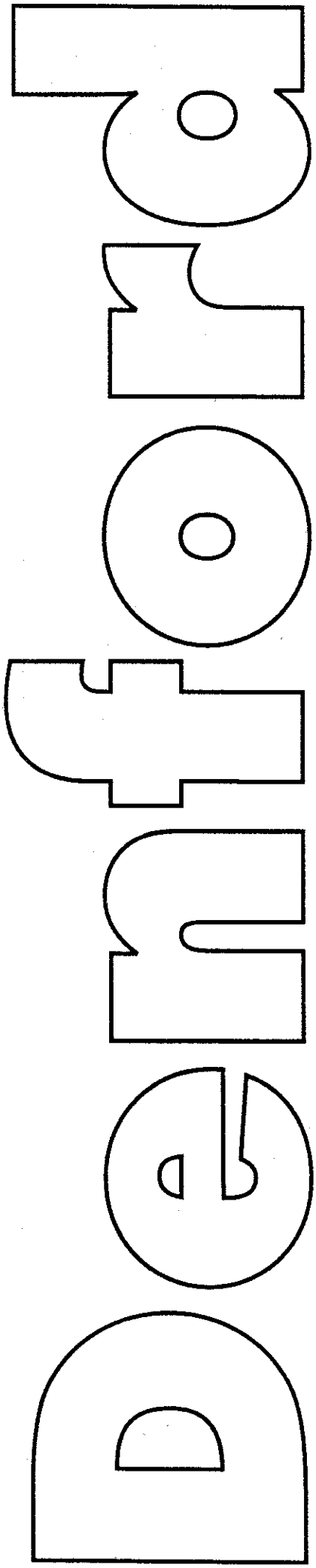

DENFORD

EDUCATION SUPPORT SERVICE

Milling Courseware

Introductory

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Table of Contents

1 Milling Aims and Objectives

The aim of this book is to teach you the basic concepts of a CNC milling machine.

What you should learn from each chapter

1. Understand the function of a CNC milling.machine;
   [Assessed by assessment Task 1]

2. Understand the 3 axes (X,Y.and Z).
   [Assessed by assessment Task 2]

3. Be familiar with the terms:-
   3.1. rotational speed and direction;
   3.2. feed rate;
   3.3. rapid traverse;
   [Assessed by assessment Task 2]

4. Know the following parts of the miller:-
   4.1. milling head;
   4.2. cutting tool;
   4.3. table;
   4.4. tool;
   4.4. emergency stop;
   4.5. work piece (billet);
   [Assessed by assessment Task 3]

5. Be aware of the following clamping methods:-
   5.1. machine vice;
   5.2. tee bolt and step clamp;
   5.3. double sided tape.
   [Assessed by assessment Task 4]

Milling Aims and Objectives

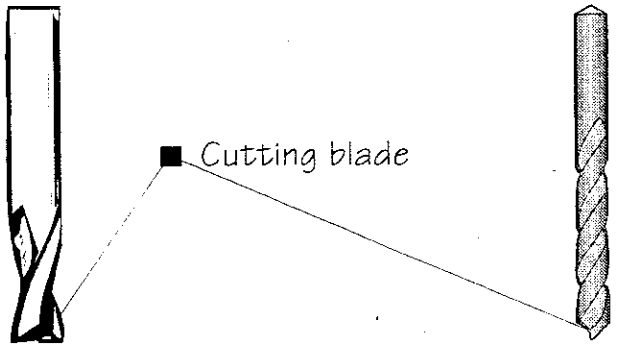
6. Be aware of the following safety aspects:-
   6.1. personal safety;
   6.2. safety of others;
   6.3. workshop safety.
   [Assessed by assessment Task 5&6]

7. How to produce a simple CNC program using a CAD package.
   [Assessed by outcome.]

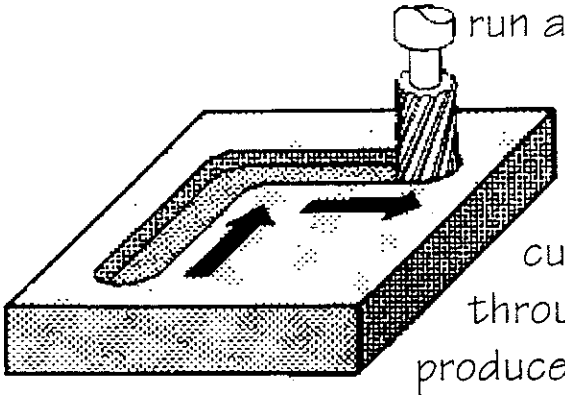
8. Using your CNC miller :-
   8.1. manufacture a component;
   8.2. set a tool offset;
   8.3. set the machine datum.
   [Assessed by outcome.]

1.1 What does a CNC milling machine do?

A milling machine works on the same principle as a drill. When a drill bit is turned around, either by hand or by an electric motor, it will cut away material by using its bottom sharp edges as blades. This is fine if you only want to make a round hole, a



milling bit or cutter has blades that run all the way up the sides of the cutter, this allows the cutter to be moved sideways in the material. Because a milling cutter can be moved sideways through the material, slots can be produced, these may be of different depths and widths.

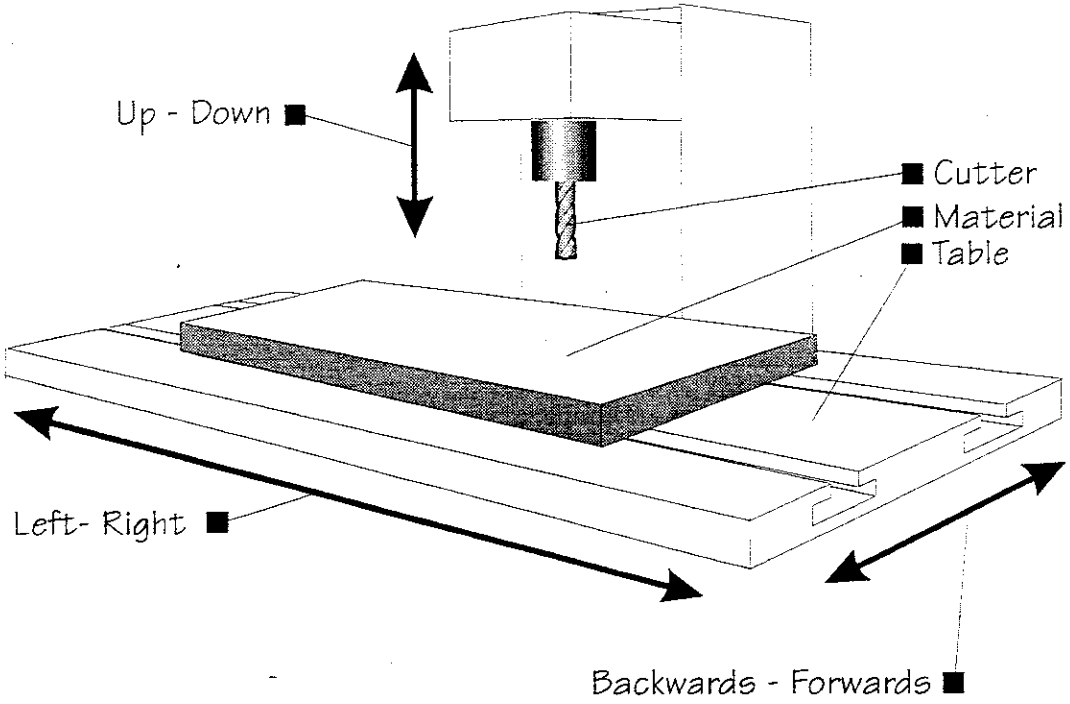


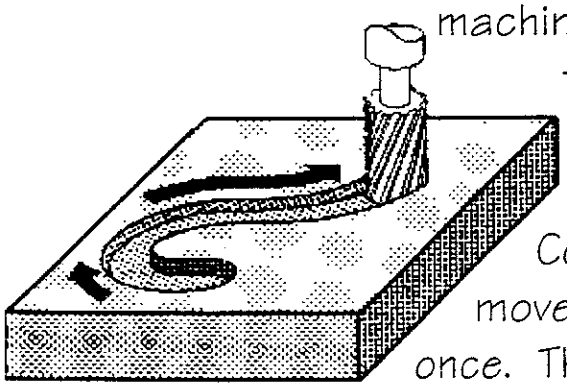
On most millers the movements left, right, backwards and forwards are produced by moving the material, fastened to a table, whilst the cutter stays still. On manual millers the movement is controlled by a skilled engineer, turning handles. Even if

What does a CNC milling machine do?

the operator is very experienced, a human can only operate in one direction at a time, this means that only straight lines can be cut.

To recap: On a milling machine there is a cutter that spins; a table that can move left, right, backwards and forwards; the material is held on the table and the cutter moves up and down, just like a drill.



