Trade of Toolmaking	
Module 1:	Induction & Bench Fitting
Unit 3:	Drilling, Counterboring & Countersinking
	Phase 2

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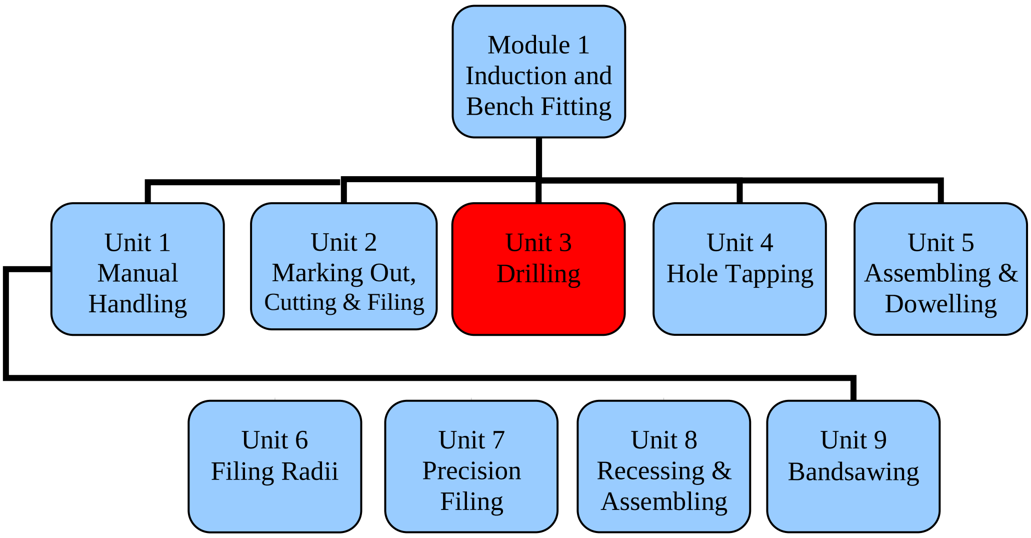
Unit Objective

On completion of this unit you will be able to create component drawings, calculate cutting/drilling speeds for drilling machines, drill components using drills, counterbore and countersink tools.

Introduction

Module one of this course covers induction and bench fitting. This is the third unit in module one and introduces the techniques associated with the creation of freehand drawings on grid paper from multi-view drawings and also in how to create detailed drawings using drawing instruments. This unit also explains how to use formulae to calculate the correct speeds,which will ensure efficient machine operation and longer tool life. It is important to use safe working procedures while operating and maintaining drilling machines.

Drilling, counterboring and countersinking operations are used through out the industry to create clearance holes for screws in order to fasten steel parts to each other. The drilled hole provides clearance for the screw thread to pass through. The counterbore tool creates a larger diameter hole to house the head of the socket head screw. The countersink tool creates a tapered hole for the countersunk head of the screw.



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

- Create freehand drawings and sketches in orthographic projection on plain/grid paper.
- Draw component part drawings using instruments in first and third angle projection incorporating simple section planes hatched appropriately.
- Calculate the cutting and drilling speeds for mild steel using drills, countersinks and counterboring bits.
- Identify the difference between bench and pillar drilling machines and identify the main parts of the drill.
- Safely drill components using a bench or pillar drilling machine using the correct speeds and feeds for the component material being machined and cutting tool being used.
- Drill clearance holes to depths. Drill pilot holes, counterbore and countersink tools to the correct depth.

1.0 Freehand Drawings Orthographic Projection

Key Learning Points

Freehand drawing and sketches in orthographic projection on plain/grid paper.

1.1 Freehand Drawing And Sketches In Orthographic Projection On Plain/Grid Paper

Multi-view orthographic projection is used in engineering drawing to represent component parts. Drawings can be sketched in freehand using plain or grid paper or more accurate and detailed multi-view drawings can be created in first and third angle projection working to BS 8888, using drawing instruments and a drafting board.

Ref: Simmons, Colin H & Maguire, Dennis E 2004, *Manual of engineering drawing*, 2nd edn, Elsevier Science & Technology, chapter 1, *Principles of first and third angle orthographic projection; Projection exercises*, p. 38.

ISBN-13: 9780750651202

2.0 Component Drawings Using Instruments in First and Third Angle

Key Learning Points

Orthographic projection incorporating section planes and hatching to BS 8888.

2.1 Orthographic Projection Incorporating Section Planes And Hatching To BS 8888

When a feature on a component is hidden or is inside the component and cannot be shown clearly on one of the projected views, then a sectioned view is taken through the part, showing the sectioned view at a right angle to the view.

