitable for reinforcing these joints.

5.2 Furniture hardware

Furniture hardware is used for both fixed and movable connections. The material is usually metal.

5.2.1 Hinges

Hinges are used to allow opening and closing or to enable movement in a structure. The first hinges were made from wood, but today other materials such as steel and brass are used.

If a hinge will be opened and closed many times over, it needs to be both strong and durable.

The choice of hinge depends in part on what is required from it.

Butt hinge

Butt hinges are the traditional type of hinge. They are made from sheet metal, which is bent and cut before being joined with a pin that is riveted at the ends, *see fig. 5.9*.

Lift off butt hinge

Lift off butt hinges work in the same way as a normal butt hinge, except that they can be separated, *see fig. 5.10*. This is useful, for example, when installing a door. *See more in section 5.3, page 82.*

Concealed hinge

Concealed hinges have an advanced design that allows them to be adjusted in different directions. They may also include a soft close or push function. The hinge is entirely invisible from the outside when the door is closed. The concealed hinge has become the most common type of hinge in the joinery industry and is widely used for kitchen cabinet doors, wardrobes and so on, where high levels of strength and durability are required, *see fig. 5.11*.

Glass door hinge

A glass door hinge is used, as the name suggests, for glass doors. It is usually clamped around the edge of the glass or glued into place, *see fig. 5.12*.

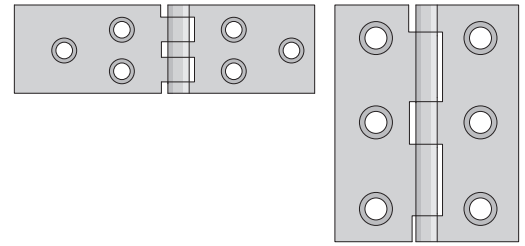


Figure 5.9 Butt hinge

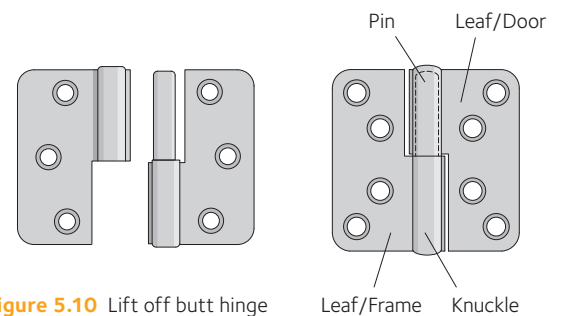


Figure 5.10 Lift off butt hinge

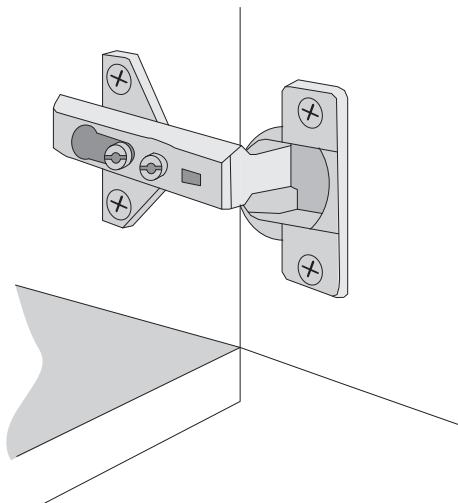


Figure 5.11 Concealed hinge

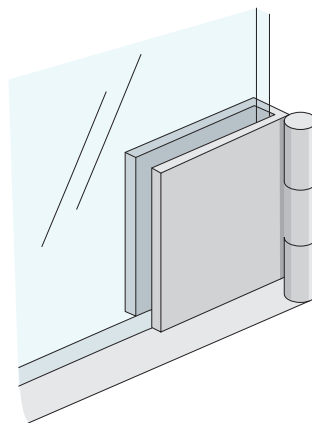


Figure 5.12 Glass door hinge

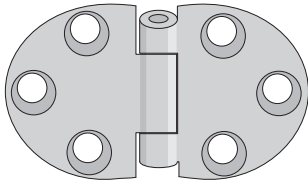


Figure 5.13 Flap hinge

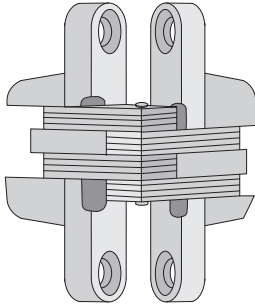


Figure 5.14 Barrel hinge

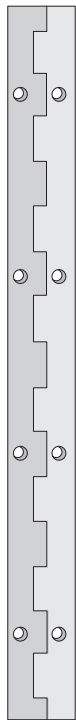


Figure 5.15 Piano hinge

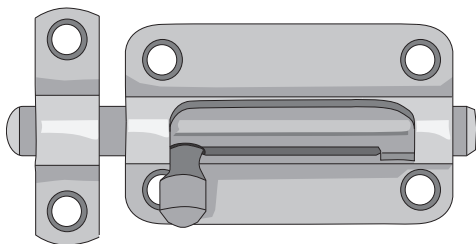


Figure 5.16 Bolt latch

Flap hinge

A flap hinge is used on a door or flap that has to open upwards or downwards. The flap hinge often has a stop function. A flap hinge with two shoulders is useful when you need a hinge with an extra wide opening angle, *see fig. 5.13*.

Barrel hinge

The barrel hinge can be fully concealed when the door is closed. It offers good strength and durability, since it has several layers that are able to take up the load, *see fig. 5.14*. This is a decorative hinge that is often made of brass.

Piano hinge

A piano hinge has high strength and stability, because the hinge is usually fitted along the whole side of a door. The piano hinge is used on doors and flaps that are subject to heavy wear and loads, such as shop fittings. The piano hinge can be ordered on a reel and then cut to the required length, *see fig. 5.15*.

5.2.2 Locks and closures

Locks and closures for furniture and interior fittings of various kinds may be needed when you want to keep doors, shutters and flaps closed, or because of a need to restrict access to the content of storage units.

Magnetic catch

Magnetic catches are available for both recessed and surface mounting. They have two parts — a magnet that is attached to the cupboard and a metal plate that is fixed to the door.

Bolt latch

When shutting double doors, the left door often bolts into the frame, while the right door bolts into the left. Bolt latches are available for both recessed and surface mounting. Used mostly for gates outdoors.

Push catches and ball catches

Push catches and ball catches have a spring-loaded mechanism, which may be adjustable. It usually just takes a push to close the door.

5.2.3 Connectors

There are various types of hardware that can be used to join parts to create a larger unit. Here are several benefits to using these fixings:

- Easier assembly in the production phase.
- Less machining.
- Can make the connection and the product more flexible.
- Different types of connectors make it possible to deliver a product unassembled and let the customer carry out the final phase of the production chain, thus reducing distribution and storage costs.
- A connector can make it possible to assemble and disassemble the product one or more times. This makes it easier to store and reuse the product.

Cross dowel and bolt

A cross dowel is a cylinder with a perpendicular through-drilled and internally threaded hole that serves as a concealed nut for a bolt, see fig. 5.17.

Stud screw

One half of a stud screw has a wood thread, while the other half has a machine thread, see fig. 5.19.

Sleeve nut and bolt

A sleeve nut has a loose head and is often used together with a furniture bolt, see fig. 5.20. The bolt has a machine thread and is fitted from the side of a structure.

Pronged T-nut

A pronged T-nut is tapped into a pre-drilled hole and has an internal machine thread, see fig. 5.21.

Threaded insert nut

The threaded insert nut has an external wood thread and an internal machine thread, see fig. 5.22.

Connecting and assembly fixings

There are many types of connecting and assembly fixings. They are often mounted on the product on delivery to the customer, who then carries out the final assembly, see fig. 5.23.

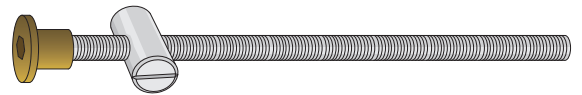


Figure 5.17 Cross dowel and bolt

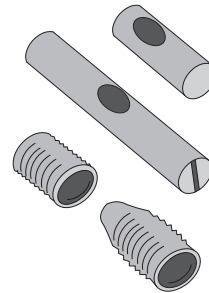


Figure 5.18 Cross dowel and guide pin

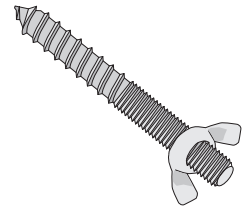


Figure 5.19 Stud screw and wing nut

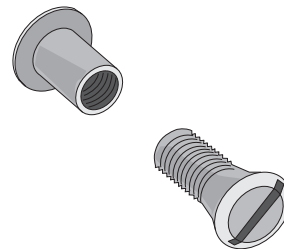


Figure 5.20 Sleeve nut and bolt

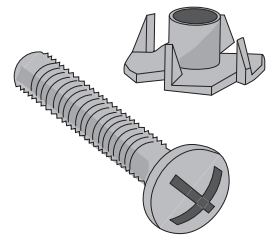


Figure 5.21 Pronged T-nut and bolt

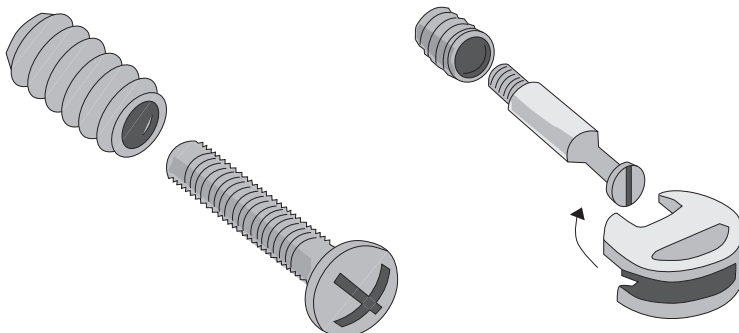


Figure 5.22 Threaded insert nut

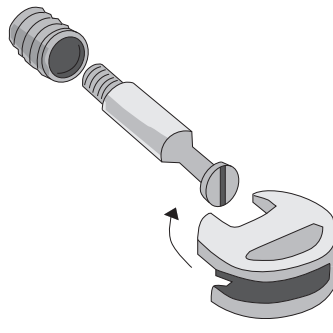


Figure 5.23 Connecting and assembly fixing

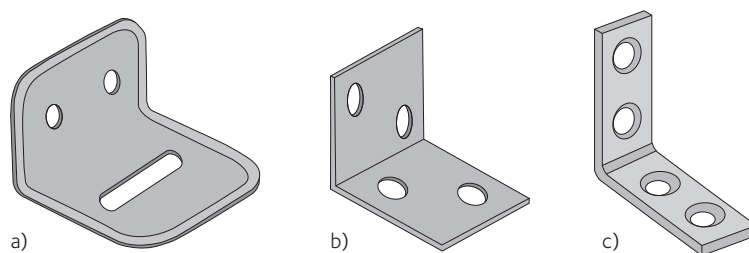


Figure 5.24 Angle brackets

- a) Stretcher plate.
- b) Angle bracket.
- c) Corner brace.

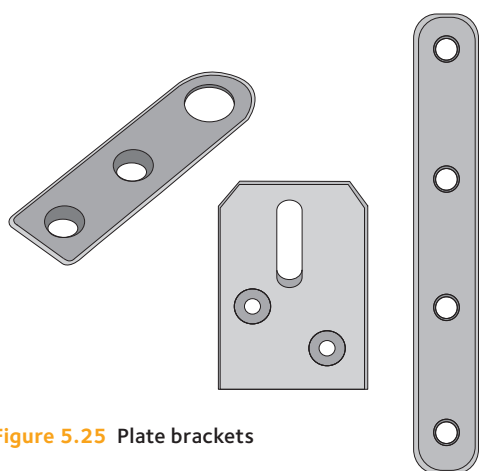


Figure 5.25 Plate brackets

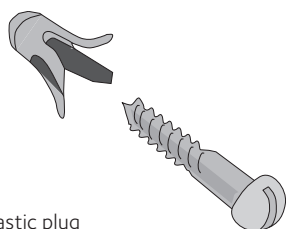


Figure 5.26 Plastic plug

5.2.4 Angle brackets

An angle bracket may be used to connect parts of furniture or other products. It is usually a bent metal plate with screw holes. The holes may be elongated to allow for movement in the material, which is particularly important when using it for a solid wood item, *see fig. 5.24 a).*

5.2.5 Fasteners

Sometimes plugs, anchors or other types of expander are used to connect elements or ensure strong mounting on a wall. The fixing expands either within or behind the hole as the screw is driven in. It is therefore important that the screw is a good fit for the fixing. Plastic plugs are the most common option and they are available in various sizes.

