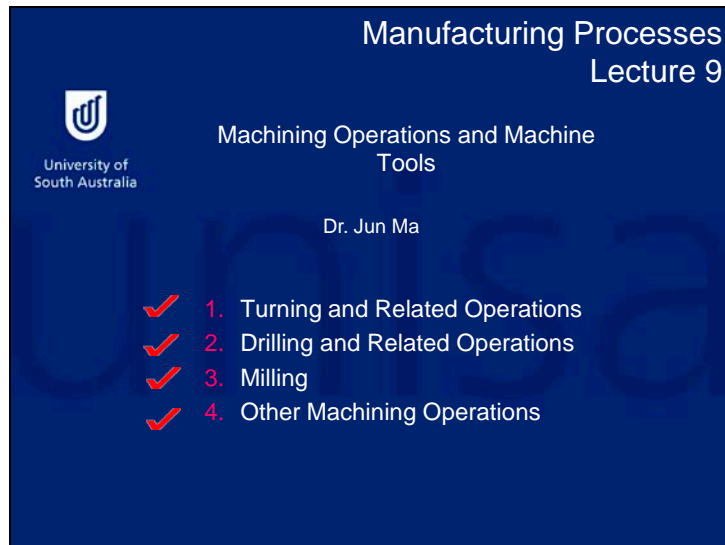



## ENR212 Lecture 9 Slides and Notes

Slide 1



Manufacturing Processes  
Lecture 9

  
University of  
South Australia

Machining Operations and Machine  
Tools

Dr. Jun Ma

- ✓ 1. Turning and Related Operations
- ✓ 2. Drilling and Related Operations
- ✓ 3. Milling
- ✓ 4. Other Machining Operations

Hello everyone, and welcome to lecture summary 9. (This lecture works through material covered in Chapter 22 of the textbook.) This lecture introduces Machining Operations and Machine Tools. Major machining operations include turning, drilling and milling. There are also other machining operations such as shaping, planning, broaching and sawing.

## ENR212 Lecture 9 Slides and Notes

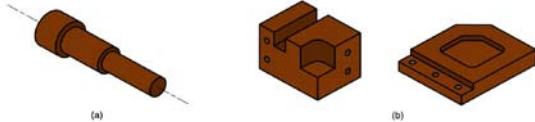
Slide 2

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University of South Australia

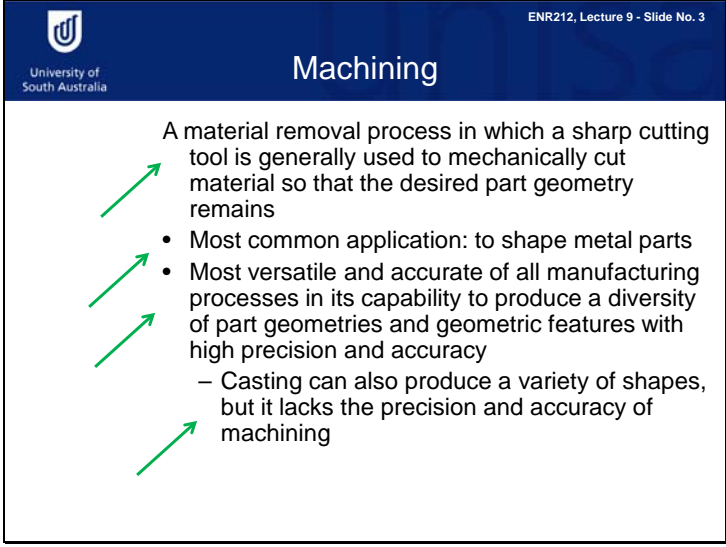
### Classification of Machined Parts

- ✓ • Rotational - cylindrical or disk-like shape
- ✓ • Nonrotational (also called prismatic) - block-like or plate-like



Machined parts are classified as: (a) rotational, or (b) nonrotational, shown here by block and flat parts.

Machined parts are working pieces which have been processed by machining. There are two types of machined parts: rotational machined parts and non-rotational machined parts. Rotational parts are cylindrical or disk-shaped and are machined on a turning machine that is a lathe; non-rotational parts are block-shaped or flat, and are generally produced on a milling machine, such as a shaper or planer.



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### Machining

A material removal process in which a sharp cutting tool is generally used to mechanically cut material so that the desired part geometry remains

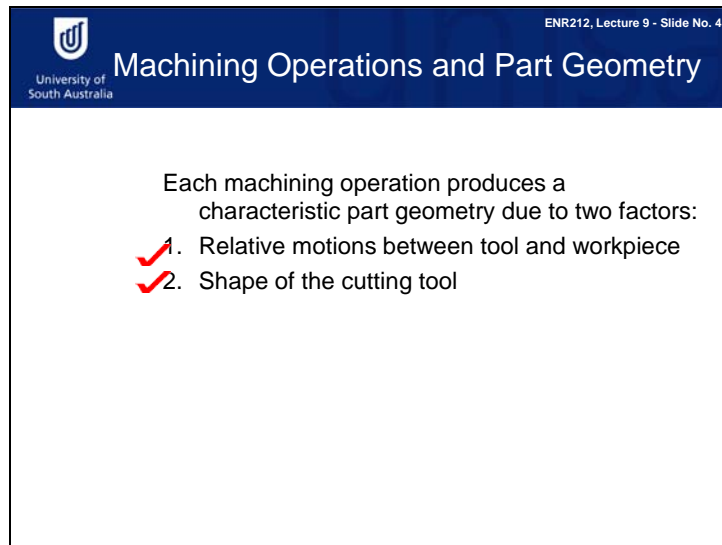
- Most common application: to shape metal parts
- Most versatile and accurate of all manufacturing processes in its capability to produce a diversity of part geometries and geometric features with high precision and accuracy
  - Casting can also produce a variety of shapes, but it lacks the precision and accuracy of machining

So, what is machining? Machining is a material removal process, in which a sharp cutting tool is generally used to mechanically cut material to produce a desired geometrical part. Machining is the most commonly used process in manufacturing. It is able to produce a very good surface finish with high precision and accuracy.

However, machining processes waste quite a lot of material. How can we prevent this? We can combine machining operations with other manufacturing processes, such as casting. For example, a primary shape can be produced by casting, and then processed by manufacturing and machining operations to produce good surface finish and high accuracy.