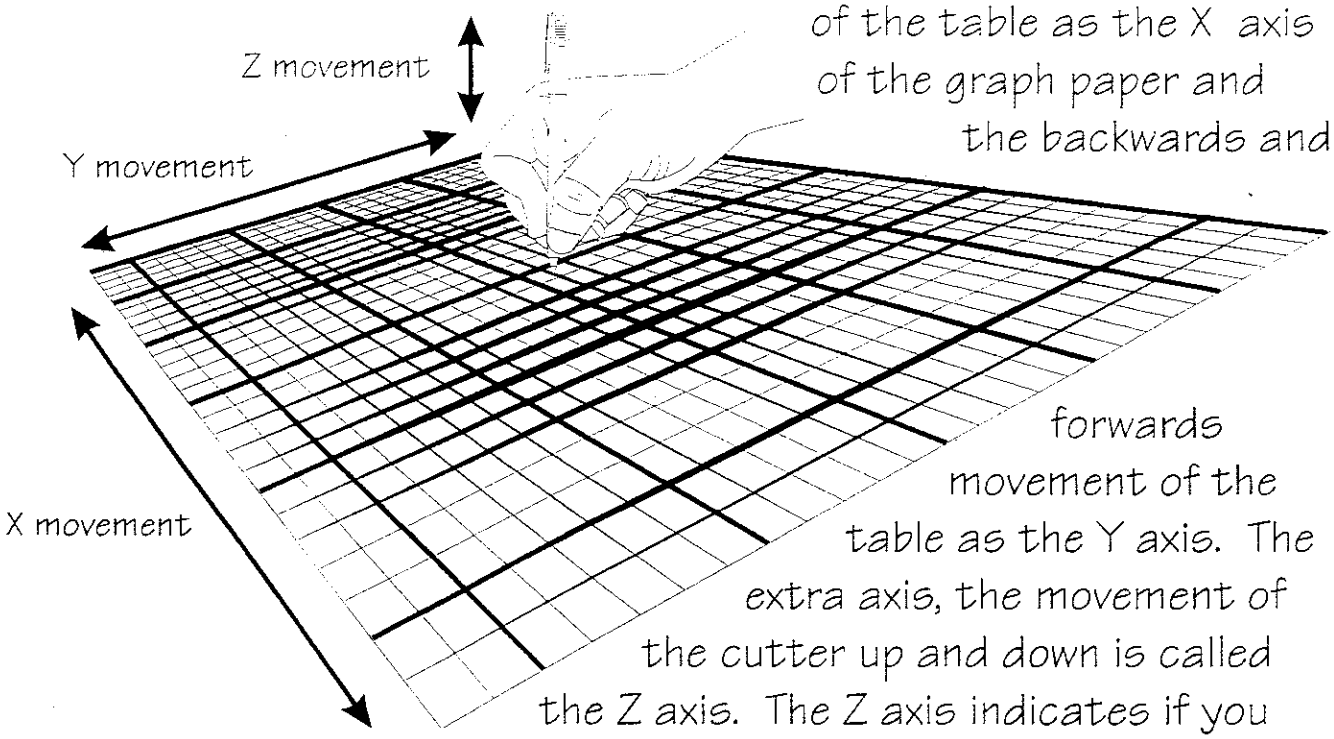


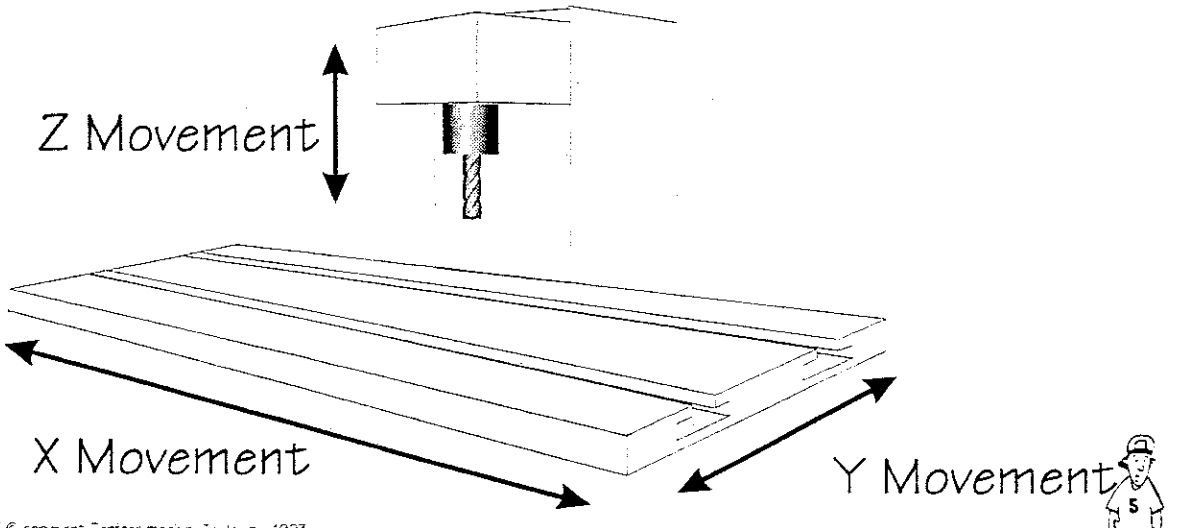
The difference between a CNC milling machine and a manual milling machine, is that the table is moved by motors, controlled by a computer (CNC standing for Computer Numerical Control). The computer can control movement in at least two directions at once. This means that the milling machine is able to move the table at any angle generating both straight lines and arcs.

2 the 3 axes of a milling machine

Now that we have seen, very simply, how a CNC miller works, let's look at the different parts and learn the correct names.

First imagine that the table of the miller is to be a piece of graph paper and your hand is holding a pencil to represent the cutting tool. We can describe the left and right movement of the table as the X axis of the graph paper and the backwards and forwards movement of the table as the Y axis. The extra axis, the movement of the cutter up and down is called the Z axis. The Z axis indicates if you are drawing on the graph paper or not. It is usual to refer to these 3 axes as the X,Y and Z. On a milling machine they look like this:

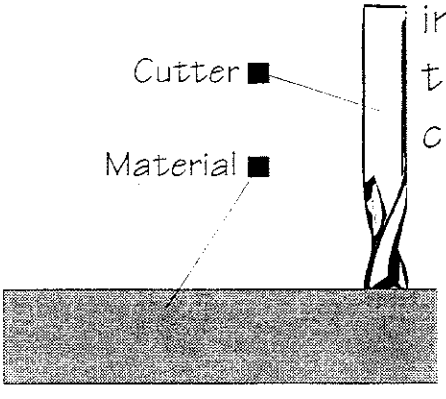




3 Feeds, speeds and movement.

Now we know what the axes are called we can look at the different ways they move.

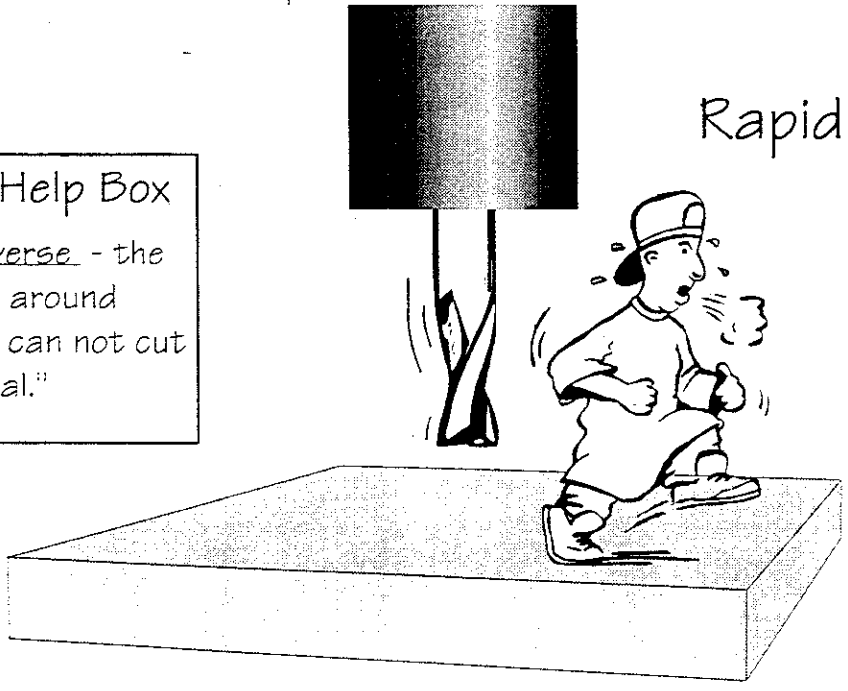
If you imagine that when the cutter is touching the top of the material or work piece then the Z axis will be zero. If you cut into the work piece then Z must be less than Zero maybe -2 mm. If you want the cutter to move around the work piece without cutting the material then you would set the Z value to +2 mm, this value is known as the 'stand off'.



It is very important in industry that a CNC miller works at maximum efficiency, so, when the cutter is not cutting, but has to move to a new position, it will move the X and Y axis as fast as possible. The fast movement of the X and Y axes when the Z axes is at the stand off position is called 'rapid traverse'.

Denny's Help Box

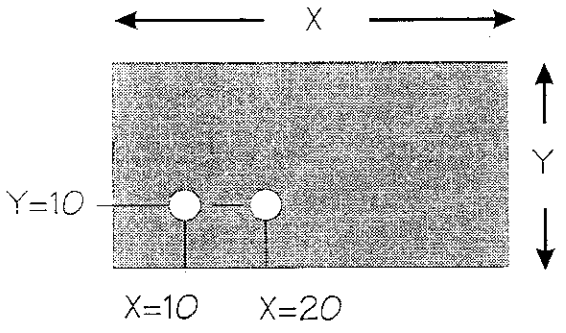
"Rapid Traverse - the tool moves around quickly but can not cut any material."



Rapid Traverse

Feeds, speeds and movement.

We mentioned earlier about thinking of the machine table as piece of graph paper, with the 2 axes X and Y. The milling machine calculates all its movements using numbers based on X and Y positions. If we told the machine to go from X=10, Y=10 to X=20, Y=10 it would move in a straight line, if the cutter was in the material though, it would cut a slot. When the cutter cuts through the material it is important that the speed at which it moves is controlled. The speed of the cutter's movement is called the 'feed rate'. The feed rate will depend upon the type of material being cut (in plastic it is usually moves about 200mm in a minute or 8 inches per minute).

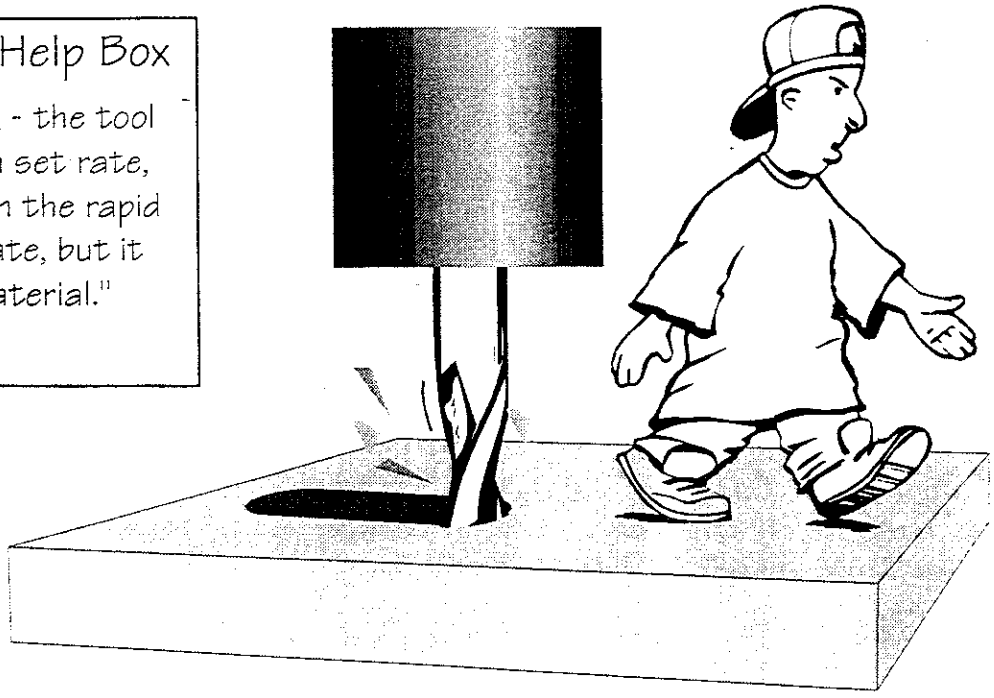


Plan view of material

Feed Rate

Denny's Help Box

"Feed Rate - the tool moves at a set rate, slower than the rapid traverse rate, but it can cut material."

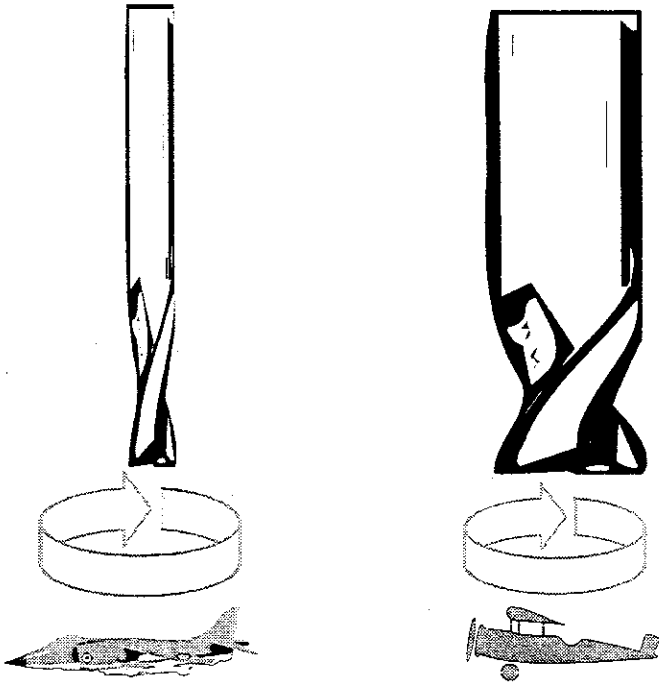


Feeds, speeds and movement.