The plugs are colour-coded according to size.

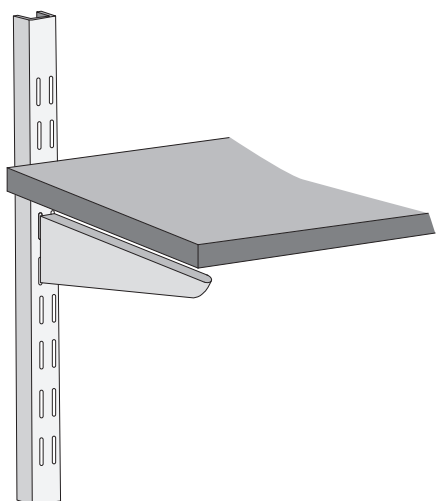


Figure 5.27 Wall rail for shelves, incl. bracket.

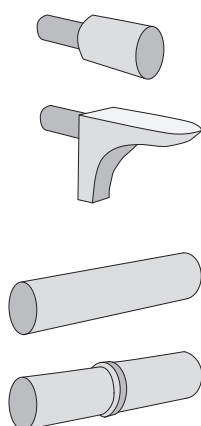


Figure 5.28 Shelf supports

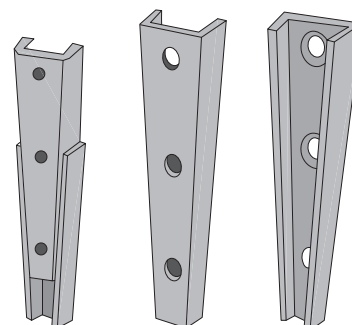


Figure 5.29 Bed rail bracket

5.2.6 Handles and knobs

It is essential that a handle or knob is ergonomically designed and easy to grip, comfortable to hold, easy to reach and functions as required. Since handles and knobs are usually visible, it is also important that their appearance is attractive. Handles or knobs are made from many different materials, *see examples of handles and knobs in fig. 5.30.*

5.2.7 Wheels, glides and feet

Wheels

If you want to be able to move an item of furniture, it can be useful to fit wheels. It is important to choose wheels that can take the intended load. The wheels may swivel or be fixed. Some wheels may be fitted with a brake. The wheels may be attached by means of a bolt hole, *see fig. 5.31 a)*, a threaded stem, *see fig. 5.31 b)*, or a top plate, *see fig. 5.31 c)*.

Double wheel

A double wheel has two wheels that run easily even on a soft surface such as carpet. The wheels tend to be plastic and are cheap to buy.

Swivel castors

Swivel castors are usually solid wheels that are made of metal and therefore are able to handle large loads. They are fitted with ball bearings or slide bearings, which means that they roll easily.

Glides and feet

To protect the floor, you can fit glides, *see fig. 5.33*, or some other type of foot to the furniture. Another advantage of glides and feet is that the furniture is quieter when moved. The foot, *see fig. 5.32*, also protects the furniture from absorbing moisture from the floor.

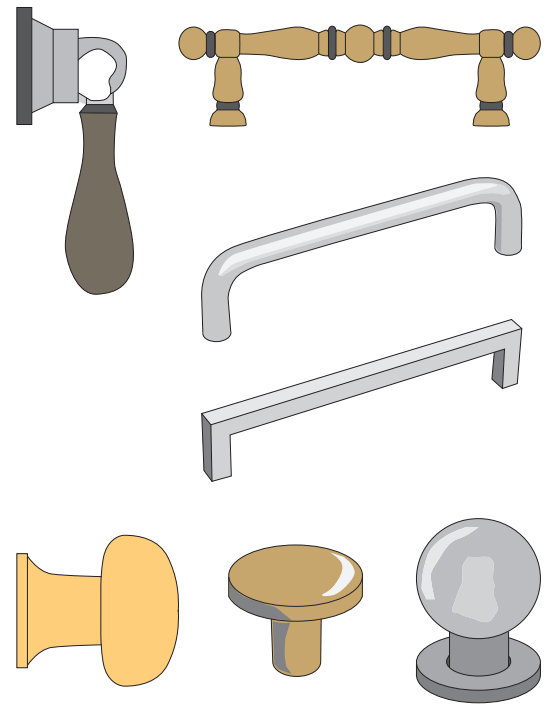


Figure 5.30 Handles and knobs.

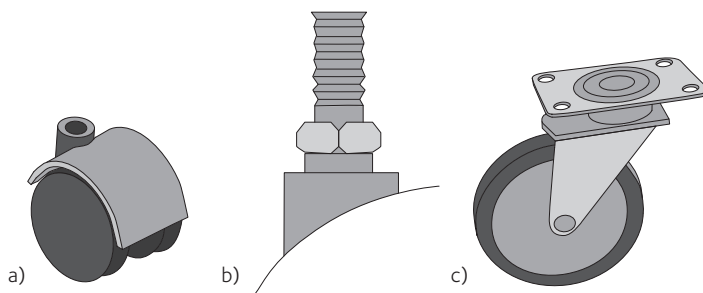


Figure 5.31 Wheels

- a) Double wheel with bolt hole.
- b) Wheel with threaded stem.
- c) Pivoting castor with screw plate.

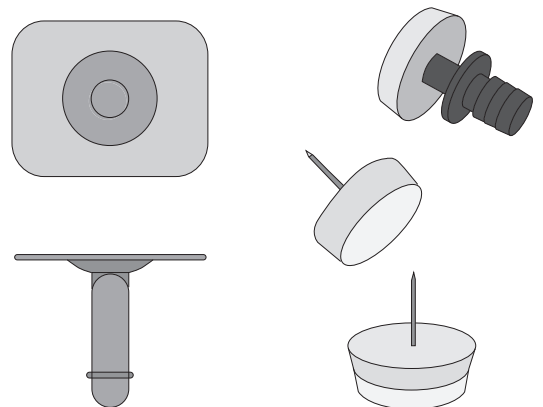


Figure 5.32 Foot

Figure 5.33 Glides

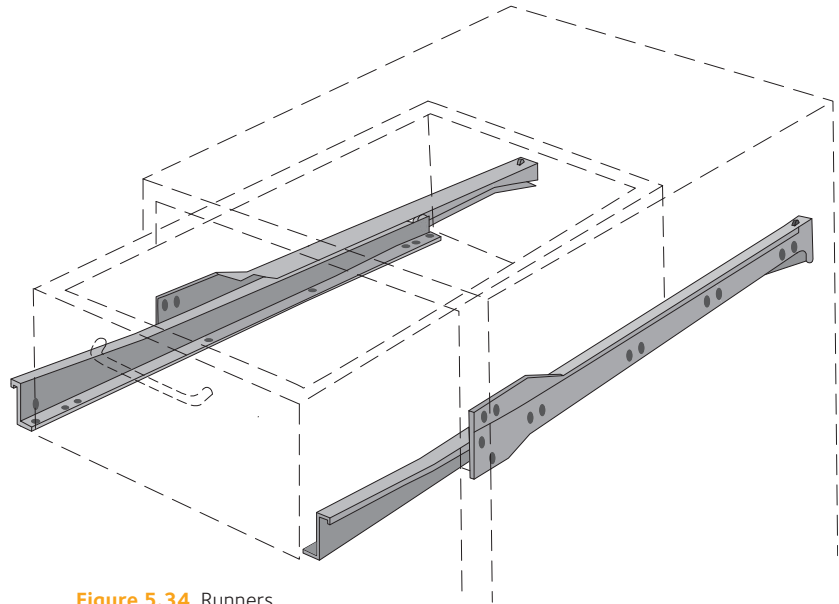


Figure 5.34 Runners

5.2.8 Runners

Runners are fittings that can be mounted on a drawer, for example, so that it can be pulled out. These fittings provide strength and a soft, easy opening and closing action. They are usually made of metal. A differentiation is often made between roller runners and ball bearing runners, depending on the type of bearing used, *see fig. 5.34*.

5.3 Door and window hardware

A wide range of hardware has been developed for windows and doors. It is important that the fittings are of good quality, as the load can be high. A firm emphasis should be placed on corrosion protection, as windows and external doors are installed in or near the outdoor climate. The fittings may be galvanised, chrome-plated or oxidised. They may also be made from stainless steel.

5.3.1 Door furniture

Lift off butt hinge

Doors make use of lift off butt hinges, *see fig. 5.10, page 77*. This means that the load is focused on a small area on the end of the pin, giving an easier and quieter action. The hinge makes it possible to lift the door off if necessary. An outer door or other heavy door will usually need three hinges, *see fig. 5.35*, two of which are fitted to the upper edge of the door jamb. The hinges are often fitted with bearings to improve the durability.

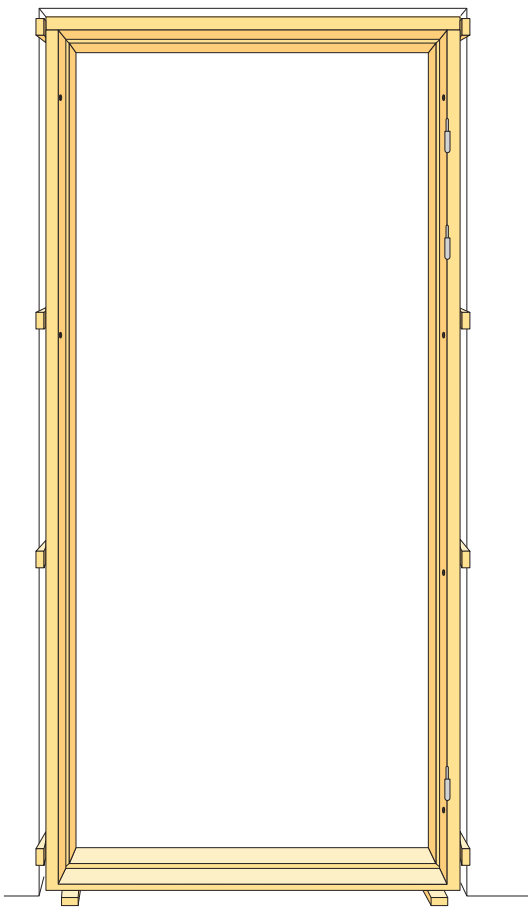


Figure 5.35 Door frame with three hinges.

Locks

The locks used for external and internal doors are usually cylinder locks or lever tumbler locks. The two types of lock differ in the position of the locking mechanism. The mortise lever tumbler lock has its locking mechanism in the lock case, while the cylinder lock has its mechanism in the cylinder, outside the lock case. Right-hung doors use a right lock and left-hung doors use a left lock.

- **Lever tumbler lock**

The locking mechanism in a lever tumbler lock comprises one or more levers, which can be placed in different orders to give different key combinations. Such locks are used for doors in homes and in simplified form as furniture locks. The number of combinations in lever tumbler locks is practically unlimited. A lock with 9 levers can produce over 20,000 different combinations.

- **Cylinder lock**

The cylinder in a cylinder lock contains moving tumbler pins. When the key is inserted and turned, the outer and inner cylinder align. A 7-pin cylinder offers over 2 million combinations. Since the cylinder is a separate part of the lock, it can easily be replaced without having to disassemble or remove the whole lock.

- **Electronic lock**

Electronic locks have become increasingly common in many contexts and allow for an infinite number of combinations. The lock may operate using an entry code or an electronic card.

Door handle

The handle used to open and close a door is usually fixed into place with bolts or a pin.

Kick plate

At the bottom of an external door it is a good idea to fix a guard that protects against damp and impact. This kick plate may be made of stainless steel, brass or copper.

