

Trade of Toolmaking	
Module 3:	Milling
Unit 9:	Precision Vee Block Assembly
	Phase 2

Published by



Table of Contents

Document Release History	3
Unit Objective.....	4
Introduction.....	4
1.0 Manufacturing A Vee Block Assembly To The Specifications On The Drawing ..	5
1.1 Use Of The Master Vee Block.....	5
1.2 Geometric And Trigonometrical Ratios: Sine, Cos, Tan Rules Triangles.....	5
1.3 Precision Machining Of Components.....	6
1.4 Measurement Of Vee Position And Dimensions: Use Of Precision Rollers To Determine Location And Accuracy	6
1.5 Deburring Of Components, Disposal Of Swarf	6
1.6 First Angle Projection: Sectional Views, Hatching, Dimensioning, Component Parts And Description Lists, Title Blocks	7
2.0 Describing And Using Specific Work Holding Techniques	8
2.1 Specific Work Holding Methods: Safety, Reduction Of Positional Changes During Manufacture	8
3.0 Drilling Holes In Tool Steel Using Correct Speeds, Feed And Techniques.....	8
3.1 Deep Through Hole Drilling: Symmetry, Application Of Coolant	8
3.2 Appropriate Cutting Feeds And Speeds For Tool Steel	9
3.3 Cutting Stresses And Strains For Tool Steel	9
3.4 Stress Relieving Techniques Used In Manufacturing.....	9
4.0 Planning And Allocating Grinding Allowances On Components	10
4.1 Job Sequence, Efficient Planning Of Grinding Allowance	10
Summary.....	11
Suggested Exercises	12
Questions.....	13
Answers.....	14
Recommended Additional Resources.....	15
Reference Books	15

Document Release History

Date	Version	Comments
25/09/2014	2.0	SOLAS transfer

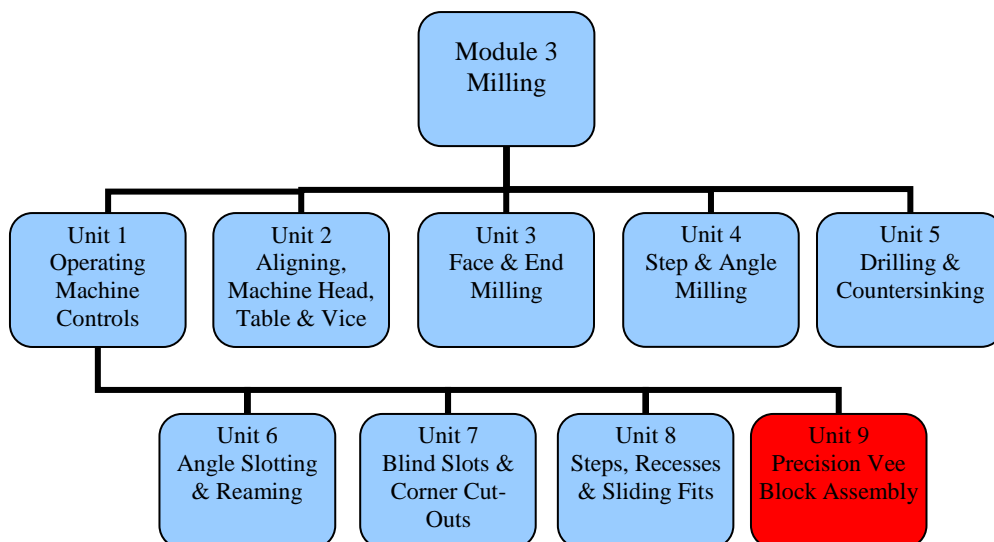
Unit Objective

On completion of this unit you will be able to mill and measure a vee block, describe specific work holding techniques and drill deep holes in a workpiece.

Introduction

Module three of this course covers milling. This is the ninth unit in module three and explains how to machine a vee groove in a workpiece, which is done by either tilting head of the machine or by setting up the workpiece in the vice at the required angle. The techniques of drilling deep holes in tool steel are also explained. If a hard material is being used, the Toolmaker needs to be able to use existing charts to obtain the correct cutting speed for that particular material. The correct spindle speed can then be calculated, which will result in a longer tool life and a better surface finish.

