Trade of Toolmaking

Module 3:	Milling
Unit 8:	Steps, Recesses & Sliding Fits
	Phase 2

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Table of Contents

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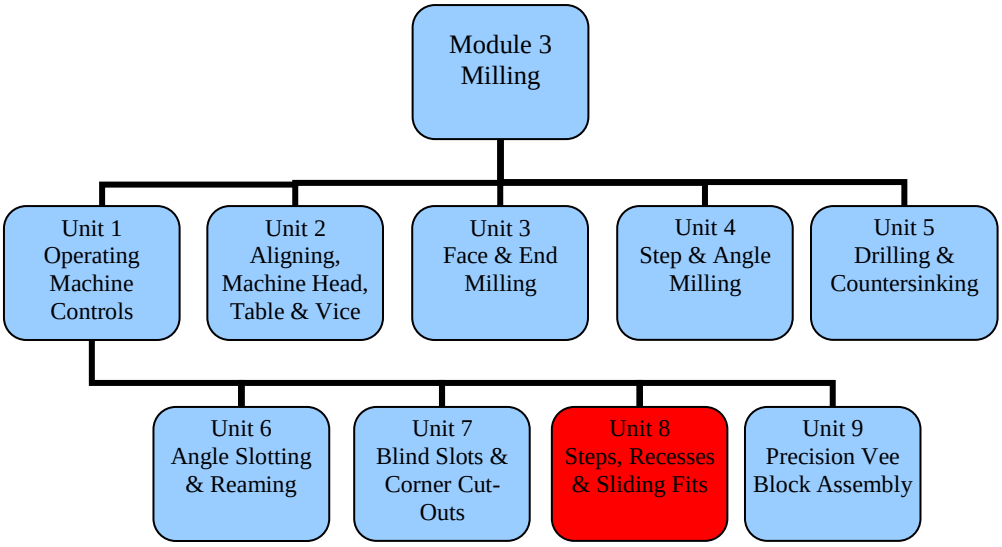
Unit Objective

On completion of this unit you will be able to mill symmetrical components and measure and analyse the function and fit of the components.

Introduction

Module three of this course covers milling. This is the eight unit in module three and explains how to machine slots in the centre of a workpiece and how to machine a stepped component that will fit snugly into these machined slots. It is important to know how to read the drawing and understand what the geometric tolerances and symbols mean.

This unit also introduces the limits and fits system, which is used to manufacture components that need to be assembled together and be interchangeable with each other. Prior to the limits and fits system, parts were individually assembled together by selection of hand fitting. This was expensive and did not allow interchangeability. The limits and fits system was introduced whereby all components are manufactured to a specific size within narrow limits.



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

- Precision mill symmetrical components to the standards on the supplied drawings.
- Measure and analyse the function and fit of the components.

1.0 Precision Milling Of Symmetrical Components

Key Learning Points

Engineering drawing: assembly, plans, elevations and end view. Importance of symmetry in mating components. Importance of centre lines to establish symmetry. Application of geometric tolerances to squareness, parallelism and angularity. Safe operation of milling machine. Removal of sharp edges on mating components. Job planning: sequence of operations.

1.1 Engineering Drawing: Assembly, Plans, Elevations And End View

The plan view is normally viewed by looking at the horizontal plane of the component, which can also be called the front view. The elevation view is normally positioned above or below the plan view and can also be called the top or bottom view. The end view is positioned left or right.

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.

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1.2 Importance Of Symmetry In Mating Components

When a slot needs to be machined in the centre of the workpiece it is important to study the drawing and understand the requirements of the tolerance bands and the geometric tolerances. A symmetry tolerance on a slot indicates that the slot is centred about the centre line of the workpiece and positioned within the limits of the specified tolerance band. This is important when two components need to fit together.

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.

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1.3 Importance Of Centre Lines To Establish Symmetry

The centre line is the theoretical centre of the component and the symmetry tolerance indicates that centre of the feature is positioned on this line. The tolerance indicates how much the feature is allowed to move about this 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 Symetry*, p 177.

