CNC Technology

Exercises

Development of a collection of reference materials containing course templates and course materials with the goal to include the latest CNC technology in the area of Wood Building & Construction

Establishment of a Centre of Competence for the Carpenter and Wood Building Profession through extension of the Centre for Carpenters in Kassel, Germany

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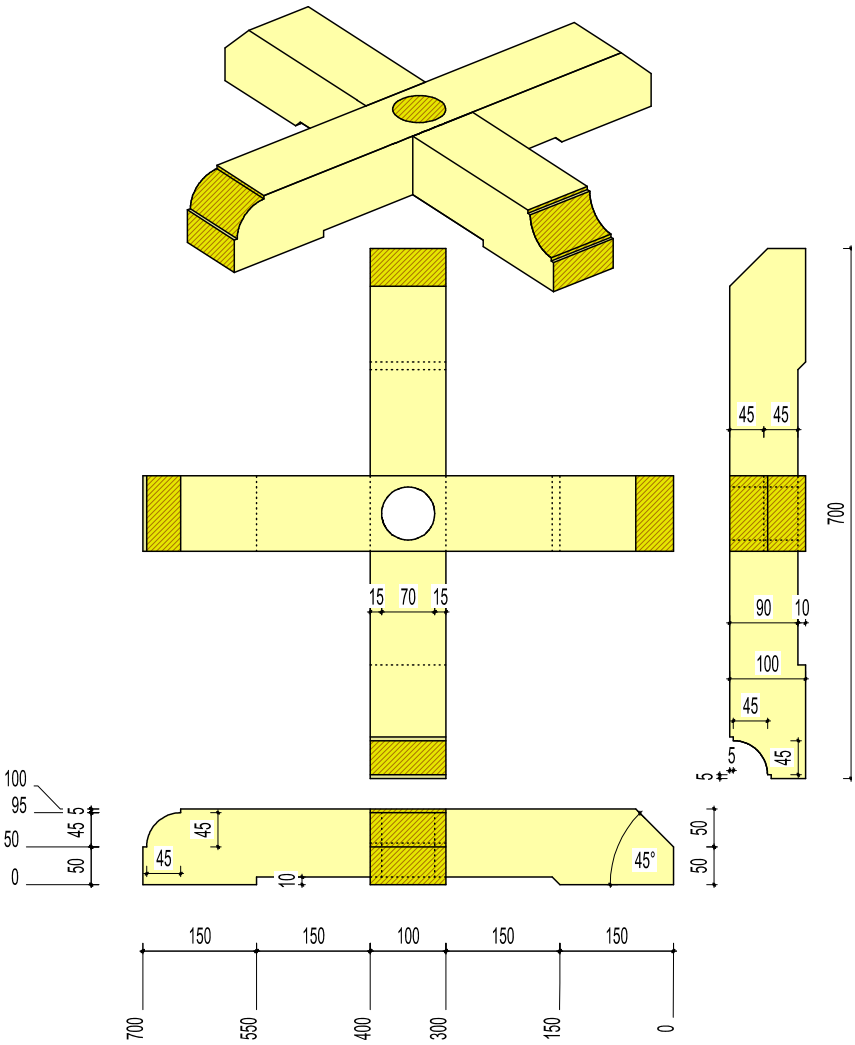
Entering of a work piece in the SPCP

Generally, work pieces are created using CAD programs and afterwards directly transferred to the machine. Using the SPCP, the data can be checked and if necessary amended and completed. To create a complete job in the SPCP is rather rare and time consuming. However, it is beneficial to create a job in the SPCP to learn more about the direct data entry.



Exercise 15:

Program the Christmas tree stand shown in the picture on the right hand side in the SPCP.

Transfer the data for this job to an external device (disc, memory stick, server).

Save the data from the storing device for this job on the hard drive of your machine, and start processing both jobs.

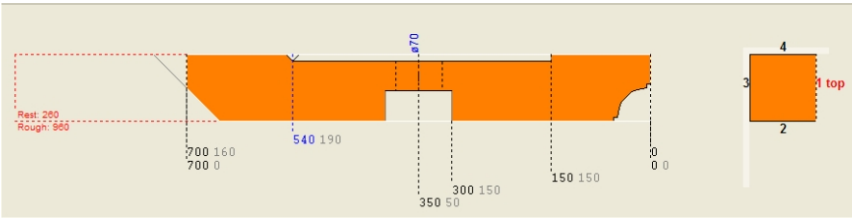
Consider that if the work piece is positioned with the contoured section at the end of the work piece, a crash could occur. The volume of the work piece is decimated considerably (due to the contour and drilling) and will start to vibrate during machining. As the cutter head is not chip limited the end mill “chips” instead of proper cutting. The impact of this force can destroy a work piece. This can be avoided by placing the contoured section at the front of the work piece.

Exercise 15 Approach:

Select a new part once the parts list is visible on the screen. If a new part is created while the previous work piece is still visible, this work piece is overwritten (generally not intended).

Therefore, if necessary, press F8 and switch to the parts list .You can also enter a new part by using the menu *Part → New Part.*

On the right hand side of the menu (if existing) are the short cut keys placed which allow for faster navigation in the program. A new part can also be created with the short cut “insert”. After that enter a name for the part and confirm by pressing “Enter”. As there are two different parts use “1” for the quantity in the sample shown. Once the width and height has been entered, add the saw cuts and finally all other processing steps. It is recommended, to program the part with the work piece positioned on the side face (regardless of final assembly and positioning during processing) as this allows for the quickest editing of saw cut depth, angle of cuts and cross-sections.