This unit also introduces other work holding devices, such as the angle plate, clamps and the dividing head.



By the end of this unit you will be able to:

- Manufacture a precision vee block assembly to the specifications supplied in workshop drawings.
- Describe and use specific work holding techniques.
- Accurately deep drill through holes in tool steel using the correct speeds, feeds and techniques.
- Plan and allocate appropriate grinding allowances on components during manufacture for precision grinding at the final stage of manufacture.

1.0 Manufacturing A Vee Block Assembly To The Specifications On The Drawing

Key Learning Points

Use of the master vee block. Geometric and trigonometrical ratios: Sine, Cos, Tan rules triangles. Precision machining of components. Measurement of vee position and dimensions: use of precision rollers to determine location and accuracy. Deburring of components, disposal of swarf. First angle projection: sectional views, hatching, dimensioning, component parts and description lists, title blocks.

1.1 Use Of The Master Vee Block

The vee block is used for machining or marking out circular workpieces. It can also be used when machining features such as slots, flats and holes.

Ref: Black, Bruce J 2004, Workshop processes, practices and materials, 3rd edn, Elsevier Science & Technology, chapter 3 *Marking out Vee blocks*, p. 474.

ISBN-13: 9780750660730

1.2 Geometric And Trigonometrical Ratios: Sine, Cos, Tan Rules Triangles

Trigonometry deals with the ratio between the sides of a right angled triangle and provides a method of calculating unknown sides and angles. Three important trigonometrical ratios are sine, cosine and tangent, usually written as Sin, Cos and Tan, where:

$$\text{Sin} = \frac{\text{Opposite}}{\text{Hypotenuse}}$$

$$\text{Cos} = \frac{\text{Adjacent}}{\text{Hypotenuse}}$$

$$\text{Tan} = \frac{\text{Opposite}}{\text{Adjacent}}$$

If a feature on a drawing, such as a drilled hole, is dimensioned at an angle of 20° and is 30mm from the origin, then the X and Y co-ordinates can be calculated using trigonometry. Draw a right angled triangle and label the longest side (hypotenuse) 30mm, label the horizontal line X (adjacent) and the vertical line Y (opposite). The X and Y co-ordinates can be calculated by using the formulae:

$$\sin 20^\circ = \frac{Y}{30}$$

$$Y = \sin 20^\circ \times 30 = 10.26\text{mm}$$

$$\cos 20^\circ = \frac{X}{30}$$

$$X = \cos 20^\circ \times 30 = 28.19\text{mm}$$

Ref: Bird, John 2005, *Basic engineering mathematics*, 4th edn, Elsevier Science & Technology, chapter 19 *Introduction to trigonometry*, p.142.

ISBN-13: 9780750665759

1.3 Precision Machining Of Components

When machining a component such as a vee block, first study the drawing and plan the sequence of operations. The first step is to machine the block to size and it marked out.

The holes should be drilled first, particularly the hole at the base of the vee, as this cannot be drilled after the vee groove has been machined. When drilling holes in the workpiece, calculate the correct spindle speed and turn on the coolant. When drilling deep holes it is important to withdraw the drill frequently in order to remove swarf and allow the coolant to flush out the bore.

A vee groove can be machined by either (i) tilting the head of the machine and rotate the head to 45° by aligning with the graduations on the head, or (ii) by tilting the workpiece in the vice by setting it up at the required angle using a master vee block or a bevel protractor.

1.4 Measurement Of Vee Position And Dimensions: Use Of Precision Rollers To Determine Location And Accuracy

The depth of the vee groove can be measured by positioning a roller gauge in the vee groove and placing two equal piles of slip gauges on the top surface at either side of the vee groove. A depth micrometer is then used to measure the distance from the top of the slip gauges to the top of the roller gauge. The drawing normally specifies roller gauge diameter, the slip gauge thickness and the distance to be measured.

