Trade of Toolmaking			
Module 3:	Milling		
Unit 7:	Blind Slots & Corner		
	Cut- Outs		
	Phase 2		

Published by



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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 define and calculate density, volume and mass. This unit will explain the techniques associated with locating datum edges, machining blind slots, reaming and jig-boring holes.

Introduction

Module three of this course covers milling. This is the seventh unit in module three and explains how to calculate the volume and mass of the workpiece prior to machining and of the material being removed. It may also be a requirement to calculate the mass of the waste being generated and the percentage waste in relation to the original workpiece.

This unit explains the techniques associated with setting up a workpiece and machining a blind slot using a slot drill, using reamers for standard holes sizes and the use of boring heads for machining large bores or non-standard sized bores.



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

- Define density and calculate the density of sample materials, volume and mass reduction due to machining..
- Locate datum edges and mill enclosed and blind slots on component parts to the specified dimensions and tolerances.
- Mill components with corner cut-outs on component parts to the specified dimensions and tolerances.
- Jig bore and ream holes accurately to central locations on the milling machine.

1.0 Calculating Density, Volume And Mass Reduction Due To Machining

Key Learning Points

Material removal: volume reduction and percentage waste. Mass and volume: material removed in internal pocket. Density of materials: calculation of density of regular shaped objects. Density of aluminium, steel, copper, brass, tool steel, tin, lead and bronze.

1.1 Material Removal: Volume Reduction And Percentage Waste

If a slot is to be machined through the block, then the percentage waste can be determined by calculating the volume of the slot and dividing it by the original volume, multiply the answer by 100 to determine the percentage waste.

Ref: Bird, John 2005, *Basic engineering mathematics*, 4th edn, Elsevier Science & Technology, chapter 24, *Volumes of common solids*, p.180. ISBN-13: 9780750665759

1.2 Mass And Volume: Material Removed In Internal Pocket

Mass is more commonly referred to as *Weight*, but in physics and engineering weight means the pull of gravity on an object. Mass is measured in kilograms and weight is measured in Newton's (kgm/s^2) . Mass $(kg) = Volume (m^3) x$ Density (kg/m^3) , therefore the Mass of the slot discussed above, can be determined if the volume is multiplied by the density value (known value taken from the data sheet).

The *Volume* of a regular object, such as a rectangular block of mild steel, can be determined by multiplying its length by breath by height.

1.3 Density Of Materials: Calculation Of Density Of Regular Shaped Objects

Density is mass per unit volume. It is the ratio of the amount of matter in an object compared to its volume, e.g. a small, heavy object, such as a block of steel, is denser than a larger object of the same mass, such as a block of wood. A data sheet is available listing the densities of all common materials.

Ref: Black, Bruce J 2004, *Workshop processes, practices and materials*, 3rd edn, Elsevier Science & Technology, chapter 13, *Materials*, p. 211. ISBN-13: 9780750660730

1.4 Density Of Aluminium, Mild Steel, Tool Steel, Copper, Brass, Bronze, And Lead

The density of the following metals is as follows:

Aluminium $= 2.8 \text{ kg/m}^3$ Mild Steel $= 7.9 \text{ kg/m}^3$ Tool Steel $= 7.8 \text{ kg/m}^3$ Copper $= 8.9 \text{ kg/m}^3$ Brass $= 8.4 \text{ kg/m}^3$ Bronze $= 8.4 \text{ kg/m}^3$ Lead $= 9.4 \text{ kg/m}^3$

2.0 Locating Datum Edges And Milling Blind Slots

Key Learning Points

Setup of work in machine vice job planning and efficiency. Use of edge finders to establish datum edges. Identification and use of end mill and slot drill cutters. Controlled slot milling. Controlled hand feed. Depth measurement.

2.1 Setup Of Work In Machine Vice, Job Planning And Efficiency

Job planning is important prior to starting any task. The drawing should first be studied and understood. The sequence of operations should be planned so as to minimise the number of setups in the vice. The correct tools and should be selected and the speeds and feeds calculated before starting the machining operations. The workpiece should be marked out prior to setting it up in the vice.

2.2 Use Of Edge Finders To Establish Datum Edges

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.