## ENR212 Lecture 9 Slides and Notes

Slide 4



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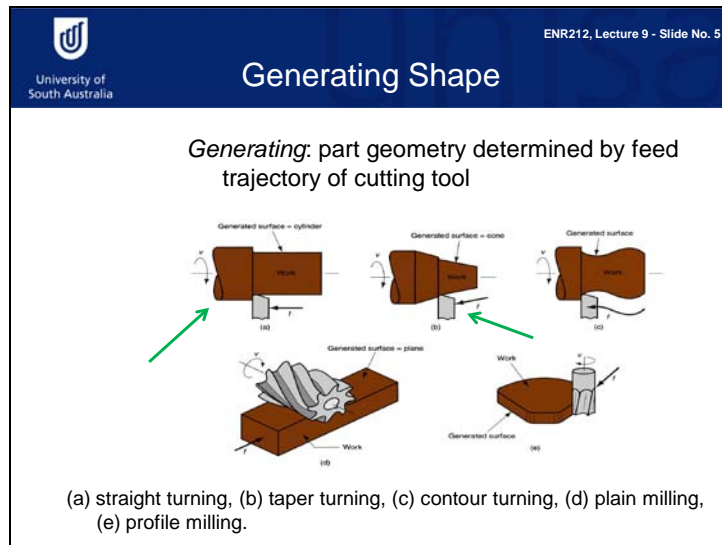
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### Machining Operations and Part Geometry

Each machining operation produces a characteristic part geometry due to two factors:

- ✓ 1. Relative motions between tool and workpiece
- ✓ 2. Shape of the cutting tool

Part geometry is essential in machining operations. Different machining operations produce different part geometries. The two basic factors determining the part geometry in each machining operation are generating and forming. Generating refers to relative motions between the tool and the workpiece. Forming refers to the shape of the cutting tool.



In generating, the part geometry is determined by the feed trajectory of the cutting tool. The path provided by the tool during its feed motion is imparted to the work surface in order to create the shape. In each of the operations shown in these figures, the speed motion in the operation removes the material, but the part shape is determined by the feed motion. For example, in figure a, the cutting tool moves in a direction parallel to the axis of the rotational work parts, so a cylinder is produced. In Figure b, the cutting tools move at an angle to the axis, so a cone is produced.

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## Forming to Create Shape

✓ *Forming* : part geometry is created by the shape of the cutting tool

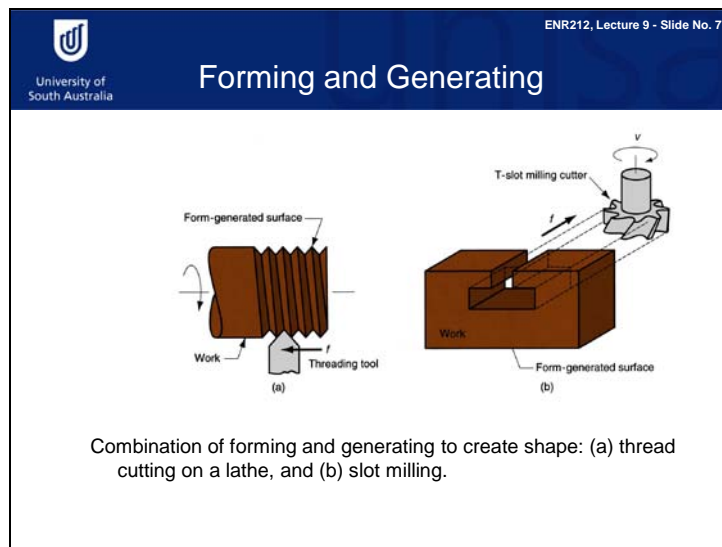
(a) form turning, (b) drilling, and (c) broaching.

The slide contains three diagrams illustrating forming processes. Diagram (a) shows form turning, where a workpiece is rotated and a form tool shapes its surface. Diagram (b) shows drilling, where a drill bit rotates and advances into a workpiece. Diagram (c) shows broaching, where a broach tool moves through a workpiece to create a hole. Labels include 'Work', 'Formed surface', 'Form tool', and 'Broach'.

In Forming , the part geometry is created by the shape of the cutting tool.

## ENR212 Lecture 9 Slides and Notes

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Forming and generating are sometimes combined into one operation, as you can see in the two operations shown in this figures. Figure a shows thread-cutting on a lathe, and figure b shows slot milling. Let's compare figure a, thread cutting on a lathe, with turning: what is the difference between the two operations? The only difference is the cutting tool. (We looked at how to produce thread using cold rolling in lecture 6, slide 12).

## ENR212 Lecture 9 Slides and Notes

Slide 8

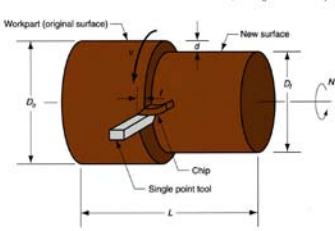
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### Turning

Single point cutting tool removes material from a rotating workpiece to generate a cylinder

- Performed on a machine tool called a *lathe*
- Variations of turning performed on a lathe:
  - Taper turning
  - Facing
  - Reaming
  - Boring
  - Cutoff



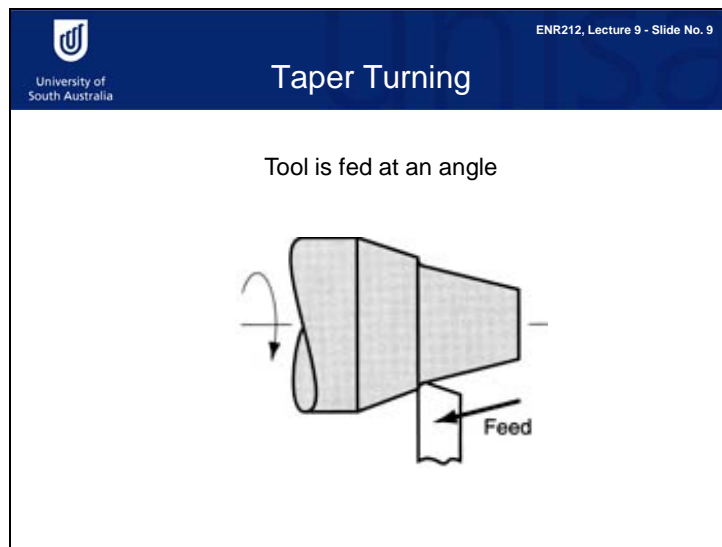
The diagram illustrates the turning process on a lathe. A cylindrical workpiece of length  $L$  is rotating with angular velocity  $\omega$ . A single-point cutting tool is moving along the length of the workpiece, removing a chip of thickness  $a$ . The original surface has diameter  $D_0$  and the new surface has diameter  $D_1$ . The diagram also shows the workpiece (original surface) and the new surface.

What is turning ? In turning, a single point cutting tool removes material from a rotating work piece to generate a cylinder. Turning is often performed on a lathe. There are five basic types of turning, which can be classified by the trajectory of the parts of the cutting tool. They are taper turning, facing, reaming, boring, and cutoff.