1.5 Deburring Of Components, Disposal Of Swarf

When the workpiece has been machined it is important to remove all burrs and sharp edges with a smooth file. Failure to remove burrs may result in injury, but could also prevent the parts from being accurately measured and from being assembled together. Swarf should never be removed with your hand, use a brush. Swarf should be safely disposed of in a bin.

1.6 First Angle Projection: Sectional Views, Hatching, Dimensioning, Component Parts And Description Lists, Title Blocks

There are two systems of projection, First Angle and Third Angle, which are based on a framework of planes at right angles. In first angle projection, each view shows what would be seen by looking on the far side of an adjacent view. In Third angle projection, each view shows what would be seen by looking on the near side of an adjacent view. The Projection symbol must be added to the drawing to indicate which system has been used.

Orthographic projection is used in engineering drawing to represent component parts, with the views in first or third angle and in accordance with BS 8888. The assembly drawing shows the components assembled together and may be sectioned to show internal parts. The individual parts are numbered on the drawing and a table lists the components, the individual single-part drawing number, the quantity required of each component.

Ref: Simmons, Colin H & Maguire, Dennis E 2004, Manual of engineering drawing, 2nd edn, Elsevier Science & Technology, chapter 4 *Principles of first and third angle orthographic projection*.

ISBN-13: 9780750651202

For components with hidden features a section can be taken through the part to the internal features. The sectional view that is taken is hatched.

Ref: Simmons, Colin H & Maguire, Dennis E 2004, Manual of engineering drawing, 2nd edn, Elsevier Science & Technology, chapter 8 *Sections and sectional views*.

ISBN-13: 9780750651202

The basic drawing consists of a single view or multiple views of the component, dimensions, notes, title block, description, scale, material and part number.

Ref: Simmons, Colin H & Maguire, Dennis E 2004, Manual of engineering drawing, 2nd edn, Elsevier Science & Technology, chapter 7 *Drawing layouts and simplified methods*.

ISBN-13: 9780750651202

2.0 Describing And Using Specific Work Holding Techniques

Key Learning Points

Specific work holding methods: safety, reduction of positional changes during manufacture.

2.1 Specific Work Holding Methods: Safety, Reduction Of Positional Changes During Manufacture

The vice is the primary method of holding a workpiece when milling. Other devices can be used such as; *Angle Plate*, which can be used to hold large plates and when machining surfaces at right angles to each other, *Clamps*, irregular shaped work can be clamped directly onto the table and machined in place, *Vee Block*, used in combination with a clamp and can be used to hold and machine cylindrical workpieces, *Dividing Head*, used to machine gears, circular array of holes etc.

Ref: Black, Bruce J 2004, Workshop processes, practices and materials, 3rd edn, Elsevier Science & Technology, chapter 11 *Milling 11.5 Workholding*, p. 184.

ISBN-13: 9780750660730

3.0 Drilling Holes In Tool Steel Using Correct Speeds, Feed And Techniques

Key Learning Points

Deep through hole drilling: symmetry, application of coolant. Appropriate cutting feeds and speeds for tool steel. Cutting stresses and strains for tool steel. Stress relieving techniques used in manufacturing.

3.1 Deep Through Hole Drilling: Symmetry, Application Of Coolant

The symmetry tolerance can be used on a drawing to indicate, for example, that two holes need to be equally spaced about the centre line. The edge finder can be used to position the centre of the spindle on the centre of the workpiece. Using the digital readout, the holes can be drilled symmetrically about the centre line.

Ref: Simmons, Colin H & Maguire, Dennis E 2004, Manual of engineering drawing, 2nd edn, Elsevier Science & Technology, chapter 21 *Application of geometrical tolerances-Symmetry*, p. 177.

ISBN-13: 9780750651202

For general purpose use, e.g. when drilling mild steel, a standard drill High Speed Steel (HSS) is used. When drilling harder materials such as tool steel, which has a high carbon content, HSS drill can be used, but to increase the tool life, drills with Titanium Nitrate Coating (TiN) or with tungsten carbide tips should be used.