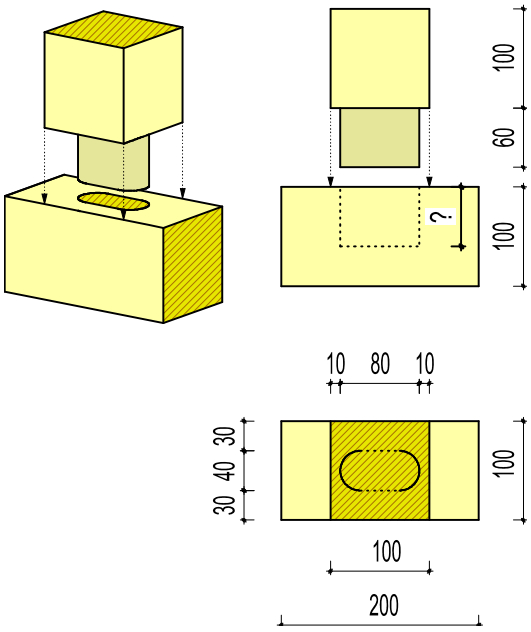
Once all processes have been entered, save by pressing F9. To avoid queries it is recommended to use the “STRG” “S” key combination instead as this command will not cause any queries. To ensure that the data has been saved properly watch for the header – after saving the note in square brackets “changed” will disappear.

The commands F7 and F6 allow you to try out different part positions. When doing so compare the production time and the length of the beams. Even if there are no errors or warnings shown in the SPCP, try to avoid that the work piece is positioned with the contoured section at the end due to the previously discussed risk of a crash.

To produce the second part efficiently change to the part list by pressing F8. With the command → *Part* → *Copy Part to* … the exact same part as programmed earlier will be produced. Only the changes for profiles, lap joints and drillings will need to be modified.

Exercise 16:

For a timber frame construction that uses many mortise and tenon joints, a compromise between a tight fit and easy assembly of the joints is required. Program the SPCP with one sample part for a tenon and one for the corresponding mortise. What needs to be considered with regard to the depth of the mortise during the design?



Process both work pieces and test fit the joint. Which error could cause the mortise to be smaller than the receiving tenon despite correct measurements in the SPCP?

What needs to be done when the fit of the joint is too „tight“ even though the machine is properly calibrated?

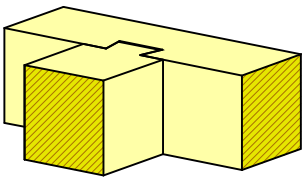
Exercise 16 Approach:

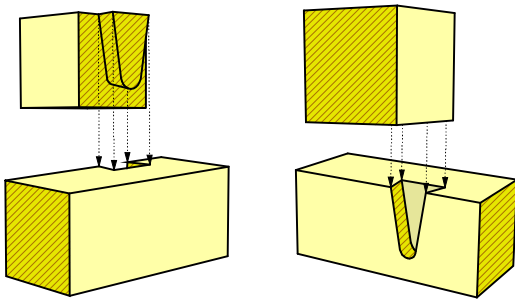
The depth of the mortise is programmed with the same value as the length of the tenon. To avoid that through the shrinking process the tenon touches the bottom of the mortise which would create a gap between the post and rail a correction of the depth of the mortise can be created by selecting machine data (d) and adding an offset percentage value which will increase the depth of the mortise automatically. A reason why a joint cannot be assembled could be that the geometry of a tool was not adjusted after sharpening and that the actual diameter of the end mill decreased. This cause for error can be eliminated through diligent machine operation. It is still possible that the connection is too tight even if the machine data for the end mill is maintained correctly. In that case adjust the tenon width and length with the appropriate offset value in the manual operation window.

In either case it is recommended to select the option “chamfer”, as this ensures that the tenon fits properly without being too loose or tight.

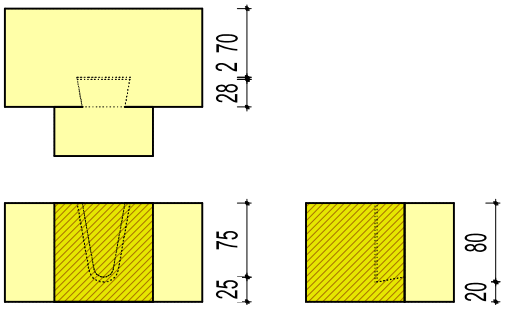
Exercise 17:

As for the tenon, test a dovetail joint. Why is there a gap between the end grain of the tenon and the bottom of the mortise?

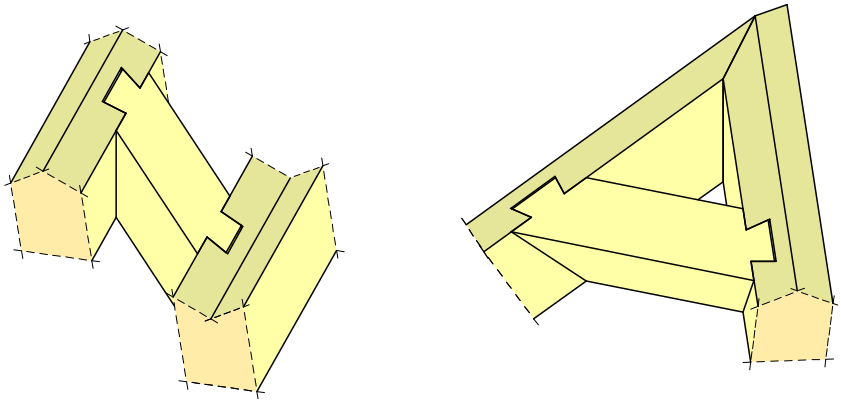




What error could cause the fit of the dovetail joint to be too tight?



Assess the dovetail joints shown on the right hand side with regard to the design.



Exercise 17 Approach:

The „gap“ is determined by the percentage value of the depth of the tenon in the machine data (d). This should prevent that the end grain of the tenon of a dovetail joint touches the bottom of the mortise and consequently pushes the joint apart in the visible area.

