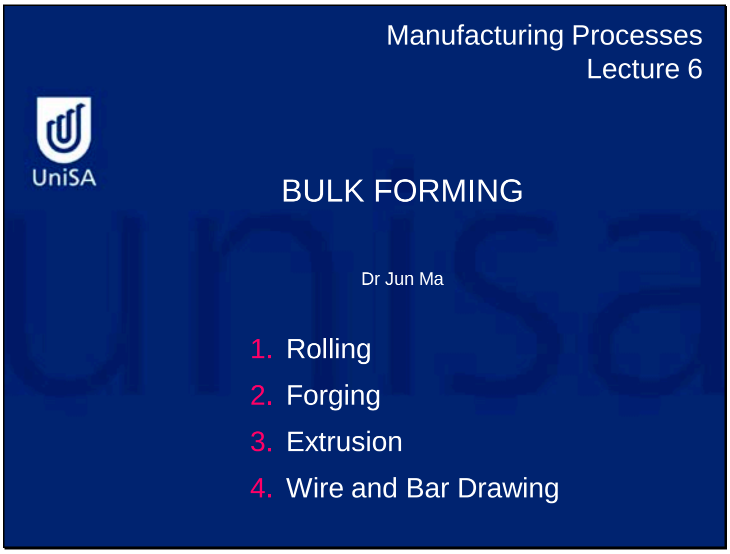
ENR212 Lecture 6 Slides and Notes

Slide 1



Hello everyone, and welcome to Lecture 6 of Manufacturing Processes. (This lecture works through material covered in Chapter 19 of the textbook.) In this lecture, we introduce major bulk forming processes, including rolling, forging extrusion and wire and bar drawing.

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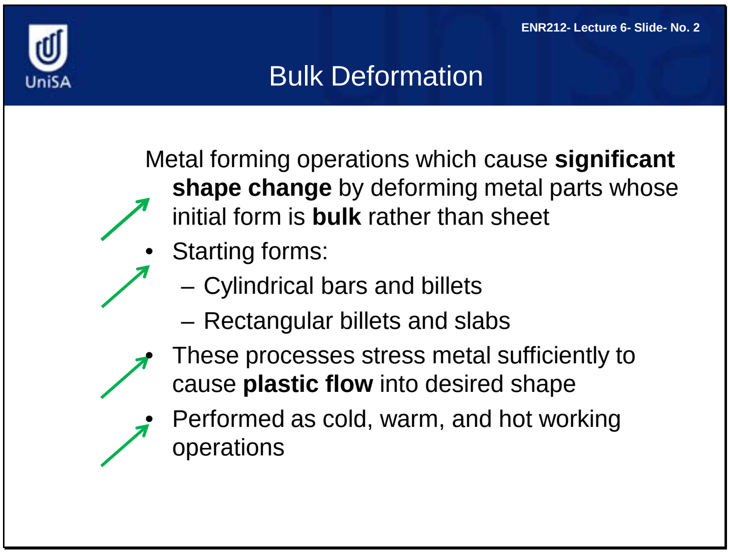

Bulk deforming is a metal forming operation which causes significant shape change by deforming metal parts whose initial form is bulk rather than sheet. The starting forms include cylindrical bars and billets, and rectangular billets and slabs. A slab is rolled from an ingot or a bloom, and has a rectangular cross section of about 250 mm by 40 mm. A billet is rolled from a bloom and has a square cross section of about 40 mm by 40 mm. A bloom is a rolled steel workpiece with a square cross section of about 150 mm by 150 mm.

These processes work by stressing the metal sufficiently to cause plastic flow into the desired shape. Bulk deformation processes are performed at cold, warm, and hot working temperatures.

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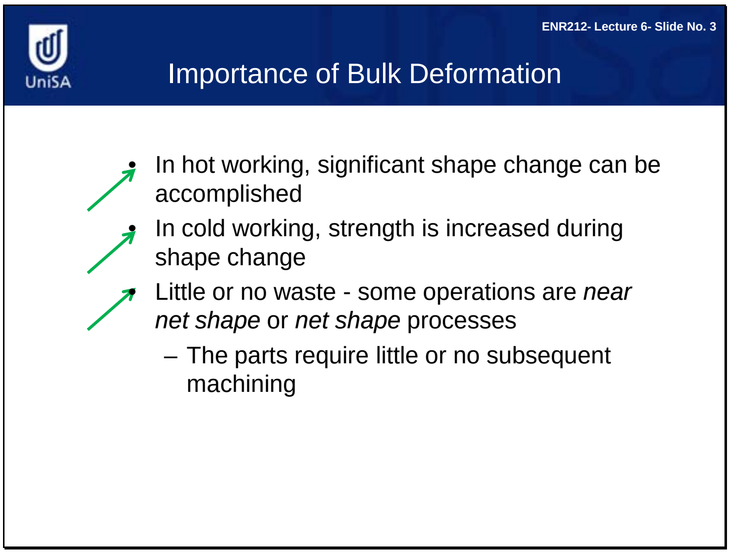

The bulk deformation processes are important for the following reasons:
In hot working, bulk deformation can achieve significant shape change in the shape of the workpiece.
In cold working, the workpiece is strengthened. Strengthening is caused by strain-hardening.
These operations produce little or no waste, allowing them to be classified as near net shape or net shape processes. They also require little or no subsequent machining.

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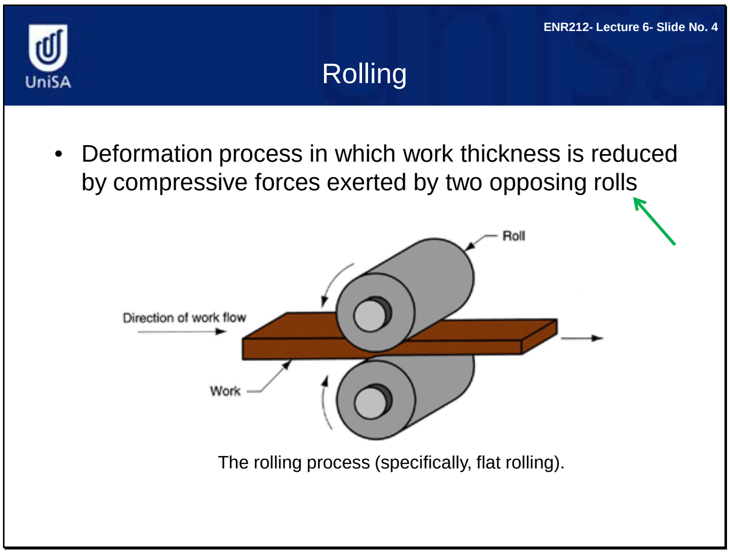

Rolling is a metal forming process in which metal stock is passed through a pair of rolls. The function of the rolls is to pull the work into the gap between them by using friction. At the same time, they squeeze the work to reduce its cross section.

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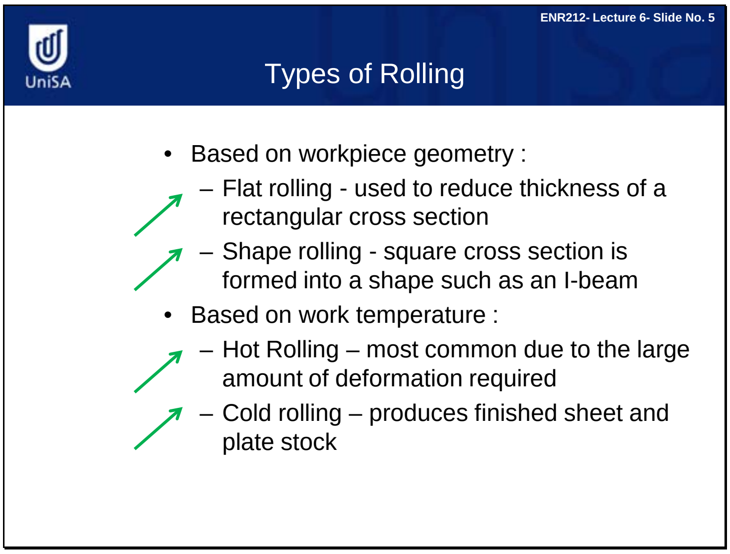

Based on workpiece geometry, there are two types of rolling: flat rolling and shape rolling. Flat rolling is the most basic process, and it is used to reduce the thickness of a rectangular cross section. Shape rolling is closely related to flat rolling. In shape rolling, a square cross section is formed into a shape such as an I-beam. Rolling can be classified according to work temperature. Hot rolling is the most common type, due to the large amount of deformation required. Cold rolling produces a finished sheet and plate stock.