When drilling deep holes it is important to use coolant and to retract the drill occasionally in order to clear the swarf and allow coolant to reach the cutting zone. The advantages of using coolant are higher cutting speeds, longer tool life, better surface finish and better swarf removal.

Ref: Black, Bruce J 2004, Workshop processes, practices and materials, 3rd edn, Elsevier Science & Technology, chapter 7 *Cutting tools and cutting fluids 7.5 Cutting fluids*, p. 124.

ISBN-13: 9780750660730

3.2 Appropriate Cutting Feeds And Speeds For Tool Steel

The correct spindle speed needs to be set for each cutter size. This is calculated by entering the cutting speed and the drill diameter into the RPM formula, where the *Cutting Speed* is expressed in meters per minute. Charts are available that recommend the correct cutting speed and the feed per tooth for a particular material, e.g. for tool steel the cutting speed is 20 metres/min. Therefore the spindle speed will be lower for the tool steel when compared to that of mild steel.

Cutting speed is expressed in meters per minute. This refers to the distance covered by the tool across the material when machining. A chart is available listing various materials and their corresponding cutting speeds. The revolutions per minute (RPM) is calculated by using the RPM formula:

$$\text{RPM} = \frac{S \times 1000}{\pi \times D}$$

Ref: Black, Bruce J 2004, Workshop processes, practices and materials, 3rd edn, Elsevier Science & Technology, chapter 9, p. 153.

ISBN-13: 9780750660730

The feed rate is important when trying to achieve a good surface finish. A high feed rate increases the forces acting on the cutter and workpiece and causes the cutter to flex to produce a rough finish. This is fine when rough machining as explained above. For the final cuts the feed rate needs to be reduced, which will result in a better finish.

3.3 Cutting Stresses And Strains For Tool Steel

Tool steel is harder than mild steel and therefore will put greater stresses on the HSS cutter. Tool steel needs to be machined in its softer annealed state and can then be hardened by heat treatment. This alloy tool steel contains carbon, manganese, tungsten and chromium. When tool steel is in its hardened state it cannot be machined with HSS tools.

3.4 Stress Relieving Techniques Used In Manufacturing

When removing large volumes of material from a block of mild steel, e.g. machining a deep slot, then it is important to rough machine the workpiece first, leaving adequate machining allowance for finishing. The part should then be removed from the vice in order to allow the material to stress relieve. This is because stresses build up in the raw material during processing and are released when machined, causing the material to distort slightly. If precision parts are being manufactured then it is important to heat treat the workpiece before final machining. This process is called *Normalising*, which refines the structure of the steel and removes strains caused by cold working. The material is heated slowly and cooled in air.

4.0 Planning And Allocating Grinding Allowances On Components

Key Learning Points

Job sequence, efficient planning of grinding allowance.

4.1 Job Sequence, Efficient Planning Of Grinding Allowance

Job planning is important prior to starting any task. The drawing should first be studied and understood. The drawing can initially be used to calculate the material requirement for the component to be manufactured. The workpiece needs to be cut from bar stock by using the bandsaw. The sequence of operations should be planned so as to minimise the number of setups in the vice. If the workpiece requires a ground finish, then an adequate grinding allowance need to be left on the surfaces of the workpiece.

Summary

Manufacturing a vee block assembly to the specifications on the drawing: The drawing should be studied and the sequence of operations planned prior to machining the vee block. The first step is to machine the block to size and it marked out.

The holes should be drilled first, particularly the hole at the base of the vee, as this cannot be drilled after the vee groove has been machined. When drilling holes in the workpiece, calculate the correct spindle speed and turn on the coolant. When drilling deep holes it is important to withdraw the drill frequently in order to remove swarf and allow the coolant to flush out the bore.

A vee groove can be machined by either (i) tilting the head of the machine and rotate the head to 45° by aligning with the graduations on the head, or (ii) by tilting the workpiece in the vice by setting it up at the required angle using a master vee block or a bevel protractor. The vee groove can be measured by placing a precision roller in the vee groove. The drawing normally shows dimension to be measured, the tolerance band and roller size.