2.3 Identification And Use Of End Mill And Slot Drill Cutters

The *End Mill* has multiple cutting teeth. The end teeth do not run all the way to the centre, so therefore cannot be sunk into the workpiece. They can be used for cutting light slots and for machining the top surface and side walls of the workpiece. The *Slot Drill* has two straight or helical cutting teeth on the cylindrical surface and end teeth that are cut to the centre. This type of cutter can be driven directly into the workpiece and then fed length ways to form a blind slot.

Ref: Black, Bruce J 2004, *Workshop processes, practices and materials*, 3rd edn, Elsevier Science & Technology, chapter 11, *Milling*, sec. 11.3, *Milling cutters*, p. 179. ISBN-13: 9780750660730

2.4 Controlled Slot Milling

When machining a slot in a workpiece, the automatic feed can be used to control the movement of the cutter, which will produce a more uniform surface finish in the slot.

2.5 Controlled Hand Feed

A slot can also be machined by using the hand feed, but this will not produce a finish as good as automatic feed. But with experience a good surface finish can be obtained.

2.6 Depth Measurement

The depth of a slot is measured with a depth micrometer. The depth gauge on the vernier caliper can also be used, but is not as accurate as the depth micrometer.

Ref: Black, Bruce J 2004, *Workshop processes, practices and materials*, 3rd edn, Elsevier Science & Technology, chapter 6, *Measuring equipment; Depth micrometer*, p. 105. ISBN-13: 9780750660730

3.0 Milling Components With Corner Cut-Outs

Key Learning Points

Milling components with corner cut-outs.

3.1 Milling Components With Corner Cut-Outs

When machining corner cut-out in a workpiece, it is important to mark out the workpiece and position it on parallels so the scribed lines are above the jaws of the vice. The corner cut-outs can be rough machined to the scribed lines, prior to using measuring instruments such as the vernier callipers, the micrometer and the depth micrometer.

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. ISBN-13: 9780750660730

4.0 Jig Boring And Reaming Holes Accurately To Central Locations

Key Learning Points

Use of telescopic gauges and slip gauges. Jig boring of holes on the milling machine. Reaming of holes on the milling machine. Achievement of toleranced dimensions and symmetry. Deburring of components: hazards avoidance, reduction of measurement errors.

4.1 Use Of Telescopic Gauges And Slip Gauges

The bore can be checked with a telescopic gauge and micrometer. It is important to recheck the bore as errors easily can be made when using these gauges. Slip gauges can be used to check the width of milled slots.

Ref: Black, Bruce J 2004, *Workshop processes, practices and materials*, 3rd edn, Elsevier Science & Technology, chapter 5, *Standards, measurement and gauging*, p. 70. ISBN-13: 9780750660730

Ref: Black, Bruce J 2004, *Workshop processes, practices and materials*, 3rd edn, Elsevier Science & Technology, chapter 6, *Measuring equipment*, p. 95. ISBN-13: 9780750660730

4.2 Jig Boring Of Holes On The Milling Machine

When holes need to be machined to a high degree of accuracy and surface finish, the jig boring tools need to be used. For smaller holes reamers can be used, but for larger holes or holes of non-standard size, the jig boring tool needs to be used. The *Boring Head* has an adjustable boring bar, which needs to be set prior to machining. The boring head is fed into the workpiece using the automatic feed in the machine head.

4.3 Reaming Of Holes On The Milling Machine

When using the *Reamer*, the hole needs to be pre-drilled. 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.

Ref: Black, Bruce J 2004, *Workshop processes, practices and materials*, 3rd edn, Elsevier Science & Technology, chapter 11, *Drilling Reamer*, p. 133. ISBN-13: 9780750660730

4.4 Achievement Of Toleranced Dimensions And Symmetry

If the holes to be bored are dimensioned from a central feature such as a hole, then this hole should be used as the datum. The spindle can be positioned accurately over the centre of this hole by using a dial indicator

4.5 Deburring Of Components: Hazards Avoidance, Reduction Of Measurement Errors

Hand held deburring tools are available for removing burrs from machined holes. When measuring the depth of a slot, it is important remove the burr with a flat file prior to using the depth micrometer.

4.6 First And Third Angle Projection, Dimensioning

Multi-view orthographic projection is used in engineering drawing working to BS 8888. 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.

