Trade of Toolmaking	
Module 1:	Induction & Bench Fitting
Unit 8	Recessing and Assembling Parts
	Phase 2

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Document Release History

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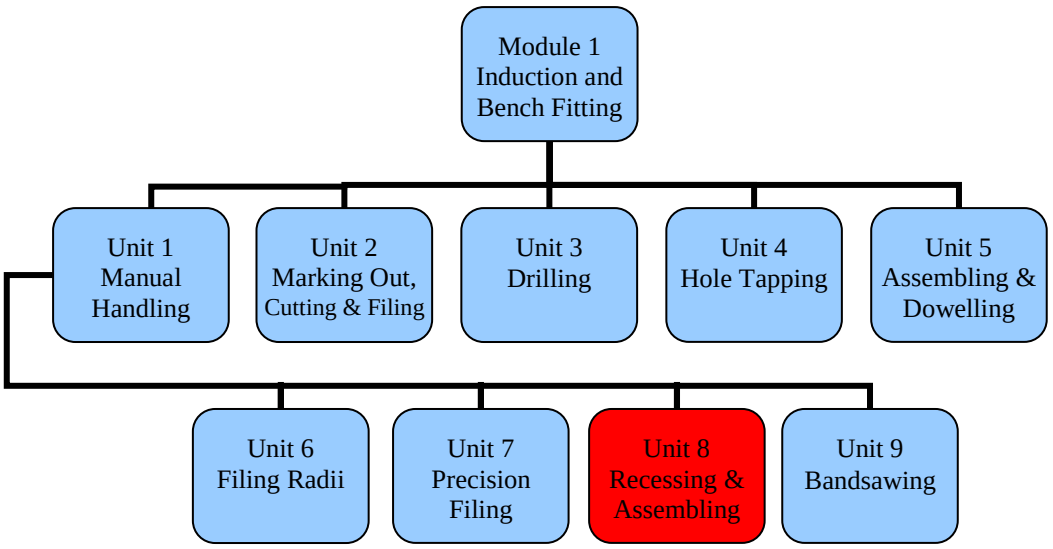
Unit Objective

On completion of this unit you will be able to do calculations using trigonometry, manufacture components with angular mating surfaces and accurately measure the components.

Introduction

Module one of this course covers induction and bench fitting. This is the eight unit in module one and explains how to calculate the lengths of the sides of components using trigonometry, the techniques associated with recessing and assembling parts and the manufacture of components that assemble symmetrically and are inter-changeable with other parts.

In industry, e.g. the automobile industry, components are mass-produced on CNC machines and need to be interchangeable with each other. This is important when a sub-part of an assembly wears or breaks and needs to be replaced. In bench fitting, parts can be created to a high degree of accuracy by using bench fitting techniques. If these parts are filed within the tolerances specified on the drawing, they will fit within any device of the same type.



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

- Calculate the lengths of the sides on components using trigonometry.
- Mark out, drill, cut, file and assemble components with angular mating surfaces to the specified accuracy and finish.
- Manufacture components that assemble symmetrically and display inter-changeability of symmetrical assembly.
- Produce a range of components to assemble correctly with symmetry.
- Accurately measure precision components.

1.0 Calculations Using Trigonometry

Key Learning Points

Calculation of true lengths using trigonometry. Use of Pythagoras theorem to calculate the length of the sides of triangles.

1.1 Calculation Of True Lengths Using Trigonometry

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 to be positioned 30mm from the origin and off-set at an angle at 20º, 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:

$$\text{Sin } 20^\circ = \frac{Y}{30}$$

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

$$\text{Cos } 20^\circ = \frac{X}{30}$$

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

1.2 Use Of Pythagoras Theorem To Calculate The Length Of The Sides Of Triangles

Trigonometry means the measurement of triangles. The Pythagoras Theorem can be used to find the length of one side or a right angled triangle if the lengths of the other two sides are known. The theorem states that for a right angled triangle the square on the hypotenuse (longest side) is equal to the sum of the squares on the other two sides.

Ref: Bird, John 2005, *Basic engineering mathematics*, 4th edn, Elsevier Science & Technology, chapter 19, *Introduction to trigonometry*, p. 142.
ISBN-13: 9780750665759

2.0 Manufacturing Components With Angular Mating Surfaces

Key Learning Points

Marking out of components, use of centre line. Geometric tolerance symbols: angular, centre line locations, hole centre location, parallelism. Accurate hole transfer between components. Deburring sharp corners. Precision filing: parallelism, flatness, squareness, surface finish. Planning the rough metal removal sequence to allow material to relieve internal stresses. Adapting learned skills and techniques to new situations in assembly.

2.1 Marking Out Of Components, Use Of Centre Line

When the mild steel plates have been filed to size, mark them out using the vernier height gauge. A *protractor* and a *scriber* are used to mark out the angled lines and hole centres are marked with a *punch*. The plates are held together with toolmakers clamps for drilling the holes.