Describing and using specific work holding techniques: The vice is the primary method of holding a workpiece when milling. Other devices can be used such as; *Angle Plate*, which can be used to hold large plates and when machining surfaces at right angles to each other, *Clamps*, irregular shaped work can be clamped directly onto the table and machined in place, *Vee Block*, used in combination with a clamp and can be used to hold and machine cylindrical workpieces, *Dividing Head*, used to machine gears, circular array of holes etc.

Drilling holes in tool steel using correct speeds, feed and techniques: For general purpose use, e.g. when drilling mild steel, a standard drill High Speed Steel (HSS) is used. When drilling harder materials such as tool steel, which has a high carbon content, HSS drill can be used, but to increase the tool life, drills with Titanium Nitrate Coating (TiN) or with tungsten carbide tips should be used.

The correct spindle speed needs to be set for each drill size. This is calculated by entering the cutting speed and the drill diameter into the RPM formula, where the *Cutting Speed* is expressed in meters per minute. Charts are available that recommend the correct cutting speed and the feed per tooth for a particular material, e.g. for mild steel, the recommended cutting speed is 30 meters/min and for tool steel the cutting speed is 20 metres/min. Therefore the spindle speed will be lower for the tool steel when compared to that of mild steel.

The advantages of using *coolant* are higher cutting speeds, longer tool life, better surface finish and better swarf removal.

Planning and allocating grinding allowances on components: As mentioned above, job planning is important prior to carrying out any machining operations. This is especially important when for example a grinding allowance needs to be added to a workpiece. The surface finish that can be achieved on a grinding machine is not possible using a milling machine, therefore extra material needs to be left on each surface of the workpiece during the milling process. The workpiece is then setup on the grinding machine and ground to the required size.

Suggested Exercises

1. What methods can be used for holding work on a milling machine?
2. Why is it important to use coolant when drilling holes?
3. Explain how an angle plate is used to hold a workpiece when it is being milled.
4. What types of drills are used for drilling mild steel?
5. Explain the term, Normalising.

Questions

1. How is the depth of a vee groove measured?
2. What safety precautions should be taken when removing swarf.
3. In order to manufacture a component, what is the minimum amount of information that a drawing should have?
4. Apart from the vice, what other work holding devices are used to hold workpieces on a milling machine?
5. Why does Tool Steel need to be machined in its softer annealed state and what elements give the tool steel its unique properties?

Answers

1. The depth of the vee groove is measured by placing a roller gauge in the vee and setting up two equal piles of slip gauges or parallels on the top flat surface. A depth micrometer is then used to measure the distance from the slip gauges to the top of the roller gauge. The roller diameter and the height in relation to the datum is normally specified on the drawing
2. Swarf should never be removed with your hand, use a brush. Swarf should be safely disposed of in a bin and safely disposed of.
3. The basic drawing consists of a single view or multiple views of the component, dimensions, notes, title block, description, scale, material and part number.
4. **Angle Plate**, which can be used to hold large plates and when machining surfaces at right angles to each other, **Clamps**, irregular shaped work can be clamped directly onto the table and machined in place, **Vee Block**, used in combination with a clamp and can be used to hold and machine cylindrical workpieces, **Dividing Head**, used to machine gears, circular array of holes etc.
5. Tool steel needs to be machined in its softer annealed state and can then be hardened by heat treatment. This alloy tool steel contains carbon, manganese, tungsten and chromium. When tool steel is in its hardened state it cannot be machined with HSS tools.

Recommended Additional Resources

Reference Books

Black, Bruce J 2004, *Workshop processes, practices and materials*, 3rd edn, Elsevier Science & Technology.

ISBN-13: 9780750660730

Simmons, Colin H & Maguire, Dennis E 2004, *Manual of engineering drawing*, 2nd edn, Elsevier Science & Technology.

ISBN-13: 9780750651202

Bird, John 2005, *Basic engineering mathematics*, 4th edn, Elsevier Science & Technology.

ISBN-13: 9780750665759