Introduction to the milling machine and the milling workpiece

Aim of this module

This module aims to provide all students who will be working in the Dreamhall with theoretical knowledge before they receive hands-on instructions from the Dreamhall supervisors. Only after acquiring this knowledge may students use these machines.

TU Delft

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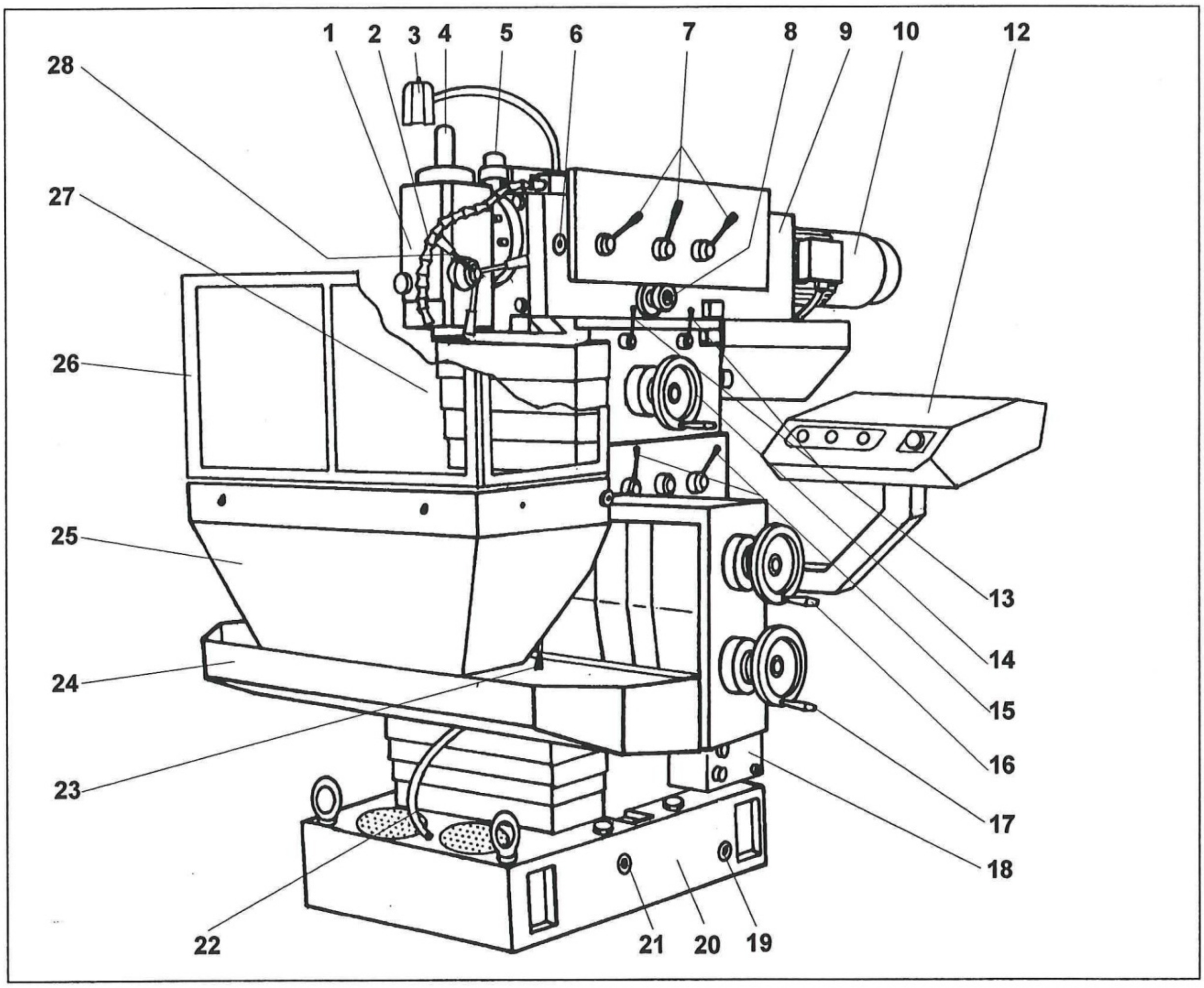

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See next page for translation into English

Parts glossary (English)

1 Vertical cutter head

2 Inlet hose with coolant

3 Lamp

4 Tightening screw for vertically positioning equipment

5 Swivel mechanism

6 Spindle box oil circulation viewport (spindle head)

7 Handle for setting rotational speed

8 Push button for positioning equipment (horizontal)

9 Spindle box with horizontal spindle

10 Driving motor

12 Console

13 Clamp handle for Y-slide

14 Feed handwheel for Y-slide

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20 Base

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22 Coolant return hose

23 Clamp handle for X-slide

24 Chip tray

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26 Safety screen

27 Switch box

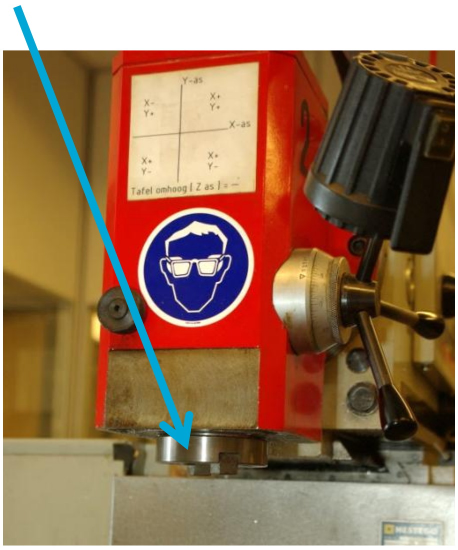
28 Quill feed engagement

Milling table

The moving part of the milling table is the cutting device, called the “cutter”. The cutter can turn and be moved in three directions over the workpiece, cutting away material from the workpiece as it goes.
The milling table consists of:

The table or bed

The image shows the bed with the machine clamp mounted on it, which holds the workpiece.
The bed of most milling machines can be moved lengthways (X-axis) and up and down (Z-axis)
The top surface of the bed moves very precisely under the cutter in the X and Y directions.



