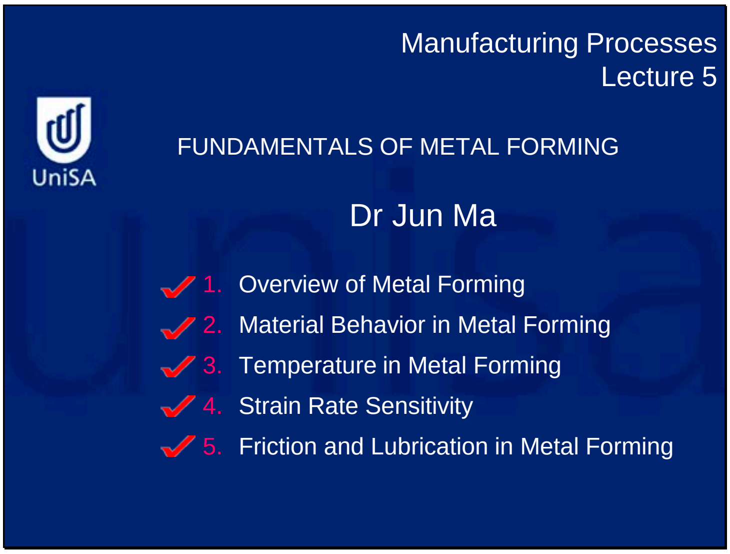
ENR212 Lecture 5 Slides and Notes

Slide 1



Welcome to lecture summary 5. (This lecture works through material covered in Chapter 18 of the textbook.) In this lecture, we will introduce the fundamentals of metal forming. We will look at the following questions:

First, what is metal forming, and what are the categories of metal forming?

Second, how do we describe material behaviour when forming metals? Material behaviour can be understood as material deformation, so material behaviour can be described by the stress-strain curve.

Third, what is the effect of temperature on metal forming. When temperature increases, strength reduces, but ductility increases.

Fourth, does strain rate matter much in metal forming?

Fifth, is friction desireable, and how can we control it?

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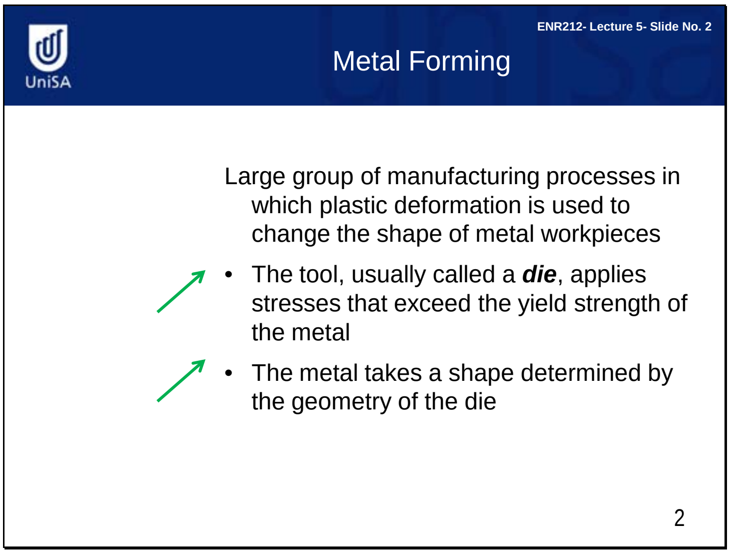

Metal forming is also called metal deformation. In metal forming, the shape of a metal piece is changed by plastic deformation, so the plastic region in the true Stress-Strain curve is important here. Metal flow is the nature of metal forming; the flow is caused by the stress applied.

The metal deformation is caused by using a tool. The tool, usually called a die, applies stresses that exceed the yield strength of the metal.

The shape of the metal product is determined by the geometry of the die.

