ZX25M Metalworking Mill

Online Training

https://wiki.hackhitchin.org.uk/index.php?title=ZX25M_mill

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ZX25M Mill

What you will get from this training

Scope of the training

These online materials are designed to get you ready to operate the Hackspace ZX25M Mill.

No prior knowledge of how to use a metal mill is assumed.

If you already know how to use metal mills, this material has been designed to get you up to speed with our particular mill quickly. Please be patient with the process and if you have any tips to improve this guide, let us know!

This guide covers what all mill users need to know in Hackspace.

Learning objectives

- How the ZX25M mill works
- How to inspect the equipment before use
- How to use it safely
- How to machine metal using the mill
- Cleaning-up after use

Training: What is expected of you

This training material gives you a complete overview of the knowledge we expect all users to be familiar with.

It also gives tips and suggestions on how to get good results. Read this document, including the linked videos and documents to clarify understanding

It’s preferable to have a project in mind BEFORE you start the practical training

Once you have read and taken in the training material, you can arrange to have an in-person session. Only once you have been assessed person-to-person can you use the equipment.

PRACTICE on the machine as soon as possible after you have finished the training – ideally within a week - expect to commit ~ 8 hours to this if you are new to machining

ZX25M Mill

Safety

How to use the ZX25M mill safely

A mill is potentially one of the most dangerous machines in a workshop, however if correctly used it is extremely safe.

It is you that makes the difference.

Operator safety rules

- Always wear eye protection - Sharp edged chips can be thrown off the workpiece at high speed;

- Make sure to not use anything that can get stuck in the machine. This includes:
  - Ties and scarves;
  - Bracelets, necklaces and rings;
  - Long sleeves;
  - Gloves;
  - Wired headphones;
  - Long hair **must** be tied up or securely held back.

ZX25M Mill safety: Setup

The safe operation of a milling machine is all down to the preparation and setup of the machine.

- Do not adjust the machine if it is capable of starting to move, or already moving.
- Rigidity, rigidity, rigidity: The limitations of the mill will generally be due to unwanted movement of the work or the cutting tool.
- Always be prepared to abandon an operation if it is becoming difficult to setup with rigidity, or the mill starts making strange noises.

ZX25M Mill safety: Operation

- Inspect the mill for cleanliness and damage
- Verify that the chuck it is secure and that the draw bar is properly engaged
- Insert a sharp tool into the correct sized collet and secure in the chuck
- Clamp your work to the mill table ensuring all areas to be milled are supported
- Use the mill!
- Shutdown
- Clean up the mill

ZX25M Mill safety: Additional checks & tips

- The most common problem is trying to remove too much work material in one pass. This can overheat the mill motor, the cutting tool or the workpiece, place stress on the mill or break the cutting tool which could fly apart.

The Six absolute No-Nos of milling

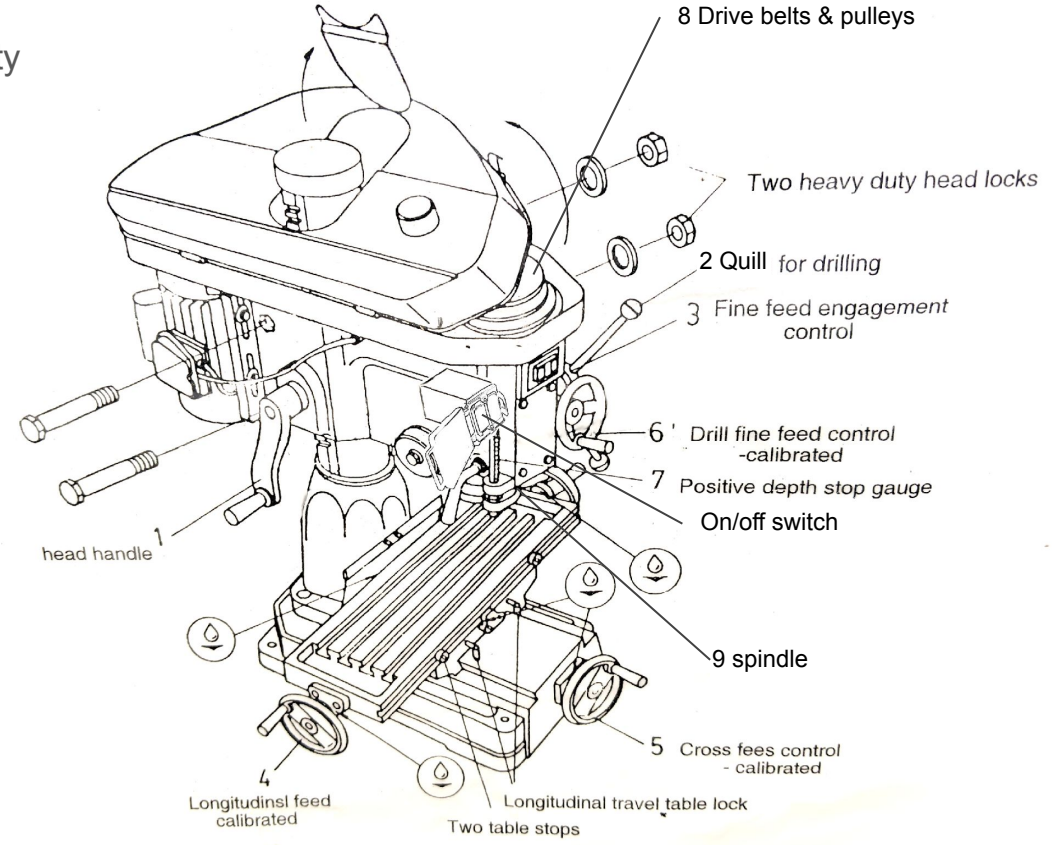
- Never let your chuck or workpiece come loose, always check everything is tight before use, also check the rest of your mill as you don’t know how competent the previous user was.
- Never start your mill whilst your tool is loose in the chuck, always check
- Never leave your chuck key in the chuck (drill chuck)
- Never allow your cutting tool to hit the vice jaws or table – always check clearance before starting the mill
- Never try to mill unsupported work. Stop and improve clamping if vibration becomes excessive

