Trade of Toolmaking	
Module 3:	Milling
Unit 6:	Angle Slotting & Reaming
	Phase 2

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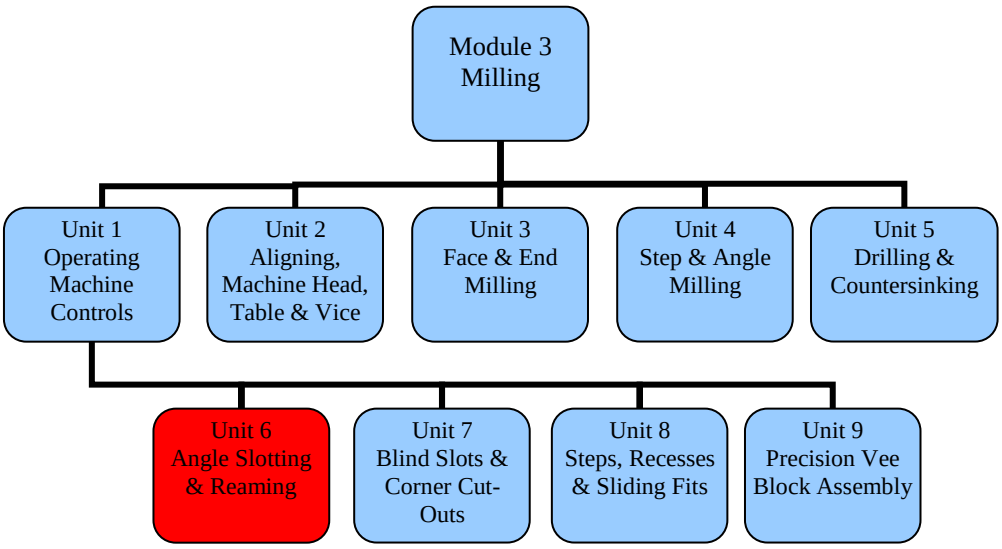
Unit Objective

On completion of this unit you will be able to locate datum edges drill and ream holes, off-set the vertical head for machining angled surfaces and use slip gauges to accurately measure slots.

Introduction

Module three of this course covers milling. This is the sixth unit in module three and explains how to locate datum edges using an edge finder, position the workpiece and drill and ream holes. This unit explains the techniques associated with machining an angled face on a workpiece by either off-setting the workpiece in the vice or by offsetting the vertical head prior to milling the angled face. Milling a slot at an angle and the use of slip gauges to accurately inspect the slot is also discussed.

Many machined components used in industry will be required to have reamed holes, angled faces and slots. Therefore learning how to set up, accurately machine and measure these features is a requirement of the Toolmaker.



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

- Locate datum edges, position a centre drill, drill and ream holes.
- Off-set machine head or workpiece for machining angular surfaces.
- Mill a vee in workpiece using roller/slip gauges to measure size and location.
- Calculate the off-set distance for universal swivel machine vice.
- Offset a universal swivel machine vice accurately using a dial test indicator.
- Mill a slot at an angle to the datum surfaces and measure its size using slip gauges.

1.0 Locating Datum Edges, Drilling And Reaming Holes

Key Learning Points

Drill sizes and reaming allowances. Calculation of speeds and feeds for reaming. Location of, drilling and reaming holes on the milling machine.

1.1 Drill Sizes And Reaming Allowances

The recommended amount of stock that a reamer should remove is 0.3 to 0.5mm depending on the size or the hole being reamed.

1.2 Calculation Of Speeds And Feeds For Reaming

The spindle speed for the drills and reamers are calculated using the RPM formula. For reaming, a general rule is to reduce the speed by at least a half and double the feed rate to that of a similar size drill. The reamer is fed into the drilled hole using coolant. The revolutions per minute (RPM) is calculated by using the RPM formula:

$$\text{RPM (standard cutter)} = \frac{S \times 1000}{\pi \times D}$$

Feed Rate (standard cutter) = feed/tooth x No. of cutting teeth x RPM

Ref: Black, Bruce J 2004, Workshop processes, practices and materials, 3rd edn, Elsevier Science & Technology, chapter 9, p. 70.

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1.3 Location Of, Drilling And Reaming Holes On The Milling Machine

The *Edge finder*, which rotates in the spindle, is used to accurately find the datum edge/s of a workpiece. The digital readout is then set to zero for both the X and Y axis. The table is moved by the distance specified on the drawing for both the X and Y coordinates. The centre drill is used prior to the drilling operation.

2.0 Off-Setting Machine Head Or Workpiece For Machining Angular Surfaces

Key Learning Points

Off-setting machine head/vice.

2.1 Off-Setting Machine Head/Vice

Angular surfaces can be machined by either (i) tilting the vertical head or (ii) tilting the workpiece.

Tilting the vertical head. This is achieved by rotating the head by the required angle using the graduations on the head of the machine.