Ref: Simmons, Colin H & Maguire, Dennis E 2004, *Manual of engineering drawing*, 2nd edn, Elsevier Science & Technology, chapter 8, *Sections and sectional views*, p. 64.

ISBN-13: 9780750651202

3.0 Cutting/Drilling Speeds for Mild Steel

Key Learning Points

Calculation of cutting speeds and feeds using formulae and charts for drilling, countersinking and counterboring. Selection of appropriate drill and pilot hole sizes for clearance holes. Multiplication and division and the manipulation of formulae.

3.1 Calculation Of Cutting Speeds And Feeds

In order to use the drilling machine efficiently it is important to calculate the correct cutting speeds and feeds using the relevant formulae and also to select the correct size drill, counterboring and countersink tools. The correct speeds and feeds will ensure more efficient machine operation and will result in reduced tool wear. When drilling using a bench or pillar drill, the feed rate is normally controlled by hand.

This is calculated by entering the cutting speed and the cutter diameter into the RPM formula, where the Cutting Speed is expressed in meters per minute. Charts are available that recommend the correct cutting speed for a particular material, e.g. for mild steel, a typical cutting speed of 30 meters/min is used and for tool steel the cutting speed is 20 metres/min. Therefore the spindle speed will be lower for the tool steel, which is a harder material, when compared to that of mild steel.

To find the correct RPM (revs per minute) setting of the spindle the following formula should be used;

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

$$= \frac{\text{S x 1000}}{\pi \text{ x D}}$$

Ref: Black, Bruce J 2004, *Workshop processes, practices and materials*, 3rd edn, Elsevier Science & Technology, chapter 7, p. 123.

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3.2 Selection Of Appropriate Drill And Pilot Hole Sizes For Clearance Holes

When two mild steel plates need to be held together with screws, the top plate will need countersunk or counterbore holes and the bottom plate will have threaded holes. If for example the threaded holes are M6, then the clearance hole for the screw hole in the top plate will need to be Ø6.1mm allow the screw to go through. The recommended clearance hole sizes can be found in various screw thread data charts, such as the Zeus Book.

Ref: Zeus Precision Charts Ltd. 2007, *Zeus precision data charts and reference tables for drawing office, toolroom & workshop,* 2007 edn, Zeus Precision Charts Ltd.

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3.3 Multiplication And Division And The Manipulation Of Formulae

Integers are whole numbers, such as 1,2,3,4 etc.. A *positive integer* is for example +4 and a *negative integer* -4. Between the negative and positive integers is the number 0, which is neither positive nor negative. The four basic signs are + (add), -(subtract), x (multiply) and ÷ (divide).

Ref: Bird, John 2005, *Basic Engineering mathematics,* 4th edn, Elsevier Science & Technology, chapter 1, *Basic arithmetic.*

ISBN-13: 9780750665759

4.0 Bench And Pillar Drilling Machines

Key Learning Points

Uses and application of parallel and taper shank drills. Drill sizes and angles, drill types, functions, centre drills, chucks and sleeves. Types and functions of different drilling machines: bench and pedestal.

4.1 Uses And Application Of Parallel And Taper Shank Drills

The drill is used to remove the maximum volume of material in a minimum period of time. The drill will not produce a precision hole. If an accurate size, roundness and good finish are required then a reamer needs to be used.

Drills are available with straight shank and taper shanks. The straight shank is held in a drill chuck. The chuck is fitted with a morse tapered shank, which fits into a corresponding morse taper in the spindle of the drilling machine. A tapered shank drill shank can be fitted directly into the tapered spindle of the drilling machine. To remove the morse tapered shank from the spindle, a narrow tapered key called a *drift* can be inserted into a slot in the spindle. It is then impacted with a mallet to hit the tang at the top of the tapered shank, which forces the tapers apart.

Ref: Black, Bruce J 2004, *Workshop processes, practices and materials,* 3rd edn, Elsevier Science & Technology, chapter 8, *Drilling* p. 129.

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4.2 Drill Sizes And Angles, Drill Types, Functions, Centre Drills, Chucks and Sleeves

Drills are available in various sizes and types. The standard helix angle is 30º and the point angle is 118º, which is suitable for cutting steel and cast iron. For drilling brass and bronze the helix angle is 20º, this is called a slow helix. Prior to drilling a hole with the standard drill, a centre drill is used to create a small tapered pilot hole, which is used to guide the drill.

The straight shank is held in a drill chuck. A tapered shank drill shank can be fitted directly into the tapered spindle of the drilling machine. Tapered sleeve adapters are used for smaller drills.