Cutter head

The cutter holders containing the cutters are clamped in the cutter head. Other tools of the correct size for the cutter head, such as a drill head or boring head, can be added.
The spindle in the cutter head turns, moving the tools with it.
In most milling machines, the cutter head can move in the Y-direction using the slide.

Slide

Fixed to the slide, the top of the machine, are the vertical cutter head on the left and the motor on the right. The motor drives the main spindle, which through a transmission drives the spindle in the vertical cutter head.

Frame

All components of the milling machine are mounted on the frame.

Milling table tools

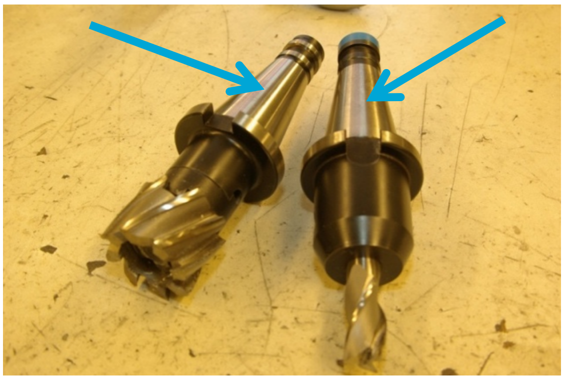
The most essential tools for milling are located in and on the toolbox near the milling table, such as universal cutters, clamping, measuring and adjustment tools, and cutter holders.

Clamping the cutter

In most cases, two types of cutter are used in the Dreamhall, shown in the picture on the right:

- The side and face cutter (left) for flat machining of the top and sides of the workpiece.
- The universal cutter for making longitudinal slots and recesses in the workpiece (right).

Both types of cutter are clamped to a cutter holder suitable for that type of cutter.



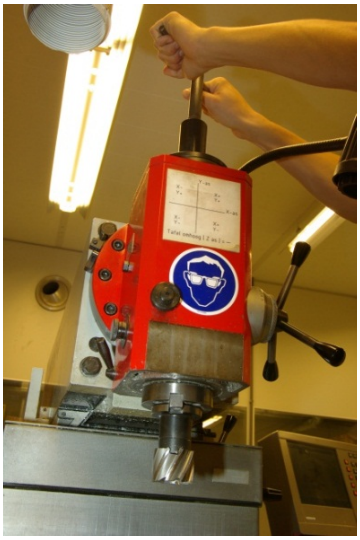
Both cutter holders have a cone on top that fits into the cone holder in the cutter head, as can been seen in the picture on the right.

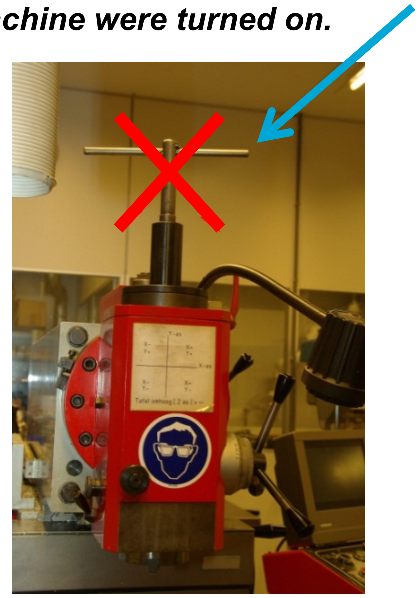
Initially, the cone and cone holder are clamped together in place. It is therefore important to keep the cone and the cone holder clean to prevent damage, which leads to imperfect clamping and off-centred turning of the cutter.

The cutter head cone is secured in the cone holder of the cutter holder in the direction of rotation by studs on the cutter head cone. The cutter holder has slots into which the studs fit.

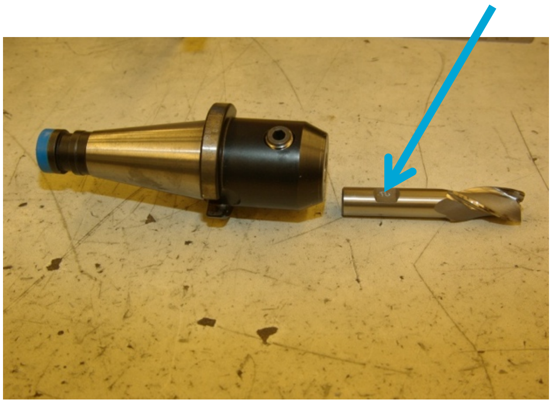
On top of the cutter holder there is a hole with an internal screw thread. To secure the cutter holder in the cone holder, this is tightened by an clamping shaft with a screw thread located in the cutter head spindle. This clamping shaft is moved using a square-head wrench.