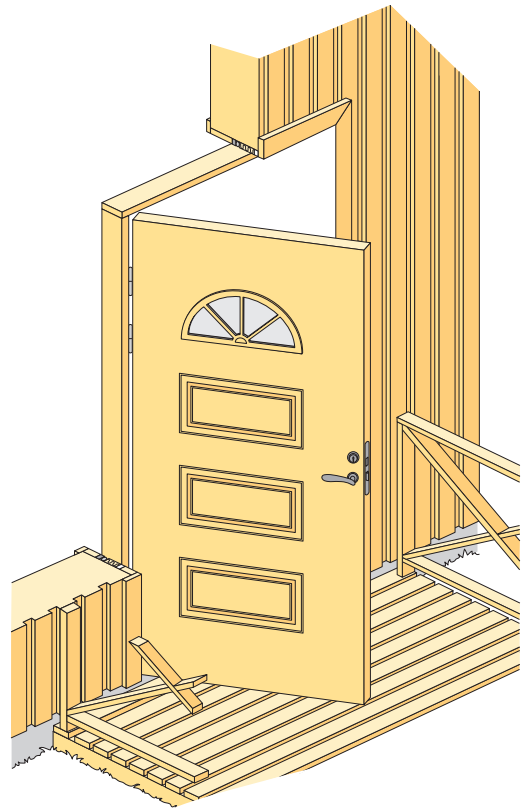


Figure 5.36 Example door with lift off hinges and lock with handle.

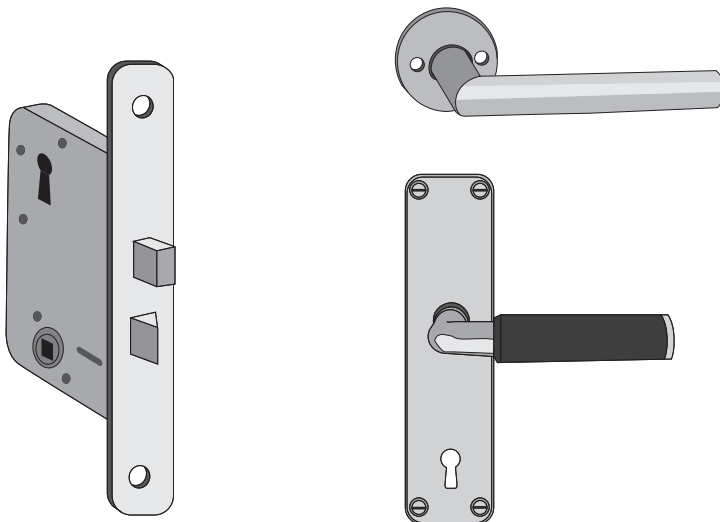


Figure 5.37 Lever tumbler lock

Figure 5.38 Door handles

Left- and right-hung doors

When standing at the side of the door where the hinges are visible, the door should open towards the person opening it. This will indicate whether the door is right- or left-hung. If the hinges are on the right, the door is right-hung (right-hand door). If the hinges are on the left, the door is left-hung (left-hand door).

5.3.2 Window furniture

Window hinge

The window hinge carries the whole weight of the window and therefore has to be substantial.

Coupling hinge

A coupling hinge holds the frames of coupled windows together and makes it possible to open the coupled window, for example to clean between the panes. This hinge should be fixed so that there is a gap of around 1 mm between the frames, to avoid the risk of condensation between the panes.

Coupling screw or coupling hook

Coupling screws or coupling hooks are used to secure the frames in place against each other. They should be fitted so that there is a 1 mm gap between the frames.

Window stays and catches

A window stay or catch can be fitted to prevent a window blowing in the wind when open. These are usually plastic or metal.

Window locks, fasteners and espagnolettes

Traditionally, window locks are used to secure a window, but window fasteners and espagnolettes may also be used. Espagnolettes can lock into the head and sill of the window frame and into a centre post or frame sidepiece.

5.3.3 Top swing windows

Top swing windows come in various forms with specialist fittings. Some hinge systems allow for the window to be swung 180° without touching anything on the inside. This allows each side of the window to be cleaned from indoors.

Gluing

Gluing involves joining two surfaces by letting an adhesive achieve mechanical or chemical adhesion. This then forms a bond between the two surfaces. Traditional adhesives have made use of natural substances to achieve adhesion, among them starch-based glues and bone/fish glue. Adhesive is usually applied in liquid form and must have a wetting effect on the surfaces that are to be glued together. This means that the adhesive must have a lower surface tension than the material to be glued, and this is a crucial factor in choosing the right adhesive. Finally, the adhesive has to set in order to transfer forces between the two materials.

After gluing, the adhesive is subject to various requirements, including resistance to moisture or water. The capacity to handle loads and temperature fluctuations over the long term can also be key factors. As such, it is crucial to know about the properties of both the adhesive and the materials to be bonded, as well as the different loads that will affect the glued joint.

6.1 Preconditions for gluing

6.1.1 Adhesion and surface smoothness

Adhesion is a kind of union. The theory is that if two surfaces come sufficiently close to each other, they form a bond. Imagine the example of two sheets of glass on top of each other. They are almost impossible to pull apart perpendicular to the surface. It is difficult, not to say practically impossible, to get two surfaces so smooth that they will completely merge.

Here, the task of the adhesive is to “fill in” the irregularities in the surface of the materials. It is sometimes said that the force that acts to bond two materials together works within a distance of 5 Å (ångströms). The ångström is a unit of measurement, where 5 Å = 0.0000005 mm; in other words an incredibly small number.

6.1.2 Surface tension

The adhesive’s capacity to wet the material is of critical importance. In this context, wetting is the ability of liquids to form interfaces with solid surfaces. This requires the adhesive to have a lower surface tension than the materials to be glued. Only then can the adhesive be absorbed into the irregularities on the surface. Differences in surface tension can be seen by releasing a drop of water onto a clean and dry surface, and onto a greasy or oily surface. In the first case the drop spreads out, while in the second it remains in place as a bead on top of the surface. Surface tension can be changed in various ways. In the example above, you can easily see how the surface tension reduces (and the wettability increases) if a little washing-up liquid is added to the water.

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Tables are available that show mutual differences between materials and also their relationship to adhesives. The key is to choose an adhesive with good wettability that can penetrate into the surface irregularities of the materials to be glued together. You can get some guidance on the choice of adhesive by releasing a drop of adhesive onto the surface to be glued and seeing how the drop behaves. You can also paint a little of the adhesive onto a square centimetre of the surface. If the surface of the glue tends to pull together, reduce in size or try to form a droplet, the conditions for good bonding are poor.

6.2 Choice of adhesive

6.2.1 Durability

When choosing an adhesive for a particular purpose, it is essential, in the first instance, to choose an adhesive that can take the stresses to which it will be subjected. Adhesives can be divided into the following four groups, according to the durability of the bond that they form:

1. Weatherproof adhesives

These are at least as durable as the wood material. They are fully resistant to weather, water and boiling. They are resistant to attack from microorganisms and they do not laminate in the event of a fire.

Examples:

- thermoset phenolic adhesive
- resorcinol adhesive
- phenol-resorcinol adhesive (min. 50% resorcinol)
- coldset phenolic adhesive (poss. risk of acid damage to wood)
- epoxy adhesive.

2. Weather-resistant adhesives

These are not quite as weatherproof as the adhesives in group 1.

Examples:

- melamine adhesive
- melamine-carbamide adhesive (min. 50% melamine)
- curing PVAc adhesive (creeps under constant load)
- isocyanate adhesive (EPI)
- polyurethane adhesive (both 1- and 2-component adhesives)
- epoxy adhesive (better durability against materials other than wood)
- acrylate adhesive.

3. Moisture-resistant adhesives

These adhesives can be applied to items that will be used indoors where there is a risk of short periods of high humidity. Examples:

- carbamide adhesive, without or with only a small amount of extender (some types have limited age resistance)
- “water non-soluble” casein adhesive (good age resistance but in fact poor water resistance)
- “water non-soluble” soya adhesive (see casein adhesive)
- curing chloroprene adhesive (high creep under constant load)
- blood albumin adhesive.

4. Adhesives for domestic use indoors

These adhesives are not water-resistant and can only tolerate high air humidity to a limited extent. They also have limited heat resistance.

Examples:

- PVAc adhesive (high creep)
- “water soluble” casein adhesive
- starch adhesive
- hot melt adhesive (high creep)
- contact adhesive (high creep)
- animal-based adhesive.

6.2.2 Method of use

In addition to durability and resistance, price and areas of use play a major role in the choice of adhesive for a particular purpose. The adhesive needs to be tailored to the production equipment available. Assembly times, press times, curing temperatures and so on must be able to fit into the production flow.

Work on preparation and dealing with any waste must also be incorporated into the assessment. If you have a recurring need for small portions of adhesive, a PVAc adhesive may prove much more economical than a carbamide adhesive, despite the higher price of the PVAc option.

6.3 Moisture content of wood

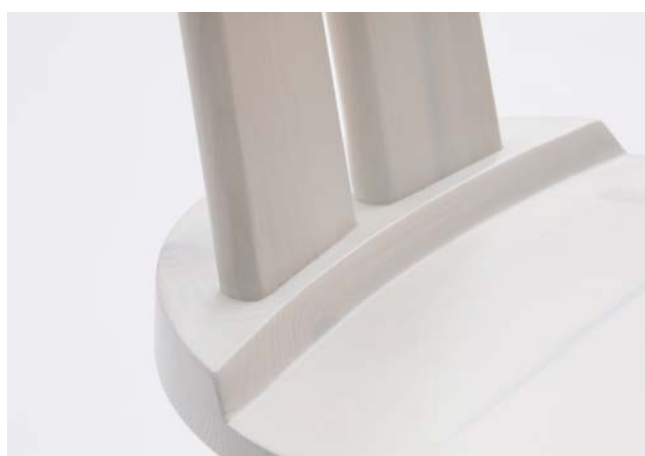
All the adhesive types mentioned will usually bond to wood with a moisture content of 5–15%. If the wood is too dry, the adhesive will find it difficult to wet the wood surface. On the other hand, if the wood is too damp, the common water-based adhesives will dry out too slowly. They will also have a tendency to be absorbed too deeply into the wood, making the actual bond weak.

Adhesives based on solvents other than water have poor wettability on wood with a high moisture content. The adhesives that perform well even with the highest moisture content in the wood are resorcinol and phenol-resorcinol adhesives. On softwood, these adhesives can form complete bonds between wood with a moisture content of up to 25% (“air dry” wood).

If, once in use, a glued wood product adopts a moisture content that is far removed from the moisture content at the moment of production, the dimensional changes that occur will cause considerable tensions within the adhesive bonds. These tensions can cause the bonds to fail through breaks in the wood or in the adhesive. The dimensional changes and tensions can also cause the object to become wavy, warped or split. It is thus important that, during production, the wood material has a moisture content that is as close as possible to the moisture content that the finished product will adopt during use. As such, it is important to measure the moisture content of the wood before gluing.



The Revolving Bookcase, Chandra Ahlsell and Anna Holmquist, Folkform.



Delilah chair, Nicholas James Soubiea, Malmstens, Linköping University.



Cone sideboard, Mikael Blomgren, Malmstens, Linköping University.

6.4 Finishing wood surfaces

For the bond to be fully effective, the adhesive must be able to penetrate unmachined wood and adhere to it. This requires a wood surface that is clean and scraped with a sharp tool.

Sawing with a specialist saw blade can produce surfaces that are suitable for gluing, but a fine, sharp cut is essential. In the case of stringent requirements for gluing, you should use double spreading, *see section 6.6.1, page 90*, and high compression to encourage the glue's penetration into the wood.

Planing and milling with sharp tools produces surfaces that are suitable for gluing. Sanding a finely planed surface is misguided. It only leaves more loose fibres on the surface. A surface that is scorched or "polished" (by a blunt tool) can, however, be sanded with a fine, sharp sandpaper. The dust from the sanding must be carefully removed. Sanding with worn sandpaper gives a polished surface that is not suitable for gluing.

A relatively new way of dimensioning wood is power sanding, which can replace planing. Power sanding uses large, specialist machines with special sanding belts. The method has its benefits, for example on knotty wood (no notches) but is negative from a gluing perspective. This is because power sanding crushes the top layer of wood cells on the surface, exactly the layer that the adhesive needs in order to bond with the wood surface. As such, the jury is currently out on its use in a gluing context, at least for high-performance bonds.