## ENR212 Lecture 9 Slides and Notes

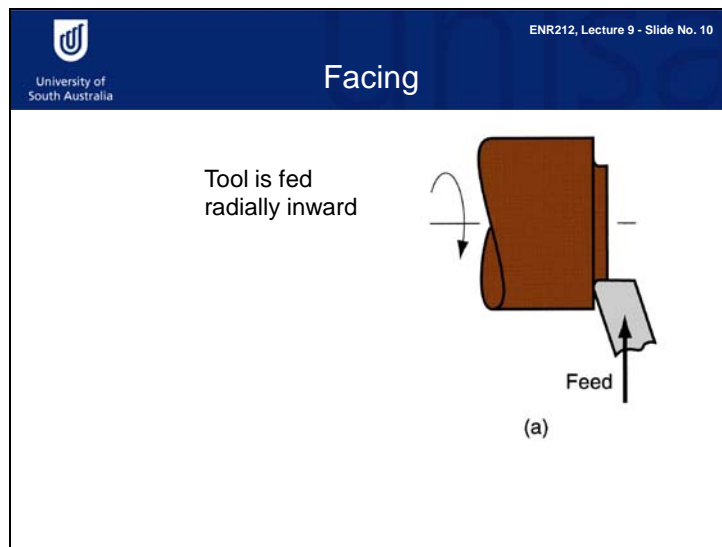
Slide 9



In taper turning, the tool is fed at an angle, so taper turning creates a tapered cylinder or conical shape.

## ENR212 Lecture 9 Slides and Notes

Slide 10



In facing, the tool is fed radially into the rotating work on one end, to create a flat surface on the end.

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### Reaming

- Used to slightly enlarge a hole, to provide a better tolerance on its diameter, and to improve its surface finish.



Reaming is used to slightly enlarge a hole, to provide a better tolerance on its diameter, and to improve its surface finish. The tool is called a reamer.

## ENR212 Lecture 9 Slides and Notes

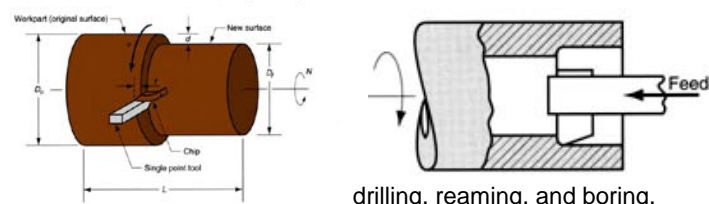
Slide 12

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### Boring

- In effect, boring is internal turning operation
- Difference between boring and turning:
  - Boring is performed on the inside diameter of an existing hole
  - Turning is performed on the outside diameter of an existing cylinder



drilling, reaming, and boring.

Boring is an internal turning operation similar to turning. Both operations use a single-point tool against a rotating work piece. The difference between boring and turning is that boring is performed on the inside diameter of an existing hole, while turning is performed on the outside diameter of an existing cylinder

## ENR212 Lecture 9 Slides and Notes

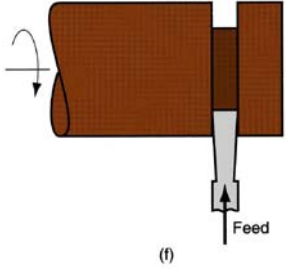
Slide 13

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### Cutoff

- Tool is fed radially into rotating work at some location to cut off end of part



Facing

(f) Feed

In cutoff, the tool is fed radially into the rotating work piece at some location along its length to cut off the end of the part. The cutoff is also called the parting.

## ENR212 Lecture 9 Slides and Notes

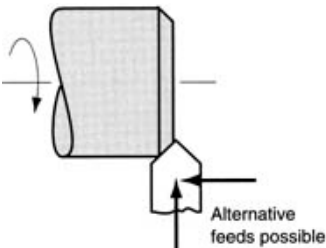
Slide 14

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### Chamfering

- Cutting edge of tool is used to cut an angle on corner of cylinder,

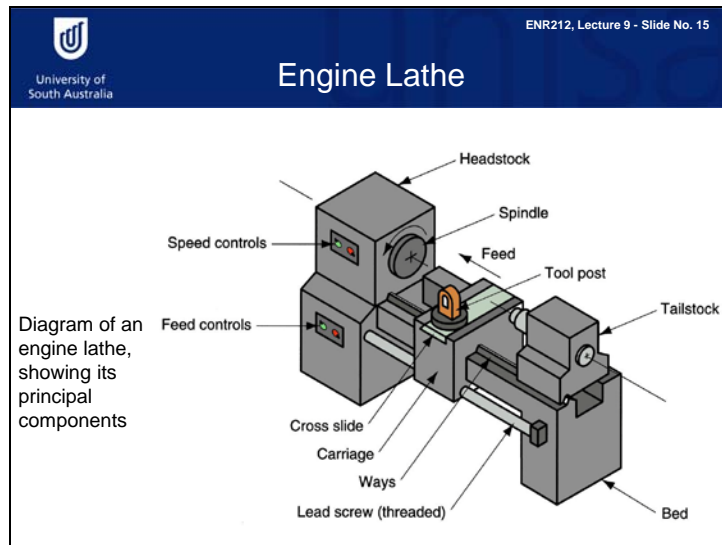


Taper turning      threading

In chamfering, the cutting edge of the tool is used to cut an angle on the corner of the cylinder, forming what is called “a chamfer”.

## ENR212 Lecture 9 Slides and Notes

Slide 15



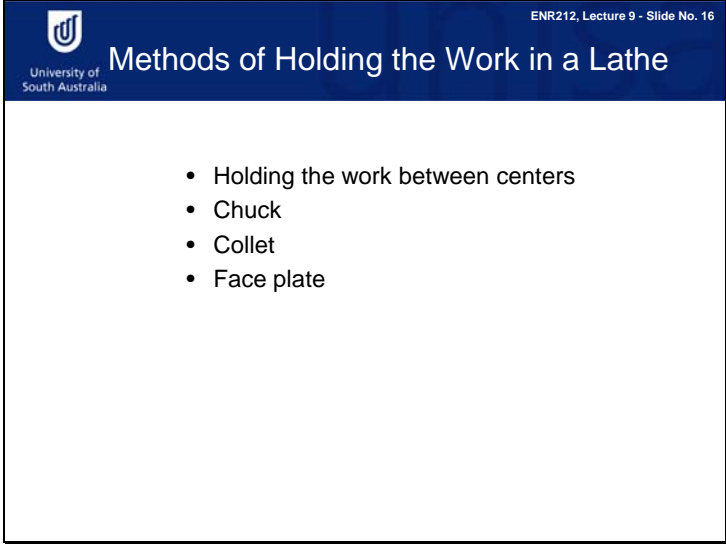
Turning is always performed on a machine called an Engine lathe. As shown in this figure, the headstock contains the drive unit to rotate the spindle, which rotates the workpiece.

Opposite to the headstock is the tailstock, in which a centre is mounted to support the other end of the workpiece.

The cutting tool is held in a tool post fastened to the cross-slide, which is assembled to the carriage. The carriage is designed to slide along the ways of the lathe in order to feed the tool parallel to the axis of rotation.

## ENR212 Lecture 9 Slides and Notes

Slide 16



The slide features a dark blue header with the University of South Australia logo on the left and the text 'ENR212, Lecture 9 - Slide No. 16' on the right. The main title 'Methods of Holding the Work in a Lathe' is centered in the header. Below the header, a white box contains a bulleted list of four methods.