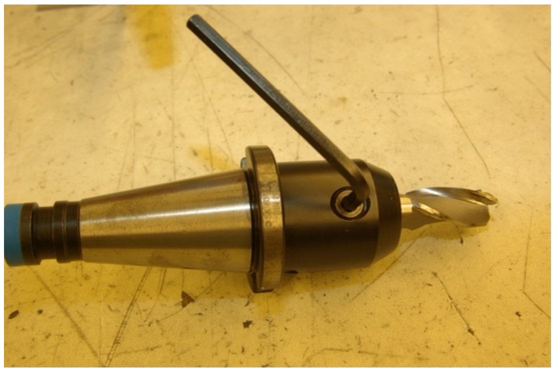
***Note:* this wrench must never be left loose on the expandable airshaft because then it would become a projectile if the machine were turned on.**





The side and face cutter is already mounted on the cutter holder.
The universal cutter is mounted in a holder that fits on the shank of the cutter. The square of the cutter shank (see arrow below) must be placed directly under the clamping pin in the cutter holder, which is then secured with an Allen key.





Before milling, a check is done to ensure that the quill clamp is secure. This clamp may only be loose during drilling, because otherwise there could be play in the cutter spindle during milling. This play may increase when the cutter hits the material, which can lead to the spindle having an impermissible play in the cutter head.

The angle of the cutting edge of the cutter can also cause the cutter to be drawn into the material, which results in it encountering too much material to cut and breaking as a result, heavily damaging the workpiece.

Clamping the workpiece

The workpiece can be secured to the table using clamping tools.
Commonly used clamping tools:

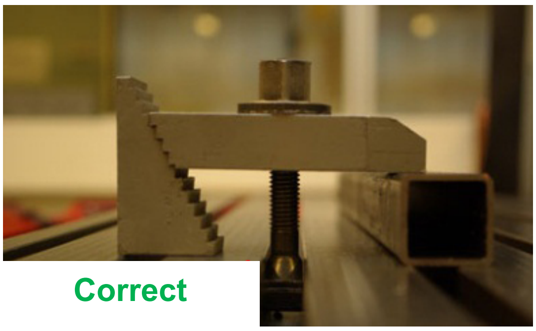
Machine clamp

Most workpieces with straight sides can be clamped using the machine clamp.

Beam clips

Beam clips can be used to fix long or ungainly workpieces directly to the bed. It is essential to use several clips for each workpiece and to clamp the workpiece to resist the direction of rotation of the cutter.

A clip consists of: a clamp, a support, and a T-bolt with a nut and ring. To achieve a secure clamping, the end of the beam must touch the material level or at a slight angle (exaggerated in the photo). This can be adjusted by setting the stepped support on the beam and the support at the correct position for the height of the workpiece.



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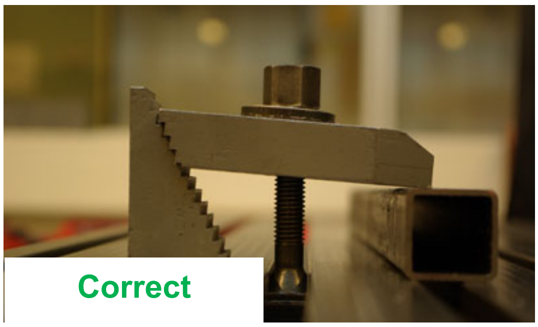

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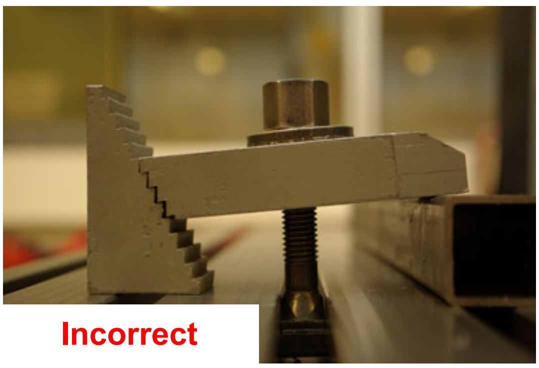

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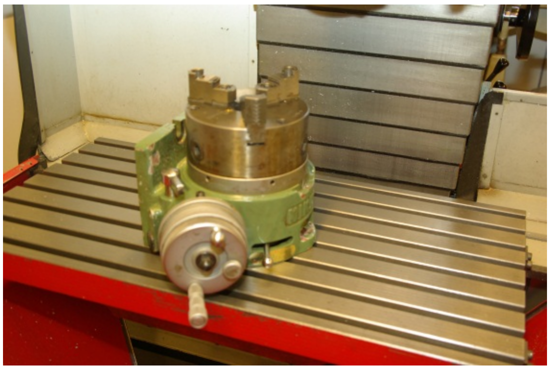
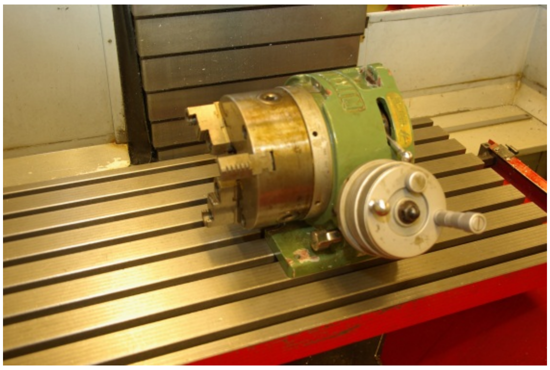
Indexing table