"Old" surfaces can sometimes be difficult to glue. In part, this is because of the chemical changes that take place on the surface, which make it less polar and thus more difficult to wet. It is therefore important that the wood surfaces are as "fresh" as possible, ready for gluing. If the surfaces are old, it is worth freshening them up with a light sanding (remove the sanding dust carefully before gluing).

6.4.1 Cleanliness

There are generally strict requirements that the surfaces to be glued together are clean. In some cases, the properties of the adhesive mean that certain impurities are acceptable. In other cases, impurities destroy all chances of a stable bond. It is therefore important that no factors are changed within a functioning gluing system, without investigating what effect a change might have. Surfaces may be machined, sanded, etched or washed. Water tends to be a better cleaner than a solvent in this context. When it comes to gluing wood surfaces, it is often enough to make sure that the material is free from dust and loose impurities. Wood surfaces that have been exposed to sun and weather need to be brushed with a wire brush or sanded to make the surface sound. The ultraviolet light in the sun's rays quickly breaks down the lignin in the outer wood fibres.

6.5 Adhesives' setting methods

Adhesive is applied in a more or less liquid form and then later sets. Adhesives can be divided into three main groups according to their setting method:

- drying: water or solvent evaporates
- curing: the adhesive cures via a chemical reaction
- cooling: hot adhesive sets as it cools.

6.5.1 Drying

Solvent-based adhesives often contain up to 85% solvent, while water-based adhesives contain around 50% water. All these adhesives will shrink during drying, as such a large proportion of the adhesive evaporates. In order for the adhesive to dry after contact, at least one of the materials being joined must be permeable. The adhesive itself comprises plastics or synthetic rubber that are dissolved or emulsified in a liquid and then regain their original properties during drying.

An alternative is contact adhesives, where drying takes place with an open joint that is then put together under high compression. A certain amount of evaporation must be possible even after joining so that all the solvent/water can disappear, ensuring a full-strength bond. This means that the joint will not be at full strength immediately after connection.

6.5.2 Curing

Curing is a chemical reaction that can be generated by mixing two different components, hence the name 2-component adhesive. An adhesive with hardener can either be supplied in two separate packs to be mixed at the time of gluing or with an integral hardener, where the gluing process is commenced with the help, for example, of heat or contact with water or air. Curing takes place at room temperature or more quickly at higher temperatures. With some adhesives, the process is initiated through UV radiation, the addition of moisture or other changes to the immediate environment. Polyurethane adhesive is an example of a curing adhesive that is available as both a 1- and 2-component adhesive. The adhesive comes in a range of forms from elastic to hard bonds. The adhesive commonly cures in contact with moisture and this can cause some foaming. Epoxy adhesives are another kind of curing adhesive, in both 1- and 2-component form.

6.5.3 Cooling

This group comprises adhesives that are heated up and softened and then left to cool and set.

Hot melt adhesive is liquid in the temperature range of around 150–250 °C. Gluing to a material that conducts heat very well can cause poor adhesion due to the adhesive setting too quickly. The speed of the process is otherwise one of the adhesive's advantages. A hot melt adhesive can set in less than a second. Hot melt adhesives are generally unable to handle large loads. EVA (ethylene-vinyl-acetate) is a large group of hot melt adhesives.

Another group of adhesives is activated by applying heat after application between the two surfaces to be joined together, for example foils, cloth and other thin materials. Heat can be applied via infrared light, hot air, a heat press, an iron and so on.



Cupboard, Mari Koppanen, Malmstens, Linköping University.

Sometimes the gases from the adhesive can be heavy. In this case, it is best that the extractor is placed so that the air is sucked downwards, in order to avoid breathing in the gases.

6.6 Gluing techniques

6.6.1 Adhesive application

It is important to apply enough of the adhesive to the joint in order to avoid various faults. The normal quantity for wood gluing is 60–350 g/m² depending on the adhesive and the absorbency of the material. Applying too little adhesive results in a bond with poor strength, and applying too much adhesive can cause bleeding. The adhesive may be forced out, resulting in a great deal of unnecessary clean-up work.

When applying adhesive, it is important that the correct amount of adhesive is evenly spread over the surface of the workpiece.

With single adhesive application, the glue is spread only on one surface. This is the most common application method within the wood industry. Double adhesive application involves spreading the adhesive over both surfaces. This method significantly increases the strength of the bond, and is recommended when gluing hard and oily woods or using low compression, for example when gluing dowels.

To facilitate wetting, it is sometimes possible to add certain solvents, in consultation with the manufacturer.

6.6.2 Gluing by hand

Gluing by hand takes a great deal of time and effort. It is difficult to achieve even application, particularly with a brush, which should therefore only be used on small and narrow surfaces. On large surfaces, it may be more appropriate to use a serrated scraper made of plastic or stainless steel. With a little practice, a relatively even layer of adhesive can be achieved in this way. You should bear in mind that the adhesive's assembly time is limited, so make sure that it does not dry before contact. The gluing process is much quicker if you prepare fully, for example by dry fitting the parts, *see section 5.1.1, page 72*.

6.6.3 Spraying

Spraying can be a practical method of adhesive application. This involves a spray gun and a pressurised container, similar to the kind used for manual paint spraying. Special nozzles are available for dowel gluing.

6.6.4 Roller application

Roller application is a common method in industrial circles. The machine may be equipped with one or more rollers. An adhesive tank is fixed to the roller, and the amount of adhesive can be controlled by adjusting the distance between the glue tank and the roller or the distance between the rollers.

Once the job has finished, and well before the glue has thickened too much, the rollers must be thoroughly cleaned with hot water (50–60°C). The grooves are cleaned with a stiff brush. Do not use a cloth and mind your fingers! Steel rollers should be protected against rust if the machine is going to be out of action for a prolonged period.

Residues of cured adhesive are often impossible to remove from the roller without damaging its surface. Adhesive rollers for applying contact adhesive are often encased to limit the evaporation of the solvent. Only specialist rubber is resistant to the strong solvents found in contact adhesives.

6.6.5 Double roller with feed roller

Simple adhesive spreaders are available in many different designs. It is most common for the workpiece to be introduced to the roller by hand. Mechanical operation of the rollers is also an option, with the workpiece held and controlled by hand.

The adhesive spreader, in its simplest form, comprises a roller that dips partially into a container of adhesive.

Two rollers give a better spread of adhesive. The space between the rollers determines how much adhesive is applied to the upper roller.

When spreading adhesive on larger surfaces, for example when layering veneers, the preference is often to use a machine that applies adhesive on two opposite surfaces of a workpiece.

6.6.6 String spreading

In this case, the adhesive comes out of many small openings along a pipe and hits the workpiece in strings as the piece is fed through the spreader. Where the spreader is wider than the workpiece, surplus adhesive usually runs down into a container and is recycled. String spreading (separately or with mixed adhesive) is used primarily in the production of glulam.

6.6.7 Compression

The compression is related to the size of the compression surface. The pressure usually does not need to be particularly great. It is important that the surfaces achieve sufficiently good adhesion. The pressure should be stable so that the adhesive does not move, and the pressure must remain in place in order to achieve the necessary hardening. Contact adhesives require high compression, which increases the strength of the bond. The pressure required depends on surface smoothness, the material and the type of adhesive. If you use too much pressure, the material can deform, while too little pressure could result in insufficient adhesion and reduced strength. The adhesive supplier's product information will contain instructions.

When laminating pine and spruce, a pressure of at least 0.6 MPa is recommended. Laminates with a thickness of 45 mm currently require pressure of 1.0 MPa. Significantly lower pressure may be needed for specialist joint filling adhesives. Factories use hydraulics, compressed air or special mechanical clamps.

Factors such as adhesive bleed and compression of the wood cause the pressure to decrease over time. When compressing using clamps, these must be retightened after 15–30 minutes.

Once the compression has been concluded, the glued items should be stacked with spacers between them to allow air to circulate around them. This allows the final part of the setting and evaporation process to take place. This is especially important when gluing wood, as it tends to involve the use of water-based adhesives. It can often take a long time for the bond to achieve its full strength – sometimes up to several days. When hot gluing, and particularly with curing adhesives, stacking without spaces can be a good idea. This way the heat will remain for longer, helping the curing process.



Thaw shelf system, Hemmo Honkonen, Malmstens, Linköping University.

6.7 Gluing terminology

Storage life

The storage life is the length of time that the adhesive can be stored before it becomes unusable (before the addition of a hardener or, for powdered adhesives, a solvent). The storage life is shorter, the higher the temperature at which the product is stored.

Working life

The working life is the time from when a chemically curing adhesive is mixed (adding the hardener, solvent or similar) until it is no longer usable. The working life is shorter, the higher the temperature.

Mixing time

The time it takes to add the hardener, solvent or other substances to the adhesive.

Assembly time

The assembly time is the time from adding the adhesive to achieving full compression. There are two types of waiting times in this context:

- The open waiting time is the time from applying the adhesive to the parts being assembled but not yet put under pressure.
- The closed waiting time is the time from assembling the parts to achieving full compression.

Closing time

The time from placing the working piece in the press to achieving full pressure.

Press time

The press time is the time from achieving full pressure until the joint is strong enough for removal. The normal pressure for wood gluing is 0.3 – 1.0 MPa, in extreme cases 0.2 – 1.5 MPa.

Joint conditioning time

The time it takes from removing the workpiece to the joint achieving full strength.

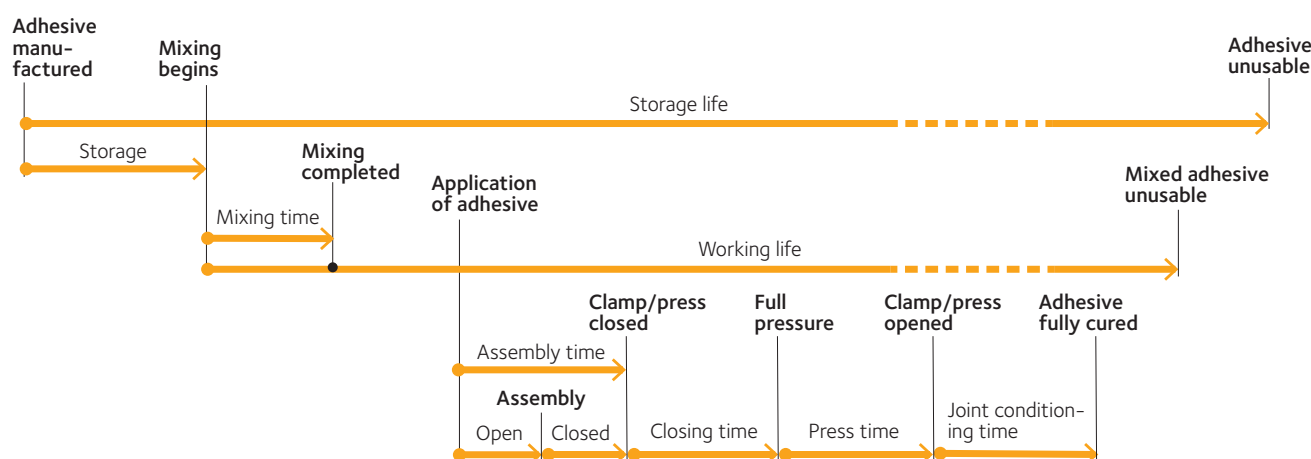


Figure 6.1 The gluing process

6.8 Compression equipment

6.8.1 Manual clamps

Sash clamp

Sash clamps are available in lengths from 0.5 to 2.5 m and can be used for making glued joints or for manual assembly of furniture, for example. A sash clamp can also be fitted with a pneumatic piston.

F-clamp

F-clamps come in a wide range of lengths and depths. The clamp jaws should be fitted with protective pads to prevent marking on the product.

Hand screw clamp

Hand screw clamps are a lightweight clamp for gentler compression, with jaws of wood. The jaws are protected with cork to avoid marks on the product.

Mitre clamp

There are various types of clamp for gluing corners on frames and so on. A mitre clamp is often fixed at 90°.

Band clamp

The band clamp comprises a band of steel or webbing material that is used with corner blocks and a tensioner to hold a whole frame in place.



Sash clamp



F-clamp



Hand screw clamp



Mitre clamp



Band clamp

6.8.2 Manual frame gluing

To check that a frame structure is straight, measure the diagonals from corner to corner. If the diagonals are different lengths, the frame is off square or warped. Adjust the clamps and check again.