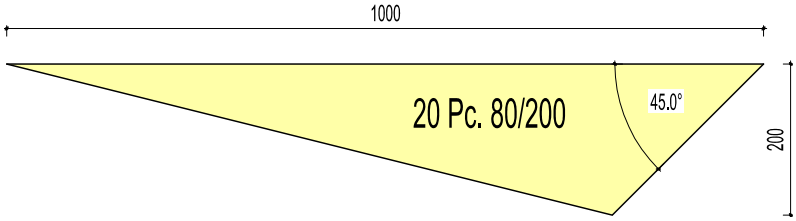
If the joint cannot be assembled, the cause could be an error in checking the tool geometry after sharpening of the knives.

If the machine data is adjusted appropriately by selecting machine data (d) – offset value a fine tuning of the tenon width and tenon recess can be made. Recommendation: The connection should be fitting tightly after one or two hits with a sledgehammer. The joint shouldn’t fit any looser as the force is transferred via the conical edge. Otherwise smallest shrinkage would lead to a looser fit of the joint.

The joint shown on the right hand side is extremely difficult to process. When a dovetail joint tenon needs to be processed on both ends of a work piece the joints have to be parallel to each other.

Exercise 18:

A roof renovation requires 20 eaves laths with a cross section of 80/200 mm. Create a new job in the SPCP based on the drawing below without using additional technical tools such as a calculator.



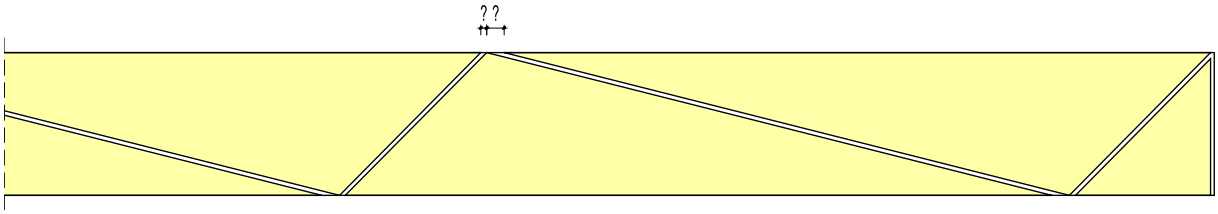
What type of support is offered by the SPCP for this project?

Which key needs to be pressed to mark exact points?

How can you utilize the context menu (right mouse button) to enter the established angle of the saw without using the numerical keys?

Which other alternative to determine the angle of the saw is provided by the option “tickmark” in the “OK” button?

Your supervisor is pleased about the speed with which you carried out the assignment. However, he does not agree with the amount of waste pieces.



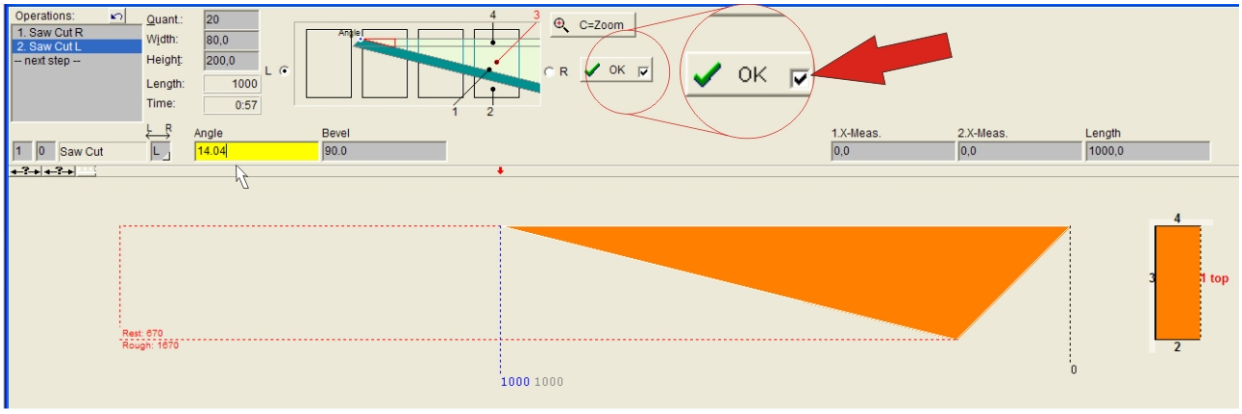
How can you minimize the waste and processing time for the next job?

If the required 20 eaves lathes should be produced by using one post, how long would it need to be?

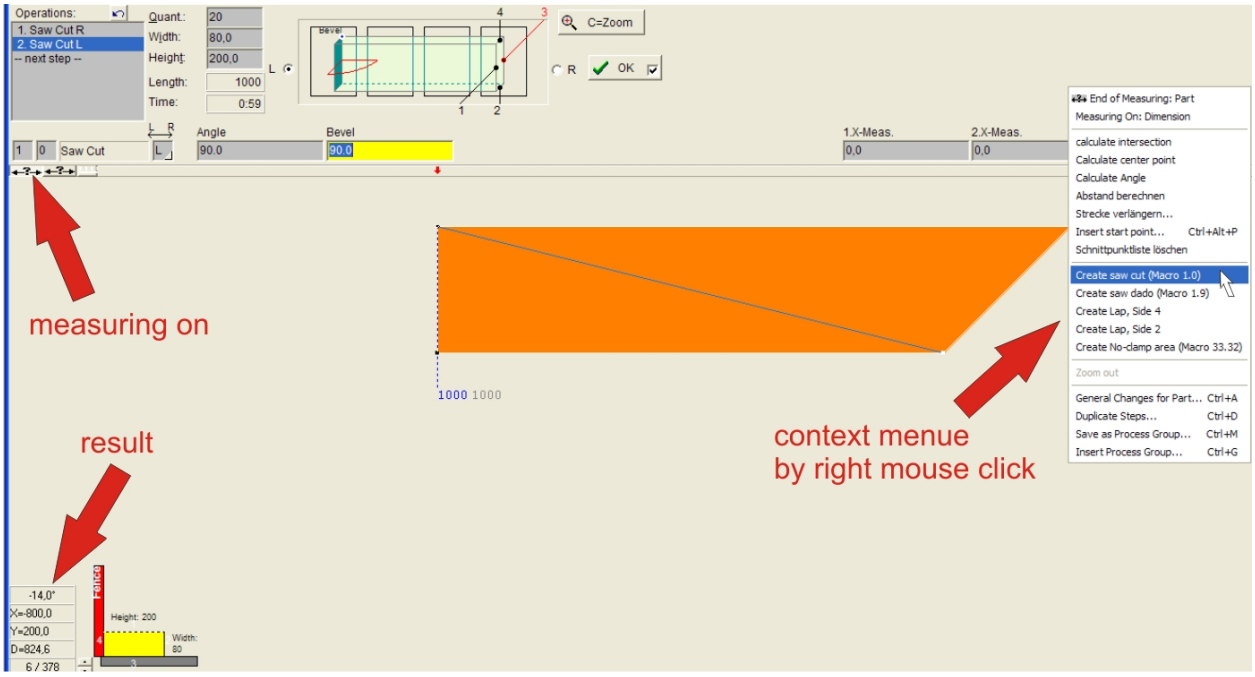
How can you calculate the waste created by cut offs subject to the angle?