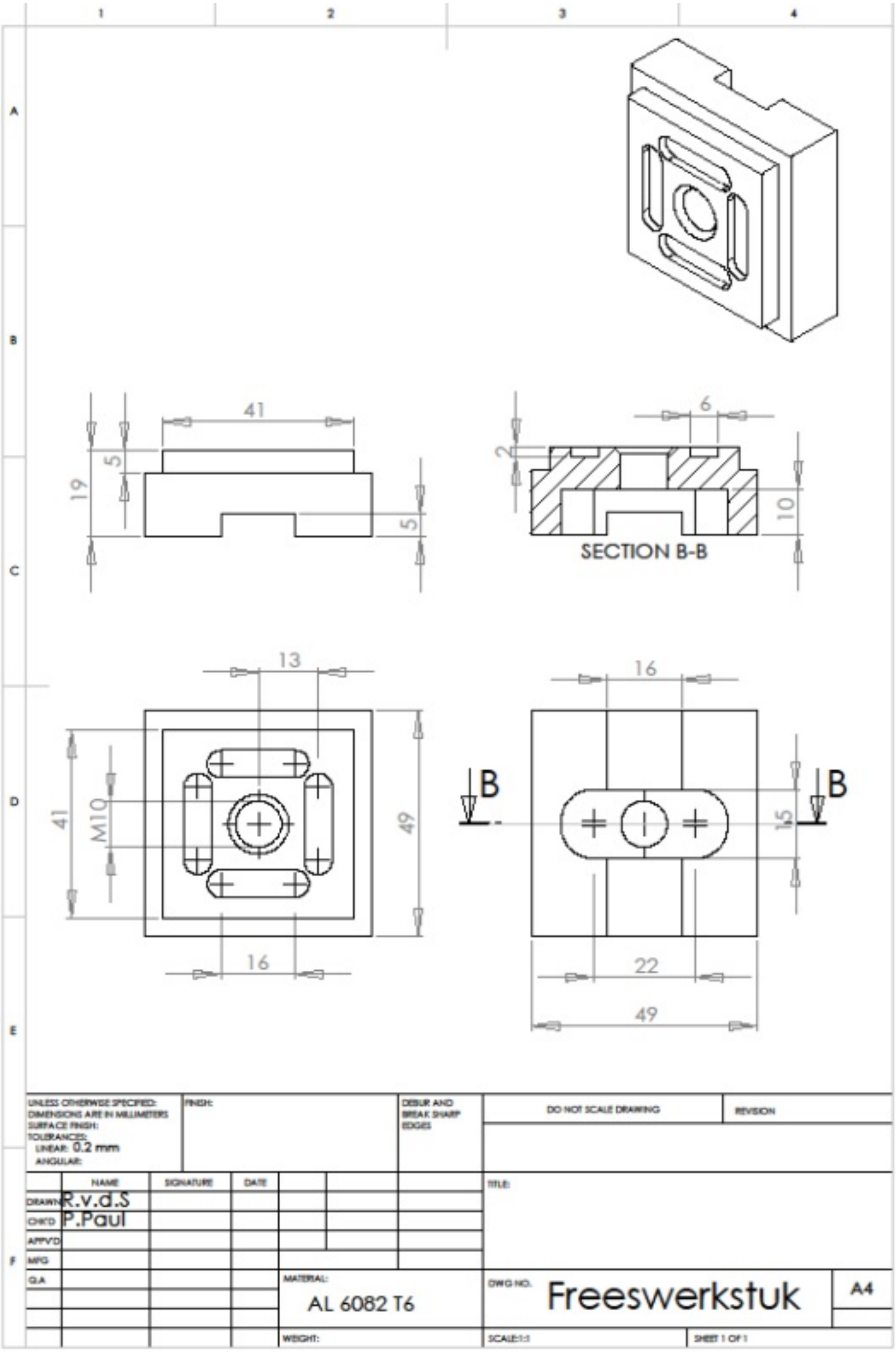
The indexing table is used to make a workpiece circularly indexed and can be fixed to the bed vertically and horizontally.





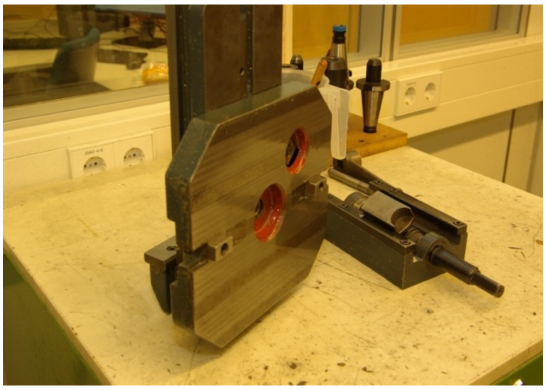
Creating a workpiece

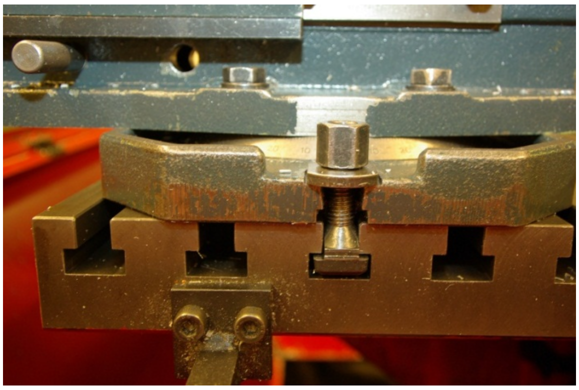
The workpiece is created according to a diagram. The diagram is prepared in line with standards and measured to fit the geometry of the machine. As a result, when creating the workpiece no measurements have to be converted, preventing mistakes from happening.