Use a set square to check that the corners of the carcass, frame or box are at right angles. Check all four corners. Lay flat frames on a level surface. You will then be able to see whether a frame is warped.

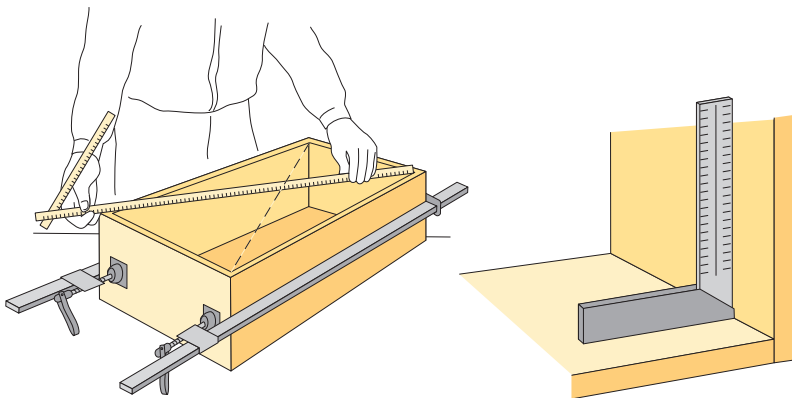


Figure 6.2 It is important to measure a frame by measuring the diagonals and checking with a set square.

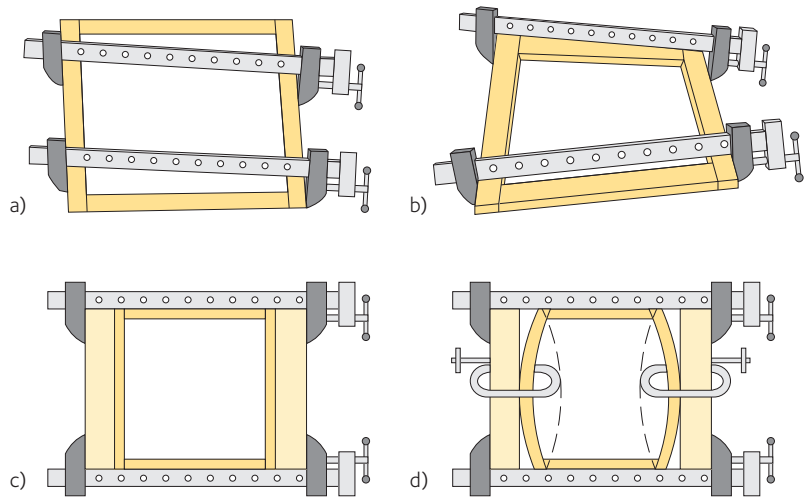
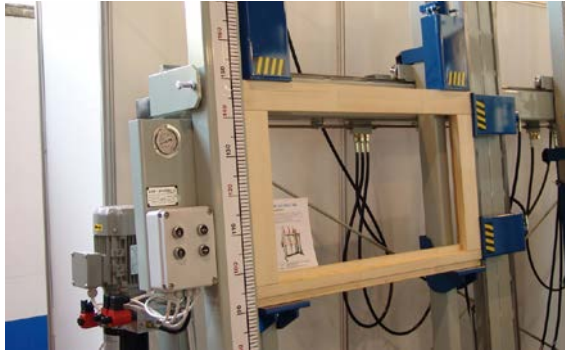


Figure 6.3 Gluing frames.



Frame press



Rotating press

If a frame is off square, *see fig. 6.3 a)*, correct it by angling the clamps so that it is brought back to the correct angle. If the frame is warped, *see fig. 6.3 b)*, position the clamps so that they pull the highest corner down and the lowest one up.

When clamping across a carcass, use large, straight pieces of wood on the front and back, *see fig. 6.3 c)*. Surfaces that bend inwards can often be corrected by forcing them in the opposite direction, *see fig. 6.3 d)*.

6.8.3 Mechanical presses

Mechanical presses are usually powered by either hydraulic or pneumatic pistons.

Frame press

A frame press can be used to glue various types of frame, including window and door frames.

Rotating press

A rotating press allows for continuous gluing of glued joints, for example. Once the gluing action is completed, the machine rotates so the next side can be released to begin gluing the next joint. The machine is equipped with a number of pneumatic pistons that can be adjusted to the size of the product.

Case clamp

Case clamps are used to glue various items in solid wood or sheet material.

Gluing table

Comprises a cast metal table that can have pneumatic pistons fitted in a range of positions.



Case clamp

6.8.4 Suppliers

Handling the adhesive and the gluing process is both sensitive and important. It is therefore essential to have the right knowledge about the adhesive and the materials to be glued in order for the product to last and to meet the expected standards. These days, function is often overlooked in favour of evidently varied requirements that certain substances must not be present in the adhesive. The problem is that all the substances in adhesive are there to perform a particular function. Unfortunately the choice of adhesive is steered too much by various assessment systems that lack knowledge of the adhesive's function, which leads to a poorer end product and a poorer environmental profile, as the element is likely to need replacing or the job redoing much earlier than if you had chosen the correct adhesive from the beginning.

Good contact with your adhesive supplier is important in ensuring that you have the right adhesive in the right place. Obviously, the adhesive suppliers are able to provide product sheets and other information, so the user can easily ascertain the adhesive's properties, areas of use and handling parameters, along with any work environment risks. The adhesive supplier can also provide information on new methods and products. The product information details factors such as:

- area of use
- moisture tolerance
- handling
- mixing ratios
- application quantity
- press times
- cleaning
- storage life
- dry content
- density
- health and the environment
- temperature tolerance
- tools and machines
- working life/assembly time
- setting temperatures
- chemical composition
- viscosity
- acidity (pH).

6.9 Gluing coated surfaces

Workpieces are often surface treated before they are glued together. This coating may well end up, for example, on tenons and mortises, if these are not specifically protected. Protecting certain parts of the workpiece is hard work and the easiest solution would be to glue the parts together even if they have a coating of paint or varnish on them. This may be possible, depending on the geometry of the surfaces and the expected quality of the end result. Some coatings are harder than others in this respect.



Bookshelf Shelf, Frida Erson and Martin Eckerberg, Formellt.

Tests show that dispersion adhesives such as specialist PVAc adhesives, EPI or related types can be made to adhere to most coatings. Each specific combination of adhesive and coating should be tested.

Some adhesive manufacturers supply special adhesives for coated surfaces. These contain a solvent to facilitate adhesion to the coating. The solvent may also serve to keep the adhesive soft for a longer assembly time.

You should consider the possibility that the glued joint will not be as strong. The method is not recommended for tenon and mortise joints subject to high loads, for example in chairs. When gluing particleboard, you can achieve glued joints that are as strong as the board itself.

The glued joints appear to be better when there is a coating on both surfaces, compared with having a coating on just one surface. This is probably because the adhesive dries more slowly, so it has more time to bond with the coating.

It may be necessary to increase the press time, particularly where there is a coating on both joint surfaces and where the layer of coating is thick.

Tests with polyurethane adhesive indicate that this adhesive can be used on all types of coated or oiled surface, with the exception of polyester that contains wax. Polyurethane adhesive also adheres to oil-impregnated wood (e.g. using the vacuum or Royal process). Whenever you are gluing to coated surfaces, you must bear in mind that the adhesive grips the coating, not the underlying wood. The strength of the bond thus depends on the strength of the coating and how firmly it is attached to the wood.

6.10 Gluing metal to wood

Metal and wood react very differently to heat and moisture. Major stresses in a glued joint between wood and metal are therefore unavoidable. Chemically curing adhesives can also add shrinkage stresses that occur during curing. On a completely smooth metal surface, the stresses will be heavily concentrated on the edges of the metal surface. If you make the metal surface coarse through sanding, sandblasting or chemical etching, the adhesive will achieve better adhesion and the stresses will be more evenly distributed over the surface. In practice, you thus need to either make sure you have rough surfaces or use adhesives that are plastic enough that they can “flow”, so the stresses are evened out.

A further problem with gluing metals is that the metal surface is almost always contaminated with grease particles. The grease comes from the metal’s previous machining or from the air. Before roughing up the metal surface, it needs to be degreased. Useful degreasers include trichloroethylene or carbon tetrachloride (toxic) or trichloroethane (less toxic). It is never sufficient just to carry out the degreasing step. After degreasing and roughing, the gluing should take place immediately, unless the surfaces can be stored in a completely clean atmosphere.

The following methods are used:

- Hot gluing in one operation. The adhesive comprises two components, a thermoplastic and a thermoset plastic. The thermoplastic may be polyvinyl formal, polyvinyl butyral or polyvinyl acetate. The thermoset plastic is usually of the phenol formaldehyde type. With some of the types, the one component is applied to the metal,

and then the other (a powder) is sprinkled on top. With other types, both components are liquid, in which case they are allowed to dry before being compressed. The curing temperature is 120–170°C. In the case of single-sided gluing of metal to wood, the sheets have a tendency to warp, with the effect increasing as the size of the surfaces increases. This method delivers very strong and durable glued joints, which is why it is used in the aircraft industry, for example.

- Gluing in two operations. Immediately after degreasing and roughing, a primer is applied to the metal. A metal adhesive like one of those mentioned above can be used as the primer. The primer can be cured in a curing chamber, although there are primers available that dry at room temperature or with just a small amount of heat. Once the treated workpieces have been allowed to cool, the next stage is to apply a regular carbamide, resorcinol or acid-curing phenol adhesive. The curing now takes place at room temperature or with the addition of just a small amount of heat. The resulting joints will be fairly strong and durable.
- Cold gluing in one operation. Only very elastic (actually plastic) adhesives are used for this. Comparatively good results can be achieved with a casein/latex adhesive or a neoprene-type contact adhesive. PVAc adhesive can be used for some metals. Contact adhesive is the easiest to use, as it adheres to the vast majority of metals. It also dissolves grease to some extent and is very elastic. As such, it is possible to skip both degreasing and roughing, at least on small surfaces. The best method for contact adhesive is to dry the adhesive with radiation and immediately pass the workpieces through a roller press. This method does not produce joints of the same strength as hot gluing or primer/cold gluing. The strength of the joint is, however, perfectly fine for many uses, such as gluing kick plates onto doors or metal foil onto plywood. Epoxy adhesive bonds extremely strongly to many metals, such as steel and aluminium. Since epoxy adhesive does not shrink during curing, it can be used against smooth metal surfaces, although a rough surface produces the best results. Epoxy adhesive has the same strength when dry as wood and often produces waterproof joints against wood materials. Polyurethane adhesive creates very strong and durable joints on both wood and metal. Acrylate adhesive and EPI also have their place here. Acrylate adhesive has the advantage that it adheres even if the surfaces have slight deposits of oil or grease. In the case of all glued joints between wood and metal that are exposed to moisture, the moisture will diffuse through the wood and the adhesive to reach the metal. This can cause corrosion on the metal surface, rust on steel and oxidation on zinc and aluminium. Over the long term, this corrosion may weaken the adhesive bond. In such an environment, the metal should thus be protected against corrosion or be inherently corrosion resistant. Structures that will be subject to loads require an adhesive that has little cold movement (creep). Such glued joints can become brittle and the connection between metal and wood will thus have low impact strength. Structures with these bonds between wood and metal must be designed so that stresses in the form of impacts and knocks can be damped within the structure through elastic deformation. Large, unbroken glued surfaces between thick metal plates and thick wooden elements should be avoided when gluing wood to metal with an adhesive that produces brittle joints.

Table 6.1 Faults that may arise during gluing and their common causes.