A milling cutter needs to be spinning, so that it can cut the material. The cutter must spin in a clockwise direction. Its speed will depend upon the type of material to be cut and the diameter of the cutter. The smaller the cutter the faster it must spin.

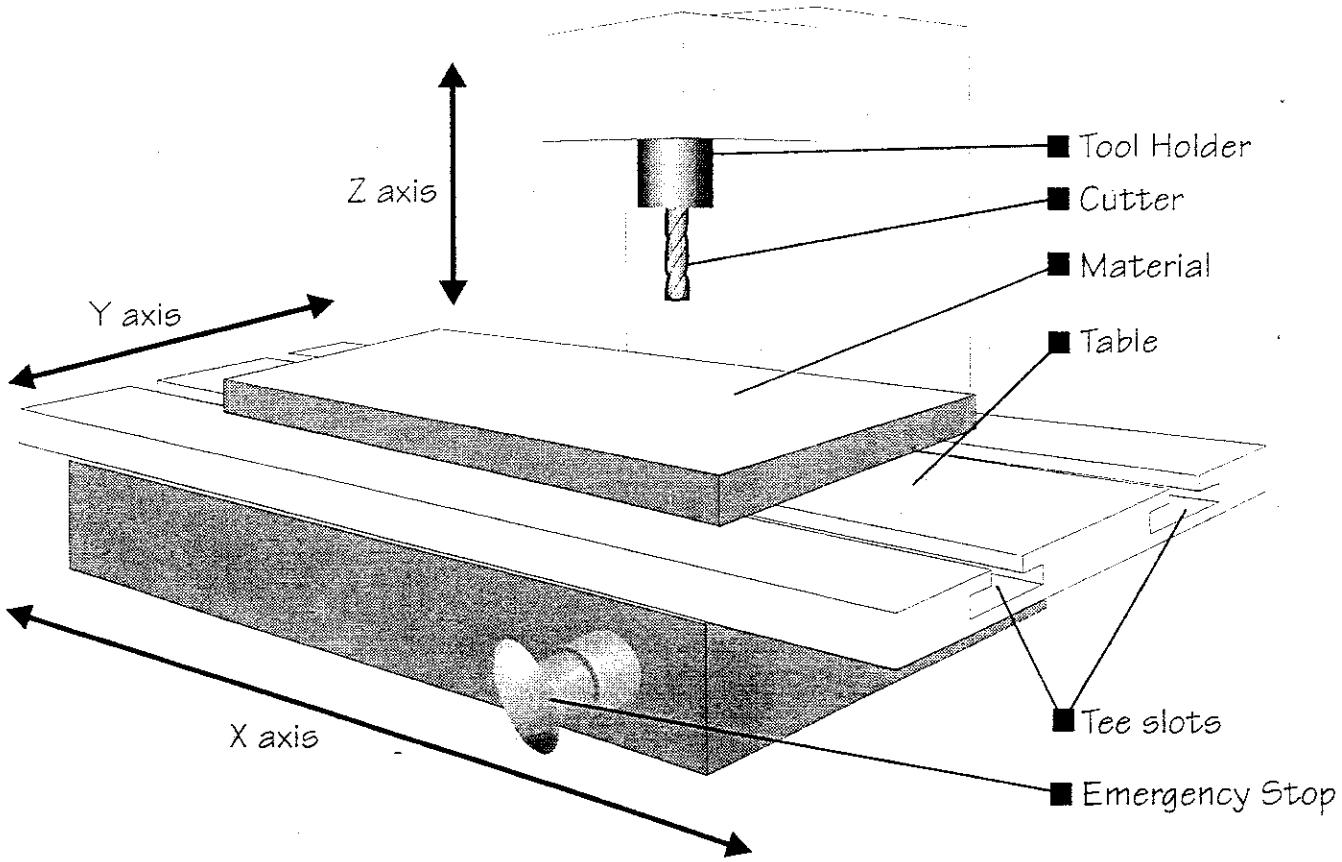
Denny's Help Box

"Rotational Speed is the speed at which the cutter spins. If a cutter has a small diameter then it must spin faster than a cutter with a large diameter."



4 Parts of a milling Machine

Like most pieces of technology a CNC milling machine has special names for some parts. Below is a diagram a of a milling machine with the most important parts labelled.

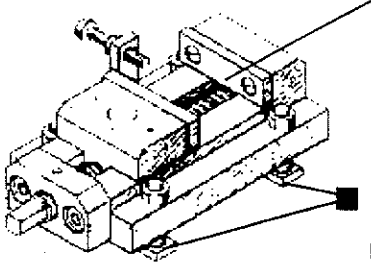


5 How to hold the work piece

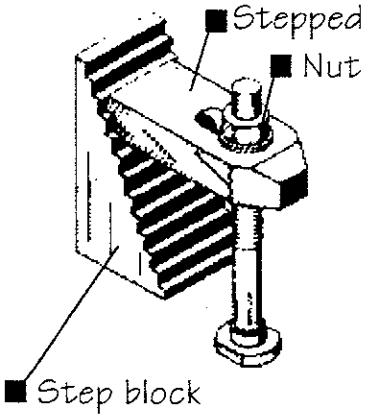
Holding the work piece to the table of the milling machine, safely and securely is very important. There are many methods of holding work pieces, the method you use will depend upon the shape and type of material you will be using.

Machine Vice

The machine vice can be used to hold large regular shapes. It can be used many times and set up to machine identically sized work pieces. It can not hold thin flat material and they are expensive.



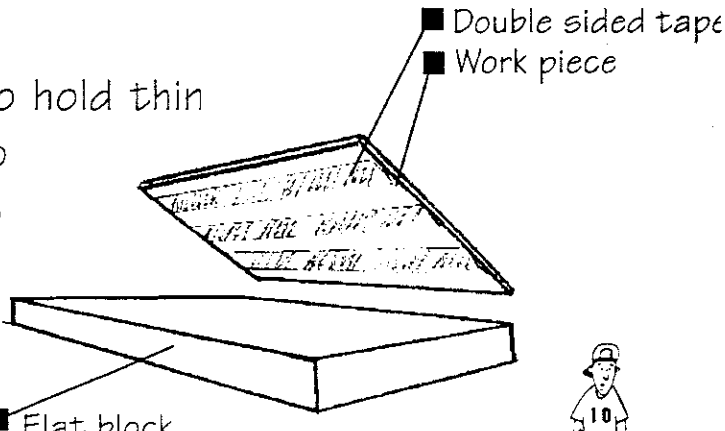
Tee bolts and Step clamp



Tee bolts come in different lengths and are held to the table using the tee slots. The work is held by the nut forcing a stepped bar onto the work, the back is held at the same height by a stepped block. The clamps are cheaper than a vice and can be used to hold large unusual shapes.

Double sided tape

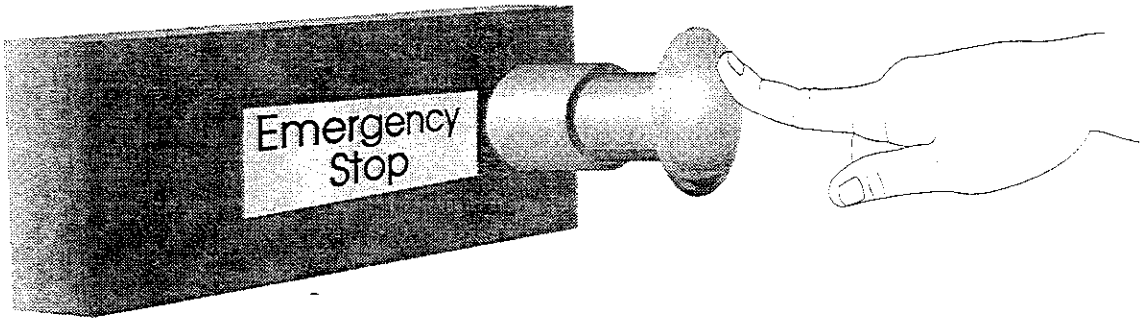
Double sided tape can be used to hold thin soft material, like plastic. It has to be stuck to a flat surface (MDF is ideal). The block can either be clamped to the table using tee bolts or held in a machine vice.



6 Safety

All CNC milling machines are fitted with an emergency stop button. The emergency stop button should be large easy to reach when operating the machine and usually red in colour. This is necessary in case the machine should do something unexpected.

Make sure you know where the emergency stop button is on the machine you will be using!



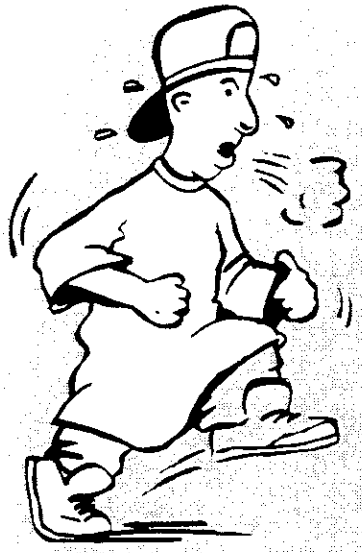
Safety Rules

Always wear eye protection when it is provided.

Make sure that you are dressed safely. No loose clothes or undone laces.

Keep long hair tied back or in a hat.

Safety Rules



Do not run in the workshop. Think of other peoples' safety too.

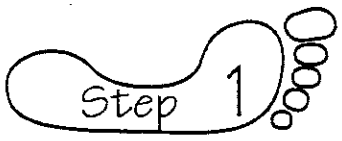
Keep the workshop and machines clean and tidy.

If in doubt, ask!

7 Getting information into your milling machine

If you own Mill CAM Designer then this section will offer a step by step guide to produce a generic G-code program for a CNC milling machine. Firstly a description of each stage will be given, followed by more detailed directions. Co-ordinates given refer to the reading on the Information Bar. Any measurements are given in metric with imperial approximations contained in square brackets.

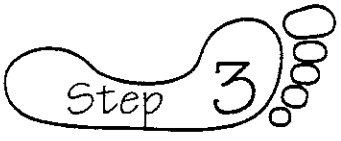
The Task Produce a name plate for Denny's Room.



- Start Mill CAM Designer by double on the icon.
- Set a material length of 160mm [6.5"], width at 90mm [4"] and height of 10mm [0.2"].
- on *OK* to proceed.
- From the *Grid* menu select 10mm [0.5"], make sure *Grid Lock* is not selected.
- on the *Step* button, set this to 1mm [0.025"].
- on the *Depth* button and set both start and finish depths to 1mm [0.05"].
- on the Cutter button, choose a 1mm [0.063"] diameter tool.

Add a border to the plate.

- the *Frame* button.
- Start drawing at x=10mm[0.4"], y=80mm [3.75"] drag the box out to x=150mm[6"], y=10mm[0.4"].



Put Denny's name on the plate.