Exercise 18 Approach:

First program the eaves lath with a 45° angle cut and at 1 m length with a square trim cut. If the “tick mark” in the “OK” button is switched on, which means that all changes are visible immediately on the screen, there is a very surprising option to determine the cut off angle on the left hand side: Place the cursor in the entry field for “Angle” which allows you to locate the angle graphically with the scroll wheel of the mouse.



The more reliable method is to use the measuring function for the exact distance. To determine exact points on the work piece, hold down the STRG key while measuring. The data is shown in a table in the lower left hand corner.



The values do not need to be read and entered. By pressing the right mouse button below the drawing of the work piece the context menu is opened which contains the measuring function. You can also change the measured length into a saw cut by selecting “Create saw cut”. The square segment on the left hand side has now fulfilled its purpose and can be deleted.

To transfer the waste optimized work piece, select the "*" key. The second work piece is also transferred. To line up the two pieces in the best way, press F6 once and F7 twice in the dialog window. Afterwards use the „←" key to switch to the cut list. Both work pieces are highlighted with "C" and with F5 connected to a processing group. For the quantity of the group enter 10. Unfortunately, the required length of the raw material is not provided automatically during the optimization process. This is calculated as follows:

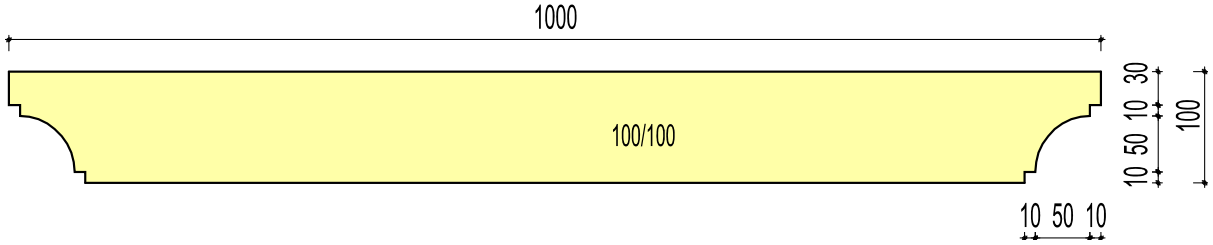
Quantity : 2 x length + "length section of the angle" + saw cuts

20 : 2 x 1,00 m + 0,20 m + (0,0065 : sin 45° + 0,0065 : sin 14°) x 10 = 10,56 m

Two or more beams that have been stacked on top of each other have to be processed, the transfer has to be programmed with „2" „/" „2" or „3" „/" „3".

Exercise 19:

Create the work piece shown below in the SPCP. Do you need a saw cut each for the front and back end of the work piece?



Use the graphical view to check on which end of the beam the profile will be processed with a climb cut (this method results in a better quality). Can you find a better position for the end of the beam that will be processed with a power cut? How can you ensure that the profiles are processed with the beam positioned perfectly? (Ensure that the size of the end mill is sufficient for the project and that the machine data is correct. Is the end mill too small, the job would become too complex through the number of additionally required rotations).

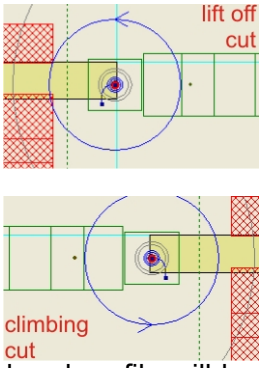
Which keys will allow you to change the order of processing steps?

You already know that the shown order in cut list is not the actual order of processing steps. Which key will show you the actual order?

How can you see with one glance (based on the colour) which way the beam is positioned during processing?

