Brunsfield Basic Milling Machine Training Notes

General Rules and safety

1. Following the *completion of basic training*, students will be permitted to use the Brunsfield Centre's workshop, and only those whom have already completed basic training will have access. Basic training will however grant limited access to the space as students will not have access to the mill, lathe, and welding area without having completed subsequent trainings for the respective equipment.

2. It is important to never work alone in the shop and to always have a supervisor on duty in the space. If working alone there is no one to help in the case of an accident or injury which makes it very dangerous.

3. Safety glasses must always be worn within the workshop. Safety glasses must be worn even if a face shield or welding helmet is being used overtop of them. Never approach anyone actively working the workshop without wearing safety glasses.

4. Proper footwear must be worn when working in the workshop to avoid hazardous situations (e.g. sparks, sharp metal, hot chips from operations) where the inappropriate footwear would cause greater levels of risk/harm. Closed-toed shoes must be worn. Not flip flops, crocs, mesh-toed running shoes or and similar style or type of footwear. Steel-toed or similar footwear is recommended when working on larger, heavier projects.

5. Clothing that is long, baggy and/or loose must be rolled up. Strings on the front of a hoodie and hanging jewelry must be tucked under a shirt or taken off. Rings must not be worn inside of the machine shop. Long hair must also be tied back and up. These rules are in place to avoid the danger of having machinery grab and pull you into them causing severe harm.

6. No food or drink should be brought into the workshop. There are many chemicals, coolants and other contaminants that can be harmful if ingested.

7. The Brunsfield centre is a serious workspace and must be treated as one. Pranks, rough-housing, and general fooling around while within the workshop will not be tolerated. Any behavior deemed unprofessional and to this way by a supervisor will be met with an immediate suspension of shop privileges.

8. All persons within the MTC and Brunsfield Centre must always be of good health both physically and mentally as well as not being under the influence of any drugs and or alcohol.

9. A first aid kit is located within the Brunsfield office (Room A139). Any injury severe or small should be reported to a supervisor and an incident report should be

filled. In the case a supervisor is not present, contact the nearest designated first aider (a list of first aiders can be found on the main door).

10. An emergency spill kit is available in the Brunsfield Centre. The spill kit can be used to clean and or contain hazardous materials that get spilled in the shop. A supervisor must be advised whenever the spill kit is used.

11. There are fire extinguishers and emergency stops located throughout the Brunsfield Centre. There is one fire extinguisher located at each of the main entrance doors, and one near the designated welding area. There are three emergency stops located at the main entrances and in the office. Students should be familiar with the location of each fire extinguisher. If an individual is not familiar with these locations, they should request the information from a supervisor their first time in the workshop.

12. Students are responsible for knowing their own limited knowledge of facilities and equipment, and to ask for assistance from a supervisor when encountering any unfamiliar equipment or processes (i.e. if you're not sure: Ask). Supervisors are there to help with any matter pertaining to the workshop and would much rather taking the time to explain something many times then having someone get injured or equipment break because of improper use of the space.

13. Before working with unfamiliar materials and chemicals, become familiar with the product's handling procedures. MSDS (Material Safety Data Sheets) info can be obtained by using the Google search engine and typing "MSDS" followed by the product name and/or asking a supervisor to see the MSDS.

14. Students as well as supervisors are entitled to a safe working environment. Safety is everyone's responsibility, thus anyone witnessing any unsafe behavior or working practices must advise a supervisor immediately.

15. Any damaged equipment must be reported to a supervisor immediately to ensure shop safety and that the issue related to the equipment is correctly addressed. A supervisor must also be notified in the case of a broken tool to ensure that the tool was being used properly as to avoid the breakage of future tools.

16. Students are responsible for keeping the workshop clean and tidy. It is required that students clean up any work areas or machines that have been used after you have finished. The floor must be kept free of debris and tripping hazards. All tools must be put back in their proper places after use. Unplug all power tools while not in use.

The Brunsfield Centre is a joint workspace for all students and a certain respect must be held for the space. It is important to treat the equipment and tools properly and with care so that everyone can have a better-quality work experience. The Brunsfield staff reserve the right to revoke shop privileges of anyone within the shop who does not respect the tools and equipment of the space as well as the rules listed above.