- on the *Depth* button, set a 2mm [0.08"] cutting depth.
- on the *Text* button, type 'Denny' in the *Input Text* box.
- on the *Fonts* button, select the 'Curved 1' font.
- Set the text to be upright, at 25mm [1"] high and 20mm [0.8"] wide.
- on OK, set a paste scale of 0.5, position the text at x=99mm [4"] and y=36mm [1.45"].

Put a border around the name.

- on the *Depth* button, set a 1mm[0.04"] milling depth.
- on the *Ring* button, centre the circle at x=115mm[4.6"], y=45mm[1.8"], drag this to a radius of 25mm[1"].

Add a picture of Denny.

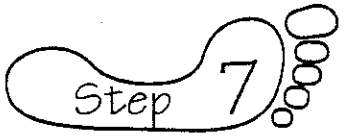
- Select Import DXF File from the File menu. Choose the Denny.DXF file from

the c:\Denford\Data directory.

- Set the Minimum line Length to 1mm [0.04"], and the Paste scaling to 1.
- Position the image at x=30mm [1.2"], y=12mm [0.5"].

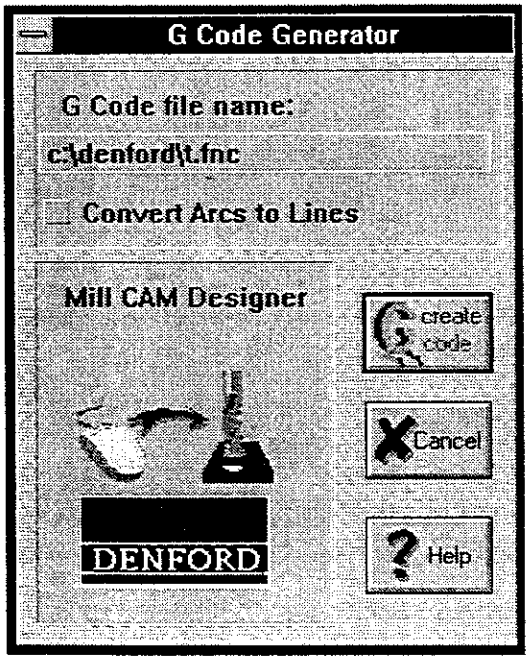
Save the design.

- Select *Save as* from the *File* menu.
- Save the file in the c:\denford\data directory as 'test', on *OK* to continue.

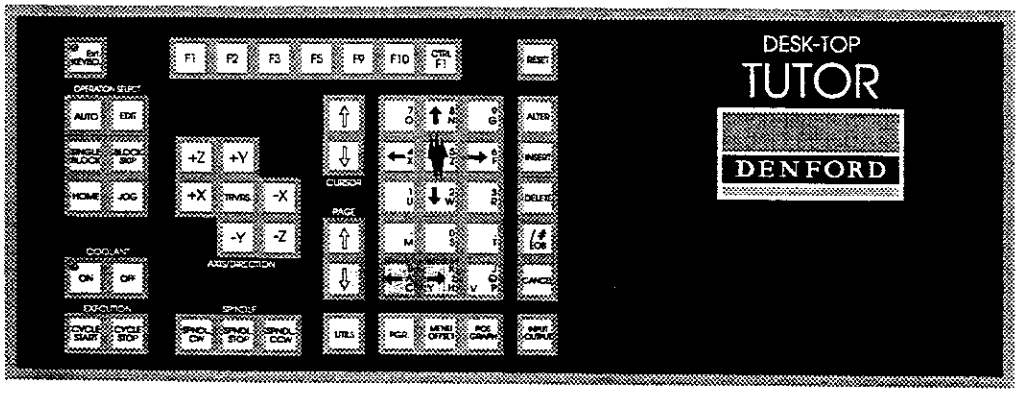


Make a G-code file.

- Select *Make a file* from *Create G-code* menu.
- Save the file in the c:\denford directory as test by *OK* to continue.
- *Create G-code* button.
- The file will now be generated an placed in the c:\denford directory, it can then be used to drive the CNC equipment you own.



Essential guide to manufacturing on the: Denford Starmill CNC milling Machine, connected to an IBM compatible computer and Desktop Tutor



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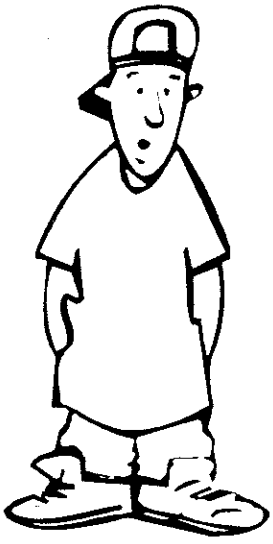
Introduction



Introducing
Denny Denford

This section has been written to enable the manufacture of a product on your CNC machine using a G-code file produced from a CAD package. It will not replace the manual supplied with your CNC machine.

The first section assumes that your machine is connected and working properly, the G-code file has been produced and the tool offsets have been set and saved.

Note

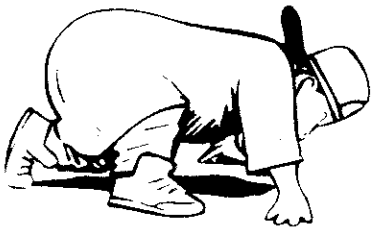
There is a section to explain the setting and saving of tool offsets if you are not sure how to do this.

Denny's Help Box

"G-Code is a series of letters and numbers that make up the language used by CNC machinery"

"CAD stands for Computer Aided Design.

1 Starting the software



Make sure that the computer is connected to the CNC machine and 'Desktop Tutor' correctly.

Change to the directory that holds the Denford Starmill software. The command to do this will have to be typed in and will look something like this [cd\denford] and press [enter].

Once you are in the correct directory you can type in the name of the program that will run the milling machine. This is: [fanucsmd *.fnc] and press [enter].

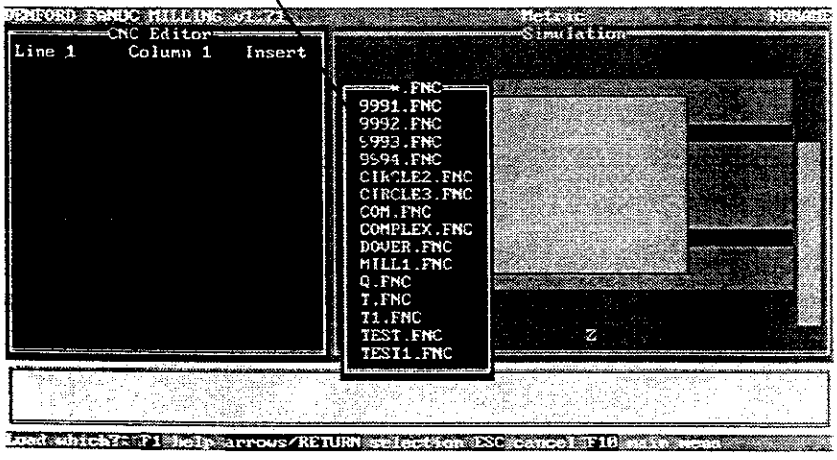
Note

The *.fnc after the program name will force the program to show any G-code files stored in the directory. If you wanted to load files from a floppy drive you would type:

[fanucsmd a:*.fnc] when in the denford directory.

List of G-code files, if any exist.

If you do not see a screen like the picture below then you may have:

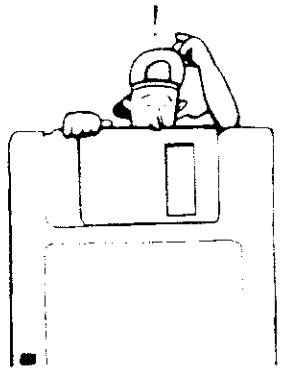


(1) not changed to the right directory,

(2) mis-typed the program name,

(3) not connected the machine correctly.

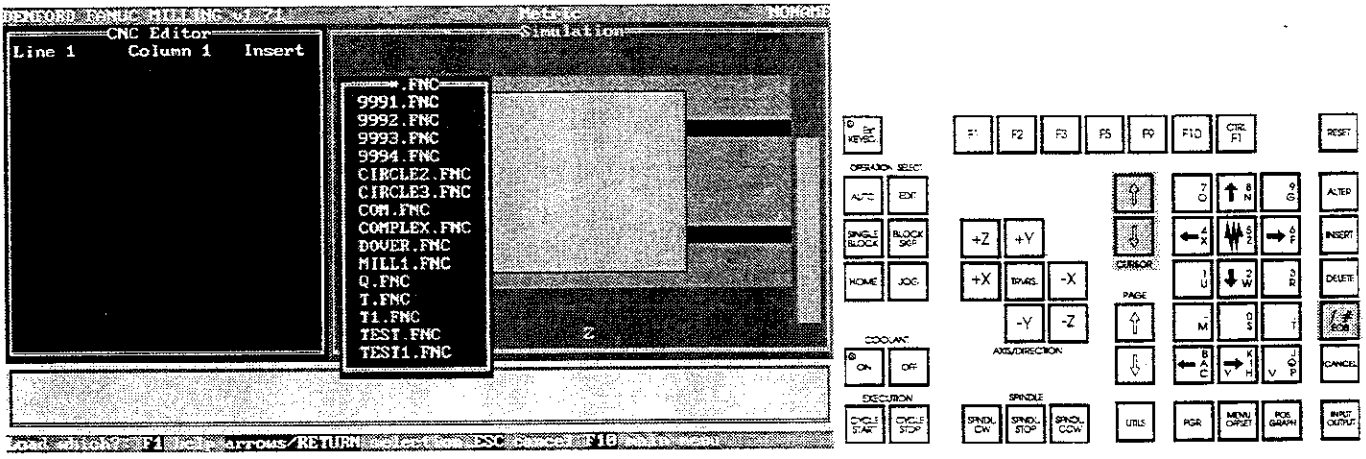
2 Selecting your file



Note

Once the program is running the computer keyboard is no longer used. Control has been passed to the desk-top tutor.

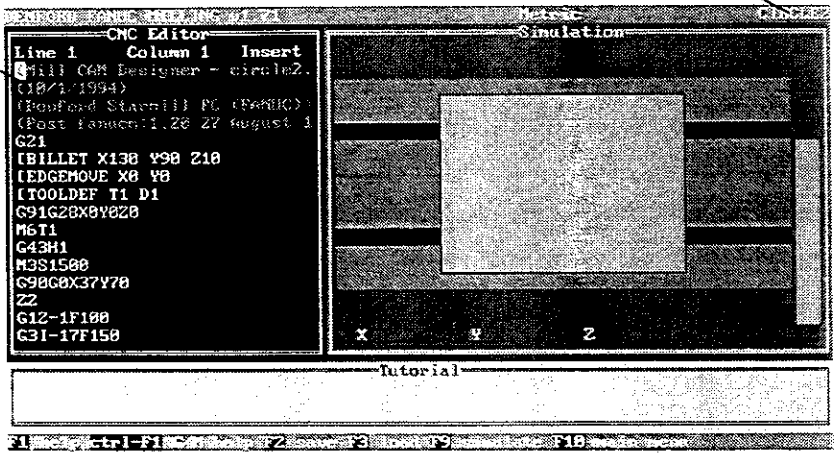
You can now select the file you wish to machine, use the arrow keys indicated and then press [EOB] key when your file is selected.



After pressing [EOB] the screen should look like this.