Gluing fault	Common causes
The glued joints lack strength	
Precuring The adhesive in the joint is glossy and has not been pressed into the wood surfaces. The grooves from the adhesive spreading can often be seen.	Hardener too fast Wrong amount of hardener Waiting time too long Room temperature too high
Air humidity too low	Assembly and closing time in the press too long
Undercuring After pressing, the adhesive is soft when touched with a damp hand.	Hardener too slow Wrong amount of hardener Press temperature too low Press time too short Uneven press temperature
Blisters Usually in the middle of the larger areas between the cross veneer and the surface veneer or between laminates and cross veneers.	Wood's moisture content too high Press temperature too high Waiting time too short Too much adhesive Too much extender
Discolouration Colour changes may occur some while after gluing.	Too much adhesive Uneven spreading Too much hardener Moisture content of wood too high
Poor adhesive flow The adhesive has not penetrated the wood surfaces.	Press time too short Insufficient or uneven pressure Wood material not level Moisture content of wood too low or too high Hardener too fast
Warping The glued structure wants to warp.	Structural imbalance Moisture content of wood too high Thin adhesive solution Not enough adhesive applied Highly absorbent material Press temperature too low or too high
Adhesive not curing or drying	Manufacturer's press time not adhered to Material is too greasy Forgotten the hardener Adhesive poorly mixed Wrong type of hardener Wrong amount of hardener Curing temperature too low Contaminants in the adhesive container or spreader
Poor moisture resistance	Adhesive has not cured properly

6.11 International standardisation

Both ISO (International Organization for Standardization) and CEN (European Committee for Standardization) are working to draw up internationally recognised testing methods and requirement levels concerning the gluing of wood materials. This is so that adhesives and glued products that have been tested and approved in one country will not need to be tested again for every country to which they are exported.

Surface coating

The choice of surface coating often comes down to a combination of practical and aesthetic considerations. You might want to make a material look like something it is not. Or get it to harmonise with something else in the same piece of furniture or in the room for which the furniture was designed. Or create contrasts, for example by juxtaposing dark and light, matt and gloss or hard and soft.

Whatever the decision, there are effects that can be achieved via the capacity of the surface to activate all the senses. A surface material can be seen, touched and smelt, and everything contributes to the way we experience it. The surface is part of the furniture's look. Surfaces communicate. What does paint, a printed pattern or a fabric do to the perception of a wooden surface?

There are ways to treat a surface that require a practised hand – French polishing is one – and there are methods that have been developed for efficient, large-scale production. Manufacturers continue to specialise in specific areas and adapt materials and methods accordingly.

What options are there for maintaining or updating a surface? Greater opportunities to change and renovate furniture also increase the scope and inclination to give it a long life, thus helping to establish a sustainable furniture culture.

7.1 Interior painting

Interior wood is given a surface coating primarily for decorative purposes. The type of paint used depends on the required aesthetic and functional end result. Sometimes, the substrate to be painted throws up limitations. The various types of paint are divided up according to their coverage and the binder used.

Wood is coated to protect it against mechanical and chemical influences. The usual aim is to protect against oil, grease, liquids and common dust, for example. If you want to accentuate the wood's natural beauty, you should use a more transparent surface coating rather than an opaque one. To avoid wood shrinking and the finished surface cracking in heated rooms, it is good to keep the air humidity at the right level, for example using a humidifier.

With wood surfaces in wetrooms such as bathrooms and laundry rooms, the surface coating also has a protective purpose. The same is true for the facing sides of coupled window frames, which should be treated in the same way as external window frames.

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Pine samples stained in various colours.

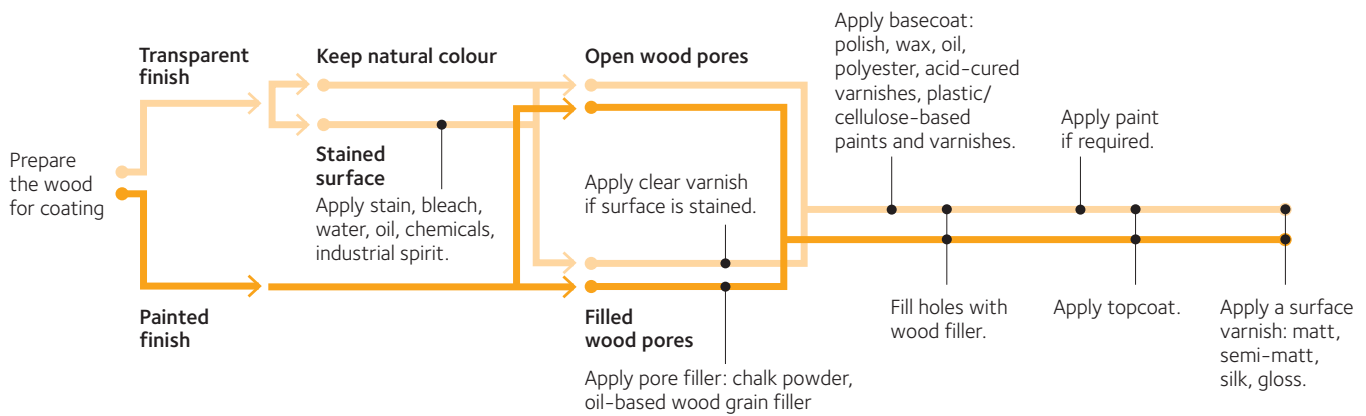


Figure 7.1 Surface coating process.



The Crane bedside table, Maja Björnsdotter, Malmstens, Linköping University.

7.1.1 Painting in the wood industry

Within the wood industry, surface coating is a specialist subject that requires knowledge and experience. Manual spray painting remains the most common application method, but automated equipment is replacing this work to an increasing extent. It is also becoming more and more common for manufacturers to specialise in a particular product area, with the surface coating material, application equipment and curing ovens tailored to a specific production process.

There are many factors to consider when looking for the right kind of surface coating. The medium, application method and wood have to work together and the surface must be suitable for the purpose of the object. Environmental requirements concerning surface coatings may be set by both clients and authorities. What is the most cost-effective and environmentally acceptable surface coating? Will the surface be exposed to a lot of water or other liquids? Harsh treatment? Will paint make the surface more attractive? Can it be stained? Should you focus on a wood type with a fine-pore or a large-pore surface?

A goal for all surface coatings on furniture, joinery and fittings is that:

- The final surface has a good, smooth finish.
- The final surface has the stated colour and shine.
- The final surface is resistant to scratches and abrasion.
- The final surface meets requirements by Möbelfakta or some other labelling scheme.
- Paints and varnishes do not give off any harmful or irritating substances during either application or drying.
- The finished film is well adhered to the substrate and is sufficiently elastic and flexible to avoid splits and crackling due to movements in the substrate.

7.1.2 Preparatory work crucial

The old adage that a well-prepared surface is half the battle remains true to this day. The finish achieved is only as good as the substrate beneath it. Preparation of the wood should be carried out with the greatest of care, as it affects the end result and, importantly, the amount of paint/varnish required. The surface should be smooth and even, and as minimally absorbent as possible. Loose wood fibres should be removed.

Before you begin applying the surface coating, the surface must be processed to its final standard and completely clean. Grease, dirt and loose material will repel the surface coating and give an uneven finish. Plane and sand down all uneven joints, hammer down nails and staples, and remove all pencil marks, as well as all traces of oil, stain, paint and other imperfections.

To avoid knots turning yellow when coating new wood, it is recommended that the knots are treated with knot sealer or shellac before priming. Careful cleaning of the substrate when repainting is essential for a successful result. Always scrape back to a sound surface and clean with a recommended cleaning agent, such as sugar soap. Usually, both new and existing surfaces require sanding. Follow the instructions from the paint supplier.

7.2 Types of surface coating

7.2.1 Clear varnish

Clear varnish is a surface coating that, after application and drying, leaves a transparent film on a wood-based substrate, for example. The varnish largely comprises a binder and an organic solvent or water, along with a small amount of additives to control the gloss and coverage. The dry content of a varnish is stated as a percentage by weight and is the amount of material that remains on the surface once the solvent or water has evaporated.

The varnish dries physically by the solvent or water evaporating away, and so is designated a 1-component product. If a hardener is added, chemical drying (curing) takes place and the system is then designated a 2-component product. Once the hardener has been added, the mix is only usable for a certain amount of time, known as the working time. UV-cured varnish is generally a 1-component material that undergoes curing under UV light, referred to as radiation curing.

As a rule, 2-component materials have better surface hardness and stackability than 1-component materials, which tend to remain soluble in organic solvents even after drying.

7.2.2 Paint

Paints, whether primer, undercoat or topcoat, are the pigmented, opaque surface coatings that cover the substrate and give a finish in the desired colour. Paints contain the same constituent substances as varnish, along with colour pigment and filler. Paints also dry physically or chemically in the same way as varnish, and are also named 1- or 2-component materials, depending on whether the addition of a hardener is required. After drying and curing, the varnished or painted surfaces should be stackable.

Additional components

Thinner/solvent

Thinner may be water or an organic solvent (a pure substance or a blend of several organic solvents). The solvent is designed to give the paint or varnish the best possible application and drying properties. The solvent regulates the viscosity (consistency). Sometimes a specialist thinner is required to resolve specific problems. Organic solvents are a necessary evil from the perspective of health, safety and the environment. It is the volatility of the organic solvent that makes the paint dry faster.

Hardener

Some types of paint will not dry without a hardener, and these fall into the category of thermosetting polymers. The products usually comprise two components, a base and a hardener, although UV coatings cure with the help of UV light.

The majority of paint types belong to the category of thermosetting polymers, including UV-cured, acid-cured, polyurethane paints and epoxy paints.

The hardeners function in a couple of different ways during the drying/curing process. Either they act as a catalyst in the mix by making it acidic (acid-cured) or they take part in the actual binder reaction, as in urethane paints, and become part of the finished film. Hardeners may be either water-based or solvent-based. When mixing the base and the hardener, it is important to follow the supplier's mixing recommendations for the right ratio. Otherwise, the product will not fully cure.

The time that the mixture remains usable after the addition of the hardener is called the working time.

Stain

Stains tend to accentuate the natural grain in the wood while also colouring it. Due to variations in the wood's capacity to absorb the stain, lighter areas will look darker and darker ones lighter. Since the stain is absorbed differently in different pieces of wood, it can be difficult to achieve a consistent colour match with stains.

Wetting agent

Light woods such as pine can be treated with a basecoat varnish that either contains or does not contain a wetting agent. A wetting basecoat gives a yellowish surface and the heartwood of pine becomes a red-brown. The properties of non-wetting coatings mean that the wood retains its light colour. Adding a whitener to the basecoat can accentuate the light colour of the wood.

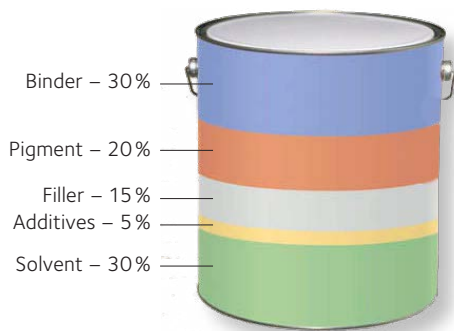


Figure 7.2 Composition of paints. Percentages are examples only.

Specialist coatings

Certain applications, such as toys for children and furniture for storage, sometimes require specialist coatings. The coatings usually used for joinery can give off substances that damage paper and sensitive fabrics. In this case it is important to comply with current legislation and be aware of the materials being used when choosing both the type of wood and the surface coating.

7.3 Environment

The choice of surface coating system depends on the appearance and function that you require for the surface, and the equipment you have available for painting. In addition to this, you may need to take account of both the work environment and the external environment.

How resistant to liquids does the surface need to be, how hard-wearing, scratch-resistant and so on? Since the mid-1960s, acid-cured coatings have been the most widely used in the Swedish wood industry, but the trend has shifted more towards water-based products and thermosetting polymer products.

If it is possible to achieve the same technical performance while still making a good environmental choice, priority should be given to water-based products and products with a high dry content. The type of solvent used also affects the choice of product from an environmental perspective.

7.3.1 Indoor environment

The binder in acid-cured coatings is primarily made up of amino resin in combination with alkyd resin. Rapid-curing products also include a small amount of nitrocellulose. The downside of amino resins is that during application and curing they release formaldehyde gas, which along with solvents is a major work environment issue. Small quantities of formaldehyde may also be released into the living environment, which for some people can cause issues such as headaches and irritation of the eyes, nose and throat. The level of formaldehyde in products has gradually fallen over the years. Some solvents have also been replaced with those that are judged to be less harmful to health.

Factors that have made the acid-curing system a frequent choice include technical advantages such as rapid curing, long working time, good surface resistance and the practicality of being easy to handle and apply.