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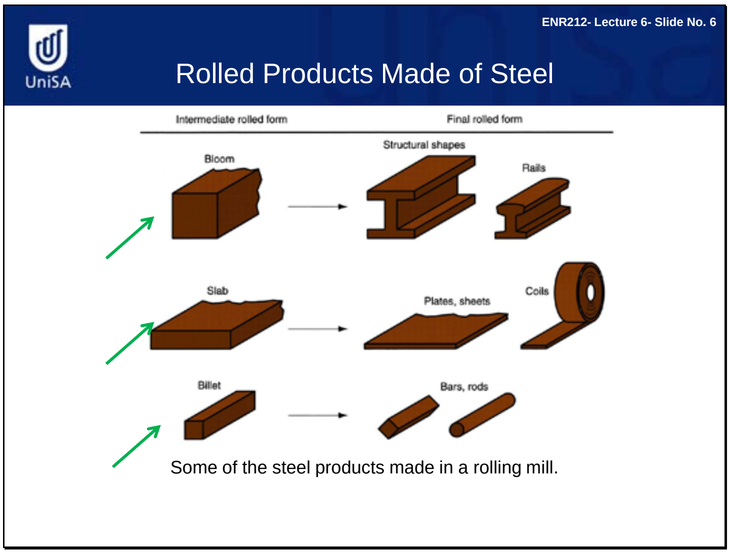

So what are some examples of rolling? In bulk deformation processes, blooms are rolled into structure shapes and rails for railroad tracks. Slabs are rolled into plates, sheets, and strips. Billets are rolled into bars and rods. Most of these processes are performed hot or warm, because hot and warming conditions can produce significant shape change. These shapes are the raw materials for machining, wire drawing, forging, and other metalworking processes.

Further flattening of hot-rolled plates and sheets is often accomplished by cold rolling. Cold rolling strengthens the metal and permits a tighter tolerance on thickness.

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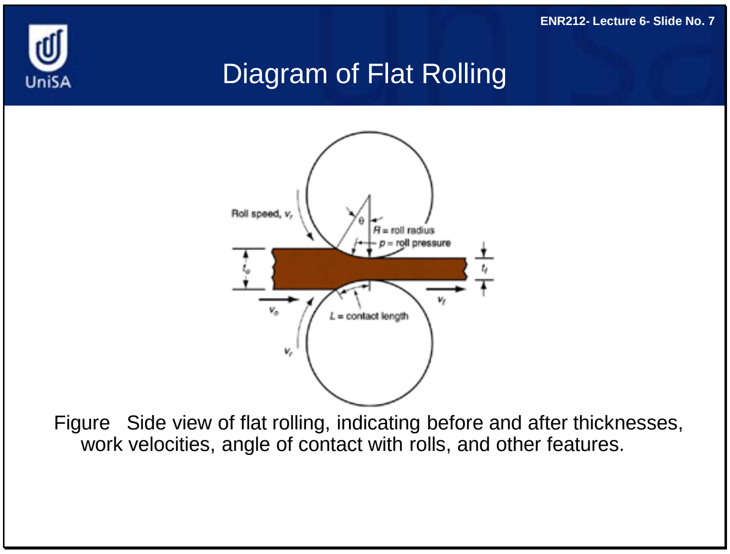

Flat rolling is illustrated in this figure. When a work piece passes through the two rolls from left to right, its thickness is reduced.

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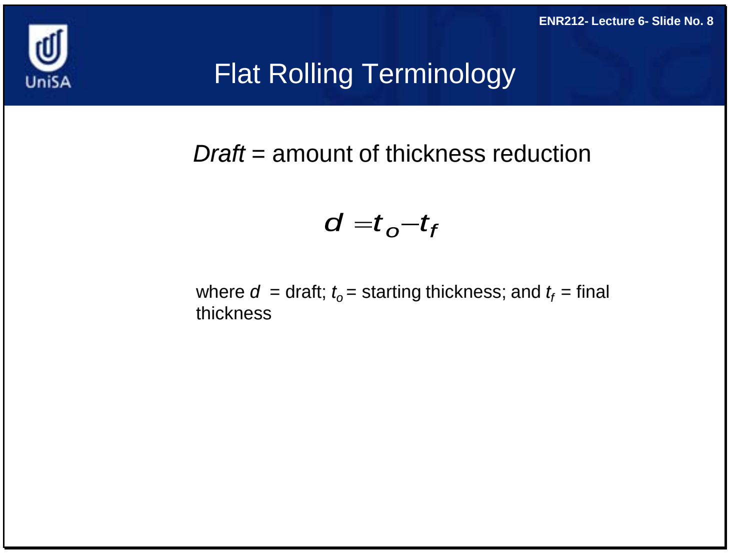

This amount of the reduced thickness is called a draft.
The maximum possible draft in a rolling operation depends on the following parameters : (a) coefficient of friction between roll and work, (b) roll diameter

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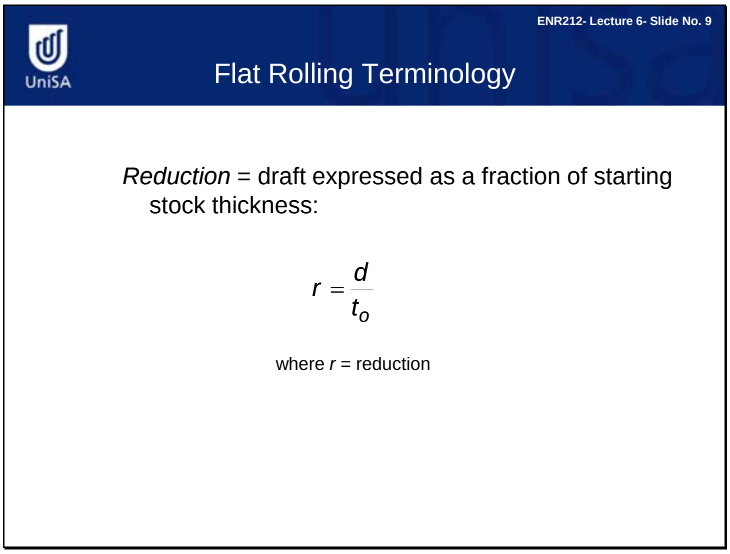

Reduction is the ratio of draft (or the change of thickness) to starting thickness

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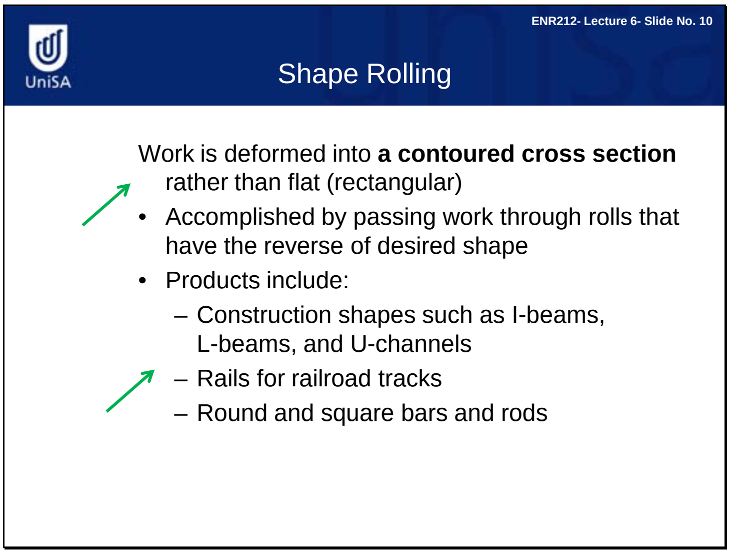

In shape rolling, a workpiece is deformed into a contoured cross section. Shape rolling products include I-beams, Rails for railroad tracks, round and square bars and rods.

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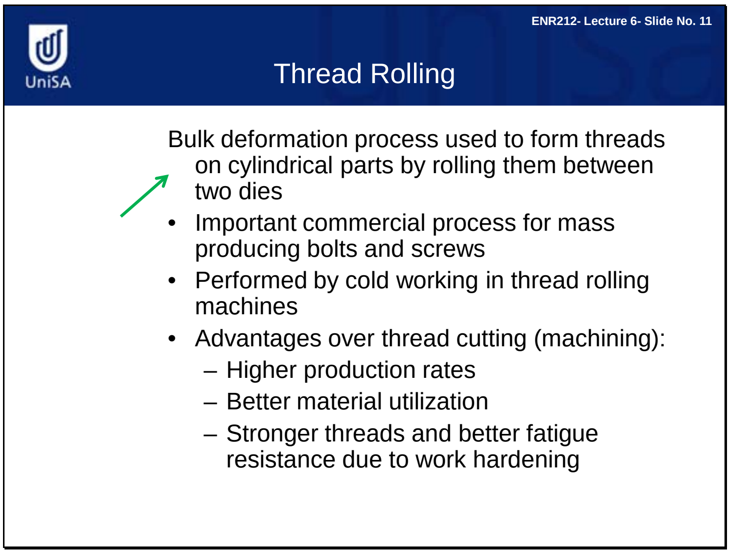

Thread rolling is used to form threads on cylindrical parts by rolling them between two dies. Is thread rolling a cold working or a warm working process? The answer is cold working.

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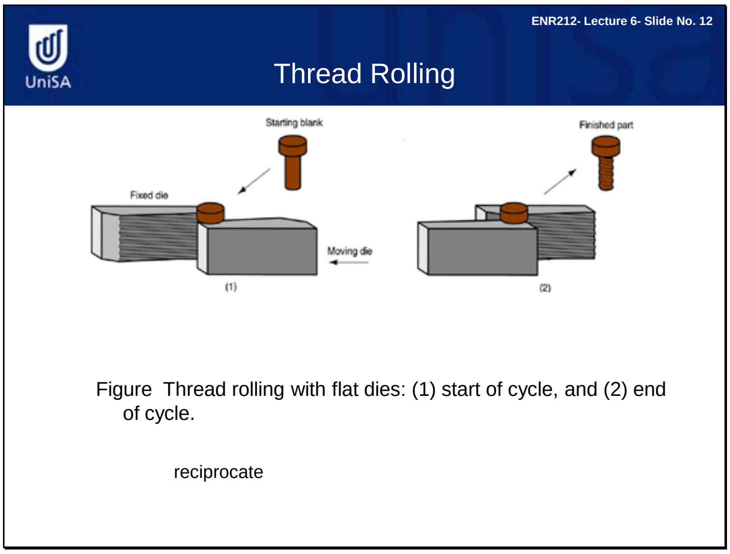

In thread rolling, the two dies reciprocate relative to each other to produce thread.