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### Methods of Holding the Work in a Lathe

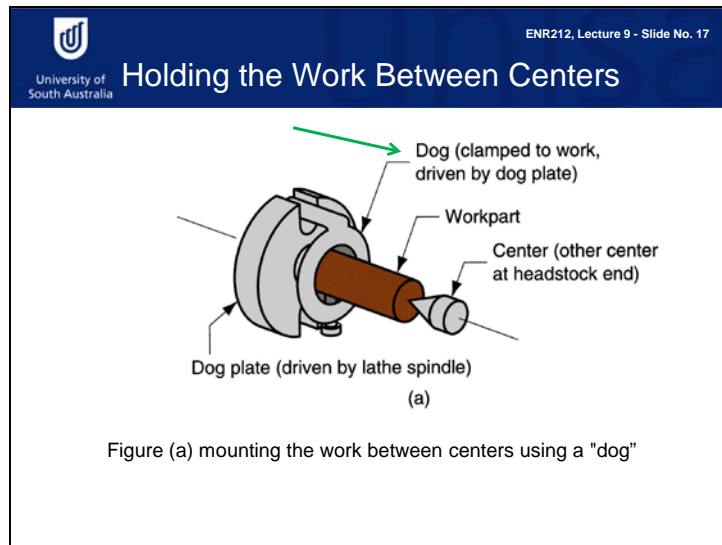
- Holding the work between centers
- Chuck
- Collet
- Face plate

There are four methods of holding the workpiece in a lathe: holding the work between centers, using a chuck, using a collet, and using a face plate.



## ENR212 Lecture 9 Slides and Notes

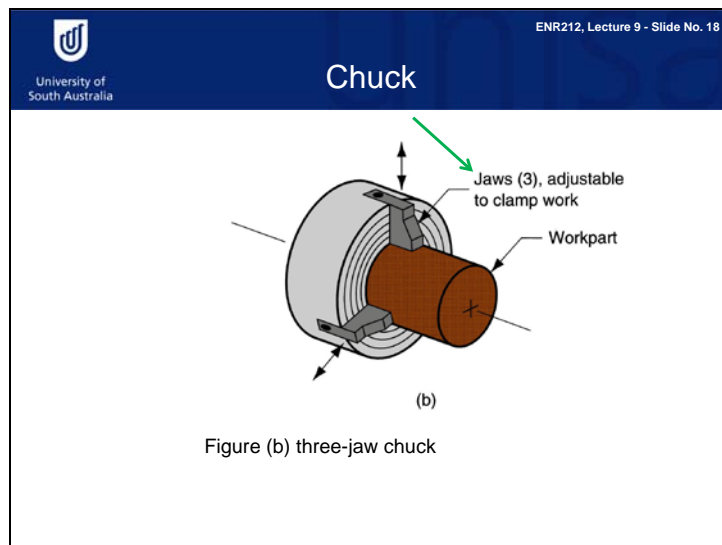
Slide 17



Holding the work piece between centres refers to the use of two centres, one in the headstock and the other in the tail stock. At the headstock centre, a device called a dog is attached to the outside of the work and is used to drive the rotation from the spindle. This method is used for large length-to-diameter ratios of workpiece.

## ENR212 Lecture 9 Slides and Notes

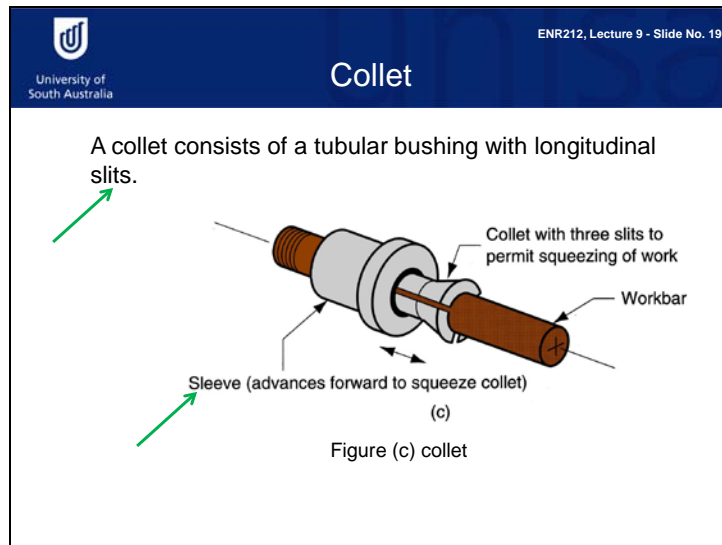
Slide 18



A chuck is a device which has three or four jaws to grasp the cylindrical workpiece on its outside diameter. This method is commonly used for low length-to-diameter ratio parts.

## ENR212 Lecture 9 Slides and Notes

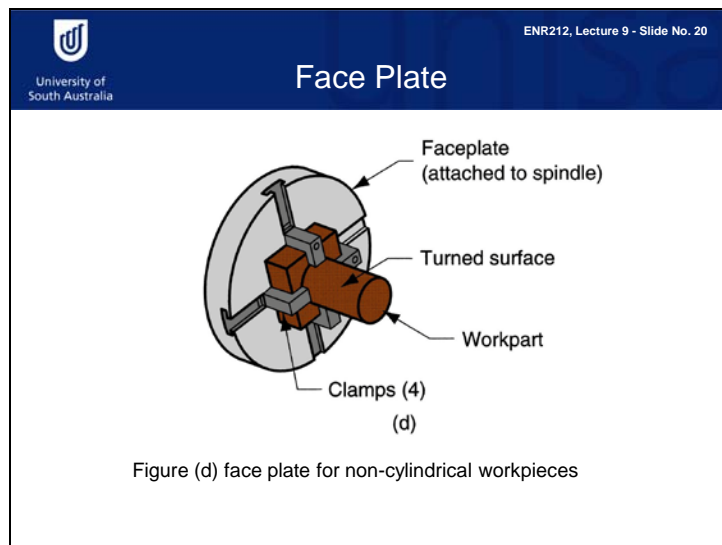
Slide 19



A collet consists of a tubular bushing with longitudinal slits. The inside end of the collet can be squeezed by a sleeve to provide a secure grasping pressure against the work piece. The limitation with this method is that you need different collets for different ranges of work pieces.

## ENR212 Lecture 9 Slides and Notes


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A face plate is a workholding device that fastens to the lathe spindle and is used to grasp parts with irregular shapes.

## ENR212 Lecture 9 Slides and Notes

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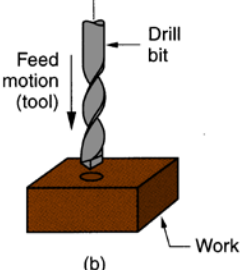


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### Drilling

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- Creates a round hole in a workpiece
- Compare to boring which can only enlarge an existing hole
- Cutting tool called a *drill* or *drill bit*
- Machine tool: *drill press*



(b)

Drilling is usually performed with a rotating cylindrical tool that has two cutting edges on its working end. The tool is called a drill or drill bit. The rotating drill feeds into the stationary workpiece to form a hole whose diameter is equal to the drill diameter. Drilling is customarily performed on a drill press.

