Trade of Toolmaking			
Module 2:	Turning		
Unit 10:	Turning & Assembling Sliding Fits & Interference Fits		
	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 apply limits, fits and tolerances to produce components. Machine and assemble male/female components to BS 4500.

# Introduction

Module two of this course covers turning. This is the tenth unit in module two and 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 and 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.

This unit also discusses the effects of heat on the workpiece and the tool and how to reduce it. It also introduces the technique of heating a bored component to a specific temperature, which will cause it to expand. The component can then be assembled with a mating shaft. When cool the component contracts, it will result in the parts been permanently assembled to each other due to the interference fit.



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

- Apply limits, fits and tolerances to produce pillars/bushes.
- Machine male/female components (holes/shafts) to BS 4500.
- Assemble sliding and interference fits.

### **1.0** Applying Limits, Fits And Tolerances To Components

#### **Key Learning Points**

Limits and fits: classes of fit; clearance, interference and transition. Hole and shaft basis system. Definitions: i.e. tolerance, nominal size, allowance, deviation. Quality of fits and adherence to standards.

# 1.1 Limits And Fits: Classes Of Fit; Clearance, Interference And Transition

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*, 2<sup>nd</sup> edn, Elsevier Science & Technology, chapter 19, p 153.

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#### 1.2 Hole And Shaft Basis System

**Classes of fit**: 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*, 2<sup>nd</sup> edn, Elsevier Science & Technology, chapter 19, *Bases of fits*, p 155.

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#### **1.3** Definitions: I.E. Tolerance, Nominal Size, Allowance, Deviation

**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. *Basic size*: This is the exact functional size from which the limits are derived and is the same for both male and female features. *Limits of size*: These are the maximum and minimum sizes of a dimension, which is indicated by the tolerance of the dimension. *Tolerance*: This is the difference between the upper and lower limits of size. *Minimum size*: This is the difference between the maximum material condition of a shaft and the maximum material condition of the hole. i.e. the largest shaft and the smallest hole giving the tightest fit that will function correctly. *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.

#### **1.4 Quality Of Fits And Adherence To Standards**

The 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.

### 2.0 Machining Male/Female Components To BS 4500

#### **Key Learning Points**

Linear expansion during machining due to heating effect on machined components. Methods of removal of heat energy from tool point. Temperature scales: Celsius and Kelvin; conversion between scales. Sharp edges, deburring. Application and use of BS 4500 limit system. Calculation of limit sizes for sliding fits using BS 4500 hole basis limit system. Manufacture of male and female components to supplied specification.

#### 2.1 Linear Expansion During Machining Due To Heating Effect On Machined Components

When a workpiece is being turned, heat is generated at the tool point and mechanical energy is converted to heat energy. This is due to the fact that energy can be converted from one form to another; it cannot be created or destroyed. The increased temperature will cause the workpiece and tool to expand and will eventually lead to the tool wear and break down. The coefficient of linear expansion is the amount by which the unit length of a metal expands when the temperature is raised by 1°C.

#### 2.2 Methods Of Removal Of Heat Energy From Tool Point

Coolant can be used to remove the heat form the tool and the workpiece.

# 2.3 Temperature Scales: Celsius And Kelvin; Conversion Between Scales

A thermometer is used to measure temperature and can be calibrated in Celsius, Kelvin or Fahrenheit. The point at which water freezes is 0°C and water boils at 100°C. The Kelvin scale measures absolute zero, which -273°C. To convert Celsius to Kelvin, simply add 273. To convert Celsius to Fahrenheit, use the formula: 9/5 + 32.

#### 2.4 Sharp Edges, Deburring

All sharp edges need to be removed from a turned workpiece as this will prevent injury and will make it easier to assemble mating components. This can be done by using one of the following methods:

- The sharp edge can be machined on the lathe by using a chamfering tool.
- Holes can be deburred with a hand held deburring tool.
- Burrs can also be removed with a hand file.

#### 2.5 Application And Use Of Bs 4500 Limit System

When machining components that need to be assembled together, the most common system used in industry is the Hole Basis system (BS 4500A). As explained above, the dimension of the hole is kept constant and the shaft is varied to provide the required fit. Using BS 4500A, a clearance fit will be produced by choosing for example a H7 tolerance for the hole and a g6 tolerance for shaft.

Ref: Simmons, Colin H & Maguire, Dennis E 2004, *Manual of engineering drawing*, 2<sup>nd</sup> edn, Elsevier Science & Technology, chapter 19, p 153.

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#### 2.6 Calculation Of Limit Sizes For Sliding Fits Using Bs 4500 Hole Basis Limit System

Using the BS 4500A data sheet, the limits of size of an Ø8mm H7 hole and Ø8mm g6 shaft are as follows:

For an  $\emptyset$ 8mm H7 hole the tolerance is 0/+0.015

For an Ø8mm g6 shaft the tolerance is -0.005/-0.014

# 2.7 Manufacture Of Male And Female Components To Supplied Specification

The hole with a H7 tolerance can be produced by drilling and then reaming the hole. The shaft with a g6 tolerance can be turned on a lathe or finish ground on a cylindrical grinder. This combination will result in a tightly toleranced clearance fit, which is sometimes called a sliding fit.