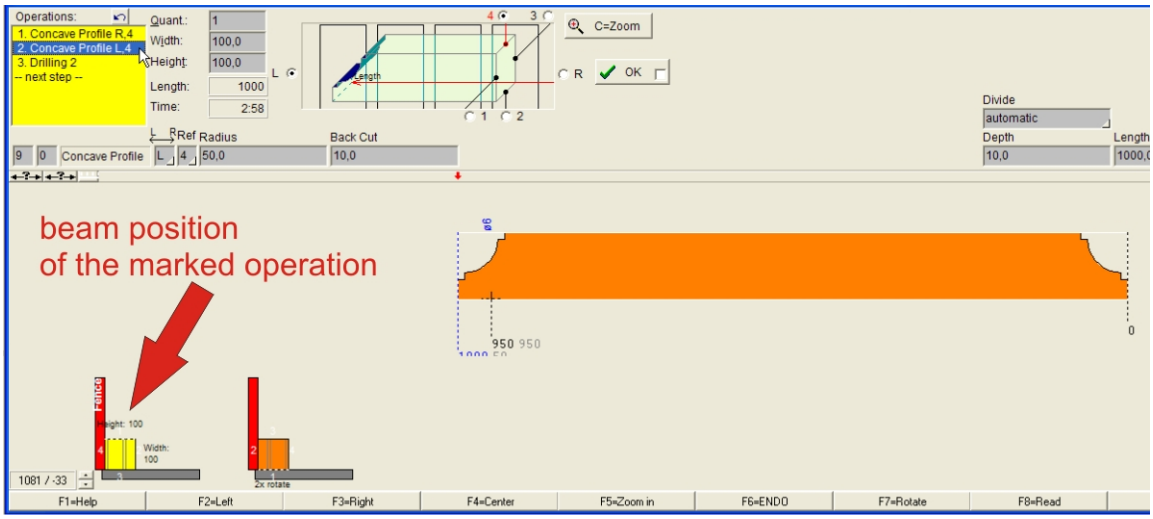
When you realize that additional steps and the change of the order of processing steps does not reach the goal of optimizing the processing quality on both ends of the work piece, the function “Fixed Order” in the graphic menu can be used to change the order of work processes as determined by the SPCP. (Attention! „Fixed Order“ can only be used in special cases and only limited to a few processing steps. In no case should the trim cuts at the front and back end of the beam be included in the fixed order. If the fixed order function is being used incorrectly a “Crash” could result for which the machine manufacturer can deny warranty claims!

Exercise 19 Approach:



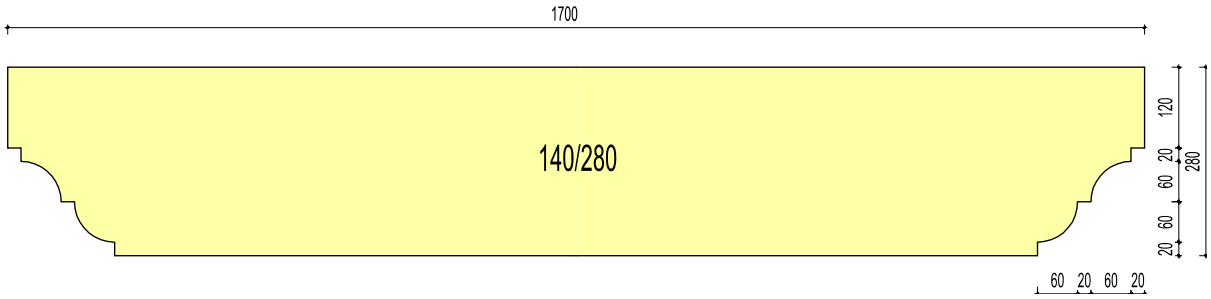
Trim cuts on the front and back end of a work piece are not necessary when processing profiles, tenons and dovetail joint tenons as those process steps are included in the job. After highlighting both jobs by pressing the STRG or SHIFT key the actual steps including the direction of the rotation of the tools can be visualized by selecting the graphic menu – detailed simulation. It is noticeable that based on the way the work piece in the example is positioned the profile on the right hand side will not be cut perfectly. The profile on the left hand side will be processed with a climb cut which will achieve optimal results. By rotating the work piece twice the right hand profile will be processed with a climb cut, too.

Therefore, the right hand profile should be cut first with the work piece positioned on side 4. After that the work piece would need to be turned twice through an additional processing step in order to cut the left hand side profile on side 2. For example, a drilling process with a drill inserted into the horizontal support could be created for the side face 2. To check if this process ensures that the left hand profile is processed after the rotations, press “B” to call up the processing steps. Alternatively, move the cursor over the left hand profile and press the left mouse button. The work piece shown in the position it will be processed (in yellow) is visible on the lower left hand corner of the screen. This will show very quickly that the creation of the drilling step will not solve the problem as both profiles will be cut in the original position and only after that the rotation occurs. This seems reasonable as the drilling was added after the left hand profile. To change the order, highlight the drilling process and move it upwards by pressing the “-“ minus key on the numerical key pad. When using a note book without a numerical key pad, activate the numerical keys that are included in the keyboard via the function keys. By using the plus key process steps can be moved backwards. As the change in the order of processing steps still doesn’t show the desired result, the only remaining option is the “fixed order” function. As mentioned in the assignment “Fixed Order” functions have to be used very carefully. If used incorrectly a crash could be the result.



Exercise 20:

The profile of the purlin shown below should be created by combining a convex and concave profile.

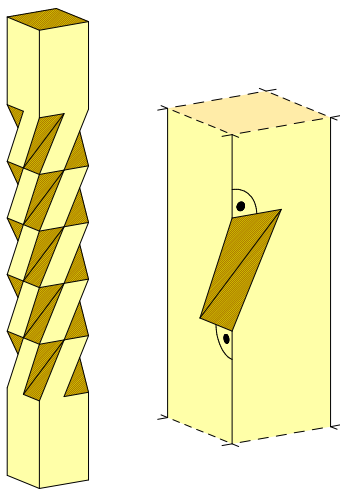


When processing a simple profile, a tenon or dovetail joint tenon trim cuts are not necessary as those are included in the macro. Why is it not possible to omit the saw cut macro for this combined profile?

What is the quickest way to copy the combined profile from one end of the work piece to the other?

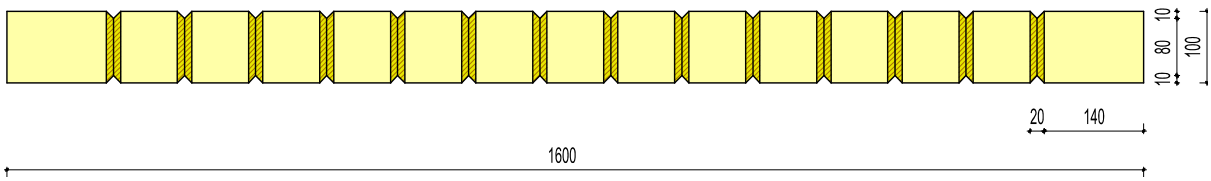
Exercise 21:

Is it possible to produce the traditional ornament shown on the right with a mill?