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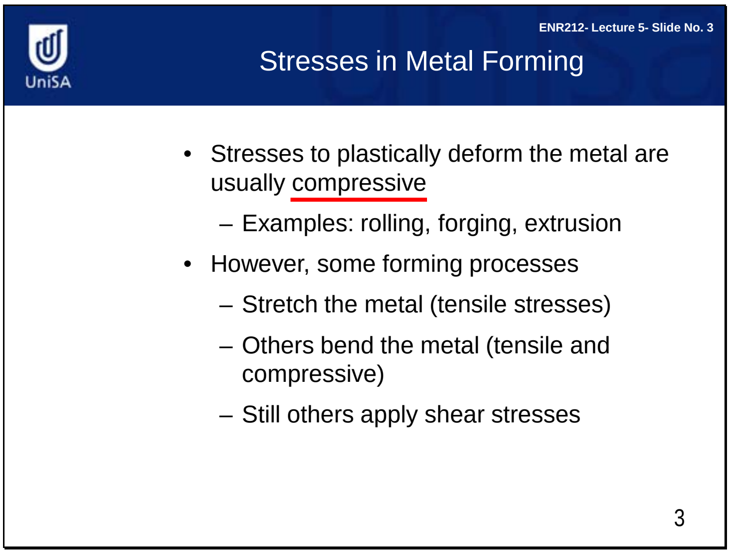

We have learnt about three types of static stresses: tension, compression and shearing. In metal forming, compression is commonly applied to plastically deform the metal. However, tension and shearing are also used in metal forming.

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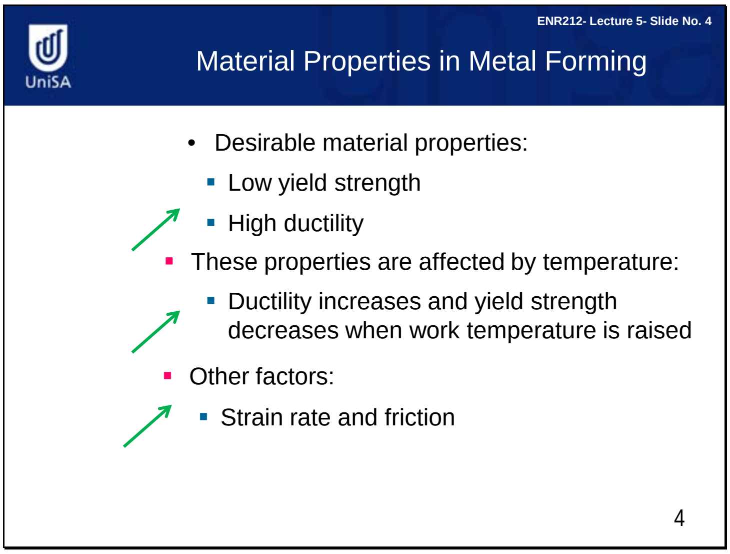

To be successfully formed, a metal must possess certain properties. Desirable material properties for metal forming include a low yield strength and high ductility. High ductility means high strain value at break. These properties are affected by temperature. When the work temperature is raised, ductility increases and yield strength decreases. Strain rate and friction are additional factors that affect performance in metal forming.

So we can sum up the three factors which affect metal forming: temperature, strain rate and friction.

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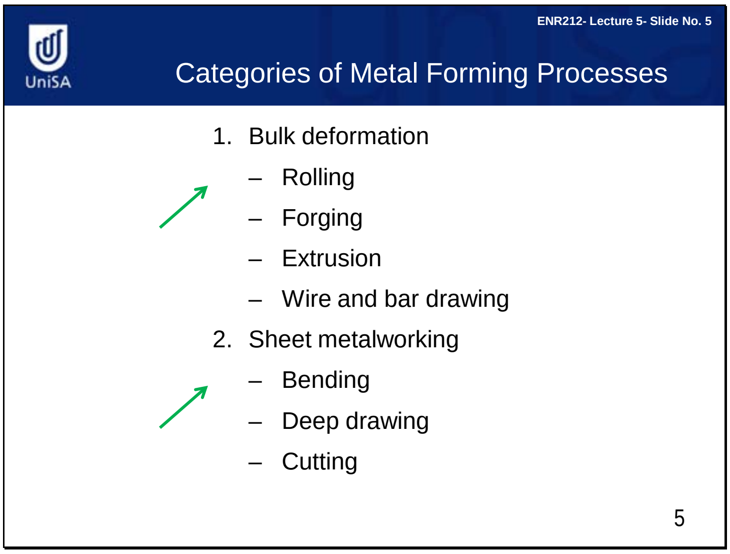
Slide 5