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Slide 22

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### Through Holes vs. Blind Holes

Through-holes - drill exits opposite side of work  
Blind-holes – does not exit work opposite side

Two hole types: (a) through-hole, and (b) blind hole.

Drilled holes are either “through holes” or “blind holes”. In through holes, the drill exits the opposite side of the work; in blind holes, it does not.

## ENR212 Lecture 9 Slides and Notes

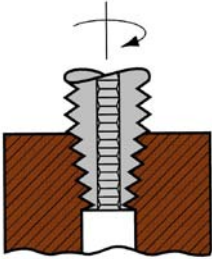
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### Tapping

- Used to provide internal screw threads on an existing hole
- Tool called a *tap*



(b) tapping

(b)

Threading

The diagram illustrates the tapping process. It shows a cross-section of a metal workpiece with a pre-drilled hole. A tap, which is a tool with external threads, is being rotated clockwise (indicated by a curved arrow) to cut internal threads into the hole. The tap is shown partially inserted into the hole, with its cutting edges forming the internal threads. The workpiece is shaded in brown, and the tap is shown in white with grey shading to indicate its three-dimensional form.

Tapping is used to provide internal screw threads on an existing hole. The tool is called a tap. What is the difference between tapping and threading? A threading operation is performed on a turning machine and produces an external thread, while tapping is normally performed on a drilling machine and produces an internal thread.

## ENR212 Lecture 9 Slides and Notes

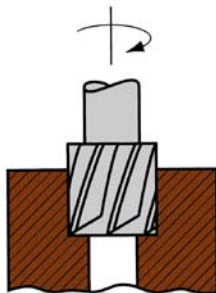
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### Counterboring

- Provides a stepped hole, in which a larger diameter follows smaller diameter partially into the hole




(c) counterboring

(c)

The diagram illustrates the counterboring process. A drill bit is shown cutting a hole into a workpiece. The workpiece is shown in cross-section with a brown hatched texture. The drill bit is shown in a grey color with a cutting edge. A green arrow points from the text to the diagram. The diagram shows the drill bit partially inserted into a hole, creating a larger diameter section at the top of the hole. A rotation arrow is shown above the drill bit, indicating the direction of rotation.

Counter boring provides a stepped hole. A larger diameter follows a smaller diameter partially into the hole.



ENR212, Lecture 9 - Slide

### Milling

a rotating tool with multiple cutting edges is moved slowly relative to the material to generate a plane or straight surface.

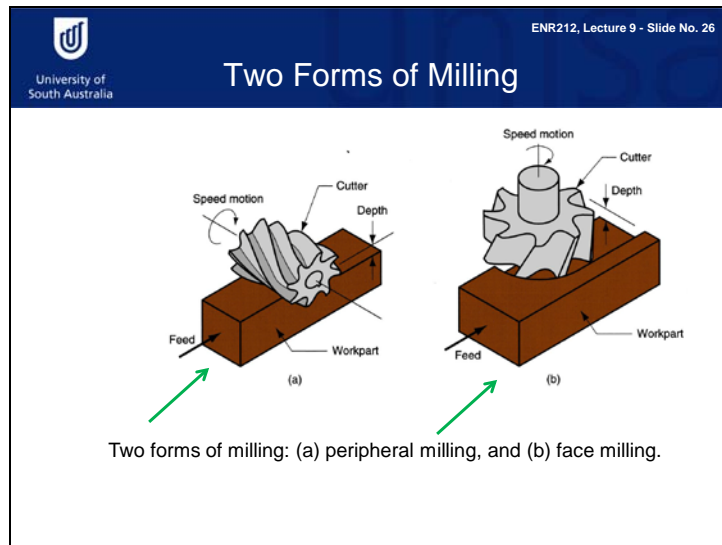
Axis of tool rotation is perpendicular to feed

- Creates a planar surface
  - Other geometries possible either by cutter path or shape
- Other factors and terms:
  - Interrupted cutting operation
  - Cutting tool called a milling cutter, cutting edges called "teeth"
  - Machine tool called a milling machine

In milling, a rotating tool with multiple cutting edges is moved slowly relative to the material to generate a plane or straight surface. The axis of rotation of the cutting tool is perpendicular to the direction of feed. Milling is often performed on a machine tool that is called a milling machine.

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There are two basic types of milling operations: peripheral milling and face milling. In peripheral milling, also called plain milling, the axis of the tool is parallel to the surface being machined and the operation is performed by cutting edges on the outside periphery of the cutter. In face milling, the axis of the cutter is perpendicular to the surface being milled, and machining is performed by cutting edges on both the end and outside periphery of the cutter.

## ENR212 Lecture 9 Slides and Notes

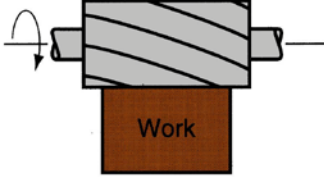
Slide 27

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### Slab Milling

- Basic form of peripheral milling in which the cutter width extends beyond the workpiece on both sides



(a)

The diagram illustrates the slab milling process. A cylindrical cutter with diagonal hatching is shown above a rectangular workpiece labeled 'Work'. The cutter is wider than the workpiece, extending beyond its left and right edges. A curved arrow on the left indicates the counter-clockwise rotation of the cutter. A horizontal line on the right indicates the direction of the workpiece's feed.

Slab milling is a basic form of peripheral milling. In slab milling, the cutter width extends beyond the workpiece on both ends.

## ENR212 Lecture 9 Slides and Notes

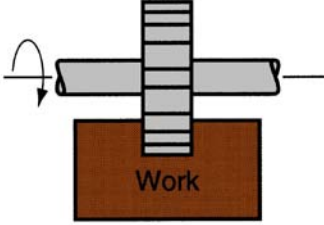
Slide 28

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### Slotting

- Width of cutter is less than workpiece width, creating a slot in the work



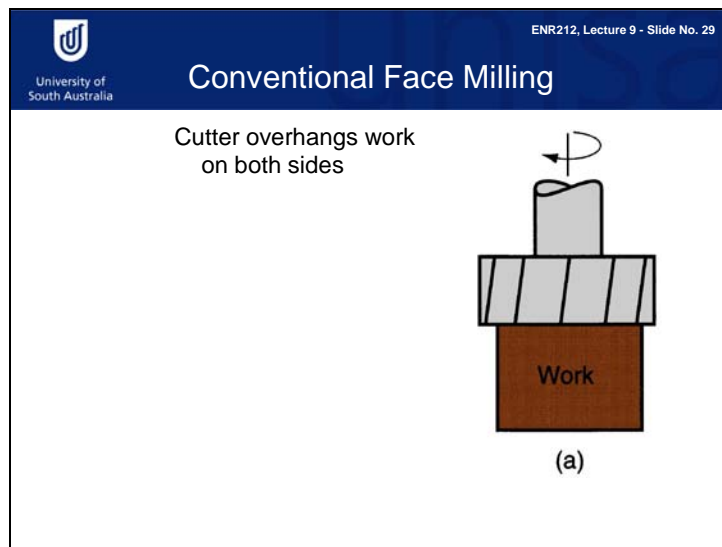
(b)

The diagram illustrates the slotting process. A cylindrical cutter with a central slot is shown cutting into a rectangular workpiece. The cutter is positioned such that its width is less than the workpiece width. A curved arrow indicates the rotation of the cutter, and a straight arrow indicates its forward movement. The workpiece is labeled 'Work'.