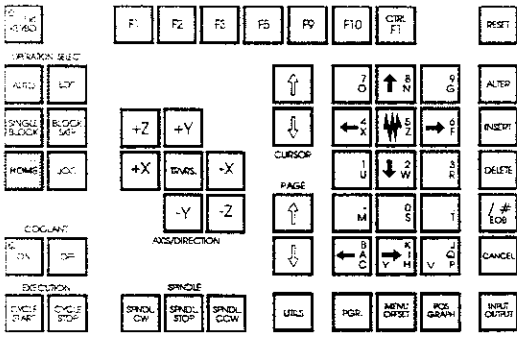
■ Name of the loaded file

■ What the G-code file looks like



3 Datuming

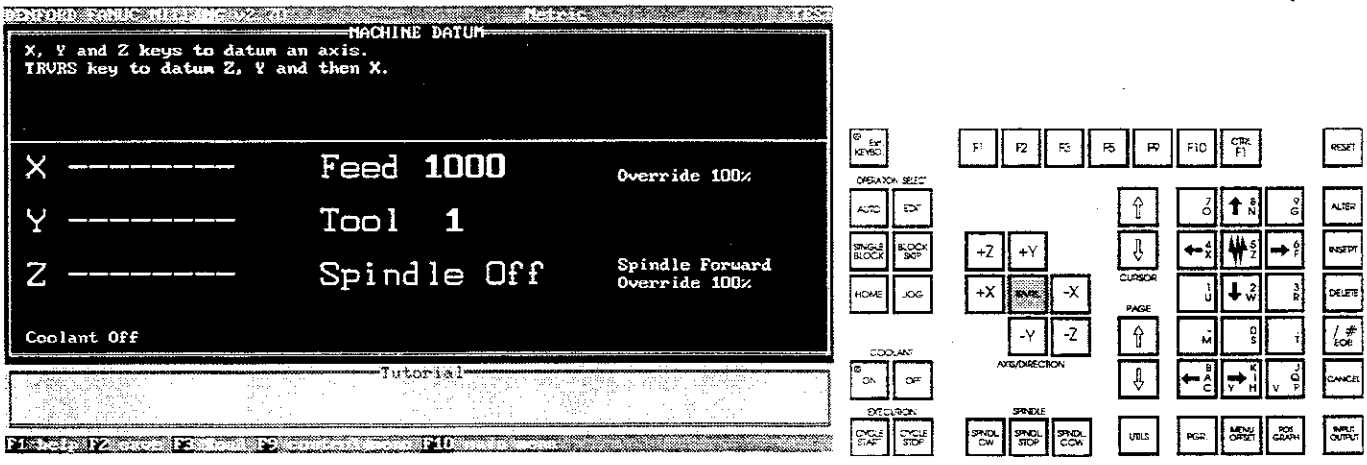
To datum the machine you must press the [HOME] key.



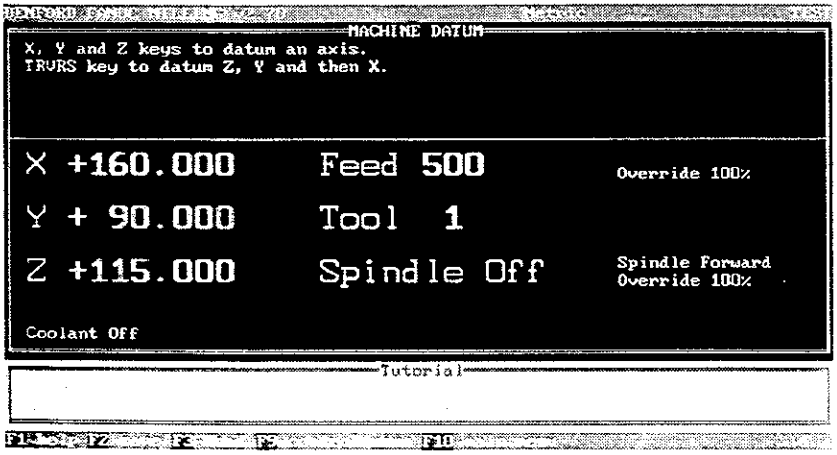
Denny's Help Box

"When the machine is setting its datum it is finding out and setting where the X, Y and Z axis are zero. It does this by moving each axis, in turn, to its most extreme limit.

Pressing the [TRVRS] key will datum all 3 axis one after the other.

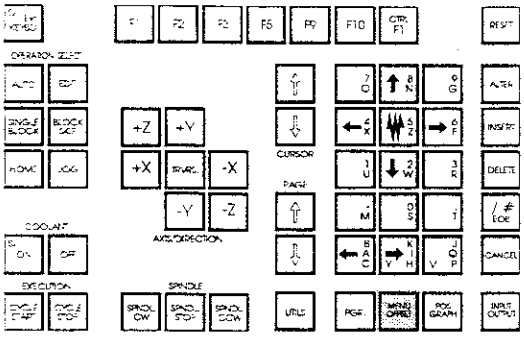


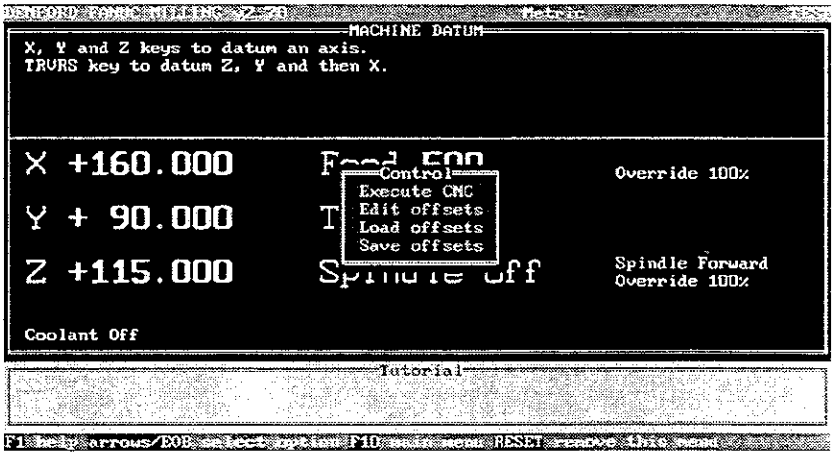
When the datum has been set, the screen will look like this.



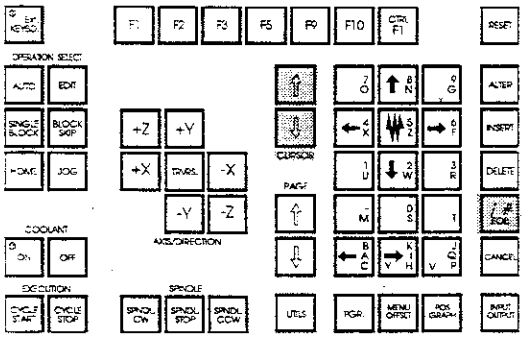
4 Loading tool offsets

Select the offset menu by pressing the [MENU OFFSET] key.





Select load offset using [cursor arrows] and select with [EOB]

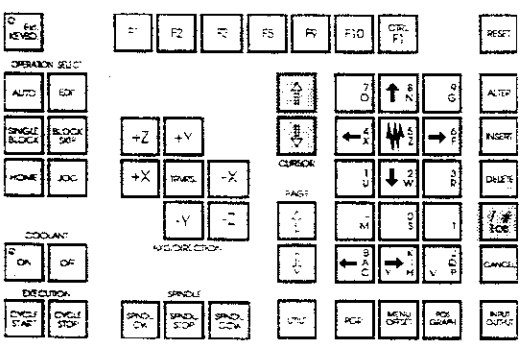


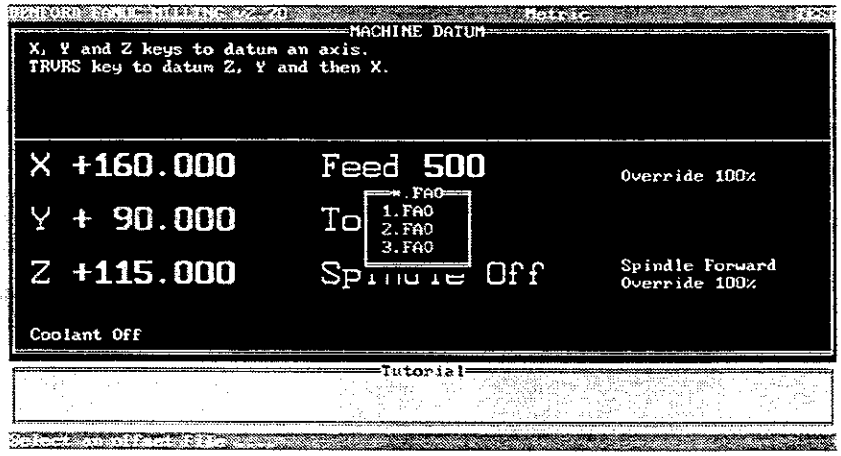
Press [EOB] again to display the selection of offset files.

Denny's Help Box

"offsets are used to store information about how long a cutting tool is. The miller can then automatically adjust when a cutter is changed"

Select the offset file you wish to load using [cursor arrows] and select with [EOB]. If none are available then see section 6 setting tool offsets.

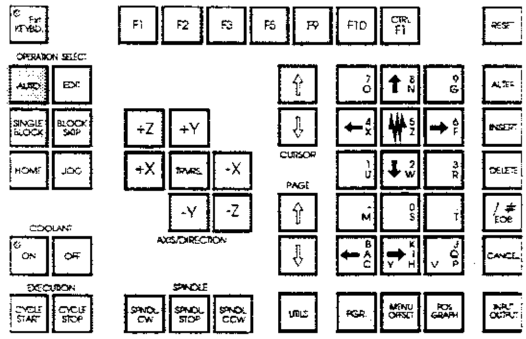


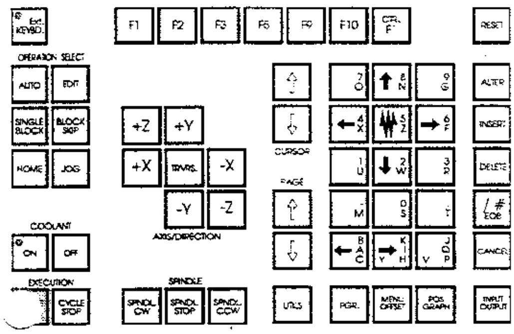


When the offset file has loaded, check the Z value has changed.

5 Running the program.

You first need to change modes, by pressing [AUTO].



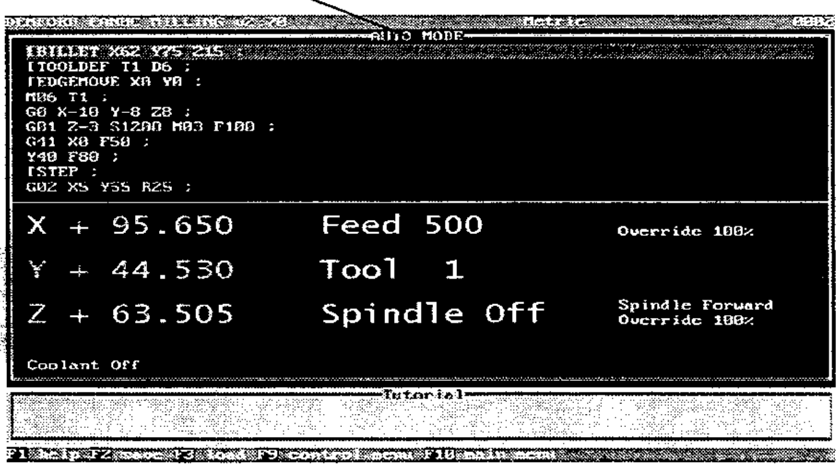


When in auto mode the milling machine can execute your G-code file. Your file will be displayed in the top portion of the screen. When you are ready to start cutting press the [CYCLE START] key.