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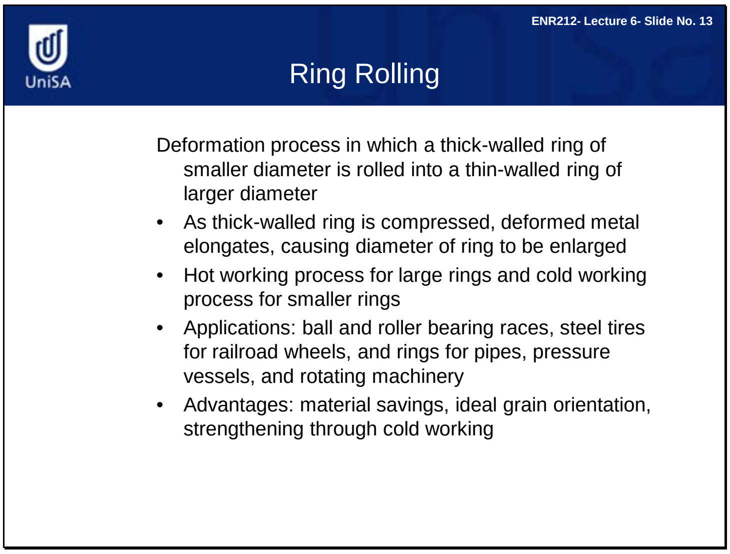

Ring rolling is a deformation process in which a thick-walled ring of smaller diameter is rolled into a thin-walled ring of larger diameter.

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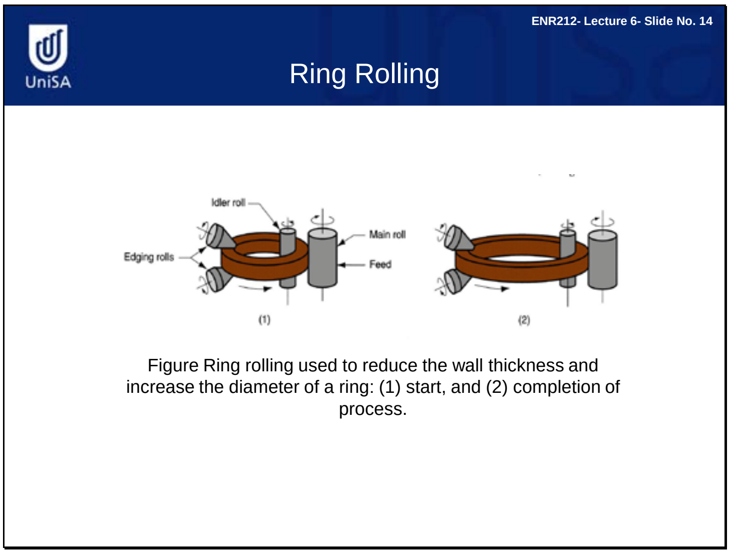

As the thick-walled ring is compressed, the deformed metal elongates, causing the diameter of the ring to be enlarged.

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Rolling Mills

- Equipment is massive and expensive
- Rolling mill configurations:
  - Two-high – two opposing rolls
  - Three-high – work passes through rolls in both directions
  - Four-high – backing rolls support smaller work rolls
  - Cluster mill – multiple backing rolls on smaller rolls
  - Tandem rolling mill – sequence of two-high mills

In rolling, equipment is massive and expensive. Mills are designed in different types of configurations, as you can see above.

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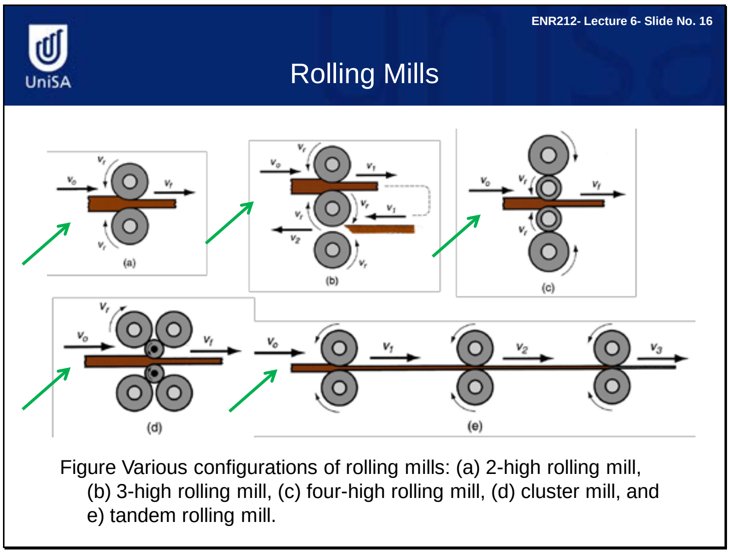

The two-high rolling mill is the basic type, consisting of two opposing rolls.
In the three-high configuration, there are three rolls in a vertical column, and the direction of rotation of each roll remains unchanged. An elevator mechanism is needed to raise or lower the workpiece.
The four-high rolling mill uses two smaller-diameter rolls to contact the workpiece with two backup rolls.
In a cluster rolling mill, more than two backup rolls support smaller-diameter rolls.
To achieve high production rates, a tandem rolling mill is often used. It consists of a number of rolling stands. With each rolling step, workpiece velocity increases.

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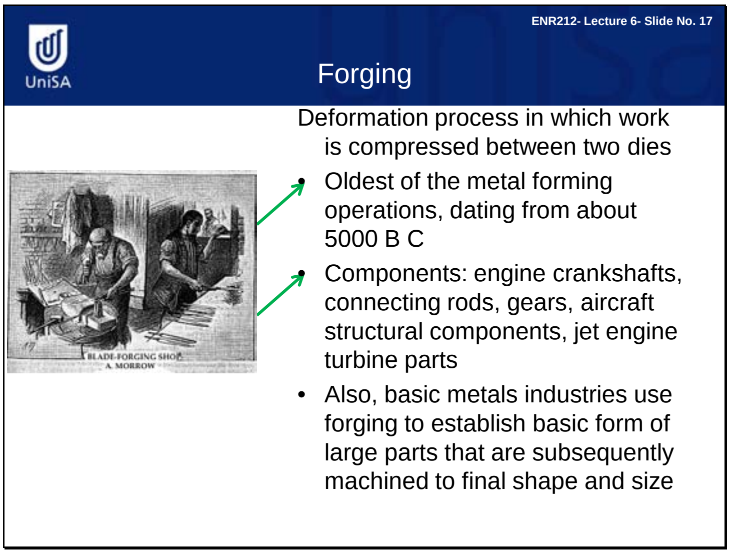

In forging, a workpiece is compressed between two opposing dies, so that the die shapes are imparted to the work.
It is the oldest of the metal forming operations, dating from about 5000 B.C.
The basic metals industries use forging to establish basic form of large parts; the large parts are subsequently machined to final shape and size, such as engine crankshafts, connecting rods, gears, aircraft structural components, and jet engine turbine parts.

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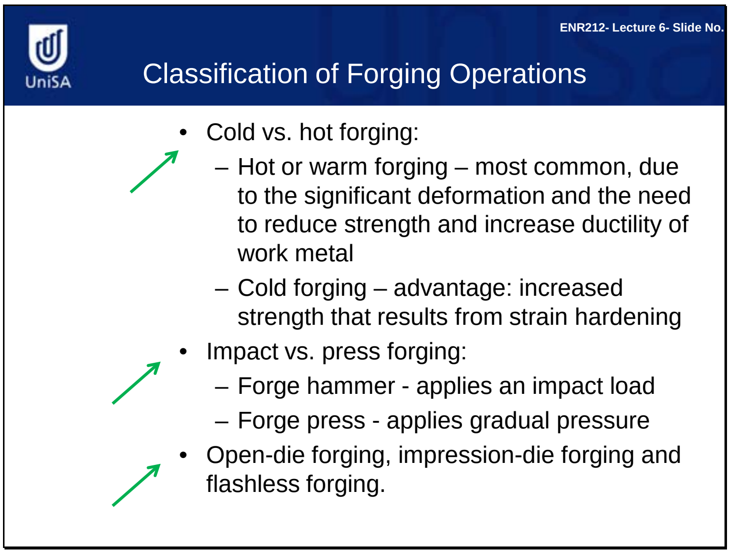

Forging is carried out in many different ways. One way to classify it is by working temperature. Hot or warm forging is most common. This is due to the significant deformation and the need to reduce strength and increase ductility of work metal.
Cold forging is also commonly used. The advantage is the increased strength that results from strain hardening of the component.
According to the way load is applied, forging can use a hammer or a press. In some forging operations, forge hammers are used, which apply an impact load, while in others forging presses are used, which apply gradual pressure. Based upon the cavities that the die and punch form, forging operations are classified into open-die forging, impression-die forging and flashless forging.