In slotting, the width of the cutter is less than the workpiece width, creating a slot in the workpiece.

## ENR212 Lecture 9 Slides and Notes

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In conventional face milling, the diameter of the cutter is greater than the workpiece width, so the cutter overhangs the work on both sides.

## ENR212 Lecture 9 Slides and Notes

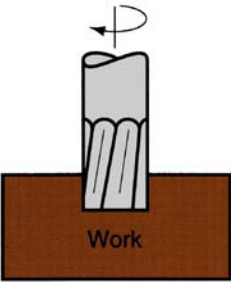
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### End Milling

- Cutter diameter is less than work width, so a slot is cut into part



(c)

The diagram illustrates the end milling process. A cylindrical end mill cutter is shown cutting into a rectangular workpiece. The cutter is positioned such that its diameter is smaller than the width of the workpiece. A curved arrow above the cutter indicates its rotation. The workpiece is labeled 'Work' and the resulting slot is shown as a narrow groove cut into the top surface of the workpiece.

In end milling, the cutter diameter is less than work width, so a slot is cut into the part.

## ENR212 Lecture 9 Slides and Notes

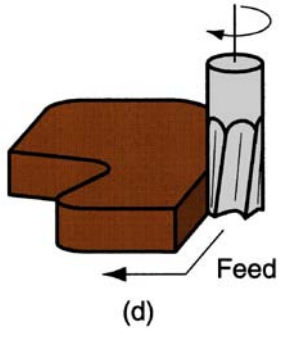
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### Profile Milling

Form of end milling in which the outside periphery of a flat part is machined



(d)

Feed

The diagram illustrates the profile milling process. A cylindrical end mill is shown cutting into a brown workpiece. The end mill is rotating, as indicated by a curved arrow at the top. The workpiece is being fed into the end mill from the right, as indicated by an arrow labeled 'Feed'. The end mill is cutting a profile into the workpiece, which is shown in a 3D perspective view. The label '(d)' is located below the diagram.

## ENR212 Lecture 9 Slides and Notes

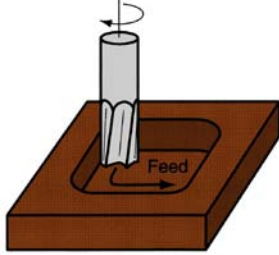
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### Pocket Milling

- Another form of end milling used to mill shallow pockets into flat parts




(e)

The diagram illustrates the pocket milling process. A cylindrical end mill is shown cutting a shallow pocket into a flat workpiece. The workpiece is a brown rectangular block with a rectangular pocket being formed. The end mill is positioned vertically, with a curved arrow indicating its rotation. A horizontal arrow labeled 'Feed' indicates the direction of the workpiece's movement relative to the rotating end mill.



## ENR212 Lecture 9 Slides and Notes

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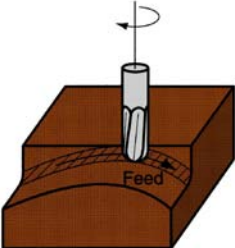


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### Surface Contouring

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- Ball-nose cutter fed back and forth across work along a curvilinear path at close intervals to create a three dimensional surface form.



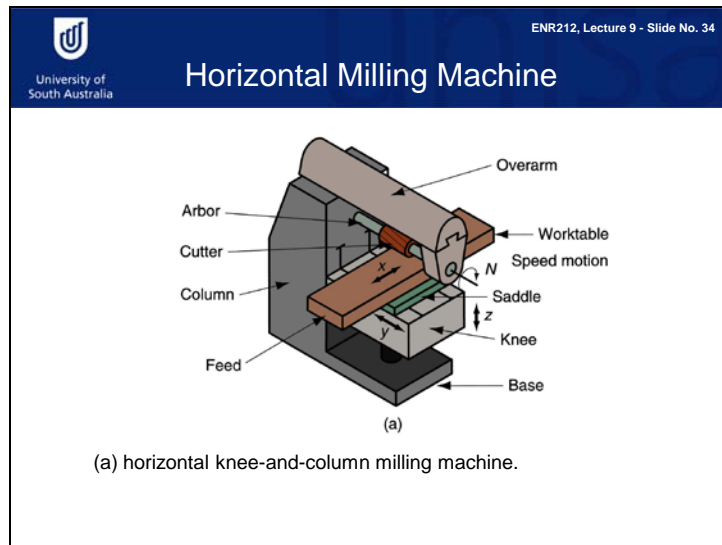
(f)

The diagram shows a 3D perspective of a ball-nose end mill cutting a curved surface into a rectangular workpiece. The cutter is positioned vertically, with a curved path indicated by a dashed line on the workpiece surface. A curved arrow above the cutter indicates its rotation. An arrow labeled 'Feed' points to the right, indicating the direction of the cutter's movement across the workpiece.

In surface contouring, a ball-nose cutter, rather than a square-end cutter, is fed back and forth across a work. It moves along a curvilinear path at close intervals, to create a three dimensional surface form. These figures and names from these slides are a potential exam topic for filling blanks or multi-choice questions.

## ENR212 Lecture 9 Slides and Notes

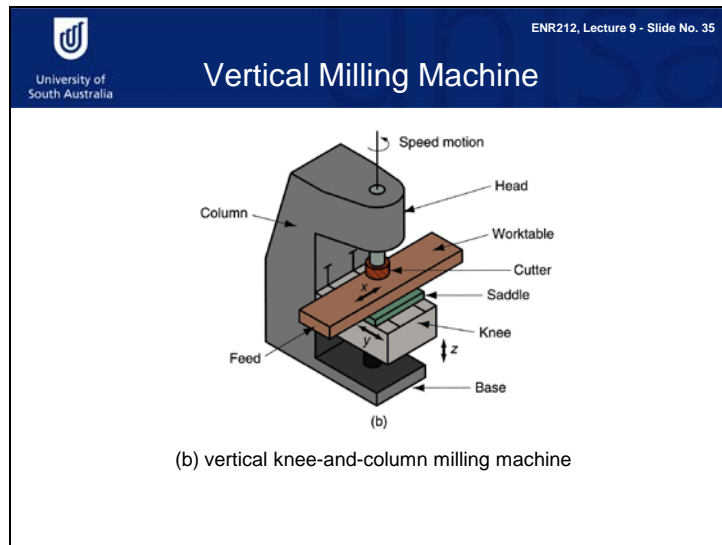
Slide 34




The machine used for milling is called a milling machine. Milling machines can be classified as horizontal or vertical, depending on the orientation of the cutting tool spindle. A horizontal milling machine has a horizontal spindle.

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The basic milling machine is the knee-and-column milling machine, which means any milling machine whose x-y table rides up and down the column on a vertically adjustable knee. The universal milling machine has a worktable that can be rotated about a vertical axis to present the part at any specified angle to the cutter spindle.