Notes

Milling Operations - Cutting speeds

When performing any kind of machining process where you are removing material the speed at which you remove that material is of utmost importance. End mills, drill-bits and other cutter-based tools are only made to withstand certain cutting conditions. As such it is critical for the life of the tool and the efficiency of the machining process that the tools are run within their working parameters. When milling with a standard endmill, the variables surrounding the operation are as follows.

The main variables to consider when milling are:

- Desired Diameter and Depth of Cut
- The type of material – For specific properties and tool selection
- The coolant selected – Specific to the type of material and tool
- Machine and work-holding – Setup rigidity
- Tool Type and Material

Considering these factors, there is still a level of understanding that is required before the correct values can be found. This comes with experience, however there is a simple equation that may be used as a starting guideline for the correct rotation speed of the cutter.

$$RPM = \frac{4 \times CS}{Dia.}$$

This starting formula takes into consideration the surface removal rate for a specific material/tool combination (denoted as **CS**) and the outmost cutting diameter of the tool (denoted as **Dia.**), and returns the recommended basic rotational speed of the tool (**RPM**). With a starting value an operator can begin the process and use their judgement to adjust the speed of the machine relative to the feedback encountered.

In general it is hard to list specific cutting speeds for each material in each situation. Some tools will contain information on their specific recommendations, however for general purpose work this is not usually obtainable. As a starting point, bellow are some recommended surface removal speeds which may be used in the general equation above.

Typical Values for SFM when using High Speed Steel (HSS) cutters are:

Steel	80 SFM
Stainless Steel	40 SFM
Brass	250 SFM
Aluminium	300 SFM
Plastics	100 – 200 SFM

With cutting tools made of carbide it is usually appropriate to run the workpiece with 2 - 3 times the recommendations above. Insert carbide tooling will usually have a specific set of values with the packaging that are optimal for the tool.

Examples

Milling with a 1/2" endmill in steel

CS (steel) =80 SFPM
Drill Dia. = ½"
RPM = 4 x CS/ DIA.
= 4 x 80/.5
= 640 RPM

Fly-cutting a surface on aluminium with a cemented carbide tool

CS (Al) (with carbide)= 600SFPM
Cutter Dia. =3" Dia
RPM = 4 x CS/DIA
= 4 x 600/3"
= 800 RPM

Since this equation provides only an approximate value for the maximum speed for a process, the feedback given from the tool and machine is the best source of understanding for what is happening (for good or for bad). The ability to interpret the feedback and the "feel" from a machine is what separates good machine operators from those with little to no experience. For example, in a milling process being performed at too high of an RPM, and/or at an incorrect depth of cut, will in some cases cause a lot of "chatter". Chatter is the machining terminology for vibration. That is, chatter is used because as the tool vibrates it makes a loud chatter-like noise. Milling operations with a significant amount of chatter can yield, in most cases, a poor surface finish or surface markings. Audible feedback is one of the best forms for understanding how the machining process is performing. If something does not sound right, then there is a good possibility that the tool is not performing within its working parameters. This skill is developed over time and it is therefore recommended to always inquire with a supervisor before performing a machining process about the recommended cutting speeds and setup.

Milling Machine

The milling machine is a machine that allows geometric shapes to be machined and created. They come in two basic formats – horizontal and vertical. The workpiece is clamped or held in a work holding device fastened to a movable table while a rotating cutter removes material from the workpiece.

Some of the key parameters of a milling machine include its table size, table travel (X, Y, Z), maximum distance from the quill to the table, the motor power, the speed range of the spindle, the method of spindle speed change (Variable, belts, gear head), power requirements, feed rate range, spindle taper, and HP.

The mills can be fitted with a variety of accessories and tools to enable them to perform a wide range of operations. Some of these include rotary tables (to mill arcs, drill bolts circle hole patterns, and perform indexing operations etc.), boring heads, tapping heads, Digital Readouts (DROs), drill chucks, vises, as well as many others.