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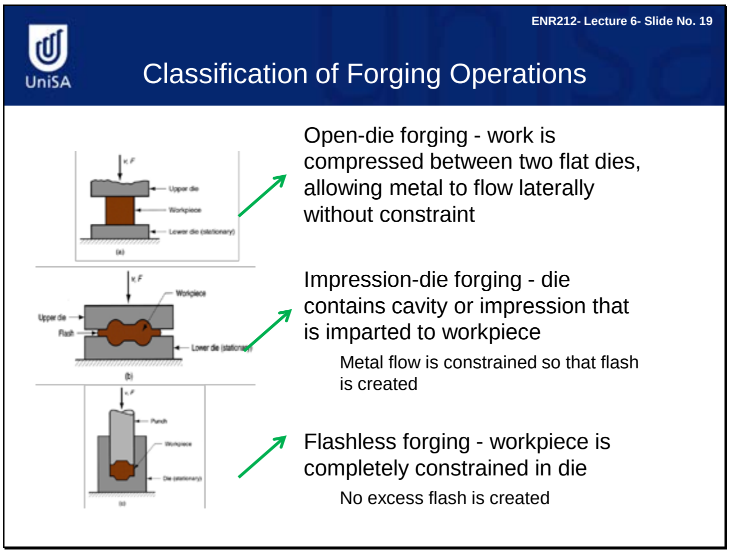

In open-die forging, a work is compressed between two flat dies, so that the metal flows without constraint in a lateral direction relative to the die surfaces. In impression-die forging, the die contains cavities or impressions that are imparted to the workpiece, thus constraining metal flow to a significant degree. Metal flow is constrained so that flash is created. In flashless forging, the workpiece is completely constrained within the die and no excess flash is created.

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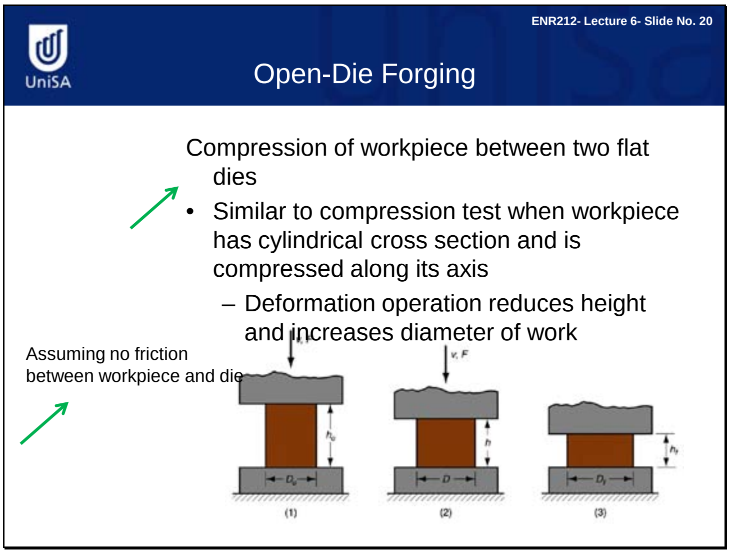

In open-die forging, a work is compressed between two flat dies. Assuming there is no friction between workpiece and die, metal flows laterally without constraint. This is similar to compression testing. Remember back to when we covered the stress-strain curve and the true stress-strain curve. The true stress-strain curve obtained from tensile testing for a given material can be used to predict stress-strain value for compression testing.

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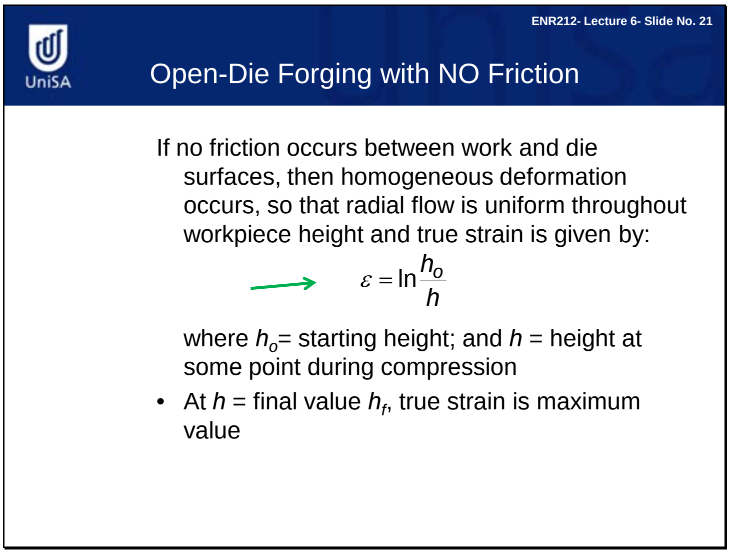

If no friction occurs between work and die surfaces, then metal flows freely between die and metal. The true strain is given by this equation; note that this equation of true strain is slightly different to the equation of true strain we covered in lecture three.

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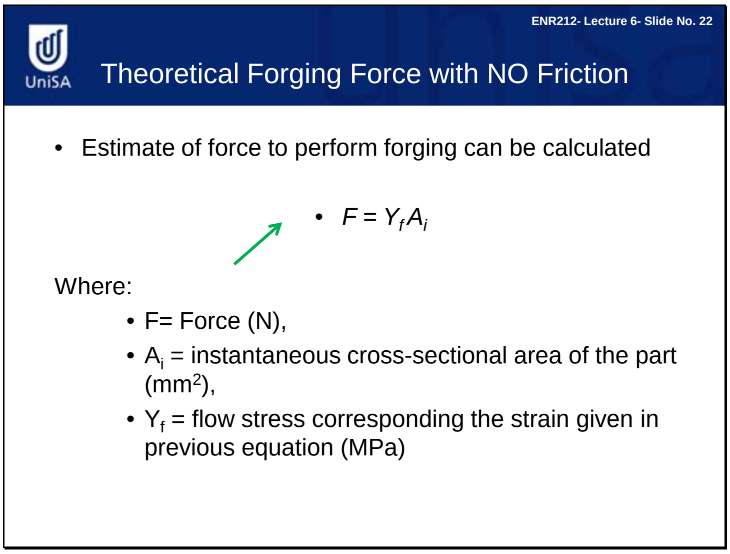

The forging force is given by this equation, which is just another format of true stress.

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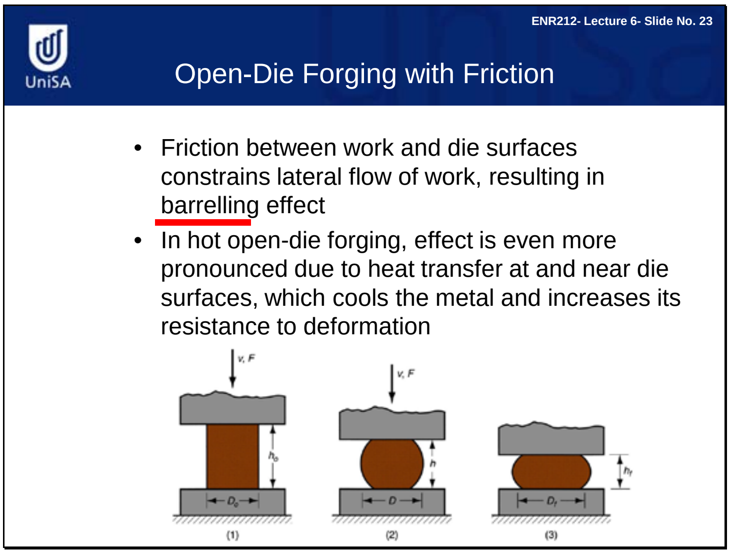

As explained, open-die forging is similar to compression testing in that they both assume the condition that no friction exists between workpiece and die. Of course, in the real world, there is always friction between the work piece and the die surfaces, which constrains the lateral flow of the piece. This results in a barrelling effect, so the cross section is not uniform. Therefore, we need to modify the equation.

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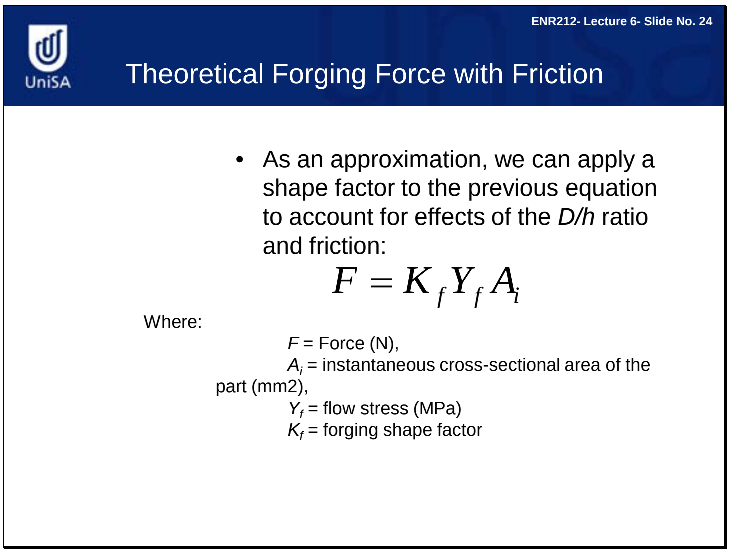

To take into account the barrelling effect, a shape factor was applied to the above equation.