ZX25M Mill

Preparation, Set-up, and Operation

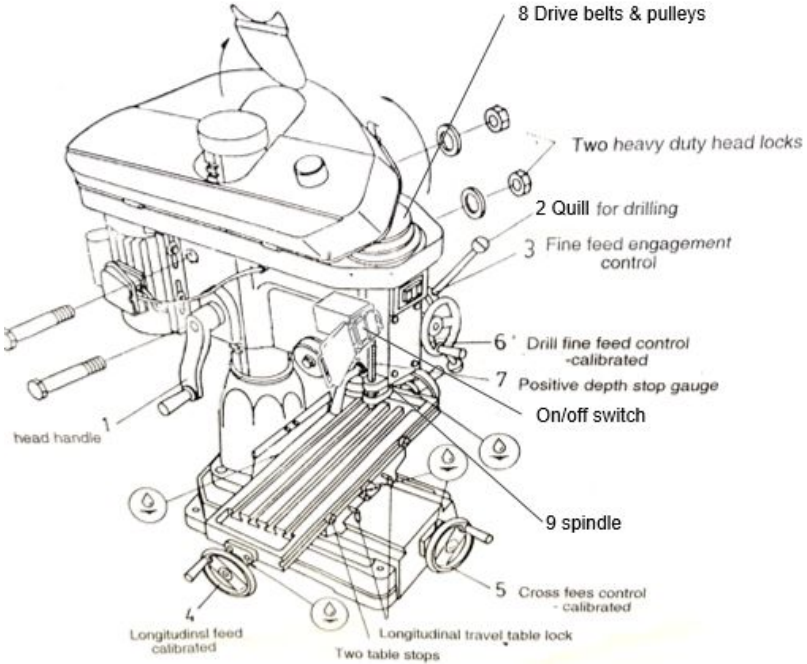
Getting to know your mill

The ZX25M mill is a simple machine but your safety and the quality of your work depend on correct setup and adjustment so it's good to spend some time getting to know the machine



Getting to know your mill

Your workpiece must be firmly supported and clamped to the milling table. You use the X and Y handles to move the table left to right and forwards and back. The Z handle raises or lowers the table to set the depth of cut.



1. Head handle lifts head to change working height
2. Quill handle is used like a drill press for drilling
3. Fine feed engagement changes between handwheel and quiill handle control of quill position
4. Longitudinal or X axis adjusts position and manual feed rate
5. Cross feed or Y axis adjusts position and manual feed rate
6. Fine feed control adjusts depth of cut
7. Positive depth stop is to allow a repeatable drill or mill depth
8. Belts are used to change spindle speed
9. Spindle accepts chucks and face mills

Personal Protective Equipment (PPE)

<u>Goggles are required.</u>

Other people working in the workshop space should also have eye protection if you are using this equipment because razor sharp metal chips will be flung across the room.

Safety specs and goggles are stored on shelf 3 in the workshop, in a box labelled Eye Protection

Do not use hearing protection. You need to be aware of your machine and people around you. If the mill is making a lot of noise, investigate the problem - feed rate, depth of cut, lubrication and / or blunt tool.

Gloves are not advised when operating the machine because if your hand catches on the chuck, gloves will catch and drag you in.

Tie back any loose clothing, and especially long hair or loose sleeves, etc. because these cause fatal accidents when they are caught/entangled.

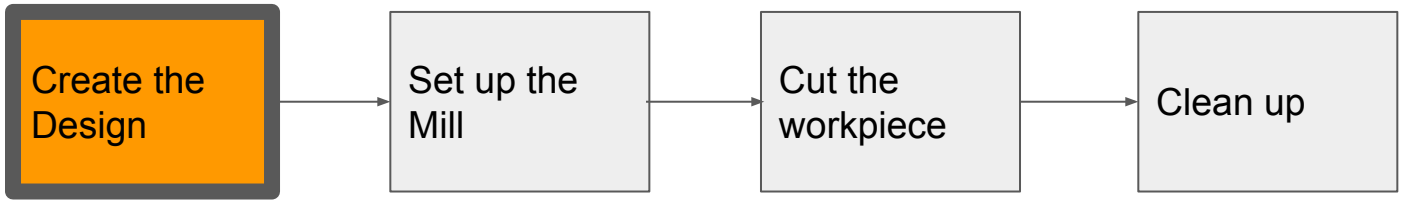
Mill Safety Hazards

As a trained user, you should be very aware of the following risks and how to deal with them:

- **Fire** - Cutting with the wrong settings could result in the material igniting.
- **Moving Parts** - keep clear of the moving parts of the machine
- **Sharp Edges** - Take care installing and removing cutting tools
- **Dust** – If dust is being created during cutting, run the workshop air cleaner throughout the job and regularly pause the mill and use the vacuum to remove dust.
- **Noise** - Ensure that you wear the correct PPE when working with the machine.
- **Projectiles** - Poorly clamped work or snapped cutters can be ejected from the mill

The risk assessment can be found here:

Milling Workflow

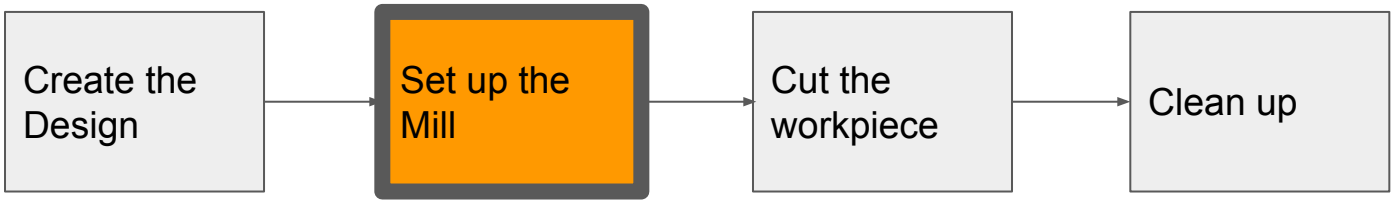


Designing for Milling

- Internal corners must be radius when viewed from above. The radius will match the cutter used, larger diameters are preferred
- Features aligned with the X/Y/Z axis are much easier to setup and machine than angles
- Deep, narrow slots are challenging (chip clearance and tool rigidity)
- Thin walls are challenging (vibration)
- Like a 3D printer struggles with overhangs, undercuts require specialist tooling to mill (appropriate dovetail, t-slot or slitting saws would need purchasing)
- Round holes will generally need to match the cutter diameter (unless a boring head is purchased or a tapered reamer can be used)
- It’s generally worthwhile to produce a drawing, even if the design is simple
- Consider the order of operations and how the material will be held whilst cutting