For internal shapes, a series of holes are drilled inside the scribed lines and the unwanted metal is removed with a chisel or by joining up the holes using a hacksaw. It is important to note that when the internal metal is removed that stresses are relieved in the metal plate and this may result in the remaining metal distorting slightly outwards. The outer metal will need to be measured again and filed if required. The internal shape can then be filed to size, using second cut and smooth files. To remove small amounts of material needle files may be required.

Ref Black, Bruce J 2004, *Workshop processes, practices and materials*, 3rd edn, Elsevier Science & Technology, chapter 2, *Hand processes*, p. 30, chapter 3, *Marking out*, p. 44.
ISBN-13: 9780750660730

2.2 Geometric Tolerance Symbols: Angular, Centre Line Locations, Hole Centre Location, Parallelism

Geometric tolerances are used when it is necessary to control more precisely the form or shape of a feature. It can be used to define straightness, flatness, angularity, roundness, parallelism, perpendicularity, positional, concentricity etc. It is recommended to use geometric tolerances for parts that fit together.

Ref: Simmons, Colin H & Maguire, Dennis E 2004, *Manual of engineering drawing*, 2nd edn, Elsevier Science & Technology, chapter 20, *Geometrical tolerances and datums*, p. 160.
ISBN-13: 9780750651202

2.3 Accurate Hole Transfer Between Components

When two metal plates need to be screwed together, the top plate is first drilled. The bottom plate is then clamped to the drilled top plate with toolmakers clamps and the drilled holes are used to guide a drill of the same size to spot the bottom plate. The correct size tapping drill is then drilled through the bottom plate.

Ref Black, Bruce J 2004, *Workshop processes, practices and materials*, 3rd edn, Elsevier Science & Technology, chapter 8, Drilling, p. 138.
ISBN-13: 9780750660730

2.4 Deburring Sharp Corners

For removing burrs from holes a hand held deburring tools can be used. Needle files can be used when removing small amounts of metal and for adding chamfers and deburring sharp edges.

Ref Black, Bruce J 2004, *Workshop processes, practices and materials*, 3rd edn, Elsevier Science & Technology, chapter 2, *Hand processes*, p. 30.
ISBN-13: 9780750660730

2.5 Precision Filing: Parallelism, Flatness, Squareness, Surface Finish

When the component has been cut roughly to size using a hack-saw, the file is used to finish the component to the specified drawing dimensions. A range of files can be used, which are available in various shapes are Flat, Hand, Warding, Square, Three Square and Half Round, depending on the shape of the component and the precision and finish required. Files such as smooth or dead smooth are used to finish the feature close to the specified drawing dimensions. A vernier callipers is used to measure the internal shape of the component as it is filed close to the required dimension. An Engineers Square is used to check squareness and the edge can be used to check the flatness of the component. At this stage slip gauges assembled to the maximum and minimum values for a specific dimension. Needle files are used to remove small amounts of material and can be used to remove material to form sharp corners. While filing it is important to continuously check the dimensions and also check that the filed surfaces are square.

Ref Black, Bruce J 2004, *Workshop processes, practices and materials*, 3rd edn, Elsevier Science & Technology, chapter 2, *Hand processes*, p. 30.
ISBN-13: 9780750660730

2.6 Planning The Rough Metal Removal Sequence To Allow Material To Relieve Internal Stresses

When material is removed from the centre of a plate, the remaining material may bulge out slightly due to internal stresses being relieved. The outer edges should therefore be rough filed and left oversize until the internal material is removed. The outer surfaces can then be filed to size. Also note that the inner surfaces will bulge out slightly, therefore do not saw too close to the scribed line.

3.0 Manufacturing Symmetrical Components

Key Learning Points

Workholding using toolmakers clamps. Clamping forces; law of the lever.

3.1 Workholding Using Toolmakers Clamps

Symmetrical components are marked out and toolmakers clamps are used to hold the plates together. The plates are then drilled and filed as explained above. The symmetrical component will be required to assemble with the mating component in either direction, therefore great care will be required when filing and measuring. It is also important to read the drawing and correctly interpret any geometric tolerances.

Ref Black, Bruce J 2004, *Workshop processes, practices and materials*, 3rd edn, Elsevier Science & Technology, chapter 3, *Marking out*, sec. *Clamps*, p. 53.
ISBN-13: 9780750660730

3.2 Clamping Forces; Law Of The Lever

The lever is a rigid beam that can rotate about a fixed point called the fulcrum. An effort applied to one end of the beam will move a load at the other end. If the fulcrum is moved close to the load, it can be lifted with minimal effort.

4.0 Producing Components That Assemble Correctly

Key Learning Points

Assembly techniques; maintaining tolerances while achieving the desires fit. Interchangeability of components, manufacture of symmetrical components.

4.1 Assembly Techniques; Maintaining Tolerances While Achieving The Desires Fit

While filing components that are required to assemble with each other, it is important to work within the limits as specified on the drawing. The component should be regularly measured and checked for squareness, flatness etc., during the filing operation. The male component should be completed first. The internal shape is then filed to within the tolerances as specified on the drawing. The male component can then be used to check that it assembles in all positions with the symmetrical component. Feeler gauges can be used to check the gap between the components and will also highlight high spots. At this stage needle files can be used to remove small amounts of material from either the male of female shapes, but it is important to keep within the tolerances as specified on the drawing.