Clamping

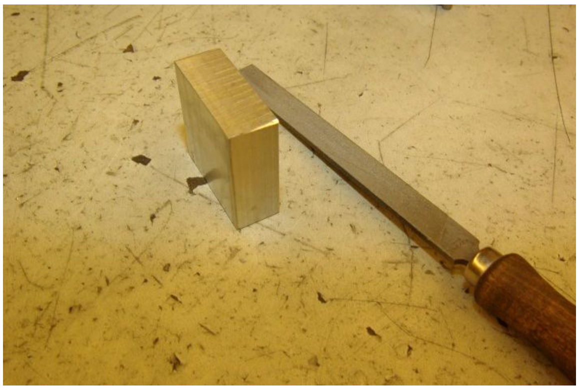
The table to which the machine clamp is fixed moves precisely parallel under the cutter. To ensure that the parallel aspect of the workpiece is transferred to the machine clamp, the machine clamp must be kept very clean in the areas where it is secured to the table.
There are studs on the flat underside that fit precisely into the T-slots on the bed and ensure a fit in the Y-direction.





The machine clamp is secured in the X-direction by T-bolts with rings and nuts that are shoved into the T-slots. When tightening the nut on the T-bolt, the machine clamp is secured to the table.

The workpiece is trimmed and cleaned, and then secured in the machine clamp. To take over the guiding of the table under the cutter as best as possible, it is important to keep the machine clamp guides and the workpiece very clean.

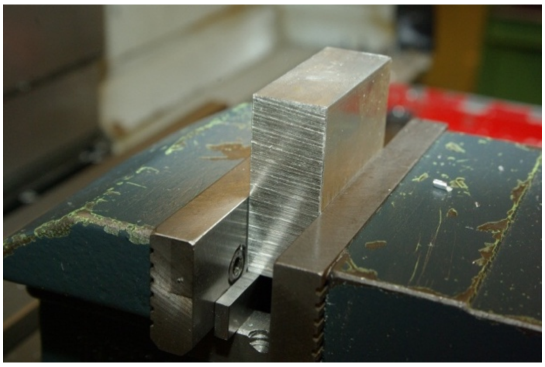


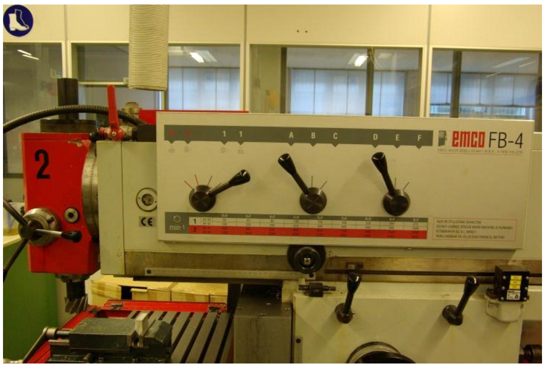
Use a file for trimming.
After every resetting of the workpiece, the machined side must be trimmed properly to get the workpiece straight into the clamp again and to prevent the opposing sides from not being parallel.

First, the edges of the workpiece are made to measure and/or the rolling mill scale is removed. In the left-hand photo, the clamped material is clamped with the flat rolled side upwards. In addition, the narrow rolled side of the material is laid on face plates. The rolled sides of aluminium beams are rolled reasonably parallel, which is used in this set-up.

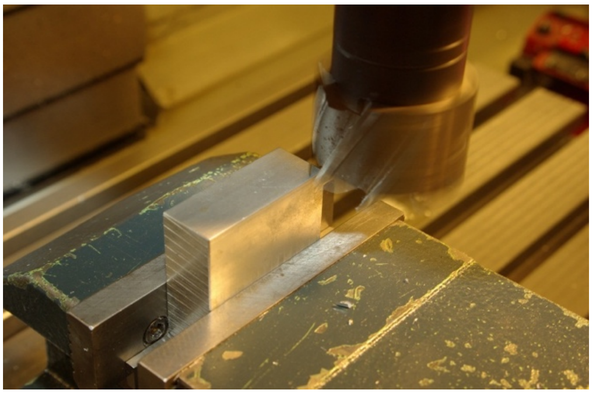
The standing side has been sawn, and thus there is no guarantee that it is perpendicular to the rolled sides.

To ensure that the underside of the material rests securely and flat on the lining plates and thus the topside can be parallel to the bottom, the workpiece is tapped with a non-recoil hammer into the securely tight machine clamp until the lining plates can no longer move.

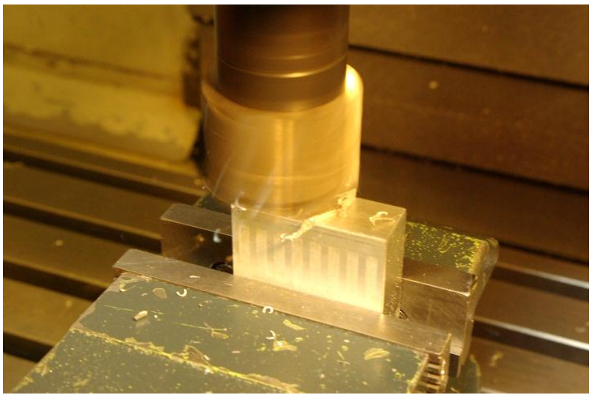




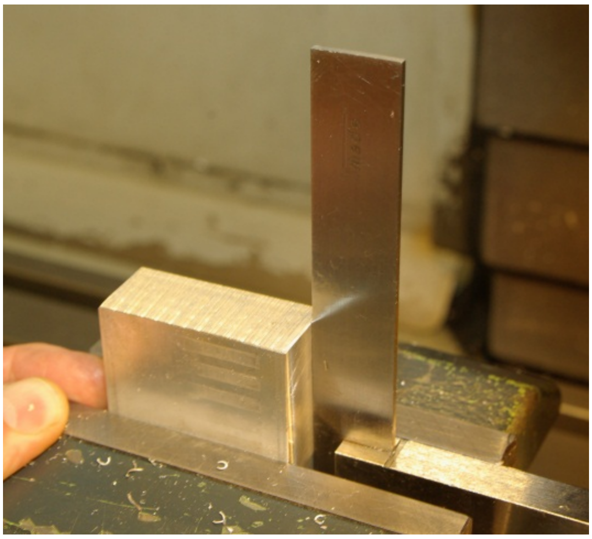
To machine the sides and the top of the workpiece, we use a side and face cutter in this case. We set the speed of the cutter using the gear levers on the side of the slide.