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1.4 Application Of Geometric Tolerances To Squareness, Parallelism And Angularity

Geometric tolerances are used when features need to be controlled more precisely. Prior to the introduction of geometric tolerances, notes were added to the drawing such as 'surface to be perpendicular to another surface' and 'surfaces to be parallel. With geometric tolerancing features such as perpendicularity, parallelism and angularity are expressed with symbols and a tolerance band. It can be used to position that particular feature in relation to a datum plane or another feature.

Ref: Simmons, Colin H & Maguire, Dennis E 2004, *Manual of engineering drawing*, 2nd edn, Elsevier Science & Technology, chapter 21, *Application of geometrical tolerances*, p 168.

ISBN-13: 9780750651202

1.5 Safe Operation Of Milling Machine

When using the milling machine it is important to wear eye protection, suitable clothing, use a brush to remove swarf and keep the machine and surrounding area tidy. Switch off the machine when not in use and in the case of an emergency press the red stop button to stop the machine.

1.6 Removal Of Sharp Edges On Mating Components

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.

1.7 Job Planning: Sequence Of Operations

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 using the bandsaw. The sequence of operations should be planned so as to minimise the number of setups.

2.0 Measuring And Analysing The Function And Fit Of The Components

Key Learning Points

ISO and BS limits and fits, principles and use of slip gauges. Care of slip gauges. Maximum and minimum material conditions. Limits and fits: classes of fits. Hole and shaft basis system. Definitions: i.e. tolerance, nominal size, allowance and deviation.

2.1 Iso And Bs Limits And Fits, Principles And Use Of Slip Gauges

The ISO and BS limits and fits system is used to manufacture components that need to be assembled together and be interchangeable with each other. The limits and fits system was introduced whereby all components are manufactured to a specific size within narrow limits. Components cannot be made to exactly the same dimensions, but the use of limits allows the components to vary slightly from the nominal dimension, but within the set limit.

2.2 Care Of Slip Gauges

A set of slip gauges consist of a range of 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. Slip gauges should be treated as delicate precision instruments. They can be damaged easily and should be stored in a secure place.

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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2.3 Maximum And Minimum Material Conditions

The *maximum material condition* (MMC) is when the part or a feature contains the maximum amount of material, e.g. a block of metal with a hole drilled through, where the external surfaces are at the maximum size allowed and the hole is at the minimum size. The *least material condition* (LMC) is where the external surfaces are on at the minimum size allowed and the hole is at the maximum size.

Ref: Simmons, Colin H & Maguire, Dennis E 2004, *Manual of engineering drawing*, 2nd edn, Elsevier Science & Technology, chapter 22, *Maximum material and least material principles*, p 179.

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2.4 Limits And Fits: Classes Of Fits

The limits and fits system has a range of (i) clearance, (ii) transition and (iii) interference fits. The Hole Basis system is the most widely used system and is more cost effective. In this system one size reamer can be used and a range of fits can be produced by varying the shaft limits.

Ref: Simmons, Colin H & Maguire, Dennis E 2004, *Manual of engineering drawing*, 2nd edn, Elsevier Science & Technology, chapter 19 *Limits and fits*, p 154.

ISBN-13: 9780750651202

2.5 Hole And Shaft Basis System

There are two bases of the limits and fits system, (i) the **Hole Basis** (Ref.: BSI data sheet 4500A) and (ii) the **Shaft Basis** (Ref.: BSI data sheet 4500B). In the Hole Basis system the hole size is kept constant and the shaft size varied to provide the required fit. Whereas in the Shaft Basis system the shaft is kept constant and the hole is varied to provide the required fit. The Hole Basis system is the most widely used system and is more cost effective. In this system one size reamer can be used and a range of fits can be produced by varying the shaft limits.

Ref: Simmons, Colin H & Maguire, Dennis E 2004, *Manual of engineering drawing*, 2nd edn, Elsevier Science & Technology, chapter 19 *Limits and fits; Bases of fits*, p 155.

ISBN-13: 9780750651202

2.6 Definitions: I.E. Tolerance, Nominal Size, Allowance And Deviation

Definitions: *Tolerance*: This is the difference between the upper and lower limits of size. *Nominal size*: The size that a component is referred to, but may not be exactly be that dimension, e.g. a Ø10mm hole may be slightly larger in order to provide adequate clearance. *Allowance*: This is related to mating parts and is the difference between the high limit of size of the shaft and the low limit of size of the mating hole. Depending on whether the fit is a clearance or interference, the allowance can be positive or negative. *Deviation*: This is the difference between the maximum, minimum, or actual size of a shaft or hole and the basic size.