Further reading: https://www.hubs.com/knowledge-base/how-design-parts-cnc-machining/#what-are-the-main-restrictions-of-cnc-design

Milling Workflow



Inspecting the Mill before work

Never skip a thorough inspection of the mill before switching its power on:

- Check the general area is clean and clear
- Check that the chuck is clear of any entanglement
- Make sure that no objects are on the mill, and that nothing is in the way of the moving table

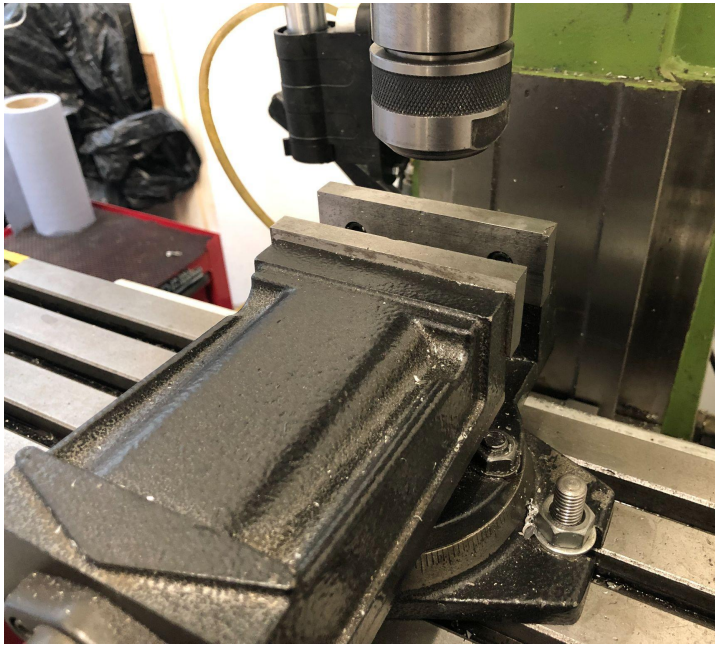
Keep the equipment owners informed if you do find a problem, as this helps Hackspace keep an eye on whether the equipment is working optimally. Please send a message to the #workshop-equipment channel on slack.

Preparing your work: Getting ready

Your workpiece must be fully supported and clamped to the milling table. If it comes loose your work will be ruined and it may cause a serious accident.

Milling can initiate vibration that can also ruin the work or break the cutter, so the setup needs to be extremely rigid.

Different materials, designs and cut operations require different work holding methods.



Secure your workpiece

Large forces are involved in milling. It is essential that your workpiece is rigidly clamped and that your clamps will not foul the cutter.

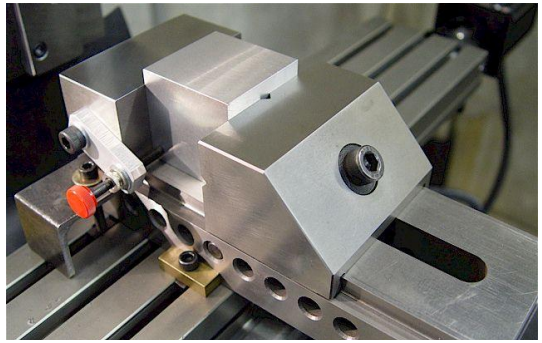
If the size of your work permits, the easiest way of holding it securely will be in the milling vice. You must position the vice such that it doesn’t impact the milling machine column when you make the cut nearest the back of the mill

If your work extends beyond the jaws of the vice it will need additional support if the mill starts to vibrate or chatter. The quality of your finish is likely to be poor

Secure workpiece

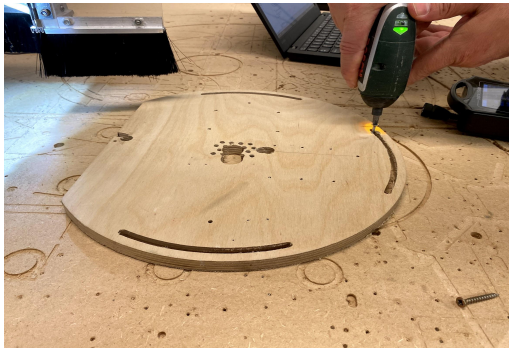
There many alternative ways to secure workpieces, the most common are:

- Clamped in a machinist’s vice



- Toe clamped to the bed

- Screwed down to a spoil board

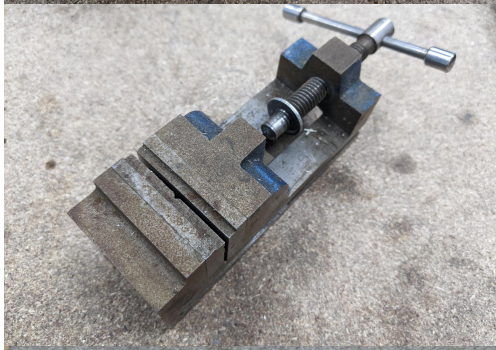


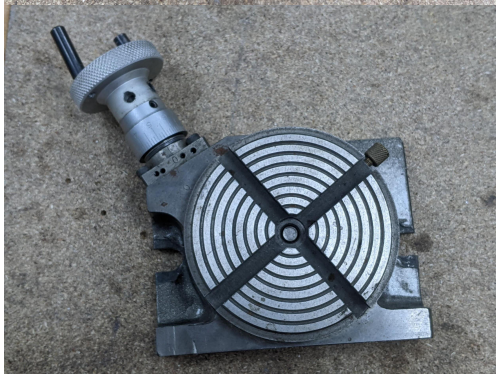
- In a rotary axis/chuck

Secure workpiece

In general the appropriate method for securing the workpiece might be:

- Billet/block/thick sheet: clamped in a machinist's vice with parallels underneath
- Very large or unusually shaped: Toe clamped to the bed (with spoil board if cutting through)
- Thin sheet: glued or screwed down to a spoil board
- Round, rod-like or working from multiple sides: on a rotary axis or using V-Blocks





Preparing your work: Making it secure

In addition to the clamps shown in the picture you will often have to use spacers to support and clamp your workpiece - take time to do this carefully

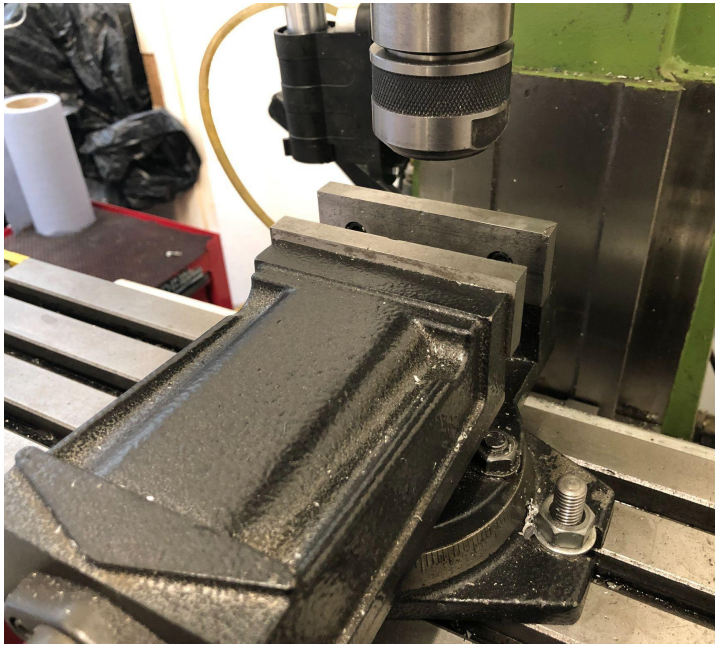
The milling vice together with parallels can be used to secure small parts. Before using the vice you will need to check that it is parallel with the table slots. Use a dial gauge mounted on the mill column if you need precision. Only adjust with the mill stopped.

Preparing your work: Getting ready

Your workpiece must be fully supported and clamped to the milling table. If it comes loose your work will be ruined and it may cause a serious accident

We have The ZX25M milling tool holder takes threaded mill cutters in suitable collets. If the Hackspace milling tool in its collet is too large to go through the hole in the chuck, pass the cutter through the tool holder and fit the collet from the rear

The drilling chuck is used for drilling operations and can also be used to align taps. **Only manual tapping is supported on this mill.** Do not engage power when tapping.



Milling Cutters - end mills

End mills are one type of cutting tool used with the milling machine. Similar to drill bits, they are available in a wide range of sizes, types and materials.

Chips caused by the cutting process will gather in the spaces between the flutes as they are cutting. If you are cutting a material that creates big chips, such as aluminum, it makes sense to use an cutter with fewer flutes, so that there is enough space for the volume of the chips. In general 3-flute cutters are preferred for aluminium, 4-flute for steel. High tooth count “burr” style cutters are not recommended for milling

Cutting tools - Hackspace’s collection

We have a selection of tools that cover many types of milling work. Refer to the wiki for more detail: https://wiki.hackhitchin.org.uk/index.php?title=ZX25M_mill

Generally the largest practical cutter should be used for the job, as they are the most robust.

There are many factors to selecting an appropriate cutter, such as the geometry, material and limitations of the machine, if you’re not confident its best to discuss it with those who are more experienced.

Safe Materials and Tools

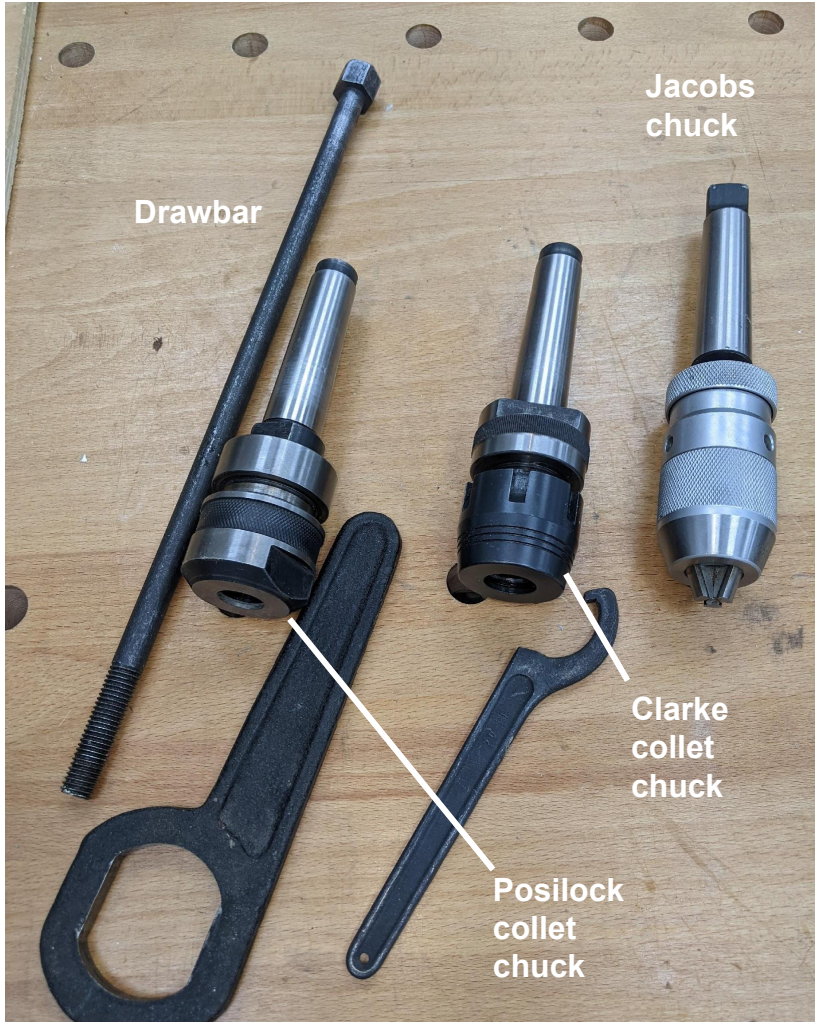
- With the correct tooling, feeds and speeds, you can mill all types of metal, wood, plastics and foams.
  - **DO NOT** cut glass or ceramics
- Take care to match cutters with correct collets
    - We have ¼”, 3/8”, ½”, 5/8”, 6, 10, 12 and 16mm collets for the Posilock chuck and 2mm, 3mm, 4mm, 5mm, 6mm Posilock-compatible cutters
    - We have 4, 6, 8, 10, 12, 14, 16mm collets for the Clarke chuck
  - Ensure the shank of the milling bit matches the collet – measure to confirm
    - Failure to do this will break the collet
    - Cutters with a thread in the end are for the Posilock collets