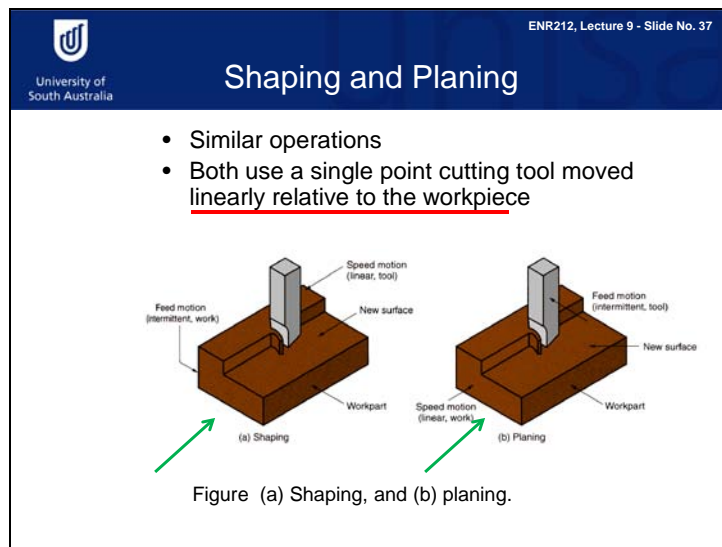
ENR212, Lecture 9 - Slide No. 36

### Machining Centers




Highly automated machine tool can perform multiple machining operations under CNC control in one setup with minimal human attention

- Typical operations are milling and drilling
- Three, four, or five axes
- Other features:
  - Automatic tool-changing
  - Pallet shuttles
  - Automatic workpiece positioning



Shaping and planing are similar operations, both involving relative motion between the tool and the work part. The difference between the two operations is illustrated in this slide. In shaping, the speed motion is accomplished by moving the cutting tool, while in planing, the speed motion is accomplished by moving the workpiece. A planing operation is best described as moving a workpiece in a linear direction past a single-point tool.



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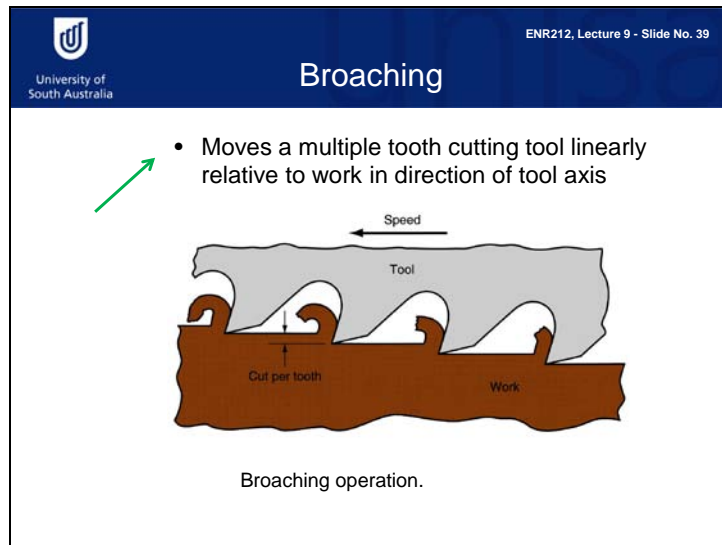
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### Shaping and Planing

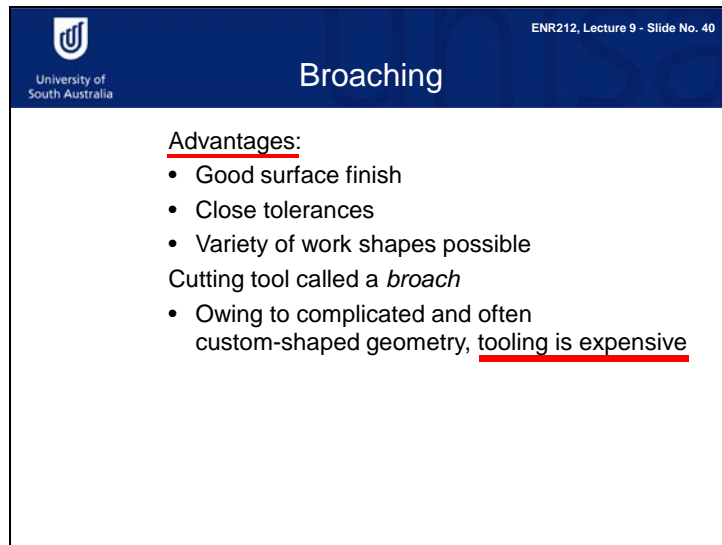
- ✓ • A straight, flat surface is created in both operations
- ✓ • Interrupted cutting
  - Subjects tool to impact loading when entering work
- ✓ • Low cutting speeds due to start-and-stop motion
- ✓ • Typical tooling: single point high speed steel tools

## ENR212 Lecture 9 Slides and Notes

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Broaching is performed using a multiple tooth cutting tool, by moving the tool in a linear direction relative to the work in the direction of the tool axis. The cutting tool is called a broach. The machine tool is called a broaching machine. A broaching operation is best described as moving a tool with multiple teeth in a linear direction past a stationary workpiece.



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### Broaching

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Advantages:

- Good surface finish
- Close tolerances
- Variety of work shapes possible

Cutting tool called a *broach*

- Owing to complicated and often custom-shaped geometry, tooling is expensive

The cutting tool for broaching is called a broach, and the machine tool is called a broaching machine. Broaching is expensive.

Now let's look again at the advantages and disadvantages of machining. Machining gives a good surface finish, has close tolerances and can produce a variety of work shapes.

However, it takes a lot of time, so it is expensive. For this reason, machining is always combined with other manufacturing processes, such as metal casting. The metal casting produces a primary shape, and then this shape is further processed by machining to produce good surface finish with close tolerances.



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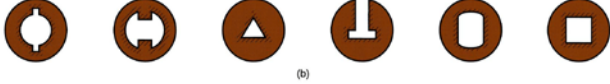
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### Internal Broaching

- ✓ Performed on internal surface of a hole
- ✓ A starting hole must be present in the part to insert broach at beginning of stroke



(b)

Work shapes that can be cut by internal broaching; cross-hatching indicates the surfaces broached.