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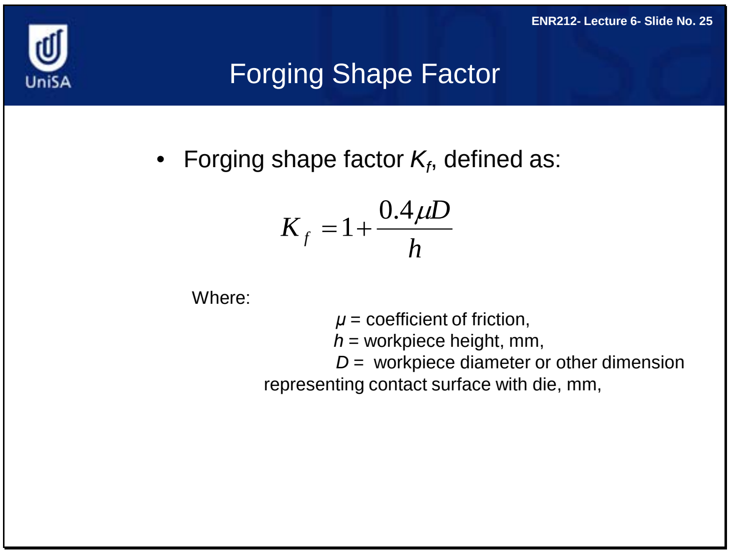

The forging shape factor is defined by this equation.

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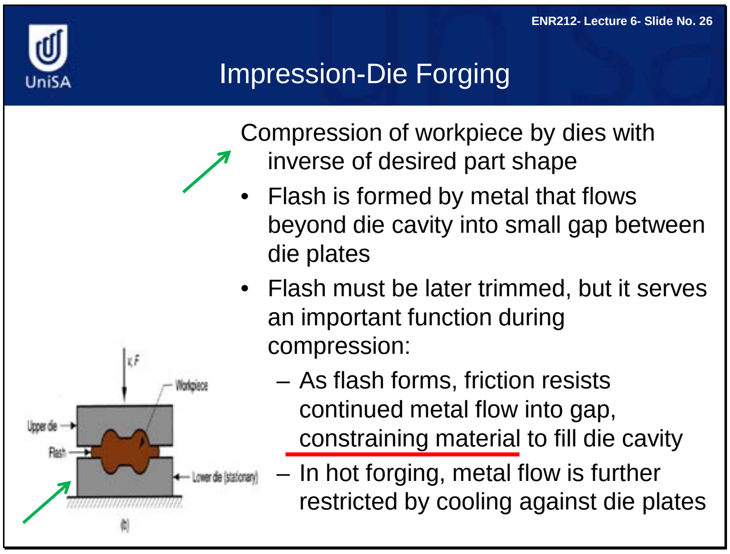

Impression die forging is performed with dies that contain the inverse of the desired shape of the part, so that the die contains the cavity or impression that is imparted to the workpiece. In impression die forging, the metal under high pressure is squeezed into the small space between the die halves at the parting line, so that a flash is created. A flash is the formation of a small piece of metal. As the flash forms, friction resists the metal flowing into the gap. This constrains the material, making it fill the die cavity.
Impression-die forging is followed by trimming, which is a shearing operation used to remove the flash on the workpiece after impression die forging.

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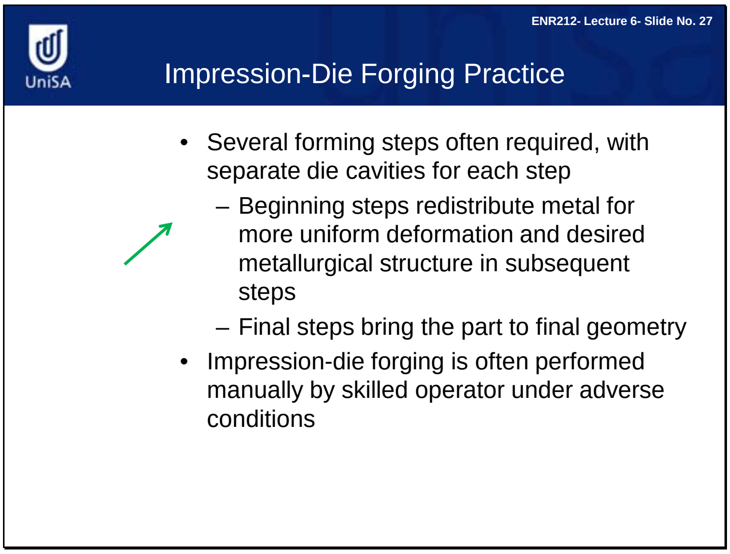

In impression-die forging, a number of steps are required. The initial steps redistribute metal for more uniform deformation and the final steps bring the part to final geometry. This sort of forging needs skilled labor.

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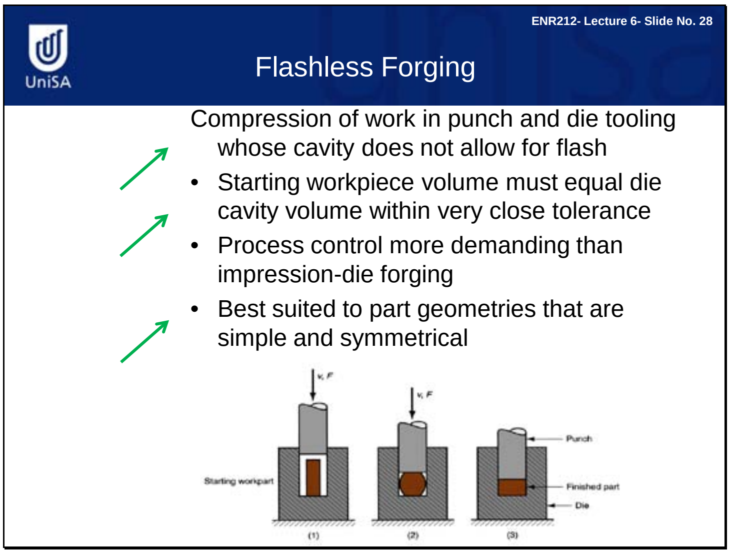

In flashless forging , the workpiece is completely constrained within the die and no excess flash is created. This is often classified as a precision forging process. The starting workpiece volume must equal the die cavity volume within a very close tolerance. This is best suited to part geometries that are simple and symmetrical.

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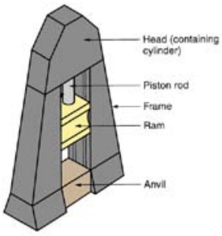
Forging Hammers (Drop Hammers)



Apply impact load against workpiece

- Two types:
  - Gravity drop hammers - impact energy from falling weight of a heavy ram
  - Power drop hammers - accelerate the ram by pressurized air or steam
- Disadvantage: impact energy transmitted through anvil into floor of building
- Commonly used for impression-die forging

Forging hammers operate by applying an impact loading against the workpiece.

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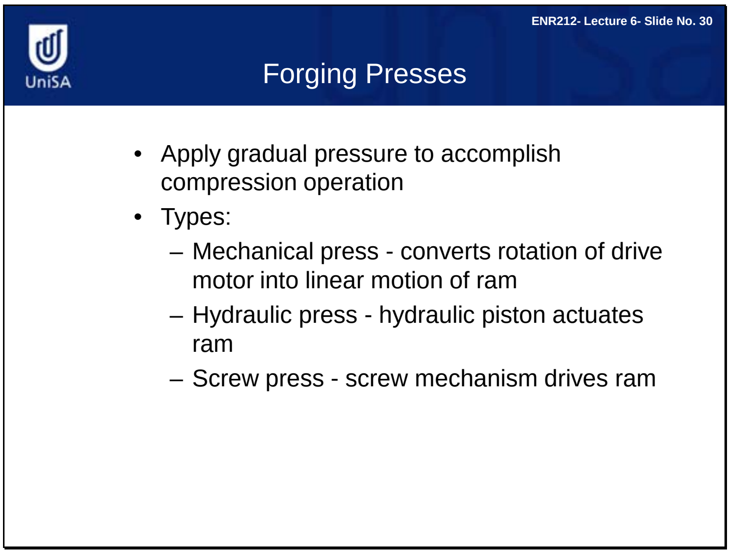

Forging presses apply gradual pressure, rather than sudden impact, to accomplish the forging operation.

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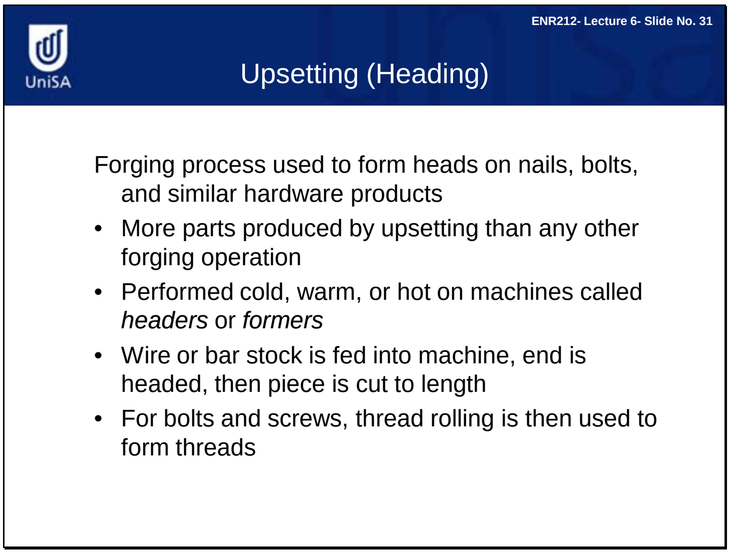

Upsetting is a deformation operation in which a cylindrical workpiece is increased in diameter and reduced in length. This is a very popular form of forging.