Holding cutting tools – chucks

- Most cutters will need to be mounted in a chuck
- For cutters with a threaded shank, the Posilock collet chuck is preferred
- For plain shank cutters, the Clarke collet chuck is preferred
- For drilling, the Jacobs chuck can be used. The Jacobs chuck must not be used for milling

- The larger face mills have an integrated morse taper so can be mounted into the spindle directly without a chuck.

- Most of the tools are secured in the spindle with a suitable drawbar



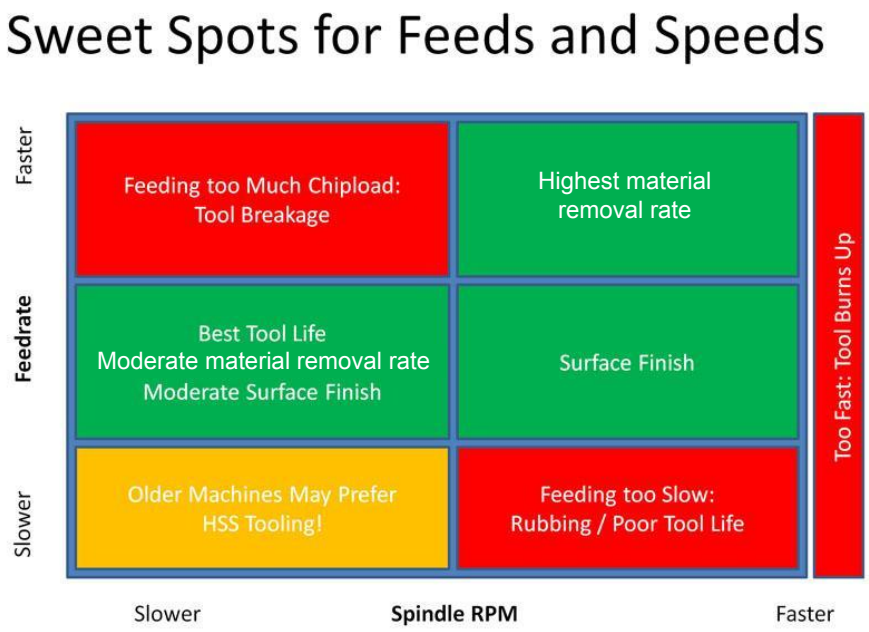
Using the Posilock chuck/collets

- Select the right collet for the tool shank diameter.
- Insert the threaded end in to the front of the collet until the thread on the shank engages with the thread in the collet.
- Screw the tool in to the collet until the thread is flush with the end of the collet.
- Unscrew the locking collar from the chuck
- Insert the assembled tool and collet in to the chuck. Ensure that the step engages with the pin in the base of the chuck. The collet should not be positioned on top of the pin.
- With the collet in the chuck fit the locking collar screwing it on to the front of the chuck and tighten until the collar stops on the shoulder.

Getting to know your mill: Cutting speed

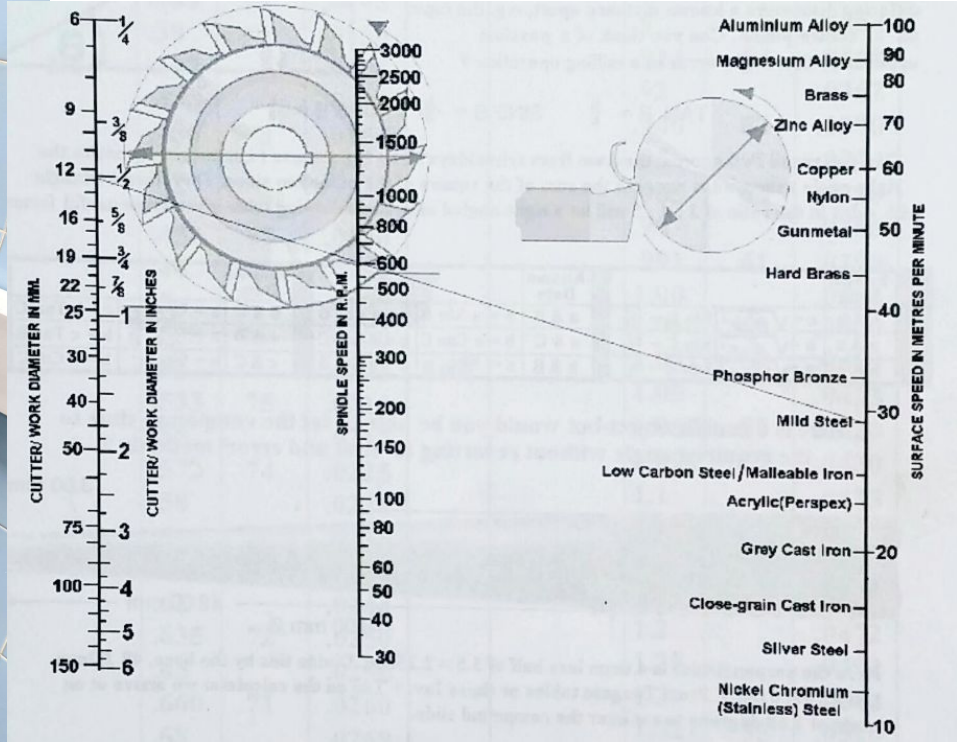
- The tool rotational speed is set by the position of the belts in the head of the mill
- The belts will need adjusting for the cutter or drill size and the material being cut. The speed will need to be lower for larger cutters, particularly in steel.
- Too much spindle speed will generate excess heat which will soften the tool and blunt it faster
- Reduce your cut depth and feed rate if the workpiece is getting too hot

Suggestion: use the speed chart on the following page (and also on the wall in the hackspace) to select the speed for cutting



Setting the spindle speed for optimal cutting

The machine **MUST** be switched off at the mains before opening the belt box.