Summary

Precision milling of symmetrical components: When a series of stepped slots need to be machined in the centre of the workpiece it is important to study the drawing and understand the requirements of the tolerance bands and the geometric tolerances. The tolerance band determines the limits of size of each feature, while the geometric tolerance can be used to position that particular feature in relation to a datum plane or another feature. For example, a symmetry tolerance on a slot indicates that the slot is centred about the centre line of the workpiece and needs to lie within the limits of the specified tolerance band. When you understand the drawing requirements you can then plan the series of operations.

When using the milling machine it is important to wear eye protection, suitable clothing, use a brush to remove swarf and keep the machine and surrounding area tidy. Switch off the machine when not in use and in the case of an emergency press the red stop button to stop the machine. 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.

Measuring and analyzing the function and fit of the components: The ISO and BS limits and fits system is used to manufacture components that need to be assembled together and be interchangeable with each other. The limits and fits system was introduced whereby all components are manufactured to a specific size within narrow limits. Components cannot be made to exactly the same dimensions, but the use of limits allows the components to vary slightly from the nominal dimension, but within the set limit.

There are two bases of the limits and fits system, (i) the **Hole Basis** (Ref.: BSI data sheet 4500A) and (ii) the **Shaft Basis** (Ref.: BSI data sheet 4500B). In the Hole Basis system the hole size is kept constant and the shaft size varied to provide the required fit. Whereas in the Shaft Basis system the shaft is kept constant and the hole is varied to provide the required fit. Both of these systems have a range of clearance, transition and interference fits. The Hole Basis system is the most widely used system and is more cost effective. In this system one size reamer can be used and a range of fits can be produced by varying the shaft limits.

Slip gauges: A set of slip gauges consist of a range of 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. Slip gauges should be treated as delicate precision instruments. They can be damaged easily and should be stored in a secure place.

Definitions: *Nominal size*: The size that a component is referred to, but may not be exactly be that dimension, e.g. a Ø10mm hole may be slightly larger in order to provide adequate clearance. *Tolerance*: This is the difference between the upper and lower limits of size. *Allowance*: This is related to mating parts and is the difference between the high limit of size of the shaft and the low limit of size of the mating hole. Depending on whether the fit is a clearance or interference, the allowance can be positive or negative. *Deviation*: This is the difference between the maximum, minimum, or actual size of a shaft or hole and the basic size.

Suggested Exercises

1. What safety measures should be taken prior to using a milling machine?
2. Why do burrs need to be removed from a machined part?
3. Explain the terms, the minimum material condition and the maximum material condition.
4. In the limits and fits system, what are the three classes of fits.
5. Explain the difference between the Hole Based System and the Shaft Based System.

Questions

1. In technical drawing, explain the terms Plan View, Elevation View and End View.
2. Why was the limits and fits system introduced?
3. Explain briefly what slip gauges are and why they are used?
4. What is the maximum material condition?
5. What are the definitions for the following: Tolerance, Allowance and Deviation?

Answers

1. The plan view is normally viewed by looking at the horizontal plane of the component, which can also be called the front view. The elevation view is normally positioned above or below the plan view and can also be called the top or bottom view. The end view is positioned left or right.
2. The ISO and BS limits and fits system is used to manufacture components that need to be assembled together and be interchangeable with each other. The limits and fits system was introduced whereby all components are manufactured to a specific size within narrow limits.
3. A set of slip gauges consist of a range of 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 or a pile.
4. The *maximum material condition* (MMC) is when the part or a feature contains the maximum amount of material, e.g. a block of metal with a hole drilled through, where the external surfaces are at the maximum size allowed and the hole is at the minimum size.
5. *Tolerance:* This is the difference between the upper and lower limits of size. Allowance: This is related to mating parts and is the difference between the high limit of size of the shaft and the low limit of size of the mating hole. Depending on whether the fit is a clearance or interference, the allowance can be positive or negative. *Deviation:* This is the difference between the maximum, minimum, or actual size of a shaft or hole and the basic size.

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