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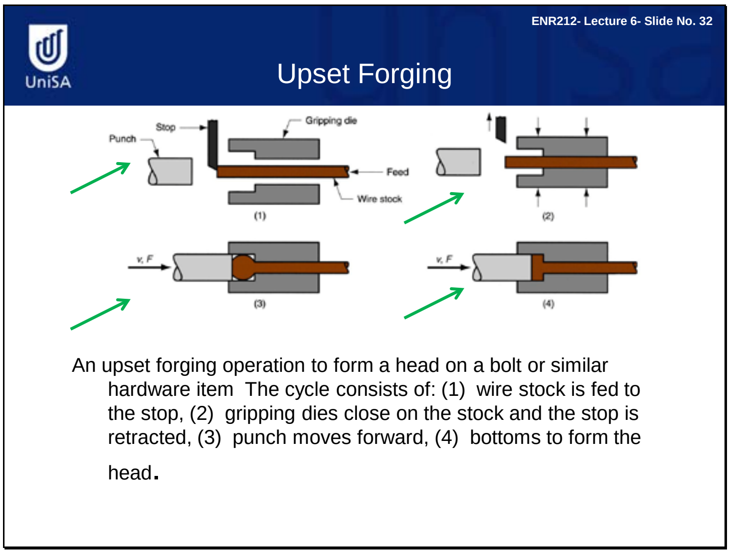

An upset forging is shown in this figure. (1) a wire stock is fed into a die and stopped by a stop, (2) the die closes on the stock and the stop is retracted, (3) the punch moves forward, (4) a head is produced.

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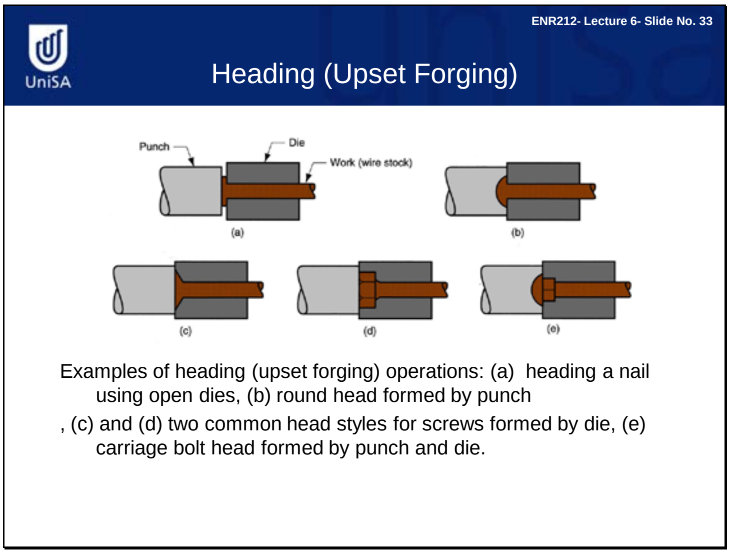

By changing the geometries of punch and die, upset forging is able to produce a variety of heads.

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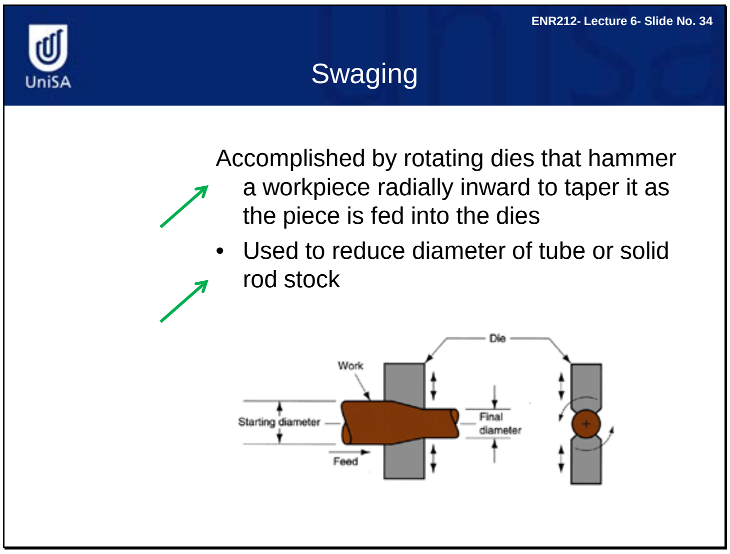

Swaging is accomplished by means of rotating dies. The dies hammer a work piece radially inward to taper it as the piece is fed into the dies.   The swaging process is used to reduce diameter of solid rod stock; the dies rotate as they hammer the work.

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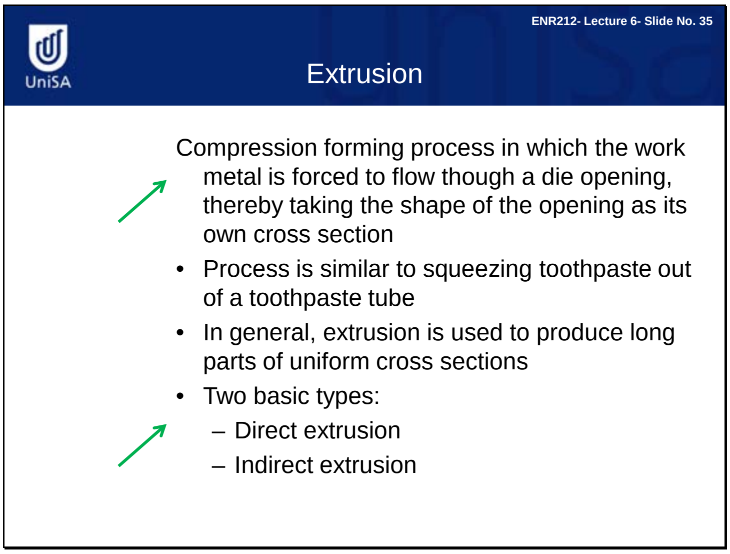

Extrusion is a compression process in which the work metal is forced to flow though a die opening, thereby taking the shape of the opening as its own cross section. There are two basic types: direct extrusion and indirect extrusion.

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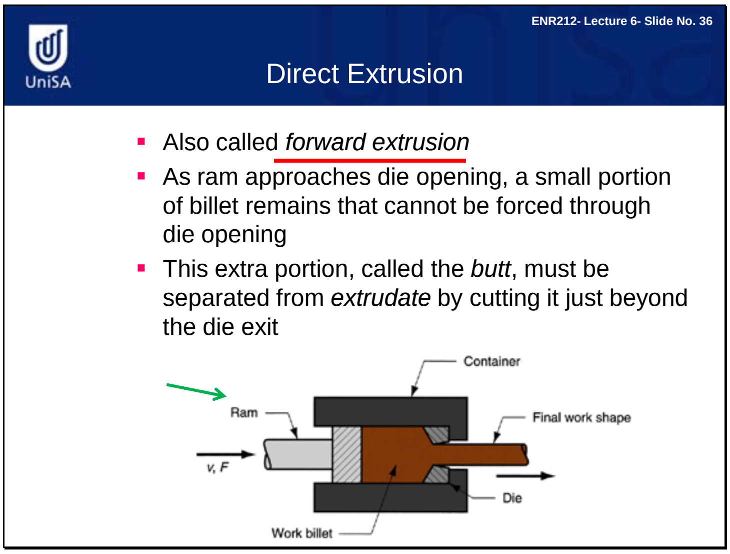

Direct extrusion is also called forward extrusion. As shown in this figure, a metal billet is loaded into a container, and a ram compresses the material, forcing it to flow through one or more openings in a die at the opposite end of the container.

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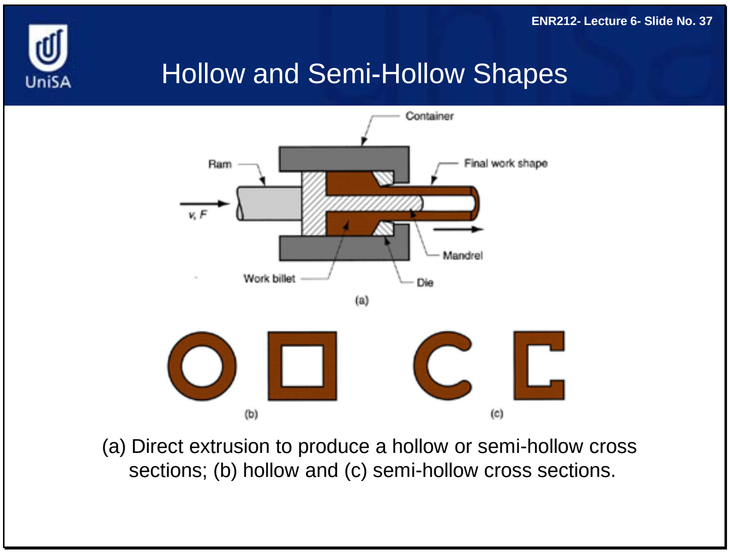

A variety of cross sections can be made in direct extrusion, by using various die openings, as you can see in figure b.