Parts of the Mill

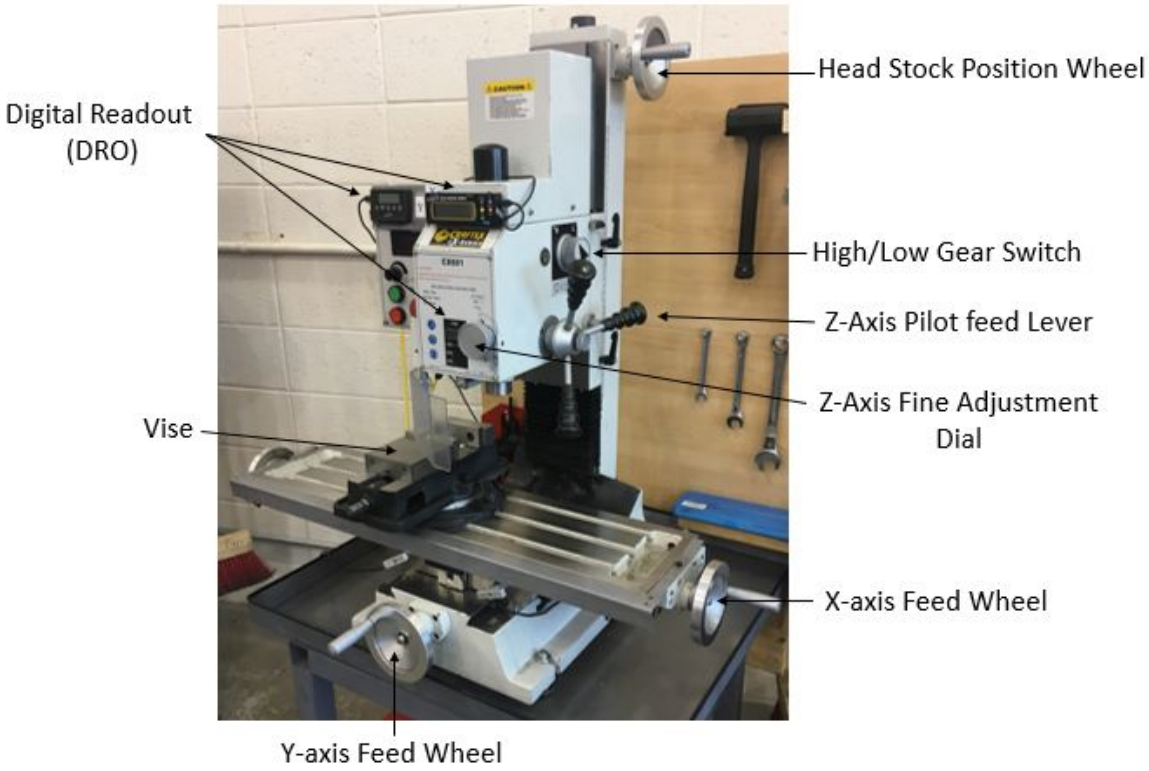

Figure 1: MTC Mill

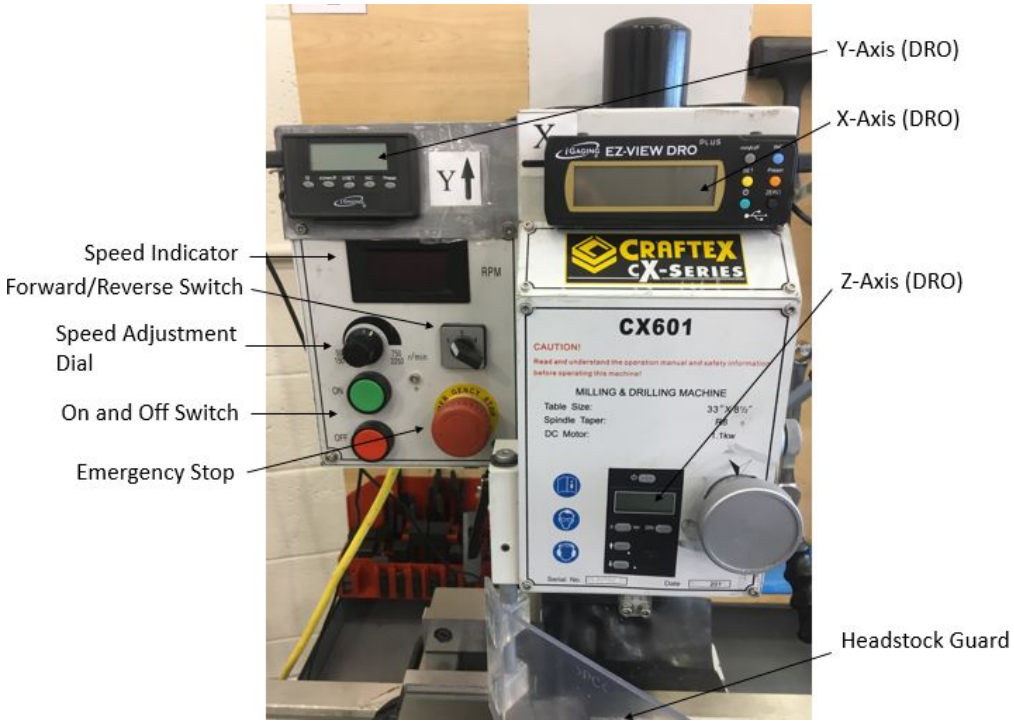

Figure 2: MTC Mill Headstock

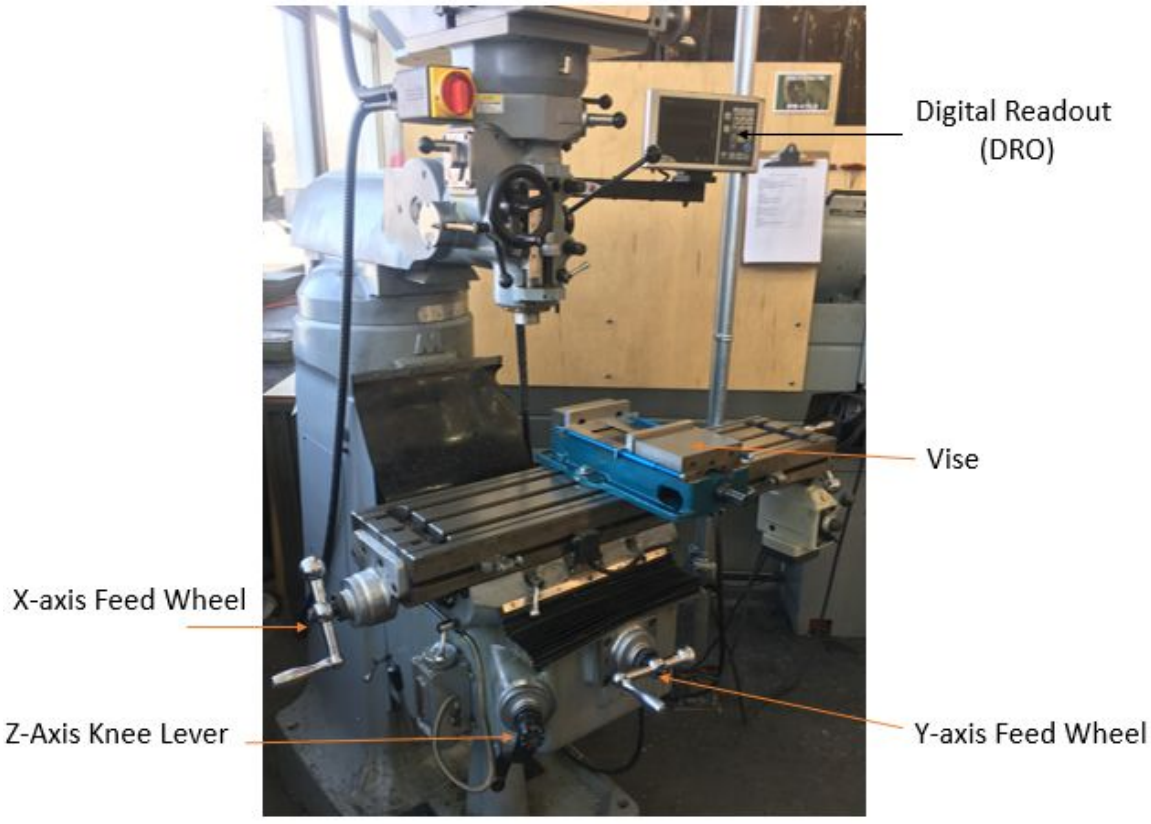

Figure 3: Brunsfield Mill

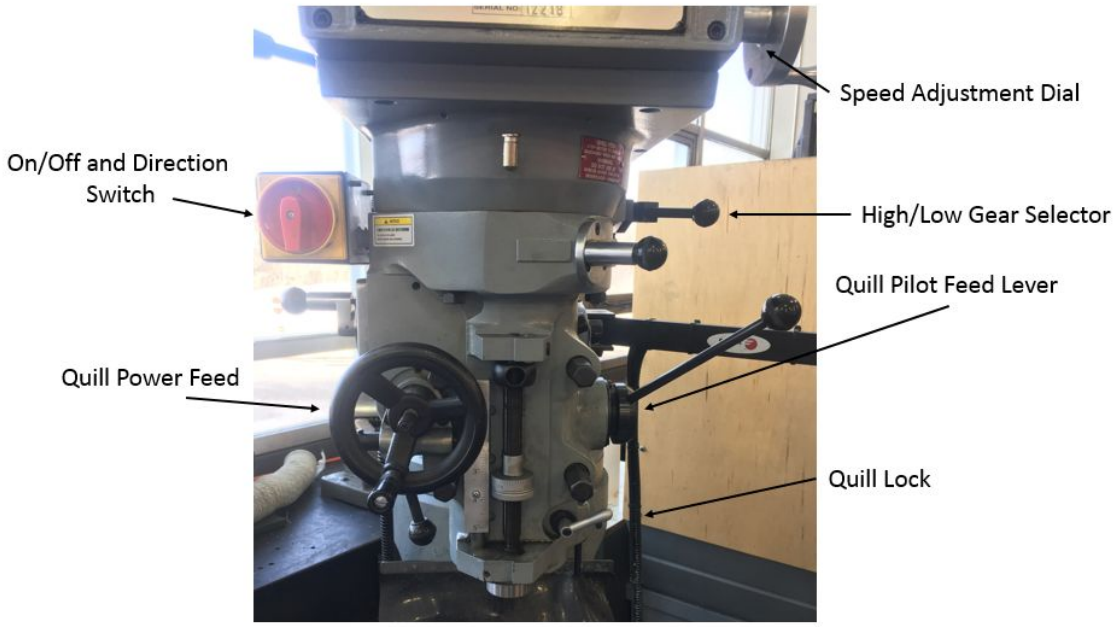

Figure 4: Brunsfield Mill Headstock

Terminology

Backlash: Backlash is a term used to identify the space of no contact on a gear train when switching from reverse to forward. As a general rule the more backlash a system the harder it is to control the precision of the instrument and therefore is something to be avoided.

Chatter: Chatter occurs when the tool bit or the workpiece is vibrating during machining leaving a patterned finish rather than a smooth finish and making a loud "chattering" noise. The simplest and usually most effective way to remove chatter is to make the tool clamping or piece clamping more rigid to try and mitigate vibration. Chatter is bad because the constant vibration of the tool will significantly decrease tool life as well as affect the overall precision of the work.