Ref Black, Bruce J 2004, *Workshop processes, practices and materials*, 3rd edn, Elsevier Science & Technology, chapter 2, *Hand processes*, p. 30.
ISBN-13: 9780750660730

4.2 Interchangeability Of Components, Manufacture Of Symmetrical Components

If multiple parts need to be interchangeable with each other, then it is important that they are manufactured within the dimensions specified on the drawing. It is also important that geometric tolerance requirements such as flatness, parallelism, positional tolerances are also within tolerance.

5.0 Accurately Measuring Components

Key Learning Points

Measurement of precision filed angles using a vernier protractor. Precision measurement of manufactured components using measurement and inspection tooling.

5.1 Measurement Of Precision Filed Angles Using A Vernier Protractor

A protractor is a device for measuring angles. A vernier protractor has a graduated scale, which enables them to be set to a much greater accuracy. Generally they have an accuracy of 5 minutes, which is one twelfth of a degree. The vernier protractor can be set to the required angle and used to scribe a line on a component, or can be used to measure the angle on a component.

Ref Black, Bruce J 2004, *Workshop processes, practices and materials*, 3rd edn, Elsevier Science & Technology, chapter 6, *Measuring equipment*, sec. *Vernier bevel protractor*, p. 100.
ISBN-13: 9780750660730

5.2 Precision Measurement Of Manufactured Components Using Measurement And Inspection Tooling

The vernier callipers, the micrometer and the depth micrometer are used to check linear dimensions of a component.

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

Summary

Calculations using trigonometry: Trigonometry means the measurement of triangles. The Pythagoras Theorem can be used to find the length of one side or a right angled triangle if the lengths of the other two sides are known. The theorem states that for a right angled triangle the square on the hypotenuse (longest side) is equal to the sum of the squares on the other two sides.

Manufacturing components with angular mating surfaces: When the mild steel plates have been filed to size, mark them out using the vernier height gauge. A protractor and a scriber are used to mark out the angled lines and hole centres are marked with a Punch. The plates are held together with toolmakers clamps for drilling the holes.

Special attention should be paid to the Geometric tolerances on the drawing such as angular, hole centre location, parallelism, flatness, squareness and surface finish.

Manufacturing symmetrical components: Symmetrical components are marked out, clamped, drilled and filed as explained above. The symmetrical component will be required to assemble with the mating component in either direction, therefore great care will be required when filing and measuring. It is also important to read the drawing and correctly interpret any geometric tolerances.

Producing components that assemble correctly: While filing components that are required to assemble with each other, it is important to work within the limits as specified on the drawing. The component should be regularly measured and checked for squareness, flatness etc., during the filing operation. The male component should be completed first. The internal shape is then filed to within the tolerances as specified on the drawing. The male component can then be used to check that it assembles in all positions with the symmetrical component. Feeler gauges can be used to check the gap between the components and will also highlight high spots. At this stage needle files can be used to remove small amounts of material from either the male of female shapes, but it is important to keep within the tolerances as specified on the drawing. If multiple parts are made to the drawing specifications they should be interchangeable with each other.

Accurately measuring components: A protractor is a device for measuring angles. A vernier protractor has a graduated scale, which enables them to be set to a much greater accuracy. The vernier protractor can be set to the required angle and used to scribe a line on a component, or can be used to measure the angle on a component. The vernier callipers, the micrometer and the depth micrometer are used to check linear dimensions of a component.

Suggested Exercises

1. Explain how to transfer holes form one plate to another.
2. Drill clearance holes for two M5 screws, transfer the holes from the top plate to the bottom plate and then drill and tap the M5 threads.
3. What device is used to clamp two plates together when drilling holes.
4. Define a lever. Sketch a simple lever showing the fulcrum, the load and the effort.
5. Using a vernier protractor and scribe a line on a mild steel plate at 20º 30´ 10´´

Questions

1. What devices are used to scribe an angled line on a workpiece?
2. How is an internal shape removed from a mild steel plate?
3. State the Pythagoras Theorem.
4. When should Geometric Tolerancing be used on a drawing?
5. What is the Vernier Protractor use for and what is the accuracy of the graduated scale?

Answers

1. A Protractor and a Scriber are used to mark out the angled lines.
2. For internal shapes, a series of holes are drilled inside the scribed lines and the unwanted metal is removed with a chisel or by joining up the holes using a hacksaw.
3. The theorem states that for a right angled triangle the square on the hypotenuse (longest side) is equal to the sum of the squares on the other two sides.
4. Geometric tolerances are used when it is necessary to control more precisely the form or shape of a feature and when components are being assembled together.
5. The Vernier Protractor is a device for measuring angles and can be used to scribe an angled line on a component. A vernier protractor has a graduated scale, which enables them to be set to a much greater accuracy. Generally they have an accuracy of 5 minutes, which is one twelfth of a degree.

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