# **3.0** Assembling Sliding And Interference Fits

#### **Key Learning Points**

Method of assembly of interference fits. Visualisation of assembled components through isometric and oblique projections of solids. Third angle projection: elevation, end view, sections, symbols.

#### 3.1 Method Of Assembly Of Interference Fits

Shafts and components with holes can also be assembled permanently by using the interference fits from the BSI data sheet 4500A. This is achieved by forcing the oversized shaft into the hole. Another method of assembling interference fits is by heating component with the hole, which expands and allows the shaft to be pressed in place. When the component cools, it contracts and locks securely onto the shaft.

#### 3.2 Visualisation Of Assembled Components Through Isometric And Oblique Projections Of Solids

Isometric and oblique sketches of components can be generated from first and third angle projected drawings. These sketches help to visualise a part or an assembly prior to manufacture. All isometric drawings are based on three axis spaced 120° apart. One axis is drawn vertical and the side walls are drawn at 30° to the right and left. In oblique drawings one of the faces of the component is parallel to the plane of projection and is drawn in its true shape. The side face is then drawn at 45° to the right.

Ref: Simmons, Colin H & Maguire, Dennis E 2004, *Manual of engineering drawing*, 2<sup>nd</sup> edn, Elsevier Science & Technology, chapter 4, *Principles of first and third angle orthographic projection*, p 33.

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#### 3.3 Third Angle Projection: Elevation, End View, Sections, Symbols

In Third angle projection, each view shows what would be seen by looking on the near side of an adjacent view. The plan view is normally viewed by looking at the horizontal plane of the component, it 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. Geometric tolerancing, which uses symbols such as symmetry, squareness, parallelism, etc, on drawings to define the form and size of a tolerance zone within which the feature needs to be contained.

## Summary

**Applying limits, fits and tolerances:** The 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.

**Classes of fit**: 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 (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.

**Machining male/female components to BS 4500**: When machining components that need to be assembled together, the most common system used in industry is the Hole Basis system (BS 4500A). As explained above, the hole is kept constant and the shaft is varied to provide the required fit. Using BS 4500A, a clearance fit will be produced by choosing a H7 tolerance for the hole, where a standard drill and reamer can be used and a g6 tolerance for shaft, which can be machined on a lathe or cylindrical grinder. This combination will result in a tightly toleranced sliding fit.

When a workpiece is being turned, heat is generated at the tool point and mechanical energy is converted to heat energy. This is due to the fact that energy can be converted from one form to another, it cannot be created or destroyed. The increased temperature will cause the workpiece and tool to expand and will eventually lead to the tool wear and break down.

Assembling sliding and interference fits: Shafts and components with holes can also be assembled permanently by using the interference fits from the BSI data sheet 4500A. As mentioned above, increased temperature will cause metal to expand. This can be used for assembling shafts into holes, by heating a bored component, which expands and allows the shaft to be pressed in place. When the component cools, it contracts and locks securely onto the shaft.

# **Suggested Exercises**

- 1. Why is the limits and fits system used in industry.
- 2. What are the three classes of fits.
- 3. What are the two bases of limits and fits and which one is more commonly used.
- 4. Using the Limits and Fits data sheet (BS 4500A), determine the tolerance for a Ø3mm H7 shaft and Ø3mm g6 hole.
- 5. Explain how to deburr the edge of a drilled hole.

# Questions

- 1. What is the most common Limits and Fits system used in industry?
- 2. Explain briefly what the Hole Based system is?
- 3. In order to permanently assemble a turned shaft into a reamed hole, what type of fit is required?
- 4. Explain how an Interference Fit is achieved by the application of heat.
- 5. Explain the following terms: (i) Limits of size and (ii) Tolerance.

### Answers

- 1. The Hole Basis system is the most widely used system and is more cost effective.
- 2. In this system one size reamer can be used for a particular hole size and a range of fits can be produced by varying the shaft limits, which can be turned or ground.
- 3. Interference fit.
- 4. One method of assembling interference fits is by heating component with the hole, which expands and allows the shaft to be pressed in place. When the component cools, it contracts and locks securely onto the shaft
- 5. (i) Limits of size: These are the maximum and minimum sizes of a dimension, which is indicated by the tolerance of the dimension. (ii) Tolerance: This is the difference between the upper and lower limits of size.

## **Recommended Additional Resources**

#### **Reference Books**

Black, Bruce J 2004, *Workshop processes, practices and materials*, 3<sup>rd</sup> edn, Elsevier Science & Technology.

ISBN-13: 9780750660730

Simmons, Colin H & Maguire, Dennis E 2004, *Manual of engineering drawing*, 2<sup>nd</sup> edn, Elsevier Science & Technology.

ISBN-13: 9780750651202

Bird, John 2005, *Basic engineering mathematics*, 4<sup>th</sup> edn, Elsevier Science & Technology.

ISBN-13: 9780750665759