Coolant: Coolant is a liquid that is applied either as a light mist or a flow of liquid at the area of contact between the tool bit and the piece. It performs several functions, the primary function being to dissipate the heat generated from the cutting. Coolant also cools the workpiece and provides lubrication during cutting to reduce tool wear. Coolant is not required on all materials and the type of coolant varies depending on the material being machined. It can produce a better surface finish on some materials.

Machining Operations

Facing Cut: A facing cut is a cut with a small depth of cut in order to true up a face of the workpiece.

Boring: Boring is an internal cut that hollows out the end of the workpiece and can be a very precise cut

Drilling: Drilling is done by using drill bit held in a drill chuck inserted into the spindle of the mill.

Grooving: This type of cut leaves a groove in the part

Slotting: An endmill can be used to plunge and move in any direction creating a slot into the workpiece.

Tapping: A mill can be used to cut internal threads into a workpiece either with manual drive or a tapping head.

Work Holding

When using a Mill, the workpiece is held securely with a vise or clamps on a table that can be moved in the X,Y and sometimes Z direction. The main spindle in the headstock then turns a tool that can then be moved into contact with the workpiece to remove material. The most common method of holding the workpiece is a **vise**. Other methods include: **Rotary tables**, **Clamps**, **Vee-blocks, Precision Parallels.**

Vise: A vise is the most standard way of holding the workpiece to the table. The vise consists of a stationary jaw and an adjustable jaw. To secure a workpiece it is positioned between the two jaws and the adjustable jaw is the clamped against the workpiece using a lead screw. A milling vise can be set up at different angles onto the table in order to machine at a desired angle away from a certain face of the workpiece. However, a milling vise is usually always set up so that the jaws of the vise are perfectly parallel with the x direction of the table. A dial indicator can be used to check the trueness of a vise.