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*, p. 33. ISBN-13: 9780750651202

Summary

Calculating density, volume and mass reduction due to machining: *Density* is mass per unit volume. It is the ratio of the amount of matter in an object compared to its volume, e.g. a small, heavy object, such as a block of steel, is denser than a larger object of the same mass, such as a block of wood. A data sheet is available listing the densities of all common materials.

The *Volume* of a regular object, such as a rectangular block of mild steel, can be determined by multiplying its length by breath by height. If a slot is to be machined through the block, then the percentage waste can be determined by calculating the volume of the slot and dividing it by the original volume, multiply the answer by 100 to determine the percentage waste.

Mass is more commonly referred to as *Weight*, but in physics and engineering weight means the pull of gravity on an object. Mass is measured in kilograms and weight is measured in Newton's (kgm/s^2) . Mass $(kg) = Volume (m^3) x$ Density (kg/m^3) , therefore the Mass of the slot discussed above, can be determined if the volume is multiplied by the density value (known value taken from the data sheet).

Locating datum edges and milling blind slots: The workpiece should be marked out prior to setting it up in the vice. 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 *Slot Drill* has two straight or helical cutting teeth on the cylindrical surface and end teeth that are cut to the centre. This type of cutter can be driven directly into the workpiece and then fed length ways to form a blind slot. The *End Mill* has multiple cutting teeth. The end teeth do not run all the way to the centre, so therefore cannot be sunk into the workpiece. They can be used for cutting light slots and for machining the top surface and side walls of the workpiece.

Milling components with corner cut-out: When machining corner cut-out in a workpiece, it is important to mark out the workpiece and position it on parallels so the scribed lines are above the jaws of the vice. The corner cut-outs can be rough machined to the scribed lines, prior to using measuring instruments such as the vernier callipers, the micrometer and the depth micrometer.

Jig boring and reaming holes accurately to central locations: When holes need to be machined to a high degree of accuracy and surface finish, reamers and jig boring tools need to be used. For smaller holes reamers can be used, but for larger holes or holes of non-standard size, the jig boring tool needs to be used. When using the *Reamer*, the hole needs to be pre-drilled. 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. The *Boring Head* has an adjustable boring bar, which needs to be set prior to machining. The boring head is fed into the workpiece using the automatic feed in the machine head. The bore can be checked with a telescopic gauge and micrometer. It is important to recheck the bore as errors easily can be made when using these gauges. If the holes to be bored are dimensioned from a central feature such as a hole, then this hole should be used as the datum. The spindle can be positioned accurately over the centre of this hole by using a dial indicator.

Hand held deburring tools available for removing burrs from machined holes. When measuring the depth of a slot, it is important remove the burr with a flat file prior to using the depth micrometer.

Suggested Exercises

- 1. Calculate the percentage waste when a 12mm wide by 12mm deep slot is machined through a block of mild steel 30mm wide by 25mm high by 50mm long.
- 2. Explain the difference between mass and weight.
- 3. Sketch as end mill and a slot drill and explain where each one is used.
- 4. What is the difference between first and third angle projection in technical drawing.
- 5. What is the meaning of Density.

Questions

- 1. What units are Mass and Weight measured in?
- 2. How is the volume of a rectangular mild steel block calculated?
- 3. What type of milling cutter is used to drill a slot in a mild steel block?
- 4. What measuring instruments are used to measure the depth of a slot and which instrument gives the most accurate reading.
- 5. What is the recommended amount of stock that should be removed by a reamer?

Answers

- 1. Mass is measured in kilograms and Weight is measured in Newton's (kgm/s^2) .
- 2. The Volume of a rectangular block of mild steel can be determined by multiplying its length by breath by height.
- 3. The Slot Drill has two straight or helical cutting teeth on the cylindrical surface and end teeth that are cut to the centre. This type of cutter can be driven directly into the workpiece and then fed length ways to form a blind slot.
- 4. The depth of a slot is measured with a depth micrometer. The depth gauge on the vernier caliper can also be used, but is not as accurate as the depth micrometer.
- 5. When using the Reamer, the hole needs to be pre-drilled. The recommended amount of stock that a reamer should remove is 0.3 when reaming holes less than Ø10mm and up to 0.5mm for drills over Ø 10mm.

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