A target was set that emissions would fall within the parameters of the German standard for emissions of formaldehyde from particleboard, known as the E1 standard. Once the target was achieved, the paint manufacturers and the Swedish wood industry considered the problem solved. However, consumers have a different opinion. There have been several rounds of debate about the risks of formaldehyde in Sweden and attention has been drawn to the existence of the substance in furniture and textiles. In Denmark and Germany, formaldehyde in the living environment has been seen as a major, serious problem. Environmental debates have led consumers to increasingly seek out products that are not harmful to the environment. One result of this has been a rise in the sales of solid wood furniture, treated with oil, wax or natural soap.

The use of volatile substances in homes, offices, schools and so on has been flagged up in relation to air quality and “sick building

syndrome”. Symptoms of this include tiredness, irritated mucous membranes and headaches. The volatile substances originate from products, materials and activities in the home. The surface coating may be a source of emissions, but it may also be a barrier.

A widely used term for volatile substances is VOC (Volatile Organic Compounds). In many contexts, the focus is often on the total level of VOC (TVOC). The term lacks a consistent definition and there is also no standardised method of analysing or measuring TVOC.

A huge number of studies have been conducted to find links between TVOC and “sick building syndrome”, but the results are far from unanimous and do not indicate any actual correlation. In other words, the available data does not suggest that TVOC would be a useful metric in terms of health.

Formaldehyde is volatile, but is measured in a different way and is not counted among other VOC. Exposure limits in this area have been set by the World Health Organization (WHO) and in Sweden by the National Board of Health and Welfare.

7.3.2 New coating systems – other risks?

As authorities introduce tougher regulations concerning low emissions and a good work environment when applying surface coatings, the industry is transferring these to the paint manufacturers, who have to develop more “eco-friendly” surface coating systems.

When switching to another type of coating, comparisons are mainly made with the properties of the paint being replaced. Questions that should be asked in this context are:

- What level of quality is required?
- What requirements are there for the durability of the surface, with reference to the product’s area of use? Can the requirements be separated into A, B and C surfaces, whereby the highest standards apply to tabletops and countertops? The requirements and the amount of coating applied are lower on vertical surfaces and lowest on hidden surfaces such as the underside of a shelf.
- What are the pros and cons of using only solvent-free coatings?
- What are the pros and cons of using combinations of different surface coating materials? Often only a small part of the production, such as certain table surfaces, need to be painted with a convertible coating. It may be better to paint the rest with a water-based coating. Perhaps combinations of coatings will provide a better work environment, greater capacity, higher quality, fewer emissions and a lower overall cost? Hardly any consumers are going to notice if furniture is finished with a water-based coating, and if they were told this was the case, the majority would see it as a positive thing.

7.3.3 Ecolabelling

There are now often requirements for some form of ecolabelling of products. Ecolabelling may apply to the whole final product or just to the surface coating. There is an abundance of different ecolabelling schemes, both Swedish and international. The systems and criteria that apply for the various schemes are constantly changing, which is why it is important to stay up to date.

Common environmental assessment schemes with requirements concerning surface coating systems are:

- EU Ecolabel
- BASTA
- Byggvarubedömningen
- Nordic Swan Ecolabel

The criteria for surface coating materials can vary from one system to another.

7.3.4 Specific requirements for surface coatings

Sometimes specific requirements are set for both the surface coating and the end product. It is important for manufacturers to keep up to date and comply with the latest legislation that applies to their area of operation.

Examples of areas where specific requirements apply include toys (EU Toy Safety Directive), electronics and wetrooms.

There may also be specific work environment requirements concerning the use of a particular method or product for surface coating. One example is coatings containing thermosetting polymers, which are subject to requirements for medical checks and training of personnel. Paints and other surface coating materials are classed as chemical products in the legislation and are to be treated accordingly.

7.3.5 Regulations and information

Current regulations on the content of products and goods are handled in Sweden by the Swedish Chemicals Agency. These regulations are rooted in European legislation. The latest information and regulations can be found on the Swedish Chemicals Agency's website www.kemi.se.

Chemical products such as paints must have a safety data sheet that can be sent to professional users. Information on the safety data sheet should include the product's contents and classification, what safety measures need to be taken during application and how waste should be disposed of. Private individuals should also be able to request safety data sheets.

Environmental product declarations (or construction material declarations) are drawn up by the supplier and provide further information about the content of the project, but also address the environmental impact of the product during manufacture, the usage phase and as waste.

Technical data sheets are drawn up by the supplier to help the user handle and apply the product correctly. Such details include the kind of substrate on which the product can be used, how it should be mixed and thinned, any dilution and mixing ratios and the optimum conditions for drying.

Current legislation and regulations (AFS) on the work environment can be found on the Swedish Work Environment Authority's website at www.av.se.



Stained pine.

Table 7.1 Properties and content of different surface coatings.

	Technology and production				
	Other name	System	Content	Solvents	Can be combined with
Alkyd coating	Synthetic enamel, also as glaze.	1-component	Alkyds and other resins, e.g. urethane binder.	Mainly white spirit and xylene. Also butanol, butyl acetate, diacetone alcohol.	Water-based paints and varnishes, urethane primer when coating windows.
Cellulose coating	Nitrocellulose (NC) lacquer.	1-component	Nitrocellulose, cellulose acetate butyrate, cellulose propionate. Other binder: alkyd resin.	Esters, alcohols, ketones, etc.	Water-based basecoat or topcoat varnish and clear UV basecoat varnish.
Caustic soda	Caustic soda/antiquing/ageing solution.	Repainting in two stages.	Pre-staining: tannins. Post-staining: sodium hydroxide.	Water	Finish with oil, wax, soap or clear varnish, which can be water-based.
Oil	Furniture oil, bio-oil.	–	Drying and semi-drying oils and alkyds from mineral or plant sources. Also synthetic oils and resins.	White spirit, citrus oil, turpentine, ethanol. Also oil-in-water emulsion.	Wax, natural soap and alkyd coatings.
Polyester coating	Styrene-free polyester.	3-component	Polyester	Butyl acetate, white spirit. Diacetone alcohol. Hardener: organic peroxide. Accelerator: organic cobalt compound.	UV-cured paints and varnishes, water-based primer.
Polyester coating	Reactive coating.	1-component 2-component	Cellulose derivative, modified polyester.	Ethyl acetate, ethanol, acetone, methyl ethyl ketone, etc. Hardener: isocyanate.	Water-based primer or UV basecoat varnish.
Polyurethane coating	Urethane, PU or DD coating.	2-component	Binder: acrylic resins, polyethers, alkyds, high-molecular epoxy resins, also nitrocellulose. Hardener: with isocyanate.	Aromatics, esters, ketones, etc.	UV-cured basecoat varnish, water-based clear varnish, primer or topcoat paint.
Acid-cured coating	Cold-cured coating.	2-component, also 1-component.	Urea and/or melamine resin and alkyd. Also nitrocellulose.	Esters, alcohols, propylene glycol ethers and their acetates, etc.	Dark "wetting", light "non-wetting" basecoat varnish, UV-cured basecoat varnish, water-based primer or topcoat paint.
Acid-cured coating	Formaldehyde-free acid-cured coating.	2-component	Modified acrylic resin and nitrocellulose. Hardener: usually p-toluenesulphonic acid.	Butyl acetate, isobutanol, propylene glycol ethers and their acetates, etc.	Dark "wetting", light "non-wetting" basecoat varnish, UV-cured basecoat varnish, water-based primer or topcoat paint.
Wood soap	–	–	Soya fatty acid, potassium hydroxide.	Water	Caustic soda-treated wood products.
UV-cured acrylic coating	UV coating, UV acrylic.	1-component	Acrylate prepolymers. Photoinitiator.	Reactive diluent.	Specialist water- or solvent-based stains, paints and varnishes.
UV-cured polyester coating	"Acrylic-free" UV coating.	1-component	Unsaturated polyester and photoinitiator.	–	Check with supplier.
UV-cured styrene-polyester coating	–	1-component	Unsaturated polyester and styrene, 5–10% butyl acetate. Photoinitiator.	(Styrene) reactive diluent.	Topcoat: UV-cured acrylic varnish, water-based paint, solvent-based paint or varnish.
UV-cured water-based clear varnish	Waterbased UV coating, WB UV coating.	1-component	Unsaturated polyester, aliphatic hydrocarbons, approx. 65% water. Photoinitiator + original film former.	Water	Other type of UV-cured basecoat or topcoat varnish, water-based varnishes, solvent-based paint or varnish.
UV-cured water-based paint	Waterbased UV paint.	1-component	Unsaturated polyester or acrylate prepolymer + original film former.	Water	Other type of UV-cured basecoat or topcoat varnish, water-based varnishes, solvent-based paint or varnish.
Water-based clear varnish or paint	Water-based (WB) coating.	1-component	Acrylate polymers, poss. also vinyl acetate, polyurethane dispersion with multiple binders.	Water, also organic solvent.	UV-cured basecoat varnish and solvent-based paints and varnishes.
Wax	Finishing wax, furniture wax, biowax.	–	Drying and semi-drying wax, often combined with alkyd oil. Also synthetic waxes.	White spirit, citrus oil, turpentine, ethanol, also water-based waxes.	Oil or natural soap.

Cont. >>>

Table 7.1 Cont. >>>

	User environment			Work environment		Environment		
	Area of use	Resistance	Consumer/living environment	Aller-genic	Waste health hazard	Waste environmental hazard	Low solvent emissions	Price index*
Alkyd coating	Furniture, interior fittings, windows, outdoor and indoor joinery.	Good resistance and durability.	Odour of newly coated surface can seem unpleasant.	No	Yes	No	2	2
Cellulose coating	Furniture, interior fittings, indoor joinery and toys.	Less good resistance and durability.	Odour of newly coated surface can seem unpleasant.	No	Yes	No	1	2
Caustic soda	Furniture, interior fittings and joinery in light-coloured woods.	Not resistant to liquids or scratching.	Details treated with caustic soda should be coated afterwards.	No	Yes	Yes	0	0
Oil	Furniture, interior fittings and indoor joinery.	Less good to good, depending on amount of oil and no. of layers applied.	Should be regularly maintained. Choose an oil that does not cause the user problems.	May occur.	No	No	4 – 5	5
Polyester coating	Furniture, interior fittings and indoor joinery.	Very high robustness, resistance and durability.	Slight odour from newly coated surfaces.	Yes	Yes	Yes	3 – 4	4
Polyester coating	Furniture, interior fittings and indoor joinery.	Good resistance and durability.	Slight odour from newly coated surfaces.	May occur.	Yes	Yes	2	3
Polyurethane coating	Furniture, interior fittings, indoor and window joinery.	Good to very good resistance and durability.	Slight odour from newly coated surfaces.	Yes	Yes	Yes	2	1 – 2
Acid-cured coating	Furniture, interior fittings and indoor joinery.	Good resistance and durability.	Release of formaldehyde can cause irritation.	Yes	Yes	Yes	2	3
Acid-cured coating	Furniture, interior fittings and indoor joinery.	Good resistance and durability.	–	No	Yes	Yes	2	3
Wood soap	Furniture, interior fittings and floors.	Poor resistance and durability.	Odour usually considered fresh and good, but requires frequent maintenance.	No	No, but can dry out the skin.	No	1	1
UV-cured acrylic coating	Furniture, interior fittings, indoor joinery and wood floors.	High to very high resistance and durability. Varies depending on binder, substrate and amount applied.	Sticky surface or sweet odour if curing incomplete.	Yes	Yes	Yes	5	5
UV-cured polyester coating	Furniture and interior fittings.	High to very high resistance and durability. Varies depending on binder, substrate and amount applied.	Odour-free	No	Yes	Yes	5	4
UV-cured styrene-polyester coating	Furniture and interior fittings where “robust” finishes are required.	High to very high resistance and durability. Varies depending on binder, substrate and amount applied.	Not normally used in Sweden for environmental reasons.	No	Yes	Yes	4	5
UV-cured water-based clear varnish	Furniture, interior fittings and indoor joinery.	Very good resistance and durability.	Good	No	Yes	Yes	5	2 – 3
UV-cured water-based paint	Furniture, interior fittings and indoor joinery.	Very good resistance and durability.	Good	No	Yes	Yes	5	2 – 3
Water-based clear varnish or paint	Furniture, interior fittings, window and indoor joinery.	Usually good resistance and durability.	Good but sensitive to heat and water.	Yes	No	Yes	5	2 – 3
Wax	Furniture, interior fittings and indoor joinery.	Less good to good depending on no. of coats and amount of wax.	Requires frequent maintenance.	May occur.	No	No	5	5

* **Price index explanation:** Pricing on a scale of 1–5. The highest mark, 5, is given to the type of surface coating that has the lowest price per square metre even if the coating has a high price per litre. The relationship between 1 and 5 does not mean that the price is five times higher or lower. It is simply a judgement on the different coating systems.