Exercise 22:

Alternatively, create the ornamental design (as shown below). How can it be produced efficiently?

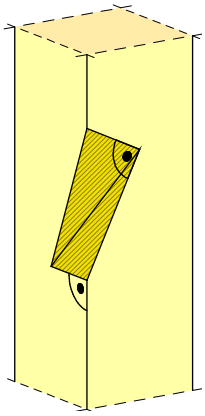


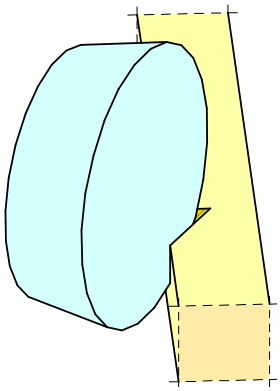
Exercise 20 Approach:

If the purlin would not have a trim cut, the convex saw cut integrated in the profile would cut off the profile in a concave way. However, if there is a trim cut at the front and back end of the work piece, the saw cut included in the profile by the SPCP will not be executed and the double profile will be processed as desired. Have the profiles been created at the beginning of the part, highlight it by pressing the STRG key and copy the data with STRG and “C” to the clipboard. After that rotate the work piece with function F6 and paste the data by pressing STRG and “V”.

Exercise 21 Approach:

No. The processing with a standard mill would look like the drawing on the left hand side. The ornament as assigned requires a special, conical shaped mill (drawing on the right hand side).



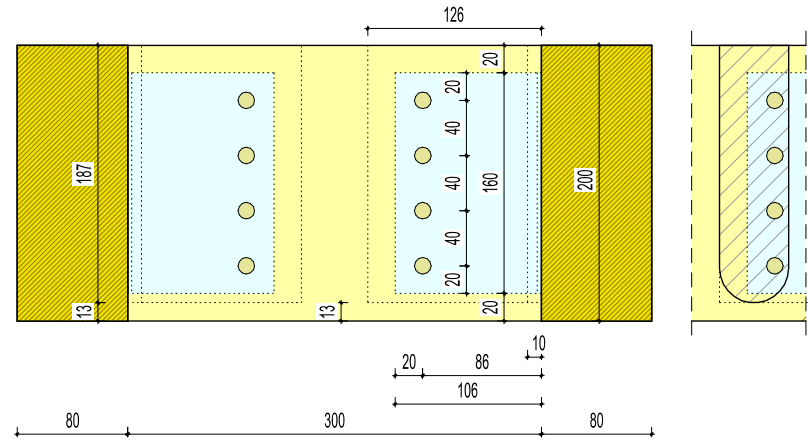


Exercise 22 Approach:

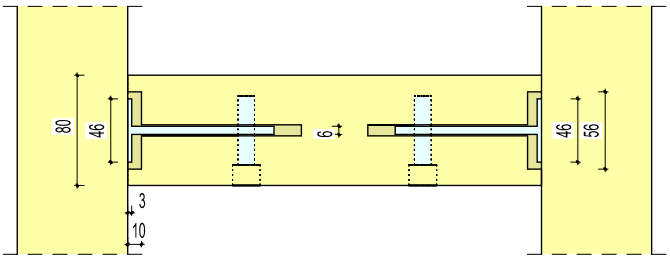
First enter a bird’s mouth. Highlight the entry and copy it to the other end of the work piece by selecting the graphic menu → *Graphic* → *Duplicate Steps* → *Duplicate and Mirror*. After that highlight both bird’s mouths and copy the entry to the clipboard with STRG and “C”, rotate the work piece with function F7 and insert the two bird’s mouths with STRG and “V”. This will create a circumferential groove. Now mark all the grooves and enter in the graphic menu → *Graphic* → *Duplicate Steps* → *Change Length* 100 und → *Number of copies:* 13 spread over the length of the work piece.

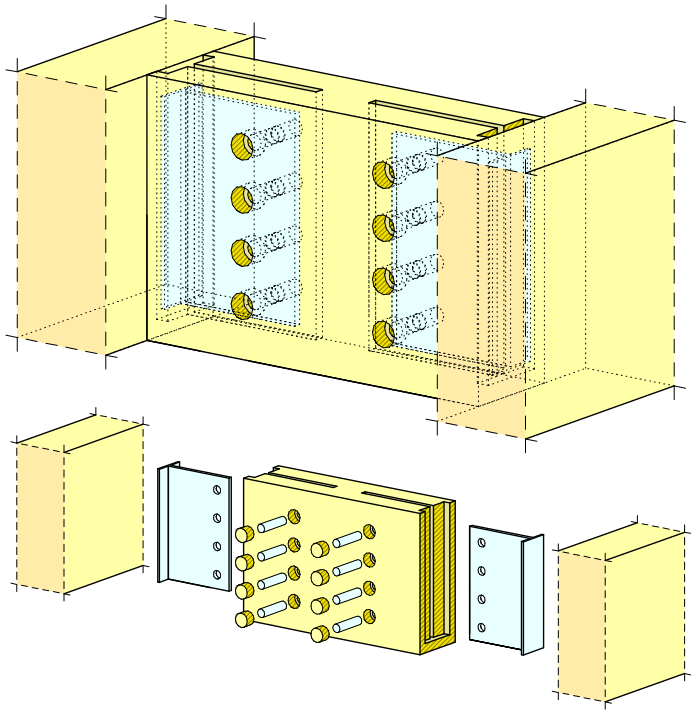
Exercise 23:

Enter the connector (shown below) into the SPCP. Generally, this kind of job is created in a CAD program. However, for this assignment the goal is to produce a hidden connection with a stopped slot and dowel pins (d=12 mm) which will be covered with wooden pegs. The programmed steps should be transferrable to other work pieces.