Ref: Black, Bruce J 2004, *Workshop processes, practices and materials,* 3rd edn, Elsevier Science & Technology, chapter 7, *Cutting tools and cutting fluids* p. 121.

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4.3 Types and Functions Of Different Drilling Machines: Bench And Pedestal

Two types of drilling machines that are used in the Toolroom are the Bench Drilling Machine and the Pillar Drilling Machine. The bench drilling machine is the simplest and is mounted on a bench. It takes drills up to 12.5mm diameter. The spindle speed is varied by altering the belt position on the stepped pulleys. The spindle is normally at right angles to the work and the feed handle is used to feed the drill into the work. The work is normally held in a vice which is mounted on the work table.

The pillar drilling machine is larger and is floor mounted. It has all the features of the smaller bench mounted drilling machine. The spindle is driven by a more powerful motor and the spindle speed is varied by a gearbox. A power feed is provided for drilling at a controlled rate into the work. Larger work can be drilled as the work table can be lowered close to floor level.

Ref: Black, Bruce J 2004, *Workshop processes, practices and materials*, 3rd edn, Elsevier Science & Technology, chapter 8,. *Drilling*, p. 129.

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5.0 Drilling Of Components On Bench And Pillar Drilling Machines

Key Learning Points

Planning procedures in relation to accurate marking out and location. Drilling machine operation, safe use of drilling machines. Friction/heat generated in the cutting process. Function and advantages of using coolant. Eye, ear and hair protection/protective clothing.

5.1 Planning Procedures In Relation To Accurate Marking Out And Location

The workpiece is marked with scribing block or a vernier height gauge to the dimensions specified on the drawing. The scribed lines should be marked from the same datum edge as specified on the drawing. For angled lines use the protractor or straight edge and scriber. For scribing radii, punch the centre point and scribe the radius using dividers.

Ref: Black, Bruce J 2004, *Workshop processes, practices and materials*, 3rd edn, Elsevier Science & Technology, chapter 3, *Marking out* p. 44.

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5.2 Drilling Machine Operation, Safe Use Of Drilling Machines

The workpiece should be clamped to the table or held in a vice. Work should never be held by hand, as high forces are transmitted by the revolving tool and the work can be wrenched from your hand causing injury. Ensure machine is stopped before adjusting belts and always replace belt guards.

Ref: Black, Bruce J 2004, *Workshop processes, practices and materials*, 3rd edn, Elsevier Science & Technology, chapter 8, *Drilling*, p. 132.

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5.3 Friction/Heat Generated In The Cutting Process

When the component is being drilled, heat will be generated at the cutting edge, due to frictional forces. This can cause the drill tip to wear and break down.

5.4 Function And Advantages Of Using Coolant

When the component is being drilled, heat will be generated at the cutting edge, due to frictional forces. This can be avoided by using coolant which cools and lubricates the work and drill. The advantages of coolant are: reduced wear on the drill, drilling speeds and feeds can be increased and a better surface finish is produced.

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

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5.5 Eye, Ear And Hair Protection/Protective Clothing

When using drilling machines and cutting tools, safe working procedures need to be applied, such as eye protection, loose clothing or gloves should not be worn and long hair should be tied back.

Ref: Black, Bruce J 2004, *Workshop processes, practices and materials*, 3rd edn, Elsevier Science & Technology, chapter 1, *Safe practices.*

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6.0 Drilling Of Components On Bench And pillar Drilling Machines

Key Learning Points

Depth measurement, use of countersink and counterboring sizes.

6.1 Depth Measurement, Use Of Countersink And Counterboring Sizes

Steel plates are normally fastened together with screws. One of the plates will require clearance holes for the screws to pass through and a seating for the head, while the other metal plate will require threaded holes. Hole tapping is discussed in more detail in Unit 4. The drilled hole provides clearance for the screw thread to pass through. When fastening the metal plates with *socket cap screws*, then a *counterbore tool* or a *drill* can be used to create a hole to house the head of the screw. For the *countersink screws* a *countersink tool* is used to create a tapered hole to house the head of the screw. The hole depth can be set by adjusting the *depth stop* and measuring with a callipers until the required depth has been achieved. All the other holes can then be drilled at constant depth.

Ref: Black, Bruce J 2004, *Workshop processes, practices and materials*, 3rd edn, Elsevier Science & Technology, chapter 8, *Drilling*, p. 129.

ISBN-13: 9780750660730

Summary

Freehand drawings and sketches in orthographic projection: Multi-view orthographic projection is used in engineering drawing to represent component parts. Drawings can be sketched in freehand using plain or grid paper or more accurate and detailed multi-view drawings can be created in first and third angle projection working to BS 8888, using drawing instruments and a drafting board.