Tilting the workpiece. This is done by setting up the workpiece in a standard machine vice at the required angle, which can be aligned with a protractor or with a sine bar and slip gauges. The workpiece can also be setup in a universal vice, which can be tilted to the required angle using graduations on the vice and then locked in place.

3.0 Milling A Vee Groove In A Workpiece And Measuring With Roller/Slip Gauges

Key Learning Points

Vee slot milling, surface finish. Use of slip gauges and rollers to measure vee slot depth and location.

3.1 Vee Slot Milling, Surface Finish

The workpiece should first be marked out prior to being setup in a machine vice. An appropriate size end mill is inserted into the spindle, which is then tilted off at 45º. The markings can be used as a guide to rough out the vee close to the scribed lines.

Ref: Black, Bruce J 2004, Workshop processes, practices and materials, 3rd edn, Elsevier Science & Technology, chapter 11, *Milling,* sec. 11.6, *Cutter mounting,* p. 185.

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3.2 Use Of Slip Gauges And Rollers To Measure Vee Slot Depth And Location

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.

Ref: Black, Bruce J 2004, Workshop processes, practices and materials, 3rd edn, Elsevier Science & Technology, chapter 5, *Standards, measurement and gauging,* p. 70.

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4.0 Calculating The Off-Set Distance For The Universal Swivel Machine Vice

Key Learning Points

Use of trigonometrical functions to calculate the sides of a triangle used for offsetting the machine vice.

4.1 Use Of Trigonometrical Functions To Calculate The Sides Of A Triangle Used For Offsetting The Machine Vice

An angle gauge block or a sine bar and slip gauges can be used to accurately off-set a universal swivel machine vice to the required angle. The sine bar is a steel block, which has a roller bars fixed at each end. One roller is placed on the base and the other on a set of slip gauges, which causes the sine bar to offset at the required angle. The slip gauge height is calculated by using trigonometry, as the distance between the rollers is known and the offset angle is specified on the drawing, therefore the only unknown is the height of the slip gauges.

Ref: Black, Bruce J 2004, Workshop processes, practices and materials, 3rd edn, Elsevier Science & Technology, chapter 5, *Standards, measurement and gauging*, p. 70.

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

ISBN-13: 9780750665759

5.0 Off-Setting A Universal Swivel Machine Vice Using A Dial Indicator

Key Learning Points

Datum edge, off-setting machine head/vice, use of roller/plunger clock to measure angular setting.

5.1 Datum Edge, Off-Setting Machine Head/Vice, Use Of Roller/Plunger Clock To Measure Angular Setting

When machining a slot at an angle, the vice can be rotated by the required angle using the graduations at the side of the vice. To get a more accurate angle, angle gauge blocks or a sine bar can setup as explained above and a dial indicator can be run along its length and the vice adjusted until the clock runs true.

Ref: Black, Bruce J 2004, Workshop processes, practices and materials, 3rd edn, Elsevier Science & Technology, chapter 5, *Standards, measurement and gauging*, p. 70.

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Ref: Black, Bruce J 2004, Workshop processes, practices and materials, 3rd edn, Elsevier Science & Technology, chapter 6, *Measuring equipment*, p. 95.

ISBN-13: 9780750660730

6.0 Mill A Slot At An Angle To The Datum Surfaces And Measure Its Size Using Slip Gauges

Key Learning Points

Line and end standard measurements (slip gauges). Machining of slots, location and machining to tolerance. Use of slip gauges to gauge the limits of size of the width of a slot.

6.1 Line And End Standard Measurements (Slip Gauges)

The distance between two lines is called line measurement, an example of this is the rule, which can be used to measure a component. The distance between two faces is called end measurement, where callipers and micrometers can be used. Slip gauges can also be used to check the distance two faces.

Ref: Black, Bruce J 2004, Workshop processes, practices and materials, 3rd edn, Elsevier Science & Technology, chapter 5, *Standards, measurement and gauging,* p. 70.

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6.2 Machining Of Slots, Location And Machining To Tolerance

A set of slip gauges consist of a range or varying size blocks that can be built up to create the upper and lower limits of the slot be checked. The polished surfaces allow the blocks to be wrung together to form a stack.

6.3 Use of slip gauges to gauge the limits of size of the width of a slot

The workpiece should be marked up prior to setting it up in the vice, which is then off-set to the required angle. The slot should be rough machined close to the scribed line. Finish one side and then use the vernier callipers to measure the slot. For more accurate measurement, two sets of slip gauges can be stacked at the lower and upper tolerance band and fine cuts taken.

Ref: Black, Bruce J 2004, Workshop processes, practices and materials, 3rd edn, Elsevier Science & Technology, chapter 5, *Standards, measurement and gauging,* p. 70.