Which problem could occur by processing the slot first and the drilling afterwards? Check if the processing steps occur in a reasonable order. How can you ensure the correct order?





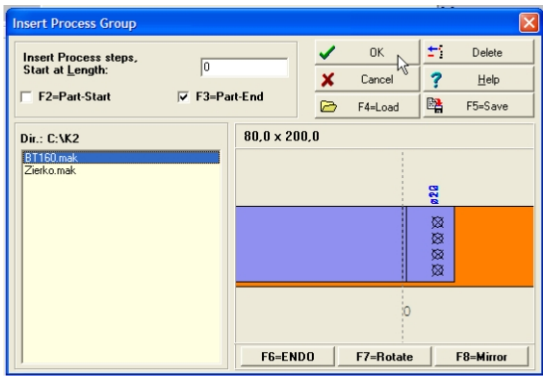
Your colleagues who assemble the wooden construction produced by you request that the connector of the beam is tensile by 0.5 mm. How can you achieve this result?

Exercise 23 Approach:

The slot is showing excessive tear out caused by the drilling which could interfere with the assembly of the steel connector. The slot won't show any tear out if the drilling is completed first. The 12 mm drill holes could be inserted via a drilling macro but can also be completed quickly when entered as single drill holes one by one and by changing the distance by 40 mm. To produce the 20 mm drill holes for the pegs quickly, highlight four 12 mm drill holes, copy to the clipboard and paste. After that change the depth and diameter for the four, still highlighted drill holes.

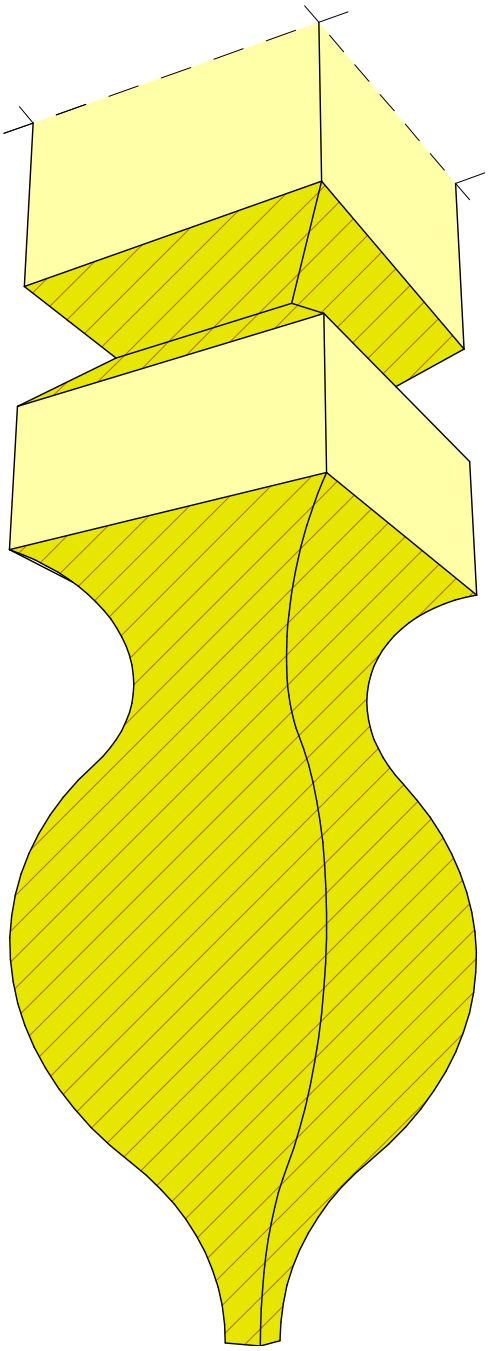
To drill the holes for the dowel pins applying tensile load in the design, highlight all 8 drill holes and change them together. If more than one job has been highlighted, the entry field "length" changes to "change of length". The value entered does not specify the new position referenced from the front end of the work piece but rather the value of the adjustment from the previous position. Therefore, in our assignment the value is 0,5 mm. To check whether the drill holes are completed first followed by the slot cut it might be necessary to change the machine data for the drills at the office PC. Otherwise it may be impossible to determine the order of the processing steps. By selecting machine data (d) – process order can be determined that the drilling should be executed before the slot cut is processed. To move the processing efficiently to the other end of the work piece and to position it for future jobs, it is recommended to save the steps as process group.