While the cutter is rotating, we just touch the surface of the workpiece. Now we know what zero is in the Z-direction and record this on the nonius or the digital readout. We move the cutter away from the workpiece and set it a few tenths of a millimetres lower. This side is now plain milled.



Once this is complete, we remove the workpiece and measure the height, and the excess material is milled off from the other side to achieve the desired dimension.



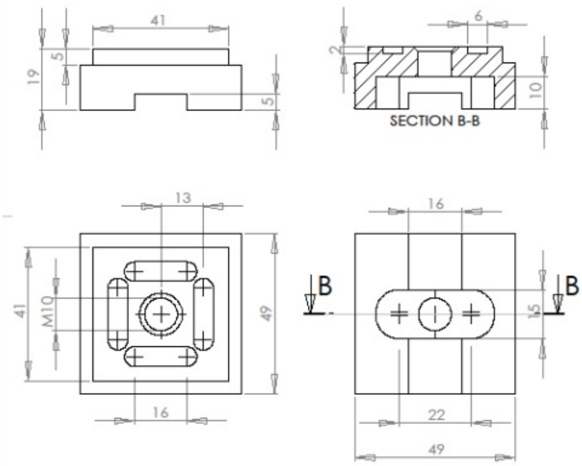
Once the rolled sides have been milled to size, the sawn sides can be made perpendicular to the milled sides. To do this, we use a try-square, with the stock part set on the supporting plates and the blade upwards. The supporting plates are parallel with the table. The plain milled side is pressed against the blade of the try-square. Once the sawn side has been milled flat, it will be perpendicular to the plain milled sides (in this case the workpiece must not be hammered on the bearing plates).

Turn the workpiece over and mill the opposite side to the desired size.
The workpiece is milled to a set thickness by laying enough bearing plates under it so the cutter cannot touch the machine clamp. Subsequently, plain mill a side here as well and then mill the other side to a set thickness.

The method of plain milling and then milling the other side to thickness ensures that all sides have the same surface, rather than one side being clean and the other still having mill scale.

The outer dimensions of the workpiece have now been achieved, and the real machining of the workpiece can start.

Because the diagram is measured from the middle, the middle of the workpiece must be determined. This is done using a wiggler, for both the X-axis and the Y-axis.



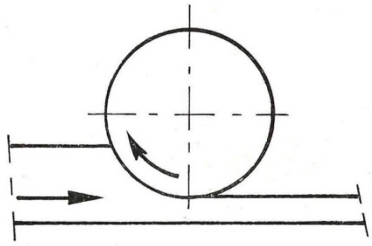
In this case, first the underside of the workpiece is machined, as shown in the bottom right of the diagram. We do this to cut both slots on the underside and part of the top side without having to change tools. The continuous slot of 16 mm wide and the keyway of 15 mm wide are both made with a 14 mm cutter.

The reason for using a 14 mm cutter is that we want to have both open sides of the slot smoothly finished. You can only achieve smooth sides when milling if these sides are climb milled.

Up-cut and climb milling

There are methods involved in vertical milling of vertical sides and horizontal milling, namely **up-cut milling** and **climb milling.** Both terms are explained by looking at several drawings.

Up-cut milling

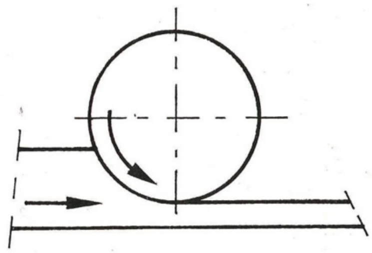


In this version, the table moves in the opposite direction to the cutter's direction of rotation. What does this mean for the cutter, workpiece and table?

The cutter tries to lift the workpiece. The cutter's chip begins very thin and ends thick. (This kind of chip is also called a comma chip.) This leads to the cutter losing its sharp cutting edges quite quickly. The workpiece's surface will be less smooth. And because the chip being cut out starts thin, the surface is wavy.

Because the cutter and the table move in opposite directions, all space between the spindle and the spindle nut of the table is pushed to one side. This promotes a smoother and less jerky movement of the table and thus of the workpiece.

Climb milling



The table moves in the same direction as the cutter's direction of rotation. The workpiece will be pressed securely into the table; this is especially important for thin workpieces.

The resulting chip starts out thick and ends thin. The cutter will lose its sharp cutting edge less quickly, and the workpiece will have a smooth surface.