Note

Once the cycle start key has been pressed then the spindle will start, all safety precautions should be observed.

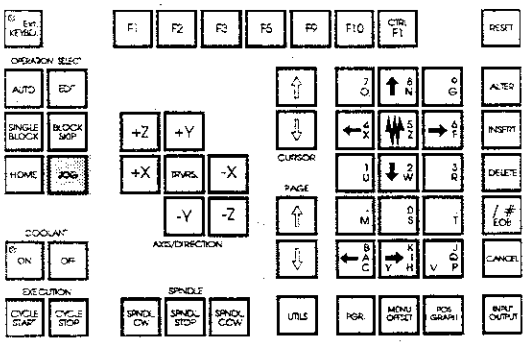
It should say AutoMode here

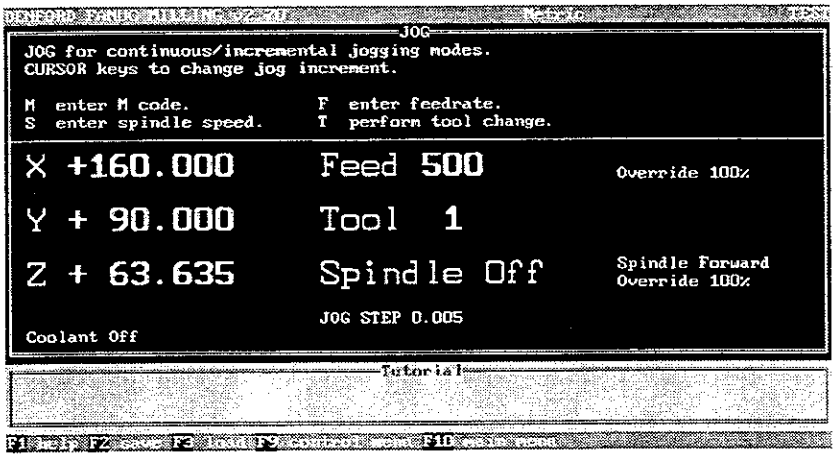


If you wish to stop the machine you can press [reset] or in an emergency you should press the emergency stop button. If you wish to pause the program you can press [CYCLE STOP] and resume again with [CYCLE START] the cutter will remain spinning using this method.

6 Setting tool offsets

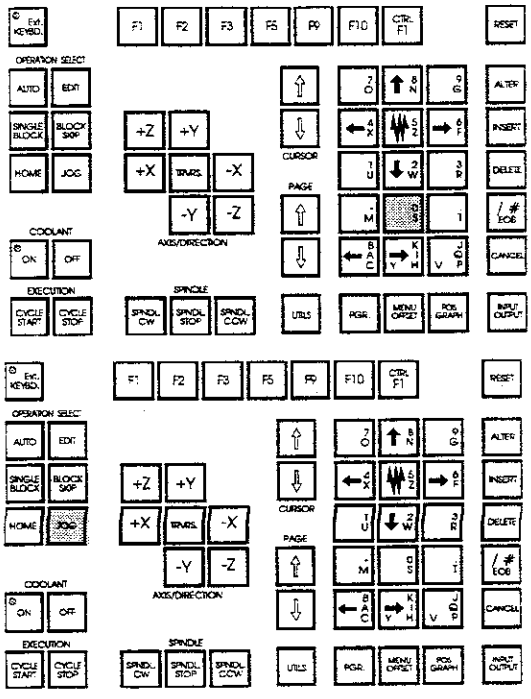
Select the jog mode by pressing the [JOG] key.



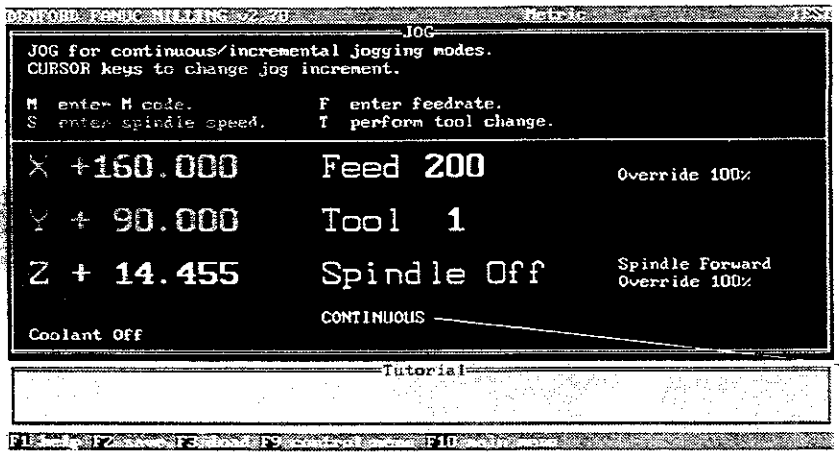


When in jog mode the miller can be controlled manually. The screen display X,Y and Z positions and spindle action. It should be off.

You can set the spindle speed by pressing the [S] key and entering the desired speed enter [1500] for now.

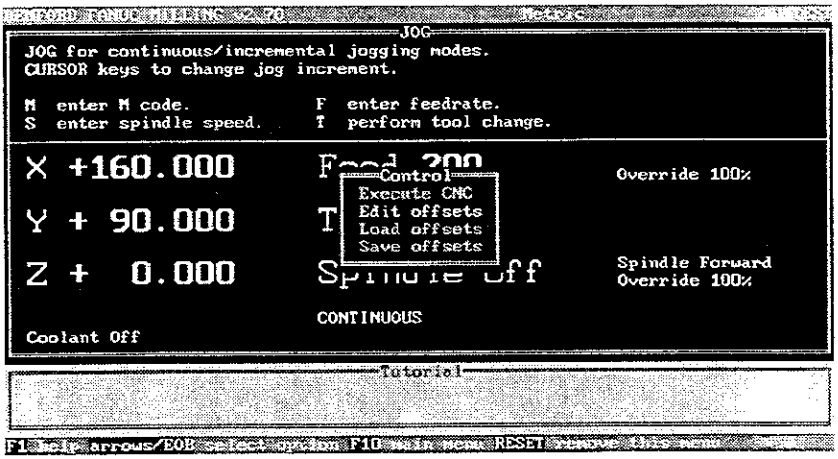


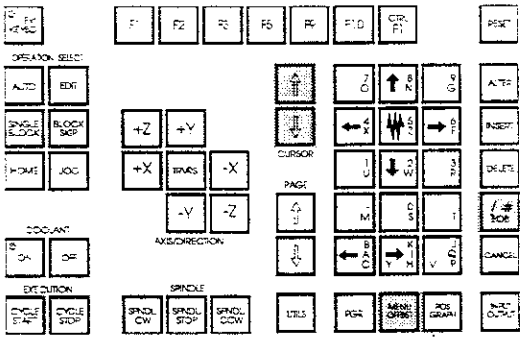
Before moving the table or cutter in any direction you need to set the movement mode to 'continuous'. To do this press the [JOG] key.



Display for continuous or jog mode.

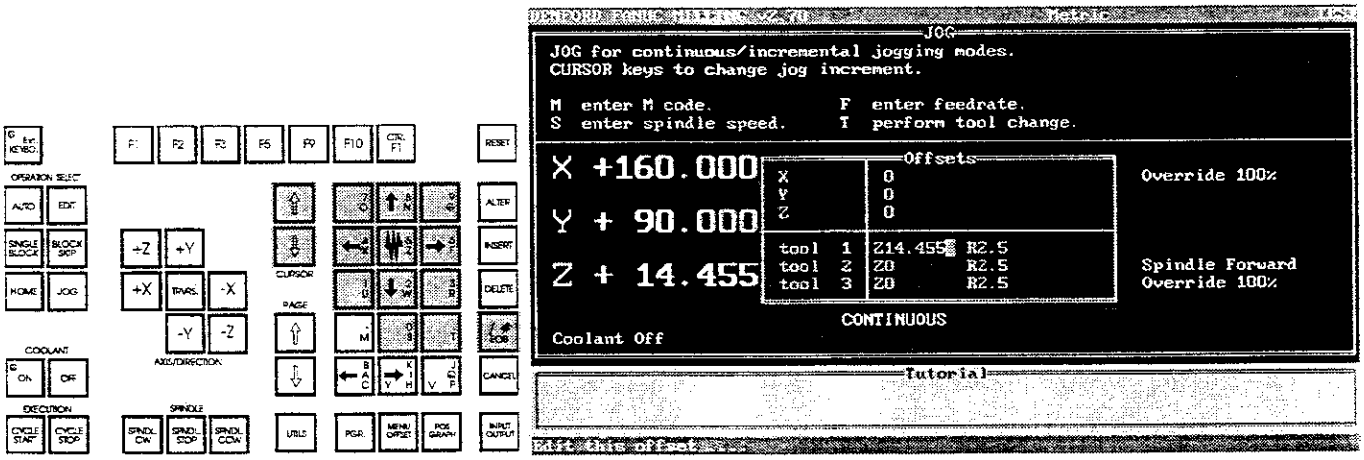
Using the [+Z] and [-Z] make the tip of the cutting tool just touch the top of the work piece(this will become the Z zero).





Select the offset menu by pressing the [MENU OFFSET] key.

This will give you four choices use the [cursor arrows] to select *Edit offsets* and press [EOB].



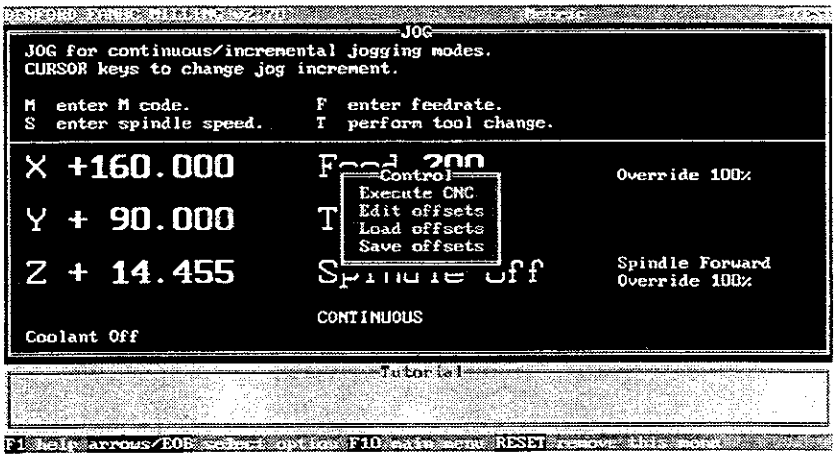
Use the [cursor arrows] to move the cursor to *tool 1* and across to *Z0*.