Changing the chuck or tool

- To change the chuck or cutter, loosen the drawbar a few turns, leaving the thread partially engaged with the chuck/tool.
- Tap the end of the drawbar with a soft-faced mallet to release the tool, then finish unscrewing the draw bar by hand, whilst supporting the chuck/tool
- Fit the new tool/collet and retighten the drawbar. Different tools/chucks may need different drawbars.

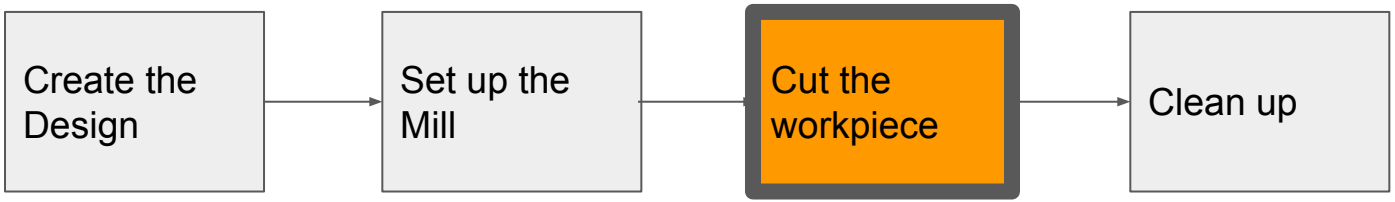
Safety: Check the chuck is secure!

You must **always** check the chuck is secure by gently tightening the drawbar before running the mill.

The mill accepts taper chucks. The chuck should be inserted smartly into the mill to engage the taper. It should not be possible to remove the chuck by pulling down.

A safety drawbar accessed from the belt compartment passes through the spindle and screws into the back of the chuck taper. **This should not be overtightened** - it is not intended to pull the chuck further into the spindle. Only use two fingers on the centre of the spanner to tighten the drawbar.

Milling Workflow



Setting up your mill

To get power to the machine:

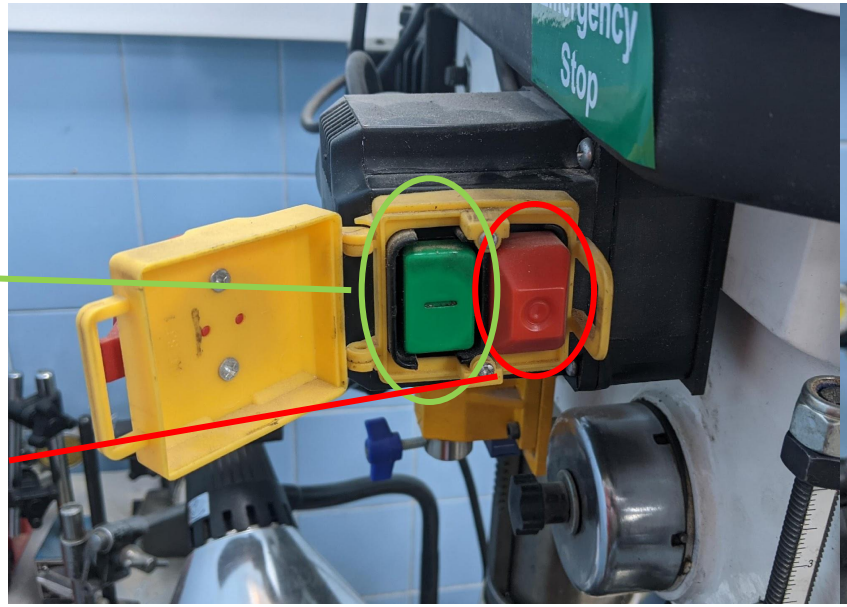
1. Switch on at the wall

If you find the mill to be unsafe, unplug it from the mains and place a notice on the mill. Inform trainers of the problem.

Getting to know your mill: Motor control

Start (clockwise)

NORMAL STOP



After the motor has been started, partially close the cover so that it can be used as an emergency off switch

EMERGENCY STOP
Press/hit cover

Safety before Starting – each and every time

Always make sure of two things when using the milling machine:

1. That the work area is safe, there is nothing lying on the mill that shouldn't be, especially the chuck key. Also check before starting that the milling cutter will not collide with anything.

2. You have nothing on you that can get caught in the chuck of the mill. Beware of loose clothing, long sleeves, jewellery and especially long hair. All of these are a total no-no. Whilst eye protection is mandatory do not wear anything that will impair your hearing – if you listen to the mill while it cuts the mill will tell you how well you are doing.

Do not use gloves as they impair the physical feed-back from the mill. You must be able to activate the stop switch and emergency stop switch instantly.

You are also responsible for the safety of all others around you, check them every time before you start the mill and ensure that they know you are starting.

Working with the graduated hand wheels

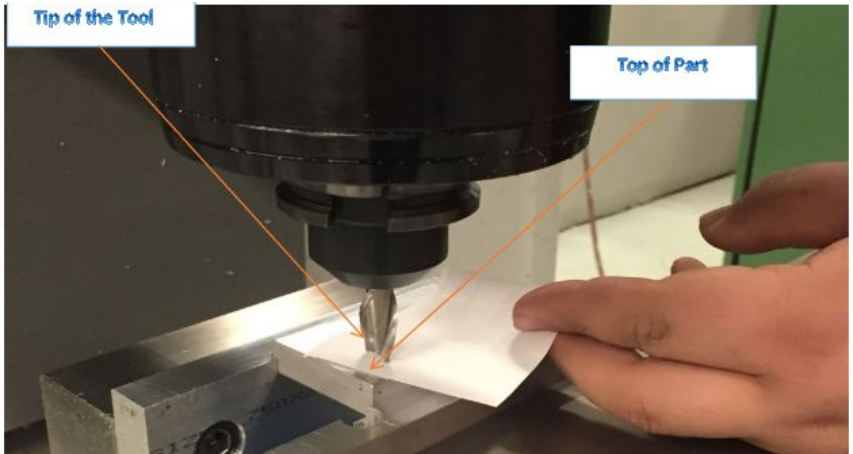
If you want two features to be accurately positioned relative to each other, using the calibrated graduations on the hand wheels is one of the best ways to achieve this.