Component part drawings using instruments in first and third angle: When a feature on a component is hidden or is inside the component and cannot be shown clearly on one of the projected views, then a sectioned view is taken through the part, showing the sectioned view at a right angle to the view.

Cutting/drilling speeds for mild steel: In order to use the drilling machine efficiently it is important to calculate the correct cutting speeds and feeds using the relevant formulae and also to select the correct size drill, counterboring and countersink tools. The correct speeds and feeds will ensure more efficient machine operation and will result in reduced tool wear.

Bench and pillar drilling machines: Two types of drilling machines are used in the Toolroom are the Bench Drilling Machine and the Pillar Drilling Machine. The bench drilling machine is the simplest and is mounted on a bench. The spindle speed is varied by altering the belt position on the stepped pulleys. The spindle is normally at right angles to the work and the feed handle is used to feed the drill into the work. The work is normally held in a vice which is mounted on the work table.

The pillar drilling machine is larger and is floor mounted. It has all the features of the smaller bench mounted drilling machine. The spindle is driven by a more powerful motor and the spindle speed is varied by a gearbox. A power feed is provided for drilling at a controlled rate into the work. Larger holes can be drilled and much larger work can be drilled as the work table can be lowered close to floor level.

Drilling of components on bench and pillar drilling machines: When using a drilling machine and cutting tools, it is important to use safe working procedures at all times. Ensure machine is stopped before adjusting belts and always replace belt guards.

When the component is being drilled, heat will be generated at the cutting edge, due to frictional forces. This can cause the drill tip to wear and break down. This can be avoided by using coolant.

Drilling of holes, counterbore and countersink holes to correct depths: Steel plates are normally fastened together with screws. One of the plates will require clearance holes for the screws to pass through and a seating for the head, while the other metal plate will require threaded holes. The drilled hole provides clearance for the screw thread to pass through. When fastening the metal plates with socket cap screws, then a counterbore tool is used to create a hole to house the head of the screw. For the countersink screws a countersink tool is used to create a tapered hole to house the head of the screw.

Suggested Exercises

1. Calculate the spindle speed (RPM) for drilling a Ø6mm hole into a mild steel plate, using the RPM formula. Use a cutting speed of 30 m/min.
2. Calculate the correct spindle speed for the following series of holes, Ø3mm, Ø6mm and Ø9mm. Adjust the spindle speed to the nearest setting on the pedestal drilling machine for each drill.
3. Sketch a Pedestal Drilling Machine and label the main parts.
4. Explain the function and advantages of using coolant when drilling.

Questions

1. Calculate the spindle speed (RPM) for drilling a Ø10mm hole into a mild steel plate.
2. Use the Zeus Book to determine the tapping drill size for an M4 screw thread.
3. Drills are available with two types of shanks, what are they and how are they used?
4. Explain the differences between the two types of drilling machines used in the Toolroom.
5. What are the advantages of coolant when drilling holes.

Answers

1. To find the correct RPM (revs per minute) setting of the spindle the following formula should be used:

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

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

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

$$\text{RPM} = \frac{30 \times 1000}{3.14 \times 10}$$

$$= 955$$

2. The tapping drill size for an M4 screw thread is Ø3.3mm (see Zeus Book).
3. Drills are available with straight shank or a tapered shank. The straight shank is fitted directly into a drill chuck. A drill with a tapered shank needs to be assembled either with a Morse tapered sleeve or can be fitted directly into the tapered spindle of the drilling machine, depending on its size.
4. The two types of drilling machines that are used in the Toolroom are the (i)Bench Drilling Machine and (ii) the Pillar Drilling Machine.
   - The bench drilling machine is the simplest and is mounted on a bench. It takes drills up to 12.5mm diameter. The spindle is normally at right angles to the work and the feed handle is used to feed the drill into the work. The work is normally held in a vice which is mounted on the work table.
   - The pillar drilling machine is larger and is floor mounted. It has all the features of the smaller bench mounted drilling machine. The spindle is driven by a more powerful motor and the spindle speed is varied by a gearbox. A power feed is provided for drilling at a controlled rate into the work. Larger work can be drilled as the work table can be lowered close to floor level.
5. The advantages of coolant are as follows: (i) reduced wear on the drill, (ii) drilling speeds and feeds can be increased and (iii) a better surface finish is produced.

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

Zeus Precision Charts Ltd. 2007, *Zeus precision data charts and reference tables for drawing office, toolroom & workshop*, 2007 edn, Zeus Precision Charts Ltd.

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