Care and maintenance

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The lifetime of a piece of furniture depends on the scope for repairs, re-use and modernising. It is not just about producing something that can be repaired and maintained, but also about the opportunities for renewal and updating, being able to take furniture with you through life's different stages.

The lifetime of a piece of furniture is also determined by its exclusivity and uniqueness. Furniture made in short runs, or as individual items, with great care and quality in the design, material choices and execution, and at a significantly higher price, has a greater chance of being looked after than something mass-produced. That makes sense. However, even furniture made in large runs for workplaces, homes and public environments can be designed for the future, their life renewed and extended. As long as its care and maintenance is factored in from the beginning.

8.1 General information

When items such as furniture and joinery are delivered, it is important that they are handed over complete and in the condition set out in the contract. At the point of the final inspection and handover, the customer or specifier should receive written advice on care and maintenance, and sometimes also instructions on how products are to be used.

8.1.1 Advice on care

Care instructions help the user to preserve the product's function and appearance.

Furniture and fittings usually comprise a combination of many different materials, which may require different kinds of maintenance. When the manufacturer is procuring materials, it is entirely appropriate to request care and maintenance instructions, warranties and so on from the material suppliers. These instructions can then be passed on to the customer along with the finished product. If a specialist product is needed for the maintenance, it is a good idea to include a pack along with details about where it can be purchased.

Sometimes, the customer asks for touch-up paint to be thrown in, but experience shows that it will rarely end up being used. A surface that has been exposed to light will often have faded and the touch-up paint may become too old to use. So it is important to state in the care instructions the type of paint used on the item, its colour, gloss and manufacturer, while also pointing out that the colour may be affected over time depending on the material's exposure.

Care instructions relate primarily to the surface material, but may also cover other parts of a fitting or item of furniture. Advice on how



House for Mother, Linköping, nominated
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to care for and maintain different surfaces and materials can vary from supplier to supplier. The relevant material supplier's recommendations should be followed in the first instance, as they can guarantee that this is the correct maintenance procedure for the material.

When the fitting or furniture is handed over to the orderer, it is important in the sign-off document, or in some other way, to require that the item is looked after and maintained as instructed in order for the warranty to remain valid.

Info for users:

- Always try to remove marks as quickly as possible.
- Untreated wood and wood treated with wax or oil is less resistant to dirt, heat and mechanical damage. These surfaces generally require more ongoing maintenance than surfaces that have been varnished or painted. On the other hand, the latter may require more effort when they need updating.
- Unpolished natural stone is extremely sensitive to grease, rust and oil marks, which can never be removed. Where wood is combined with natural stone, great caution is therefore recommended during care and maintenance.
- Never use products that contain a scourer.
- Woodwork in façades, such as doors and windows, must be maintained as instructed by the manufacturer. Note that window cleaning agents containing ammonia can discolour wood, even with a surface coating.
- Avoid furniture care products that contain silicone, as it can make repainting difficult.
- Matt surfaces are generally more sensitive than glossy surfaces.

The above advice is general in nature. There are many resistant clear varnished surfaces, but there are also those that hardly deserve the name. Our advice applies to resistant surfaces.

Always use the mildest cleaner first. If this fails to work, use as strong a cleaner as the surface coating and material can tolerate. Also think about what adjacent materials can handle.

Always test the cleaner on an area out of sight before you use it on a mark, to ensure that the surface coating and the material are not affected and dissolved.

Light solid wood darkens and dark solid wood lightens over time. The speed of any colour change depends on how much light the wood is exposed to. Some surfaces may be light-damaged on delivery, but with that damage disappearing after a week or so. Colour change due to light can be reduced by a UV filter in the surface coating. The process will not be stopped, but it will be slowed down.

Table 8.1 Examples of actions for cleaning and maintenance.

Note that not all actions are suitable for all types of substrate.

Action	Description
1	Soap and damp cloth. Wipe afterwards with a damp cloth to remove soap. Then go over with a dry cloth.
2	White spirit (aliphatic naphtha) or petrol. Wipe afterwards with a damp cloth to remove the solvent. Then go over with a dry cloth. In some cases, the surface will need to be coated afterwards.
3	1 part acetone, 3 parts methylated spirit. Wipe afterwards with a damp cloth to remove the solvent. Then go over with a dry cloth.
4	Methylated spirit, petrol or acetone. Wipe afterwards with a damp cloth to remove the solvent. Then go over with a dry cloth.
5	Methylated spirit. Wipe afterwards with a damp cloth to remove the solvent. Then go over with a dry cloth.
6	Synthetic cleaning agent, possibly with ammonia. Wipe afterwards with a damp cloth to remove the solvent. Then go over with a dry cloth.
7	Synthetic cleaning agent or aliphatic naphtha. Wipe afterwards with a damp cloth to remove the solvent. Then go over with a dry cloth.
8	Cold water + ammonia. Synthetic cleaning agent.
9	Synthetic cleaning agent. Wipe afterwards with a damp cloth to remove the solvent. Then go over with a dry cloth.
10	Synthetic cleaning agent and oxalic acid. Wipe afterwards with a damp cloth to remove the solvent. Then go over with a dry cloth.
11	Chemically pure petrol or fine sandpaper in some cases.
12	Paraffin oil or linseed oil.
13	Fine sandpaper, then treat with paraffin oil.
14	Polish with turpentine.

8.2 Care instructions

In the case of composite materials, surface maintenance information should be sourced from the supplier of each material and surface coating. The instructions should be made as easy as possible to understand, preferably with clarifying illustrations. Make sure that they can easily be kept with the furniture, rather than being cleared away

Table 8.2 Care instructions for furniture and interior fittings.

Problem	Untreated wood	Untreated solid wood	Wax-treated solid wood	Painted resistant surfaces	Varnished resistant surfaces
Dirty surface	Action 1 Eraser Sandpaper	Action 1	Action 1	Action 1	Action 1
Very dirty surface	Action 1 in first instance, then 2 and 11.	Action 1 in first instance, then 2 and 13.	Action 1 in first instance, then 2.	Action 1 in first instance, then 2.	Action 1 in first instance, then 2.
Paint flecks	Action 3, then 11.	Action 4, then 13.	Action 2, then 13. Finish with wax.	Action 2, then 2, 5 and 7.	Action 1, then 2, 5 and 7.
Severe paint flecks	Action 4 Action 11	Action 4 and 13	Action 2, then 13. Finish with wax.	Action 1, then 2.	Action 1, then 2.
Marks from ink ribbon, ballpoint pen, ink, lipstick, etc	Action 11	Action 5 and 13	Action 2, then 13. Finish with wax.	50% methylated spirit or action 2.	50% methylated spirit or action 2.
Marks from fruit, berries, cream, oil, wine	Action 11	Action 1 and 13	Action 1, 2 and 13. Finish with wax.	Action 1, then 2. If no help, sand and repaint.	Action 1, then 2. If no help, sand and repaint.
Marks from chocolate, coffee, tea, grease, shoe polish	Action 11	Action 2, 7 and 13	Action 1, 2 and 13. Finish with wax.	Action 1, then 2. If no help, sand and repaint.	Action 1, then 2. If no help, sand and repaint.
Marks from blood	Action 11	Cold water + action 13	Razor blade, action 1, then 13. Replace oil with wax.	Razor blade + action 1	Razor blade + action 1
Marks from urine, vomit, excrement	Action 11	Action 1, 7 and 13	Action 1. If no help, sand and paint.	Action 1 in first instance, then 2.	Action 1 in first instance, then 2.
Marks from rust	Action 11	Action 10 and 13	–	Action 1 in first instance, then 10.	Action 1 in first instance, then 10.
Marks from heat	Action 13 without oil	Action 13	Action 13. Replace oil with wax.	Sand and repaint.	Sand and repaint.
Maintenance of dry surfaces	Action 12	Action 12	Wax	–	–
Maintenance of scratched surface	Action 13 without oil	Action 12 and 13	Action 13. Replace oil with wax.	–	–
Light scratches	Light sanding.	Polish with oil.	Polish with wax.	Polish with furniture polish.	Polish with furniture polish.

Cont. >>>

after a while. The idea is that the instructions will stay with the furniture for many years. It is also worth making the care instructions available online. The care instructions should include contact information so that the customer can contact the point of sale or the manufacturer with any questions about the surface coating or the substrate.

Table 7.1 Cont. >>>

Problem	Surfaces coated with water-based paint products	Plastic crates	Low- and high-pressure laminate	Linoleum	PVC mats
Dirty surface	Action 1	Action 1	Action 1	Action 1	Action 1 Soap flakes
Very dirty surface	Action 1 in first instance then 2, but not petrol.	Action 1 in first instance, then 2 and 3.	Action 1 in first instance, then 3.	Action 1 in first instance, then 2 + polishing with solvent-based floor wax.	Action 1
Paint flecks	Action 1, then 2 and 7.	Action 4	Action 4	Razor blade + action 1	Action 4
Severe paint flecks	Action 1, then 2.	Action 4	Action 4	Razor blade + action 1 or 2.	Action 4
Marks from ink ribbon, ballpoint pen, ink, lipstick, etc	50% methylated spirit or action 2.	Action 4 + citric acid.	Action 4 + citric acid.	–	Action 5
Marks from fruit, berries, cream, oil, wine	Action 1, then 2. If no help, sand and repaint.	Action 1 + citric acid.	Action 1 + citric acid.	Action 1	Action 6
Marks from chocolate, coffee, tea, grease, shoe polish	Action 1, then 2. If no help, sand and repaint.	Action 6	Action 1 Action 4, citric acid.	Action 7 Action 2 Action 7	Action 7
Marks from blood	Razor blade + action 1.	Razor blade + action 1.	Razor blade + action 1.	Razor blade + action 1.	Action 8
Marks from urine, vomit, excrement	Action 1 in first instance, then 2.	Razor blade + action 1, possibly citric acid.	Razor blade + action 1, possibly citric acid.	12 % vinegar essence	Action 6
Marks from rust	Action 1	Action 1 + razor blade.	Action 1	12 % vinegar essence	Action 10
Marks from heat	Action 1	Action 1 + razor blade.	Action 1	12 % vinegar essence	–
Maintenance of dry surfaces	–	–	–	Polish with wax.	Action 1
Maintenance of scratched surface	–	–	Fine sandpaper + polish with turpentine	–	–
Light scratches	Polish with furniture polish.	Action 14	Action 14	Polish with wax.	Polish with wax.

The interior surface coating of wood should be maintained as the coating is worn down and the decorative and protective properties deteriorate. Surfaces that are subject to mechanical wear or exposure to moisture require more regular maintenance. Sunlight often causes colour differences between exposed and unexposed surfaces on pictures, rugs and tables, for example. The most common reason for maintenance is aesthetic rather than functional, with a desire to change the colour or the whole piece of furniture. Different paint systems have different technical lifetimes, so the choice of surface coating should be carefully considered when applying a first coating or repainting.

As a manufacturer, it is important to provide good information about surface maintenance, mark removal and damage repairs. The damage can easily get worse if the customer does the wrong thing. The wrong cleaner can etch a mark into the surface, so that it cannot ever be removed. It is important that the customer does not use strong chemicals to remove marks, without being sure that they are the correct choice for the particular type of mark and material.

All wood material changes in damp environments. Different woods and wooden structures change to varying degrees — solid wood details more than veneered materials. Be careful to describe this in the care and maintenance instructions.

Warranties for the various products are always handed over on delivery of the furniture. Note that different warranty periods may apply for different materials and products. Make sure that all the components of the item have at least as long a warranty period as the whole item.

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Swedish Wood's aim is to increase the size and value of the market for Swedish wood and wood products in construction, interior design and packaging. Through inspiration, information and education, we promote wood as a competitive, renewable, versatile and natural material. Swedish Wood also lobbies on behalf of its members on key industry and trade issues.

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