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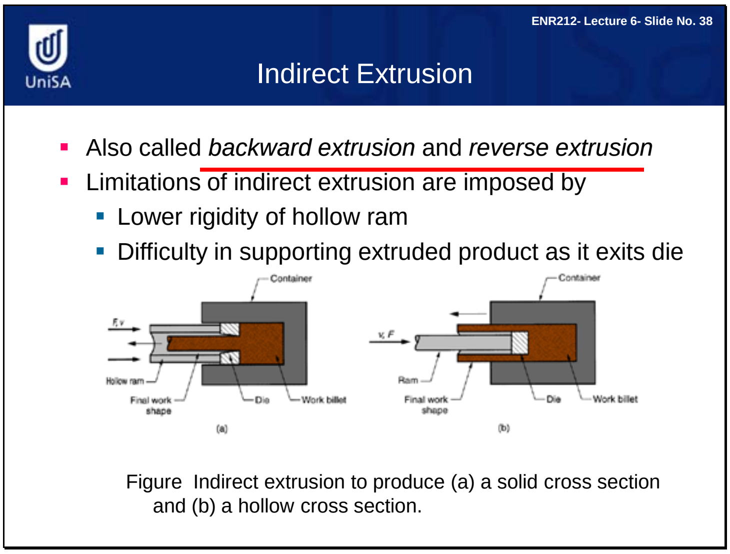

Indirect extrusion is also called backward extrusion and reverse extrusion. In indirect extrusion, the die is mounted to the ram rather than at the end of the container. As the ram penetrates in to the workpiece, the metal is forced to flow through the clearance in a direction opposite to the motion of the ram.

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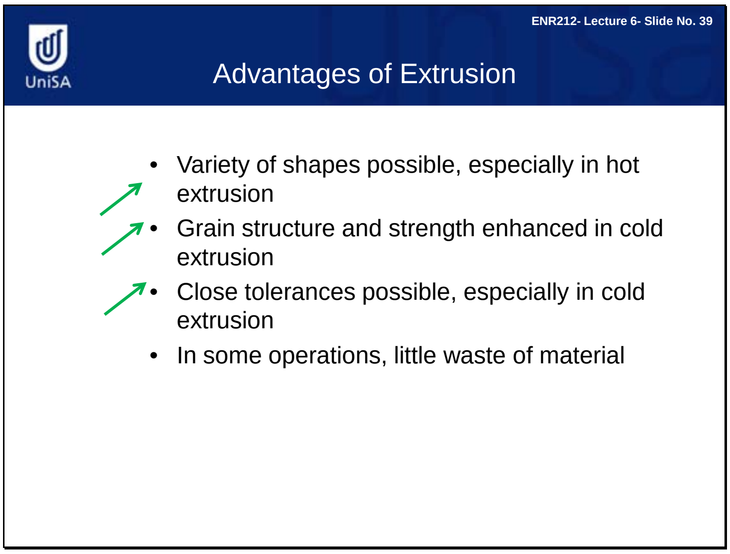

Advantages of extrusion include the following:
1 A variety of shapes can be made by changing dies, especially in hot extrusion.
2. It produces desired grain structure, and strength is enhanced in cold extrusion.
3. Because metal is extruded through a die, the extrusion produces close tolerances and there is little waste.

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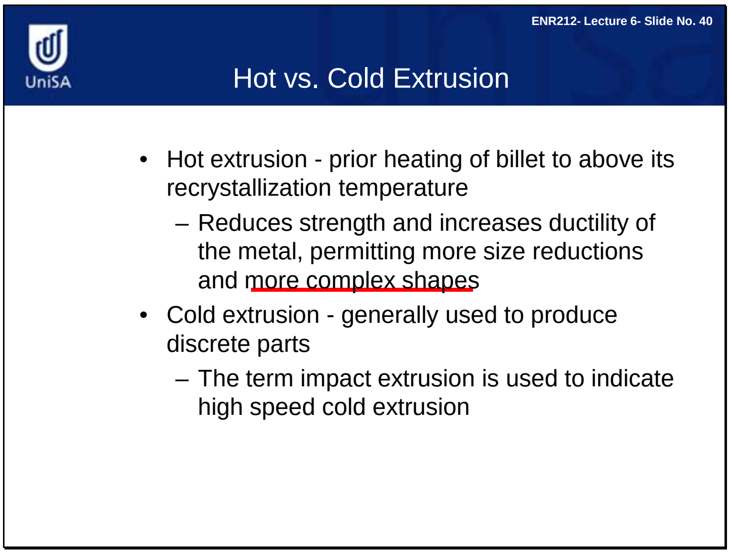

So how are hot extrusion and cold extrusion different? Hot extrusion needs prior heating. It is able to produce more complex shapes, due to the high ductility of metal at high temperatures.

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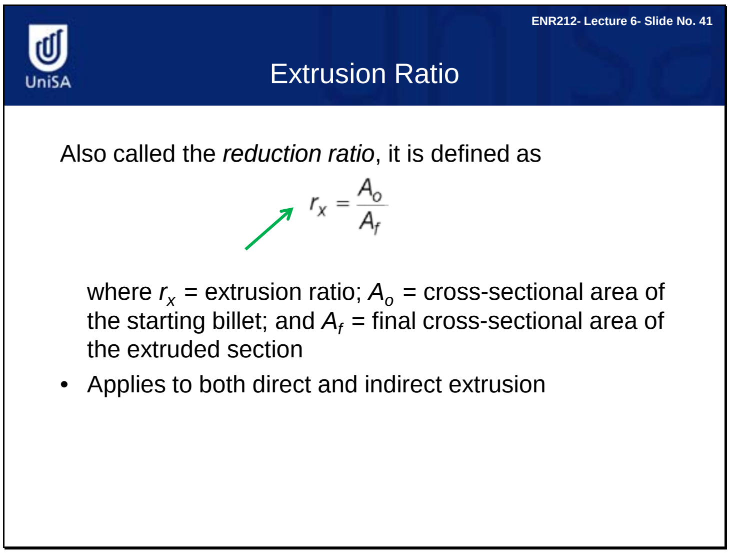

The extrusion ratio is the ratio of the starting cross section area to the final area.

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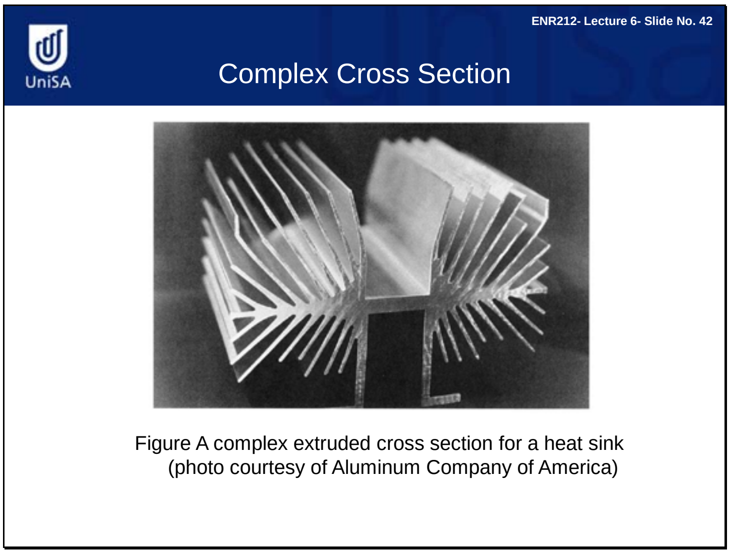

This photo shows you a heat sink. Do you think that this was produced using cold extrusion or hot extrusion? The answer is hot extrusion.

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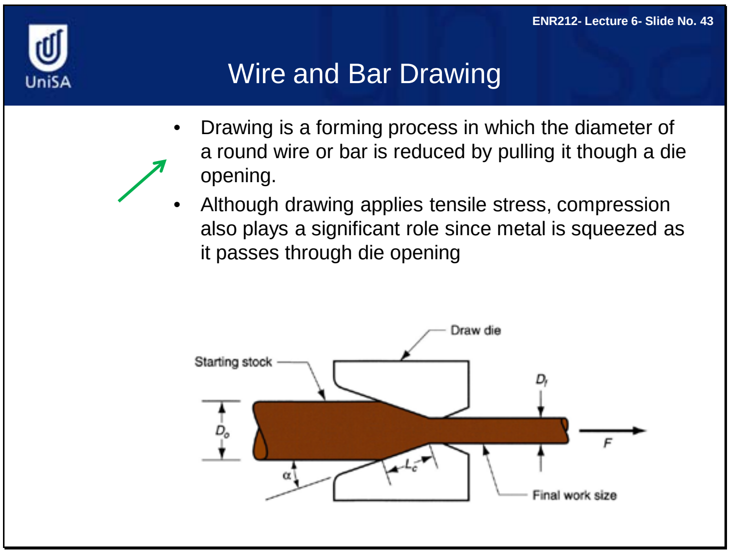

Wire and bar drawing is a forming process in which the diameter of a round wire or bar is reduced by pulling it through a die opening.
It is similar to extrusion, but the work is pulled through a die in drawing, where it is pushed through in extrusion.