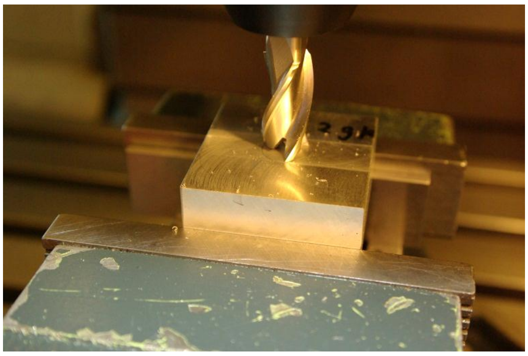
There is a major disadvantage with this method of milling, however. As the table moves with the cutter's direction of rotation, the spindle and the spindle nut have to be set without play or have a compensation device.
If not, the table will move with a jolting motion. This can easily lead to the cutter breaking and is bad for the milling table's bearings and main shaft.
A milling table that allows climb milling must have a special device that enables the spindle and spindle nut to be free of play.

If we use a cutter of the same size as the planned slot width in vertical milling, one side of the cutter climb mills the slot while the other side up-cut mills the slot, which would result in one smooth and one rough raised side.

By selecting a smaller-diameter cutter than the planned width of the slot, and compensating in the slot's transverse direction, both sides are climb milled and achieve a smooth raised edge.

Creating slots and keyways

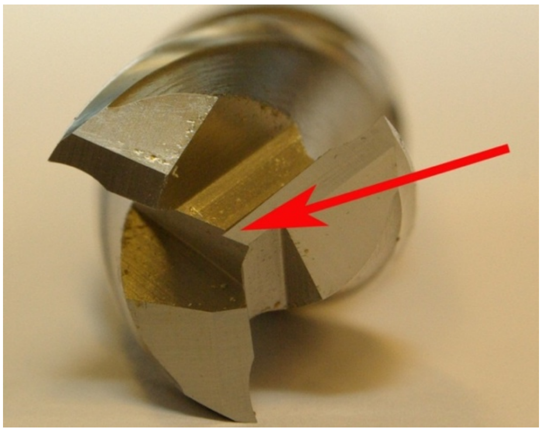
Start with a continuous slot because this is the shallowest.
The depth that a cutter can remove at one go is roughly 1/3 of its diameter. So a 14 mm cutter can just achieve a depth of 5 mm, allowing the continuous slot to be made in one pass.



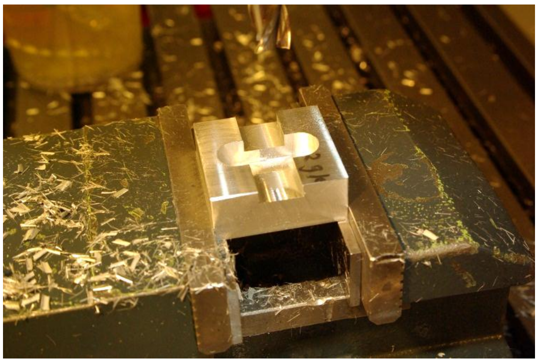
The middle is determined with the wiggler, and the zero point of the Z-axis is determined by the cutter by positioning it so it just touches the top of the workpiece. This is Z=0.

The smaller diameter of the cutter is compensated by positioning the cutter far enough from the centre line that it compensates the deviation of the radius from the planned radius. Thus, by positioning a 14 mm cutter 1 mm off-centre, both the + and – side of the 16 mm slot will be reached.

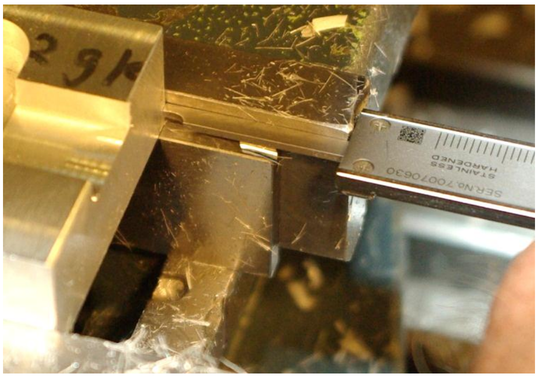
Subsequently, the keyway can be milled in the same way as the slot: first 5 mm deep (the maximum depth of one cutter pass), after which the cutter is set to the required depth in the hole while rotating and the keyway is milled at depth.



The universal cutter also cuts over the entire diameter of the face side as one of the cut edges extends over the centre line of the cutter.



Now this side of the workpiece is finished, and the workpiece can be turned around.



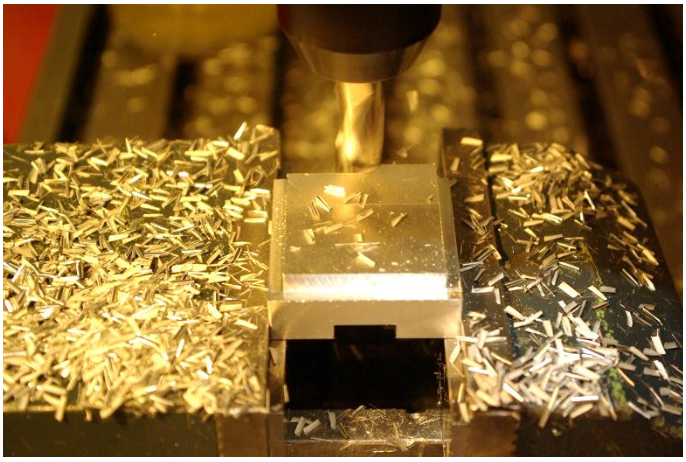
To avoid having to determine the centre again using the wiggler (reset and reposition tool), we first measure the distance between the side of the fixed jaw of the machine clamp and the workpiece. We do this using the depth spring of the slide gauge. This gives us a fixed point on the X-axis.

There is already a fixed point on the Y-axis, formed by the fixed jaw of the machine clamp. Once the workpiece has been turned around and the Y-axis is fixed (fixed jaw of machine clamp), we can position the same side of the workpiece against the depth spring of the slide gauge, and the middle of the workpiece will be exactly back on the zero of the Y- and X-axes.