The process generally involves establishing a datum, the winding the hand wheel whilst counting the turns, and finishing on the correct graduation. Care needs to be taken to account for backlash and cutter diameter.

A datum can be established through many methods, common approaches are by “touching off”, taking a skim cut, or using edge finders.

Datum from an edge or top of work using paper

1. Ensure the bed is clear of all loose tools, clamps and other objects
2. Position the tool slightly outside the edge of the workpiece, or just above the surface
3. Slowly wind the appropriate hand wheel to progress the material towards the cutter or reference dowel
4. Checking the gap with a piece of paper. Wind slower as you approach nipping the paper
5. Adjust the graduated dials on the hand wheels to read zero in that position



Datum from an existing hole

Video: https://www.youtube.com/watch?v=YoN_MSuqzE0

Methods:

1) Gauge Pin
2) Dial Test Indicator
3) Coaxial bore gauge
4) Transfer punch/centre drill
5) Edge finder - kept in the drawer labeled Draw Bars & Pin Chucks

Cutting notes

- Use centre-drills to establish an accurate small spot or pilot hole before drilling
- Face mills can be used to get flat top surfaces
- Bullnose mills can be are used to create semi-circular base slots.
- Corner rounding end mills are used to create radiused chamfers. Similar with chamfer mills
- If the mill, shrieks, vibrates or bogs down when cutting, adjust your depth of cut and feed rate.
- Use lubricant to minimize tool and work heating.

Making the part match the drawing

There are a number of methods to ensure the part you make meets your design. The most common are:

1. Mark the design onto the material before milling, using engineers blue and marking equipment such as scribes, centre-punch, height gauge, calipers, square etc.
2. Establish a datum position then use the dials on the hand wheels to position the cutter according to the design.
3. Measure the part as you go, and creep up on the final dimension.

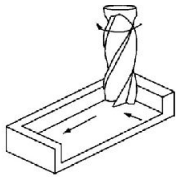
All these methods have limitations. 1) is generally ok for cosmetic parts but is challenging to be more accurate than +/-0.1mm. 2) & 3) can achieve +/-0.01mm with care. 2) can be challenging to keep track of the number of turns. 3) is tricky with one-shot operations like the position of a drill or a cutter-width slot.

Method 1: Marking a v-groove centre-line: https://youtu.be/yGNOGnyN7UU?t=39
Method 2, Using edge finders to establish a datum: https://youtu.be/clyGMpfjVRw
Method 3: Machining to a target thickness by measuring: https://youtu.be/TL0OsfFkBL8?t=277

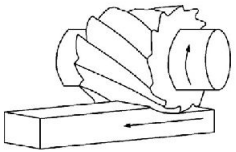
Two types of milling operations

The two types of basic milling operation are:

- (a) End milling
- (b) Peripheral milling



(a) End milling



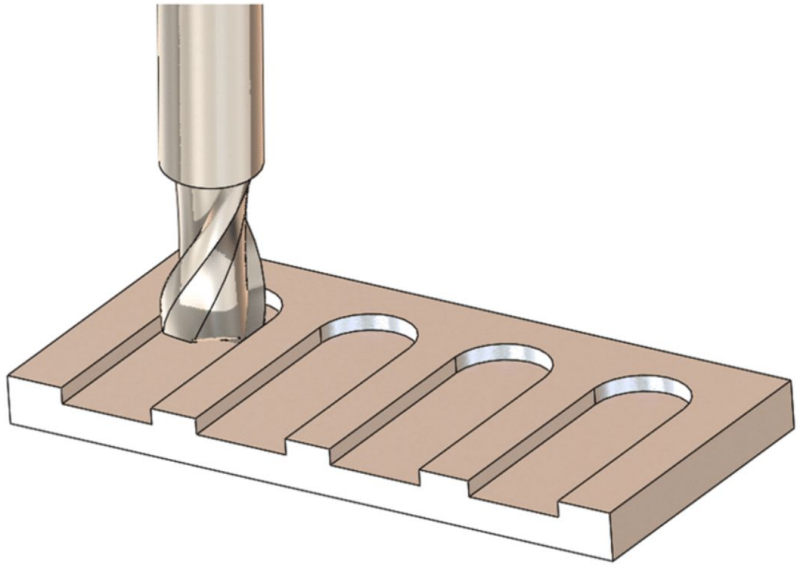
(b) Peripheral milling

Cutting a slot

Centre-cutting cutters can be plunged into the work to start a cut.

Your instructor will demonstrate a cut to you then you can do one.

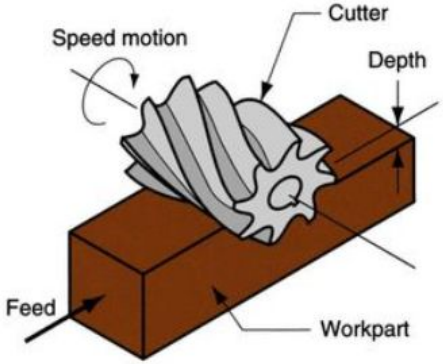
Always be careful that you do not drive the cutting tool into the vice or table.



Schematic of slot-milling process

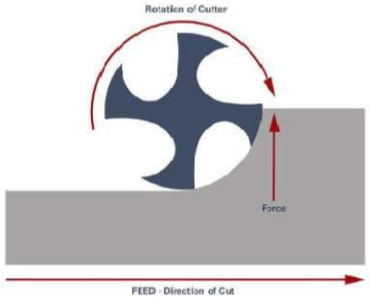
Making a peripheral cut

This type of operation involves bringing the tool into the side of the work.