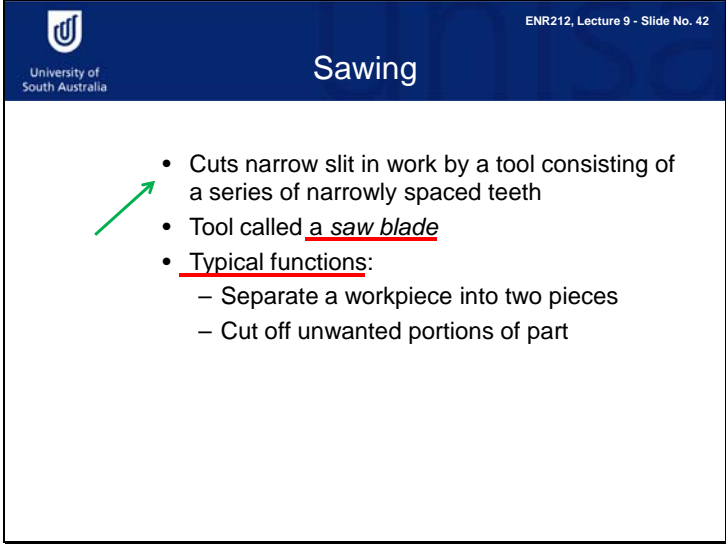
turning and boring

Internal broaching is accomplished on the internal surface of a hole in the part. Therefore, a starting hole must be present in the part so that the broach can be inserted at the beginning of the broaching stroke. This figure shows some of the common shapes.

What is the difference between internal broaching and external broaching? Internal broaching is accomplished on the inside surface (hole) of a workpiece, while external broaching is performed on one of the outside surfaces of the part.

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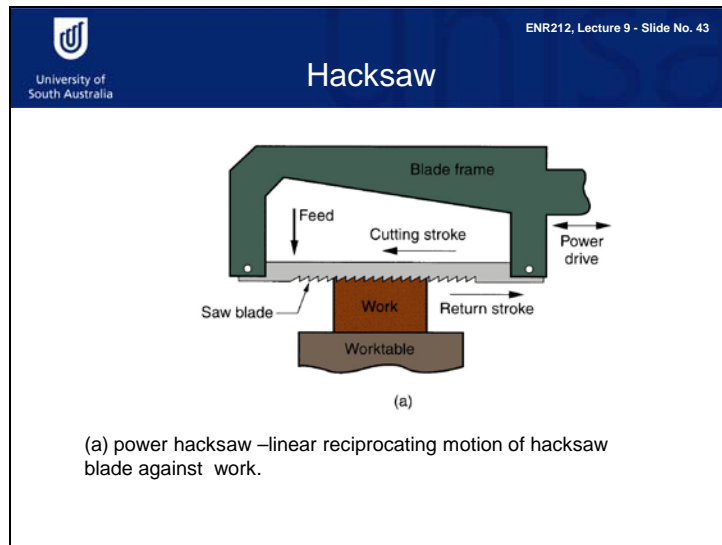
### Sawing

- Cuts narrow slit in work by a tool consisting of a series of narrowly spaced teeth
- Tool called a saw blade
- Typical functions:
  - Separate a workpiece into two pieces
  - Cut off unwanted portions of part

Sawing is a process in which a narrow slit is cut into the work by a tool consisting of a series of narrowly spaced teeth. The cutting tool is called a saw blade. The saw blade separates a workpiece into two pieces or cuts off unwanted portions of a part.

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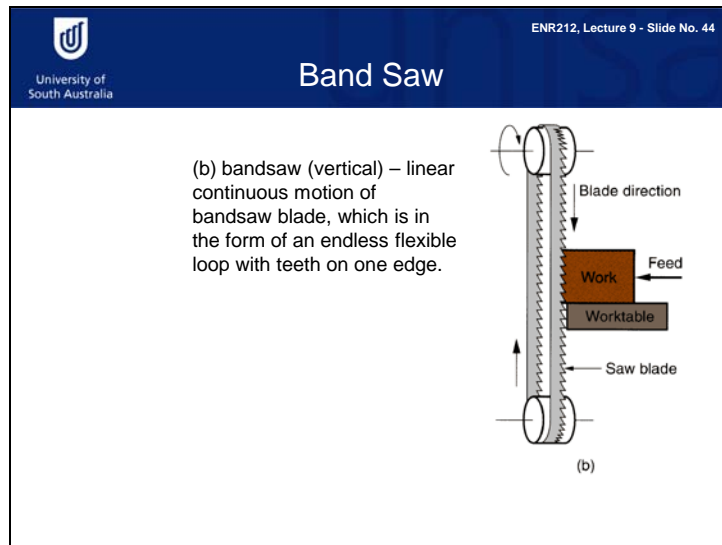
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There are three basic types of sawing, depending on the type of blade motion involved. Hacksawing involves a linear reciprocating motion of the saw against the work. It is interrupted.

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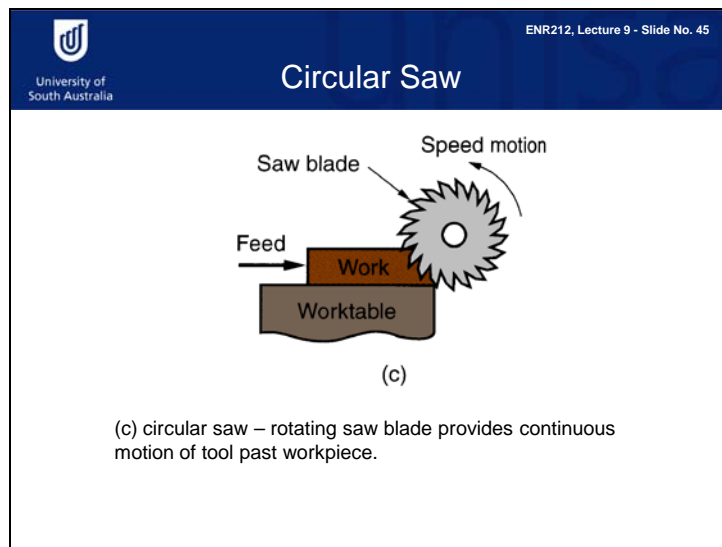
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Bandsawing involves a linear continuous motion, using a bandsaw blade made in the form of an endless flexible loop with teeth on one edge.

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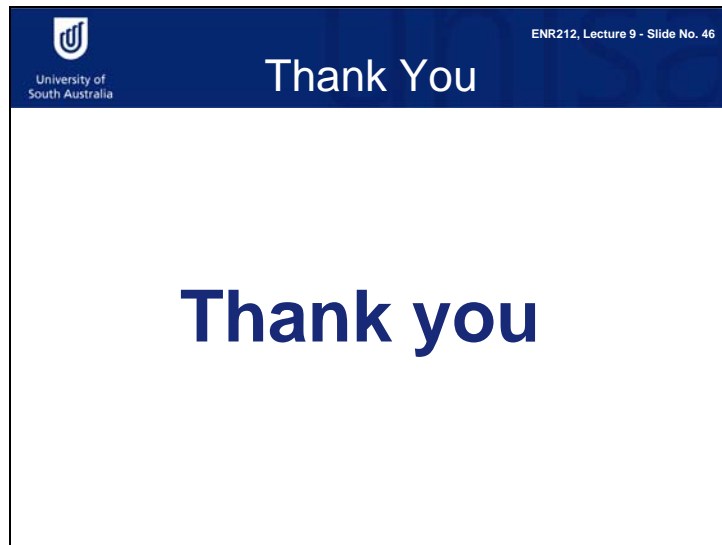
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Circular sawing uses a rotating saw blade to provide a continuous motion of the tool past the work.

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Thank you for your attention.