The Z-zero has not changed either, because the workpiece remains the same thickness when being turned around.

Do not forget to deburr all milled sides with a file while turning the workpiece around.

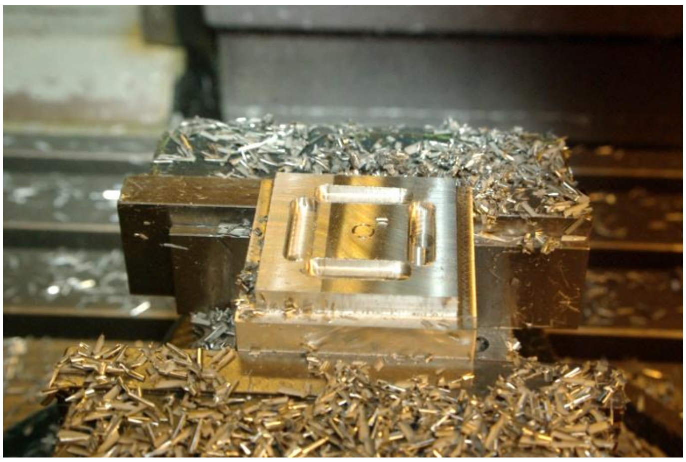
Then the machining that can be done using the same cutter, such as the recesses along the edges, is carried out.



According to the diagram, four 6 mm keyways must now be made. Again, we take a cutter that is one size smaller and compensate for it, in both the width and length of the slot. The centre-to-centre distances of the slots are given, but with a smaller cutter another linear measure than the given centre-to-centre distance must be milled, to compensate for the smaller diameter of the cutter.
The newly installed cutter must again be zeroed in the Z-axis. Zeroing in the X- and Y-axes is not necessary, as these have remained the same.

Because a smaller cutter has a higher rotational speed, it needs cooling with Nebol (for aluminium) or cutter fluid (for steel) because there is a slight risk that the material to be removed may start melting onto the cutter, producing additional heat, so-called 'pitting'.

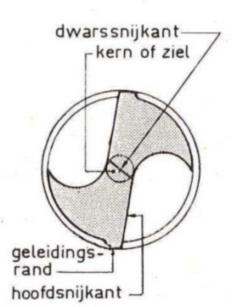
According to the diagram, the milling is almost complete. Only the hole with a screw thread remains to be done.

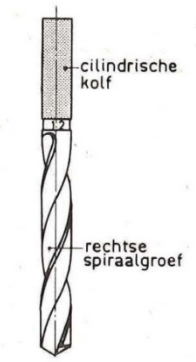


Boring holes on the milling table

We start by placing the drill head into the vertical milling head and loosening the clamp of the drill quill.

After the correct place to drill has been determined, a centre drill bit drills a centre hole. Then a drill bit of the correct diameter can be used.





The centre drilling (and any preparatory drilling) is done because a drill bit has a web (see drawing). This web makes it impossible for a drill bit to enter the material exactly at the right spot. The web will always ‘search’ over the material. To prevent this ‘searching’, the centre drill bit is used (photos); this is a very short drill bit with a relatively thick shaft. This centre drill bit is fixed tightly in the drill head so it is almost impossible for the drill bit to ‘search’ and it enters the material at the correct place. Centre holes are available in different diameters.

A centre hole is always drilled down to about halfway through the bevel of the shaft to ensure a secure guidance of the next drill bit.

Depending on the drill bit to be used, a diameter for the centre drill bit is chosen that will drill 0.8× the diameter of the web of the subsequent drill bit.
Then the drill bit is used to make a hole of the correct depth.

Once the hole is drilled, an angled ‘search edge’ drilled in the hole according to the diagram. It is created using a countersink, which is also available in different diameters. It is needed to better centre the tap with which the screw thread is created and get a better grip.

Countersinks are also used for trimming holes. A countersink is always used at a rotational speed of about 150 rpm. If the countersink turns faster than that, the cutting edges will slide over the material and not remove anything; there is also the risk that the countersink will “dance”, producing a very irregular surface and chamfer.


Then the tap can be inserted into the hole to tap the screw thread. Using a manual T-handle, screw the tap into the material. To ensure that the tap goes in straight, it is guided through a centre point which is clamped in the drill head. Exerting light pressure, the centre point is pressed into the centre hole of the tap and the T-handle is turned with the tap using light pressure, so the tap is pulled into the hole and taps the thread into the material. Every two rotations, turn the tap back half a rotation to break the chips created so they do not stick in the hole or damage the top of your thread. Once the screw thread has been tapped over the entire length of the hole, the tap is unscrewed, and the workpiece is finished according to the diagram.

Safety

- Fix each workpiece to be milled securely in a proper clamping device such as a machine clamp or use beam clips. Workpieces that are not properly clamped may come loose and cause considerable injury or damage.

- Never get your hair or loose items of clothing too close to a rotating cutter. If you have long hair, tie it back or wear a hairnet. If your hair or a part of your clothing gets caught in the machine, you could sustain very severe injuries.

- Always wear industrial clothing with tear lines when machining.

- Always wear safety goggles when performing machining operations.

- Safety shoes are obligatory in the workshop.

- Never grab hold of a rotating cutter.

- Never measure your workpiece while the cutter is still rotating.

- Never pick up a cutter by the cutting edge.

- Never remove chips from a rotating cutter – they are razor sharp.

- Remove chips only using a chip rake and only when the machine is off.