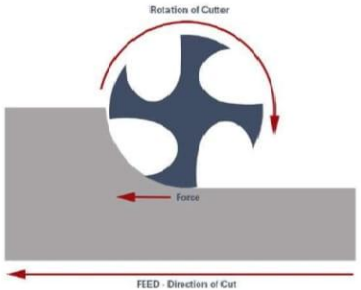


Compared to face milling, peripheral milling is more effective at removing large amounts of material from workpieces. This is because it uses the sides of the milling cutter rather than the tip. It also distributes the cutter wear more evenly, so cutters last longer.
Avoid climb milling except on very light passes, otherwise there may be self-feeding, positive feedback, high tooth engagement, followed by ejection of the work or a snapped cutter.

Climb Milling



Conventional Milling



Remove the material in a series of passes. Don't try to remove too much material in one pass as the finish will be poor and the mill might be overloaded

Drilling operations on the mill

The mill is the ideal tool to use if you need to drill accurately positioned holes in metal. You may need to change the milling chuck for a drill chuck

The drill chuck must be secured in place with the drawbar. The drawbar should not be overtightened - it is used to retain the chuck, not pull it into the taper.

Use the quill lever like a drill press to plunge the drill into the work

Use lubricant and consider the spindle speed

Drilling a hole into an angled workpiece

If you try to drill into an angled or circular workpiece your drill will wander and is quite likely to break, potentially causing a hazard. You need to first mill a flat face and use a centre or slot drill to ensure your drilling operation is safe and accurate.

There is an excellent YouTube by Joe Pie explaining this and showing how to safely drill into angled and round material

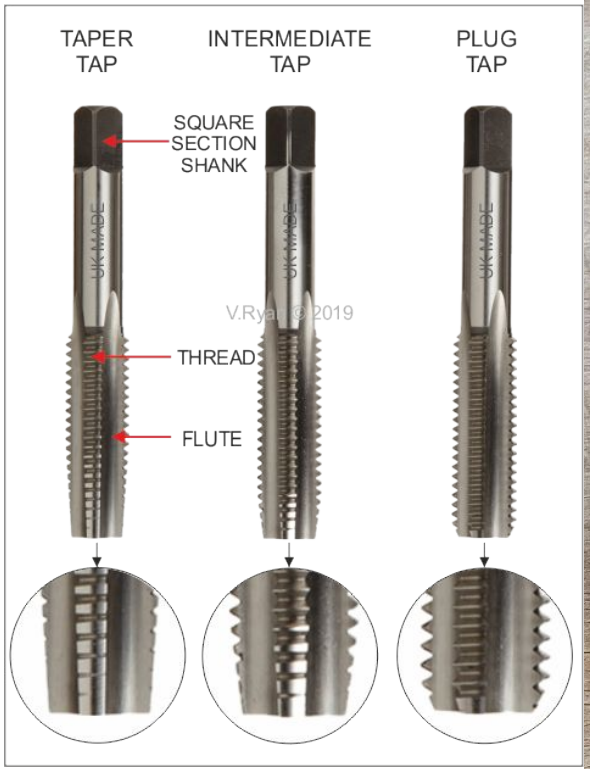
https://www.youtube.com/watch?v=e3dPUvgKRBU

Tapping

Do not tap under power in the Hackspace milling machine - it will not work and is unsafe

You can and should use the drill chuck to hold your tap to start the thread manually

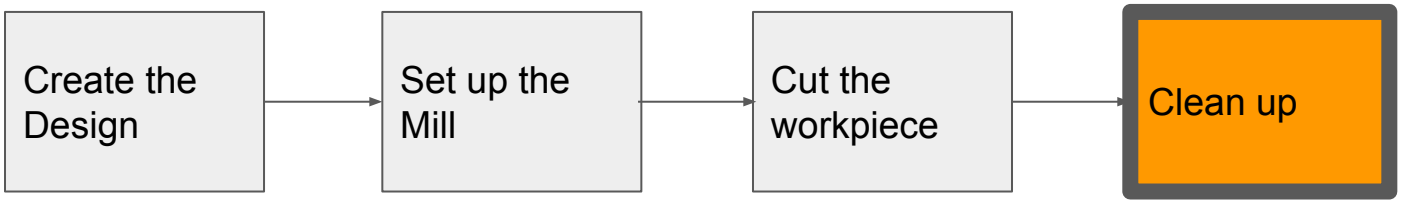
- The power must be off
- The tap must be firmly secured in the chuck. Start with a taper tap.
- Use the drill quill lever to advance the tap into the correct sized hole
- Gently apply downward pressure on the quill as you rotate the chuck by hand
- Lubricate your thread with tapping compound
- Finish with a tapping tool holder once the thread has started perpendicular to the hole



Shutdown at end of work

- Hit e-stop and then turn off at the wall.
- Its best to leave an empty chuck in the spindle to reduce the chance of the spindle bore rusting

Milling Workflow



Cleaning the mill: keep it clean!

- Take work out, replace all the bits you may have changed/removed, brush stuff off the swarf from slides and other surfaces with the paintbrush and swarf.
- Clean out the sump tray surrounding the mill .
- **For cleaning up gloves are mandatory.**
- **Swarf is razor sharp and can go septic if it gets under your skin.**

The six absolute No-Nos of milling

- Never let your chuck or workpiece come loose, always check everything is tight before use, also check the rest of your mill as you don’t know how competent the previous user was.
- Never start your mill whilst your tool is loose in the chuck, always check
- Never leave your chuck key in the chuck (drill chuck)
- Never allow your cutting tool to hit the vice jaws or table – always check clearance before starting the mill
- Never try to mill unsupported work. Stop and improve clamping if vibration becomes excessive

Further reading

- This introductory series is a good primer on all aspects of milling: https://youtube.com/playlist?list=PLY67-4BrEae9m8v20LNARIRI9Pd9bdFRZ
- "Workshop Practice Series“ from specialinterestmodelbooks.co.uk/ - very cheap at ~£7 each