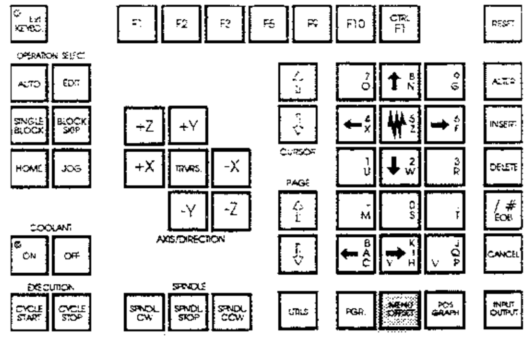
Enter the Z value, using the [number keys], that is displayed to the left of the offset screen. Then press [EOB] to confirm the offset. After pressing [Reset]he Z value will change to zero.

7 Saving tool offsets

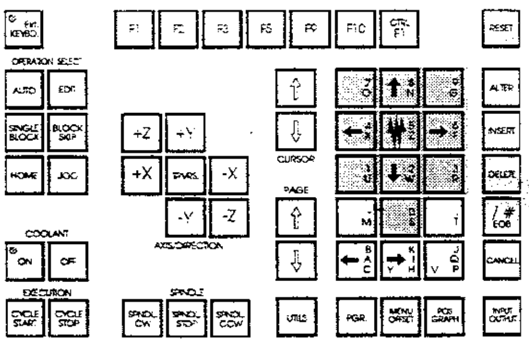
To save the offset select the offset menu by pressing the [MENU OFFSET] key.

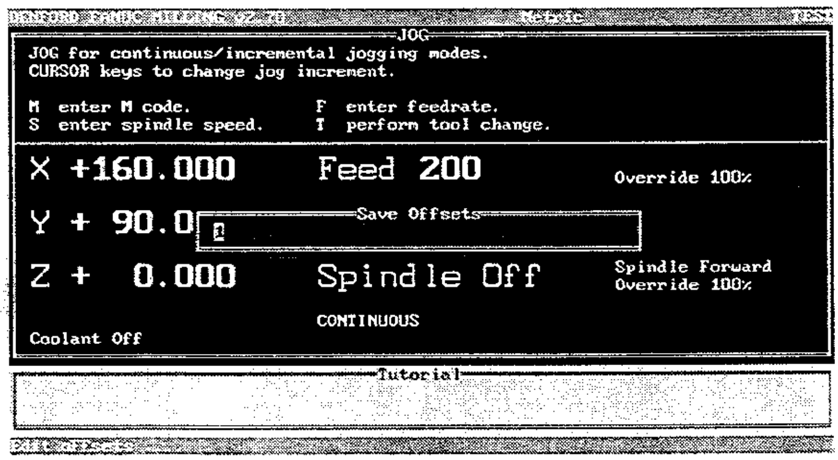
Then select *save offsets* and press [EOB].



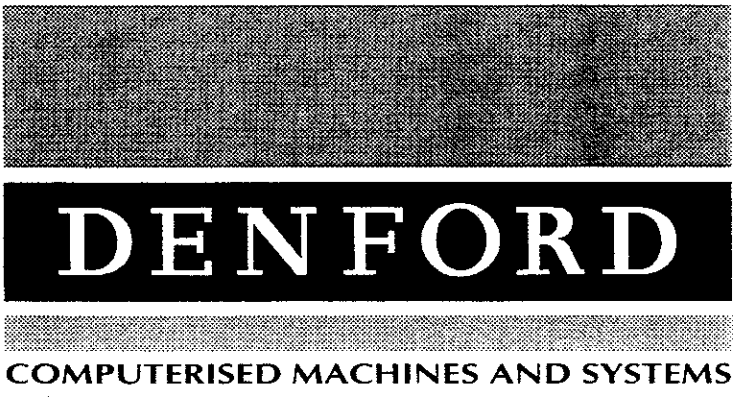


Enter a number, this will be the file name for the offsets. This can be loaded at any time in the future. Confirm this name by pressing [EOB].





Assessment Sheets



Name _____ Form _____ Date _____

6

Assessment

Task 1 [The CNC milling machine]

Answer the following question:-

(a) What is the difference between a milling cutter and a drill bit?

(b) Explain how the table is moved on a CNC milling machine.

(c) Give two advantages that a CNC milling machine has over a manual milling machine.

(d) Name two the two type of movement used on a CNC milling machine and when they would be used.

Name _____ Form _____ Date _____

Assessment

Task 2 [Terms used in milling]

/6

Explain what the following terms mean.

(a) X & Y axis _____

(b) Z axis _____

(c) Feed rate _____

(d) Rotational speed _____

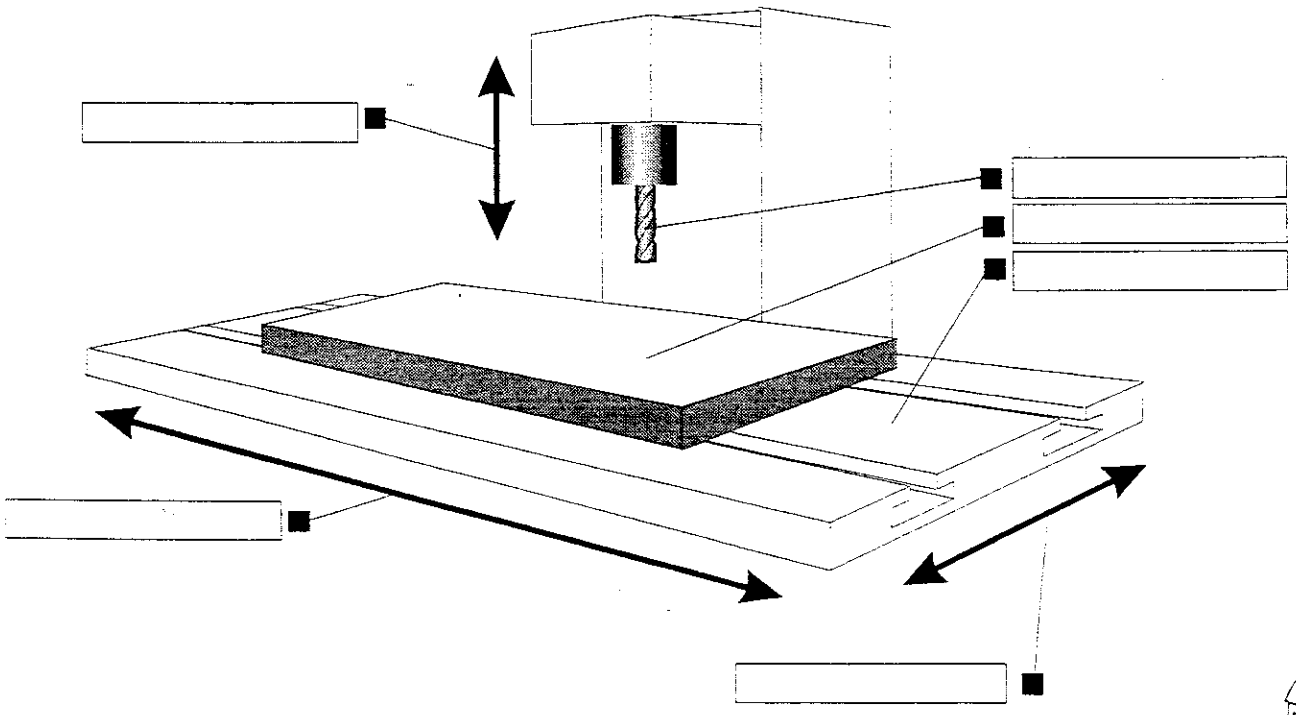
(e) Billet _____

(f) Table _____

Task 3 [Parts of a milling machine]

/6

Fill in the labels on the diagram below.



Name _____ Form _____ Date _____

Assessment

Task 4 [Fixing methods]

Draw and label three methods of holding the work piece on the table of a milling machine.

12

Machine Vice

'Tee' bolt & Step Clamp

Adhesive Tape

Name _____ Form _____ Date _____

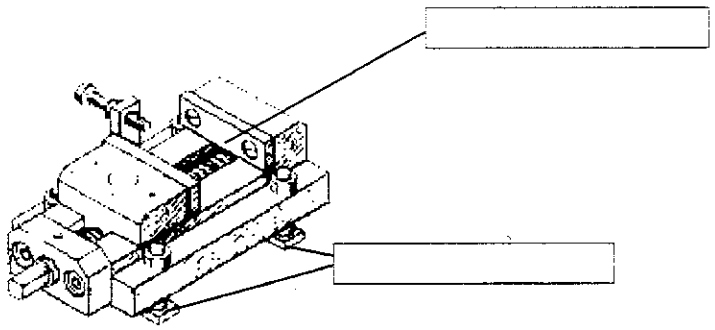
Assessment

Task 4 [Fixing methods]

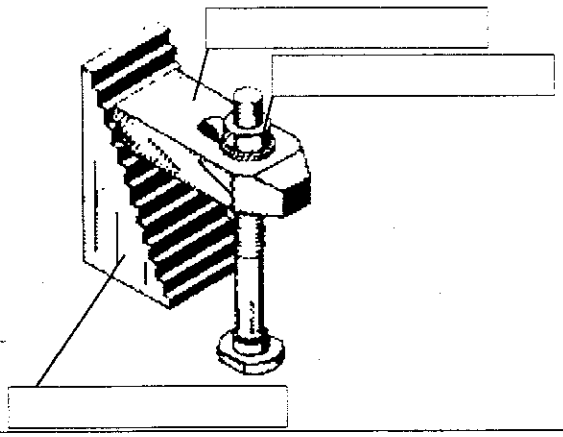
Draw and label three methods of holding the work piece on the table of a milling machine.

12

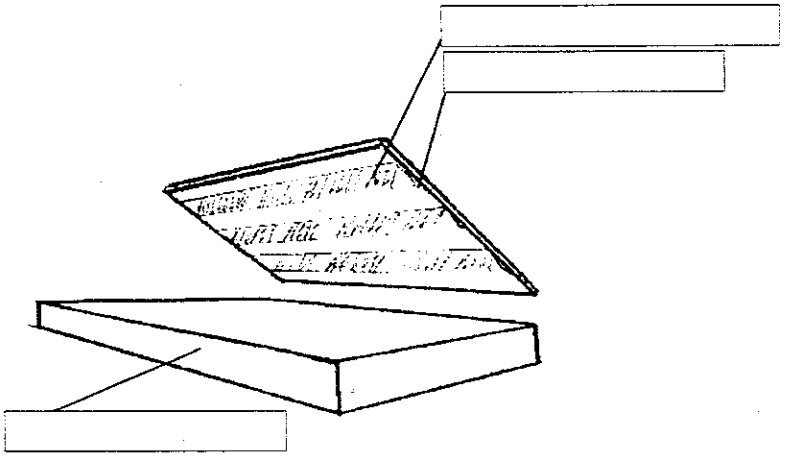
Machine Vice



'Tee' bolt & Step Clamp



Adhesive Tape



Name _____ Form _____ Date _____

Assessment

Task 5 [Safety rules]

6

Write down six safety rules you should observe when in a workshop or using a machine.