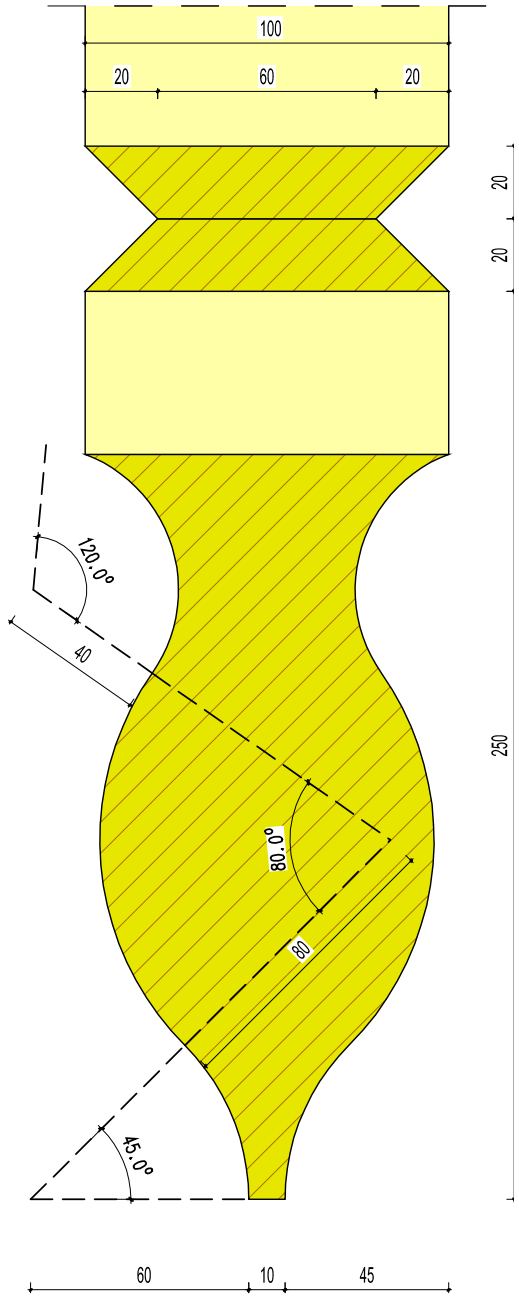
For this purpose highlight all production steps except for the saw cuts and select the *Graphic menu → Save as Process Group*. Do not use special characters for the name of the process group. To transfer the process group to the other end of the work piece select *Graphic menu → Insert Process Group*. Also select "part end" and F6=rotate, to ensure that the steps are inserted at the backend of the work piece. Occasionally it happens that the process group is placed outside the part even if the parameters are correct. In this case select the "Undo" function above the tool bar and repeat the process. It is noticeable that the drill holes at the end of the work piece are shown in black which means they are positioned on reference side 1 where generally no drill unit is placed. Therefore, unnecessary rotations will occur. Therefore, select all drill holes which are marked with "1" and change the reference side to "3". If this change is not possible for several highlighted process steps the reason could be the tick mark in the "OK" button. Remove it temporarily to change the reference side. After that use function F7 to determine a work piece position that requires only few rotations and check whether the slot is cut after drill holes have been executed.



Exercise 24:

Enter the four-sided ornamental profile by using “Free Profiles”. Which process steps will allow you to minimize the chip load from the end mill in order to increase the lifespan of the knives? How can you ensure that this pre-work is executed before the “Free Profiles” are processed?



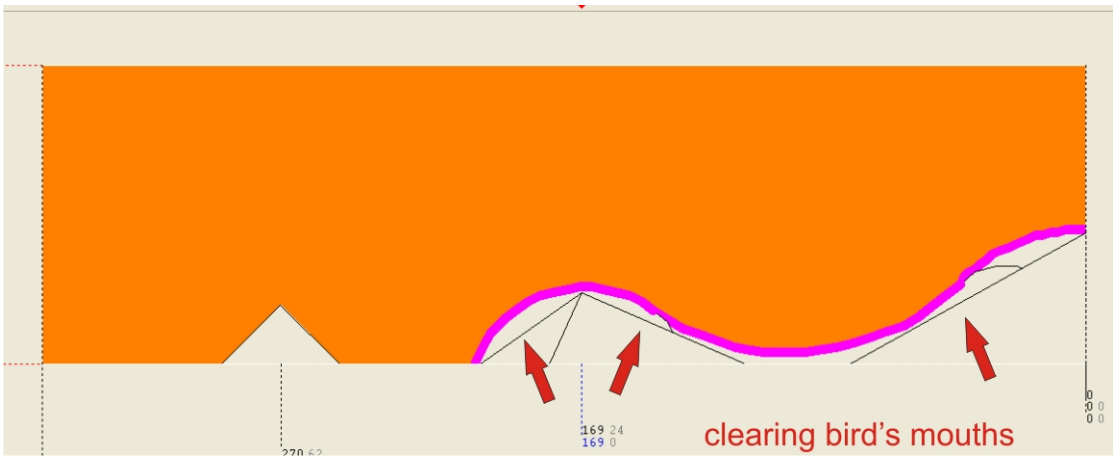


Assess the tool path and cutting direction in the detailed simulation.

How can you avoid poor processing quality and tear out through the use of pre-machining?

Exercise 24 Approach:

Following the two saw cuts enter the bird's mouth on reference side 4. The free profile should be entered on side 1 even though the end mill will process side 4. Otherwise the contour cannot be controlled. When using free profiles the first step is always to determine a starting point. The measured profile can be described by mid point circles. The starting angle should be 0° to avoid a break in the arches. Caution: "d Angle" is defined differently from CAD programs: positive values for clockwise directions and negative values for counter clockwise. After the entries for the free profile are completed process rough shaping cuts with the universal mill before cutting the exact contours with the end mill. Three rough cuts will achieve the objective. Such rough cuts can be easily defined with the tick mark in the "OK" button and the scrolling wheel in the entry fields "d angle" and "depth".



Those bird's mouths should be highlighted and moved above the free profile to ensure they are executed first. This has to be checked in the process list. Following that run a simulation to test whether there is a risk of tear out when processing the free profile. This is actually the case when the end mill exits the work piece. Therefore, add a pre-machining step that will reduce tear out. A saw slot causes very little tear out, however, it requires a number of rotations. Ensure to move the saw slot command above the free profile when determining the processing order.

Even if the testing of the processing steps shows that the rough cuts and saw slots are executed before the free profile, this might change when the processes are transferred to the other end of the work piece. It is possible that the end mill processes the detailed contours and the universal mill hits "air" when attempting to process the rough cuts. Therefore, it is recommended to use the fixed order function. Again the advice in this regard is to eliminate the initial trim cuts and only fundamental steps should be included in the fixed order. If applied incorrectly a crash could be the result. To move the processing to the remaining 3 reference sides of the work piece highlight all processing steps (except for the trim cuts) and save as a process group. After the rotation of the work piece with F7 paste the process group. Repeat this sequence twice. If the 4 sided profile is intended for other parts, highlight all process steps (except for the trim cuts) and save as process group.