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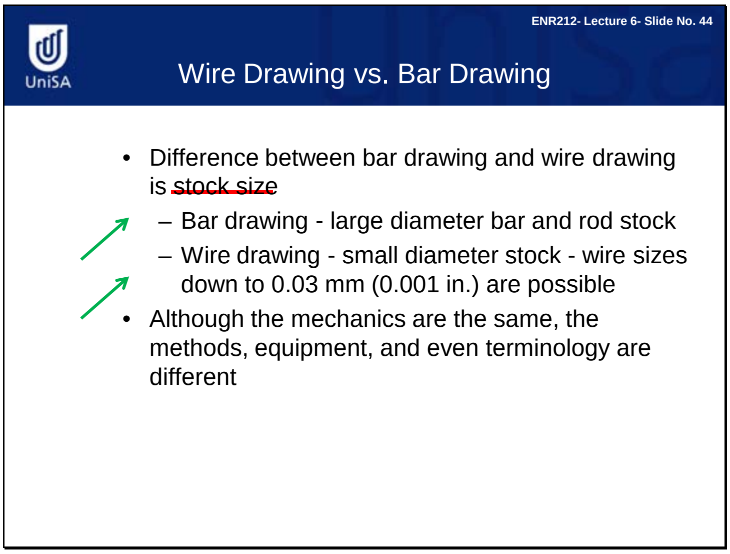

The basic difference between bar drawing and wire drawing is the stock size that is processed. Bar drawing is used for large diameter bar and rod stock. Wire drawing is applied to small diameter stock, with wire sizes down to 0.03 mm (0.001 inch) being possible.

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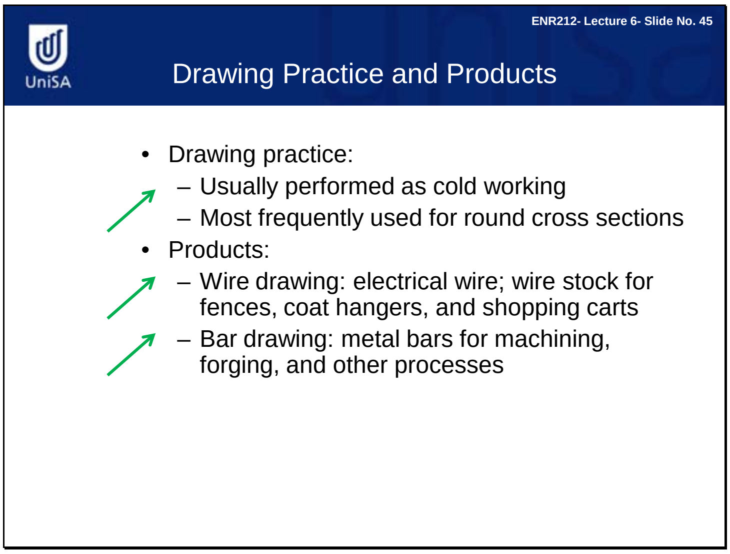

Drawing practice is usually performed as a cold working operation. It is usually used to produce round cross sections, but squares and other shapes are also drawn. Wire drawing is an important industrial process, providing commercial products such as electrical wire and cable, wire stock for fences, coat hangers, and shopping carts, and rod stock to produce nails, screws, rivets, and springs. Bar drawing is used to produce metal bars for machining, forging, and other processes.

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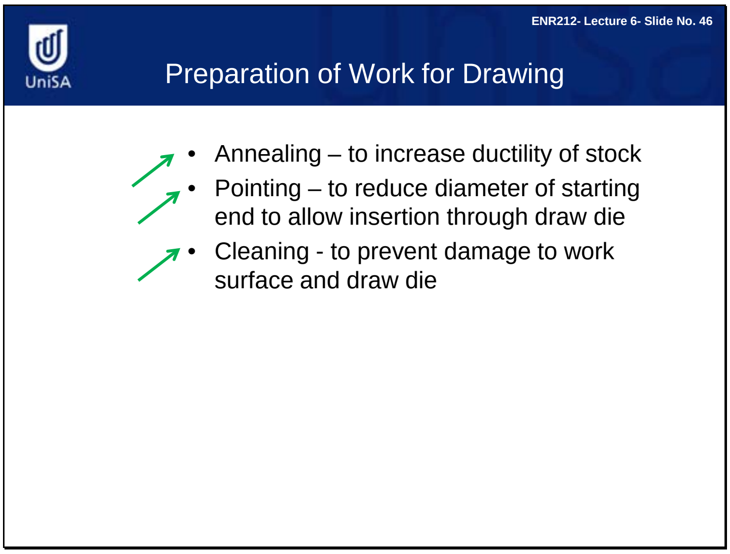

Three steps of work are needed to prepare a workpiece for drawing.

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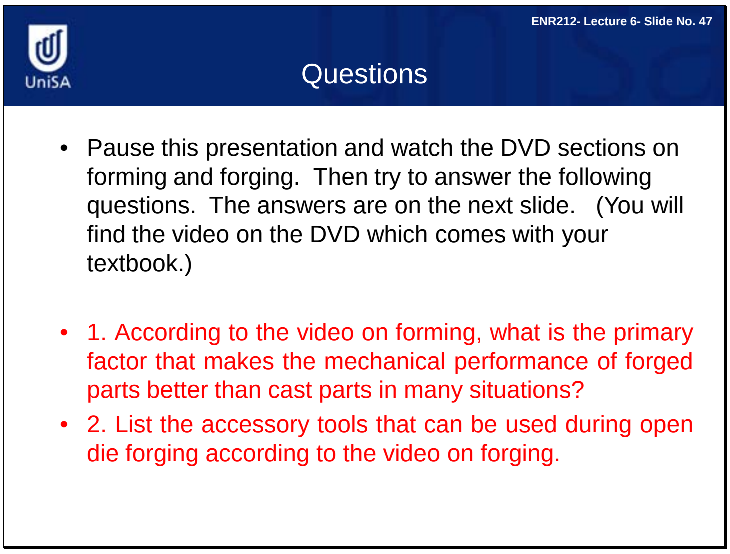
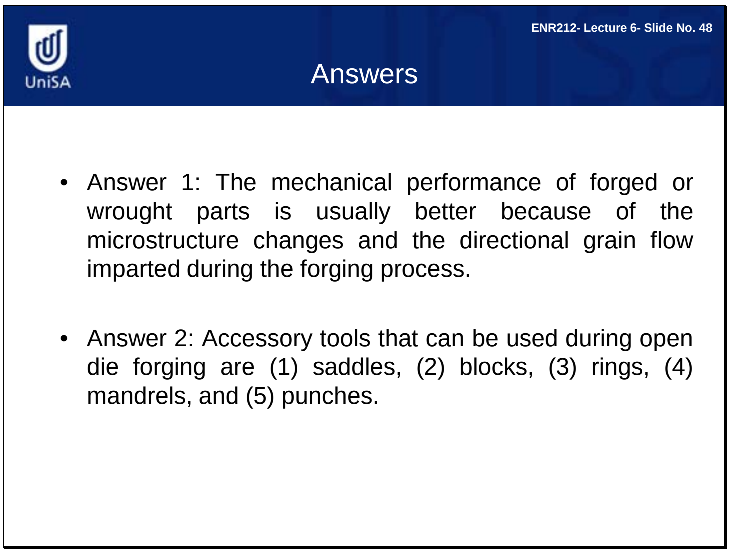


Now pause this presentation and watch the DVD sections on forming and forging. Then try to answer the following questions. The answers are on the next slide. (You will find these videos on the DVD which comes with your textbook.)

Slide 48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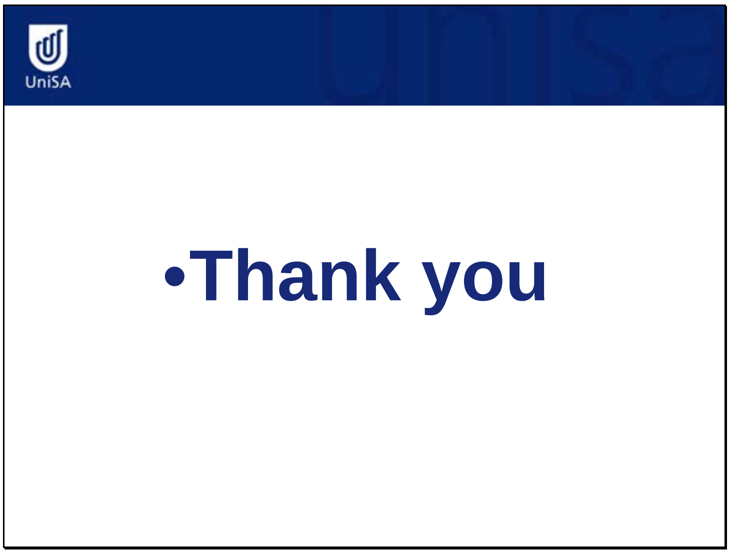
Answers
• Answer 1: The mechanical performance of forged or wrought parts is usually better because of the microstructure changes and the directional grain flow imparted during the forging process.
• Answer 2: Accessory tools that can be used during open die forging are (1) saddles, (2) blocks, (3) rings, (4) mandrels, and (5) punches.

Slide 49



Thanks for your attention.