1. _____

2. _____

3. _____

4. _____

5. _____

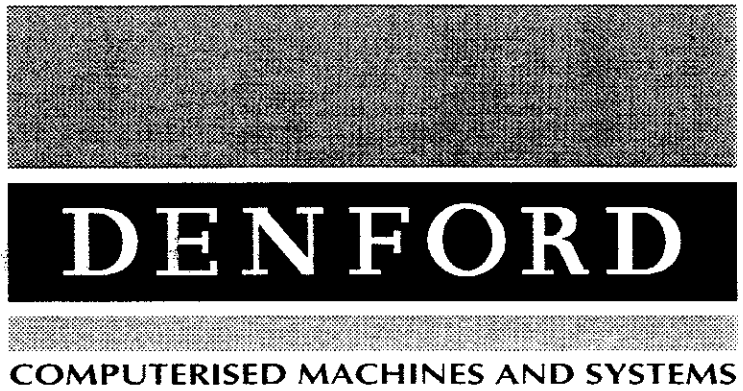
6. _____

Task 6 [Safety rules]

6

Using the blank page provided design and draw your own safety poster for one of the rules above.

Assessment Sheets Answers



6

Task 1 [The CNC milling machine]

Answer the following question:-

(a) What is the difference between a milling cutter and a drill bit?

A milling cutter has teeth on its side, this allows it to be moved side ways through the material.

(b) Explain how the table is moved on a CNC milling machine.

The table on a CNC milling machine is moved by motors. The motors are controlled by a computer, this allows angled lines and arcs to be generated.

(c) Give two advantages that a CNC milling machine has over a manual milling machine.

A CNC milling machine can cut angled lines and arcs.

A CNC milling machine can be used by someone who is not a skilled engineer.

(d) Name two the two type of movement used on a CNC milling machine and when they would be used.

Rapid traverse: Used when the cutter is not in the material, this is a very fast movement so it saves time.

Feed rate: Used when the cutter is in the material. The rate at which the machine moves will depend upon the material and size of cutter being used.

Task 2 [Terms used in milling]

6

Explain what the following terms mean.

(a) X & Y axis — *Movement of the table, left, right, backwards and forwards.*

(b) Z axis — *Movement of the tool up and down.*

(c) Feed rate — *Used when the cutter is in the material. The rate at which the machine moves depend upon the material and size of cutter being used.*

(d) Rotational speed — *The speed at which the tool spins, usually in the clockwise direction. The speed will depend upon the diameter of the cutter and the type of material being cut.*

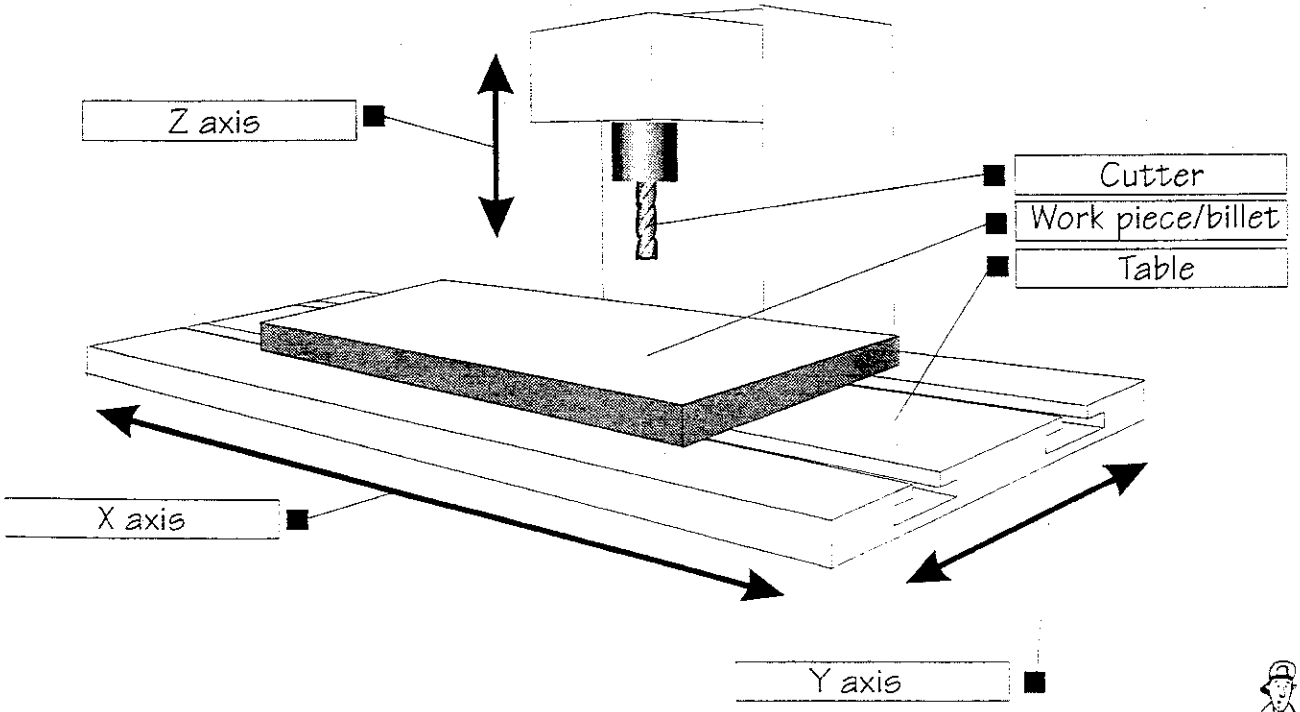
(e) Billet — *The piece of work that is to be cut.*

(f) Table — The flat surface of the machine that moves in the X and Y axes. The billet is fastened to this.

Task 3 [Parts of a milling machine]

6

Fill in the labels on the diagram below.

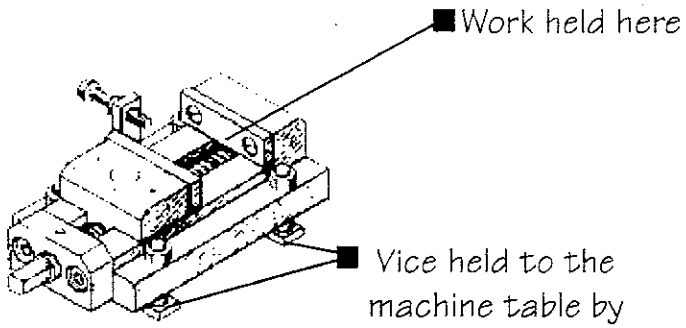


Task 4 [Fixing methods]

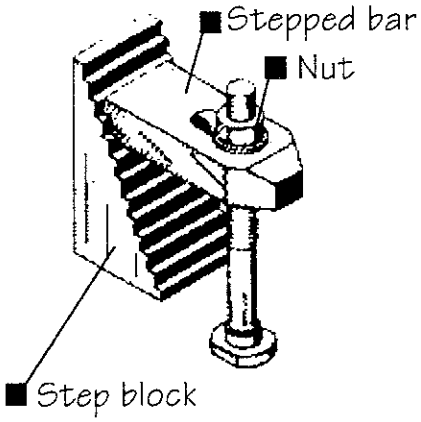
Draw and label three methods of holding the work piece on the table of a milling machine.

12

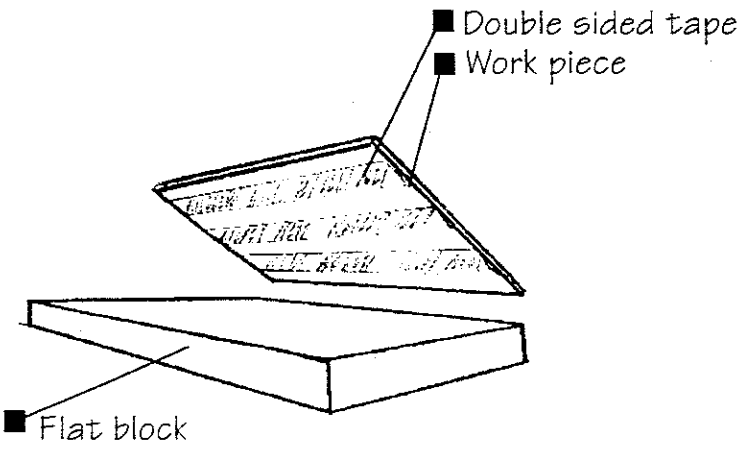
Machine Vice



'Tee' bolt & Step Clamp



Adhesive Tape



Task 5 [Safety rules]

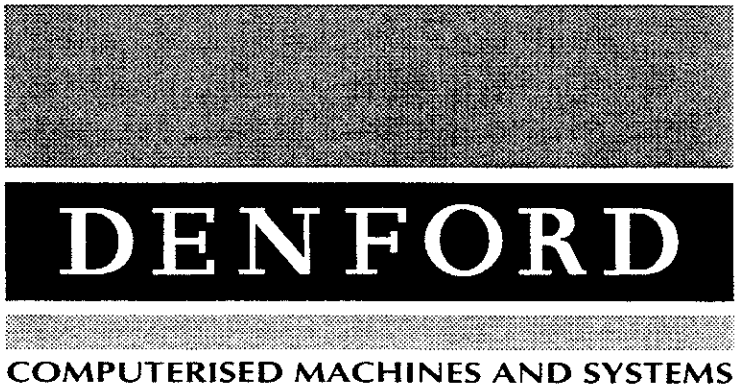
Write down six safety rules you should observe when in a workshop or using a machine.

6

Assessment

1. Always wear eye protection when it is provided.
2. Make sure that you are dressed safely. No loose clothes or undone laces.
3. Keep long hair tied back or in a hat.
4. Do not run in the workshop. Think of other peoples' safety too.
5. Keep the workshop and machines clean and tidy.
6. If in doubt, ask!

Safety Posters



Safety-1

Always wear eye protection when it is provided.

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Safety-2

Keep long hair tied back or in a hat.

DENFORD

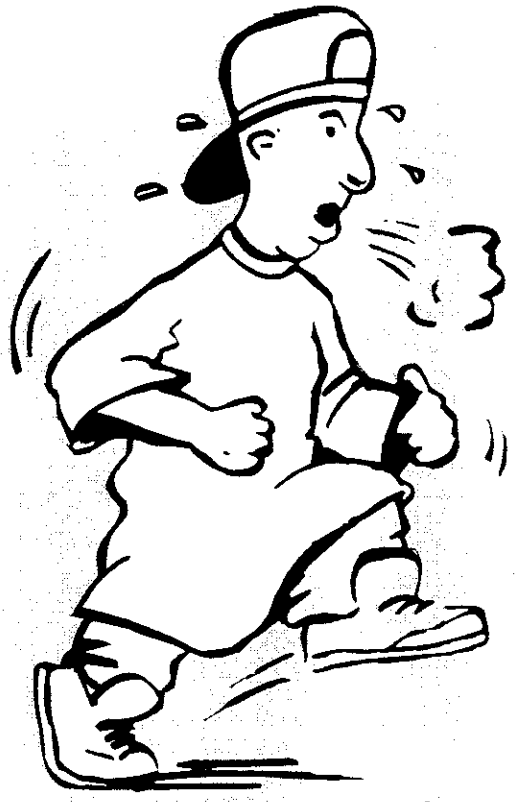
Denford Machine Tools Limited

Safety-3

Make sure that you are dressed safely. No loose clothes or undone laces.

DENFORD **Denford Machine Tools Limited**

Safety-4



Do not run in the workshop. Think of other peoples' safety too.

DENFORD **Denford Machine Tools Limited**

Safety-5

Keep the workshop and machines clean and tidy.

DENFORD

Denford Machine Tools Limited

Safety-6

If in doubt, ask!

DENFORD

Denford Machine Tools Limited

Name _____ Form _____ Date _____

Safety

Denford Machine Tools Limited