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Summary

Locating datum edges, drilling and reaming holes: The *Edge finder*, which rotates in the spindle, is used to accurately find the datum edge/s of a workpiece. The digital readout is then set to zero for both the X and Y axis. The table is moved by the distance specified on the drawing for both the X and Y coordinates The centre drill is used prior to the drilling operation. The spindle speed for the drills and reamers are calculated using the RPM formula. The recommended amount of stock that a reamer should remove is 0.3 to 0.5mm depending on the size or the hole being reamed. For reaming, a general rule is to reduce the speed by at least a half and double the feed rate to that of a similar size drill. The reamer is fed into the drilled hole using coolant.

Off-setting machine head or workpiece for machining angular surfaces: Angular surfaces can be machined by either tilting the vertical head to the required angle or by tilting the workpiece.

Milling a vee groove in a workpiece and measuring with roller/slip gauges: The workpiece should first be marked out prior to being setup in a machine vice. An appropriate size end mill is inserted into the spindle, which is then tilted off at 45º. The markings can be used as a guide to rough out the vee close to the scribed lines. 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 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 will be on the drawing.

Calculating the off-set distance for the universal swivel machine vice: An angle gauge block or a sine bar and slip gauges can be used to accurately off-set a universal swivel machine vice to the required angle. The sine bar is a steel block, which has a roller bars fixed at each end. One roller is placed on the base and the other on a set of slip gauges, which causes the sine bar to offset at the required angle. The slip gauge height is calculated by using trigonometry, as the distance between the rollers is known and the offset angle is specified on the drawing, therefore the only unknown is the height of the slip gauges.

Off-setting a universal swivel machine vice using a dial indicator: When machining a slot at an angle, the vice can be rotated by the required angle using the graduations at the side of the vice. To get a more accurate angle, angle gauge blocks or a sine bar can setup as explained above and a dial indicator can be run along its length and the vice adjusted until the clock runs true.

Milling a slot at an angle and measure using a slip gauge: Slip gauges can also be used to check the distance two faces. A set of slip gauges consist of a range or varying size blocks that can be built up to create the upper and lower limits of the slot be checked. The polished surfaces allow the blocks to be wrung together to form a stack. The workpiece should be marked up prior to setting it up in the vice, which is then off-set to the required angle. The slot should be rough machined close to the scribed line. Finish one side and then use the vernier callipers to measure the slot. For more accurate measurement, two set of slip gauges can be stacked at the lower and upper tolerance band and fine cuts taken.

Suggested Exercises

1. What is the recommended amount of stock that should be removed by a reamer?
2. Calculate the speed and feed for reaming a Ø10mm hole.
3. Explain the difference between line and end measurement.
4. Machine 10mm wide vee grooves using two methods (i) by tilting the head of the machine and (ii) by offsetting the workpiece with a protractor.
5. Using an end mill, machine a 10mm wide slot by 8mm deep into a mild steel plate. The tolerance of the 10mm dimension is +/- 0.06, therefore to check the slot 'wring' two stacks of slip gauges at the upper and lower limits; (i) 9.94 and (ii) 10.06.

Questions

1. How is an angular surface machined on a workpiece?
2. Explain how a workpiece is machine by (i) Tilting the vertical head and (ii) Tilting the workpiece
3. How is the depth of a vee groove measured?
4. Calculate the spindle speed for reaming a Ø12mm hole.
5. Explain how a slot is machined at an angle in a mild steel block.

Answers

1. Angular surfaces can be machined by either (i) tilting the vertical head (ii) tilting the workpiece or (iii) using a chamfering tool.
2. **Tilting the vertical head:** This is achieved by rotating the head by the required angle using the graduations on the head of the machine. The workpiece is held in the vice and machined at the inclined angle.
   Tilting the workpiece: This is done by setting up the workpiece in a standard machine vice at the required angle, which can be aligned with a protractor or with a sine bar and slip gauges. The workpiece can also be setup in a universal vice, which can be tilted to the required angle using graduations on the vice and then locked in place
3. 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.
4. To find the correct RPM (revs per minute) for a Reamer, use the RPM formula to get the spindle speed for the corresponding size Drill and divide the answer by two to get the Reamer spindle speed.

$$\text{RPM} = \frac{\text{Cutting Speeds in metres per minute x 1000}}{\text{Circumference of cutter in millimetres}}$$

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

Using a typical cutting speed of 30 meters/min for mild steel and 3.14 for л, the spindle speed is calculated as follows:

$$\text{RPM (Drill)} = \frac{30 \times 1000}{3.14 \times 12}$$

$$= 796$$

$$\text{RPM (Reamer)} = \frac{796}{2}$$

$$= 398$$

5. When machining a slot at an angle, the vice can be rotated by the required angle using the graduations at the side of the vice. To get a more accurate angle, angle gauge blocks or a sine bar can setup as explained above and a dial indicator can be run along its length and the vice adjusted until the clock runs true.

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