Rotary Table: A rotary table is used to hold the workpiece and be adjusted to rotate the workpiece at specific angles. A rotary table is perfect when a process needs to be reproduced several times at different angle such as gear cutting or knurling.

Clamps: Clamps can be used to hold down a workpiece that has a complex geometry that cannot be held with a conventional vise. The clamps come in various different shapes and sizes in order to accommodate a wide variety of clamping positions. The clamps are positioned in slots that are machined into the table of the mill to provide clamping anywhere along its surface.

V-Blocks: V-Blocks are blocks that have a large V shape cut into one side. The cutout portion is meant to hold a circular workpiece which is then clamped into place using a lead screw. Vee-blocks are meant to be used in combination with a conventional vise, the blocks are precision ground similar to the jaws of a milling vise as to not damage its surface under clamping force.

Precision Parallels: Precision Parallels come in various sizes of precision ground rectangular slates. These slates are used in a conventional milling vise to lift the workpiece off the bottom of the vise. Lifting a workpiece becomes important when drilling holes or other machining processes where the tool would otherwise come into contact with the vise.

Tool Holding

Collets: Collets are usually made to hold specific sizes of round stock and are tightened with a drawbar running through the center of the main. They can be fast to use and are accurate for aligning the tool to the spindle axis. Collets are often used to hold endmills due to their ability to take axial and radial loads.

Collet Chucks: Collets chucks are held in the spindle the in the same manner as collets. Once a collet chuck is held in the spindle it can then be fitted with a special snap in collet to hold the tool. The snap in collets are tightened separately from the chuck itself. The main advantage of using a collet chuck is that the collet can be changed much easier and quicker than conventional collets.

Drill Chucks: Similar to the previous tool holding methods the drill chuck is secured into the spindle of the mill. The drill chuck can then be used to hold drill bits and perform drilling operations. It is important to note that drill chucks must **never** be used to hold end mills and perform milling operations as it is not made to withstand any radial loads. A drill chuck under radial loads will sustain heavy damage to its internal components affecting precision and performance.

Boring Head: A boring head is attached to the spindle and is used to perform boring operations using a boring tool.

Tools

End mills: End mills come in two basic varieties. Centre- cutting and non-center cutting. Centre cutting end mills can be used to plunge into a workpiece in operations such as slotting and pocketing. Non-Centre cutting end mills can only enter a workpiece from the side or a pre-drilled hole that is large enough to give adequate clearance for the center noncutting part of the end mill See Figure 5.

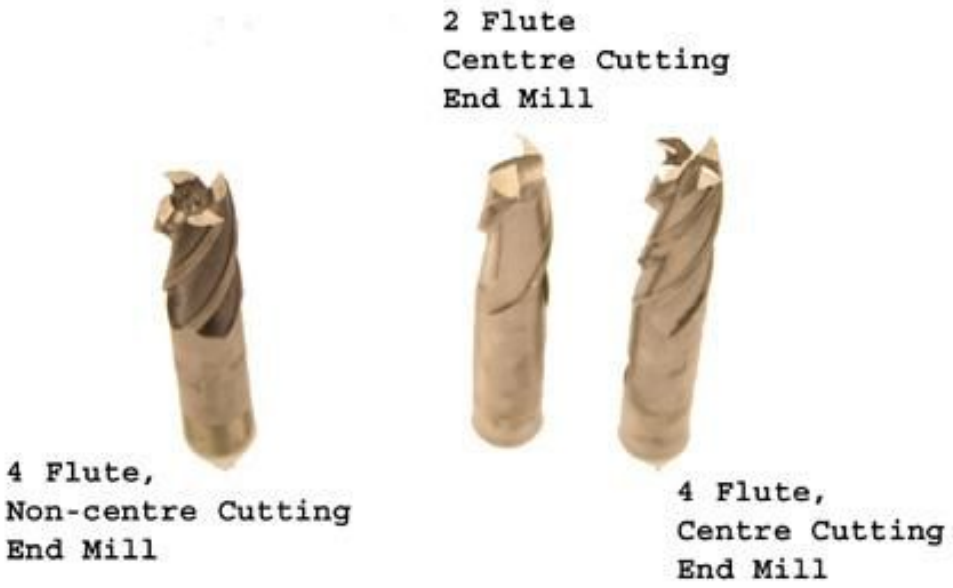

Figure 5: Different Types of Standard Endmills

Specifications for end mills include tool material, cutter diameter, shank diameter, number of flutes, flute length, LH or RH spiral, spiral lead angle.

Drill Bits

Most drill bits have two flutes, spiraling upward. The outer edges of these flutes have lands that cut the outer diameter of a hole. The chisel edge of a drill bit is used to cold work and push the material towards the lip of the drill bit so it can then be cut away. It is this cold working chisel that makes cutting into hard materials such as steel require such a large down pressure while drilling. Drilling pilot holes help the chisel get deeper into the material and push away the material with less down pressure required.

Drill bits being long to be able to drill deep holes are very susceptible to bending forces. Allot of force is required when drilling a hole into a virgin piece so that the chisel edge can grab into the piece and pierce its way forward, while the drill bit is trying to chisel its way in it begins to bend under the strain. This bending can easily cause a drill bit to break or to drill very inaccurate holes. This further explains the necessity of drilling good pilot holes and using a center punch to mark the holes.

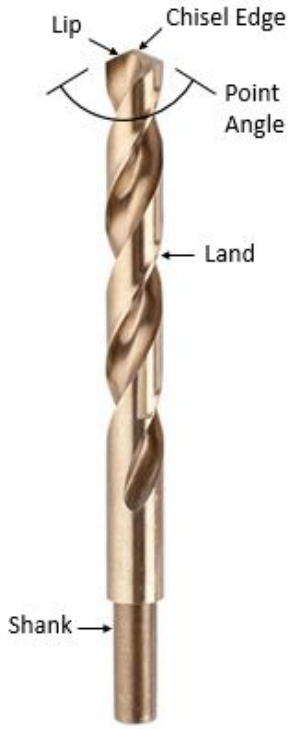

Figure 6: Twist Drill Bit

Edge Finder

Edge finders are precision ground tools which consist of a cylinder cut into two pieces. The two pieces are held together using a preloaded spring, allowing the two to be separated see Figure 7.

Figure 7: Example of An Edge Finder

The smaller end of the bottom cylinder can be pressed up against an object such as the vise or the workpiece, then positioning the tool so that the two larger cylinders become perfectly concentric that position can be used as a reference point on the DRO's or the dial indicators of the mill. The main purpose of the reference points found using the edge finder is to create a coordinate system that can be used to perform the required milling operations.

Mill Safety

1. Users operating any rotating machinery must not wear any rings, necklaces, neckties or wristwatches. Avoid loose clothing: if you have loose fitting sleeves, roll them up or cover them with a lab coat. Long hair must be tied back securely. Safety glasses must be worn at all times. Do not wear gloves, as they can get caught in the cutters in the mill

2. Pieces to be milled must be held securely to the table by clamps, a vise or some other work holding device.

3. Stand at all times when using the machine; do not ever attempt to operate it from a sitting posture. Do not leave the mill running unattended.

4. Be aware at all times of the location of the switch and emergency stop buttons and make sure that you can always reach them easily.

5. Emergency stops must be used only in emergencies. They must never be used to turn the machine on and off. If the emergency stop is used, make sure the mill is turned off before pressing the start button on the panel.
6. Run the mill only at speeds suitable for the cutter size and the material being machined Use a lubricant on the workpiece when machining (except brass).

7. Ensure that the quill lock is engaged before machining unless drilling.

8.Check to see what speed the mill is set to before machining and use the mill within the speed range calculated for the specific process. It is very important to only change the speed of the milling machine while the machine is running to not damage the variable speed transmission

9. Do not touch the cutters or other rotating parts when the mill is operating. If you have to clear chips from the bit use a wire brush. Never attempt to clear chips or oil using a wiper - it could easily get caught in the cutter. Make sure that rags and swarf are kept away from the cutter.

10. If you are drilling through a piece, make sure that you do not drill into the table, vise or rotary table.

11. When drilling, start the hole with a centre drill first. Large holes are best drilled by starting with a small hole and enlarging it in steps, adjusting the speeds as needed.