Metal forming processes can be classified into two basic categories: bulking deformation and sheet metalworking. This classification is based on the volume to surface ratio of the starting materials. Bulking deformation includes rolling, forging, extrusion, and wire and bar drawing. Sheet metalworking consists mainly of bending, deep drawing and cutting.

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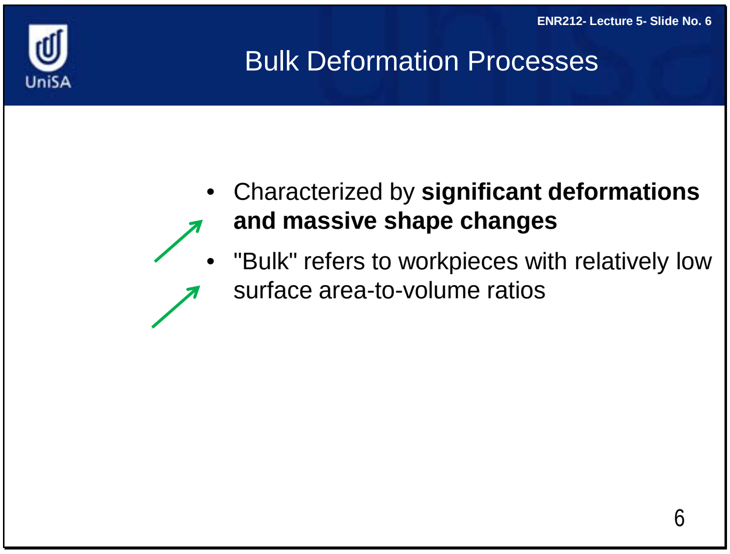

Bulk forming is a metal forming operation which causes significant shape change by deforming a metal part; the initial form of the metal part is bulk rather than sheet. Bulk deformation processes are generally characterized by significant deformations and massive shape changes. The term "Bulk" describes the workpieces that have a low area-to-volume ratio.

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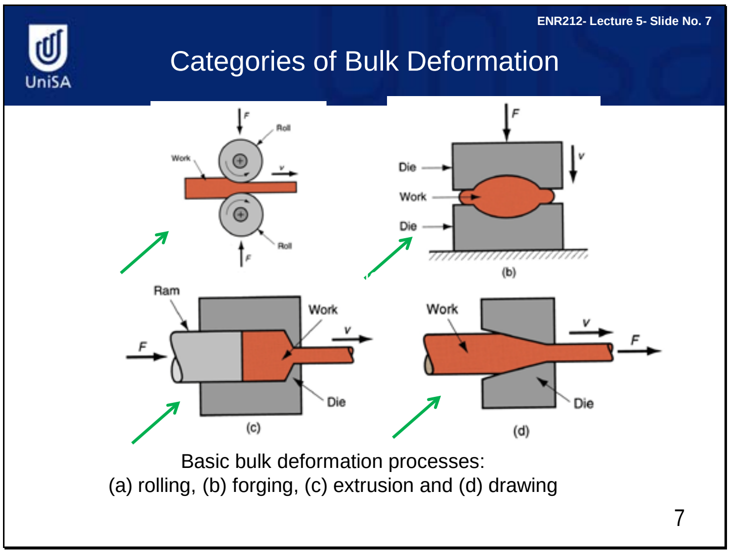

Bulk deformation includes rolling, forging, extrusion and drawing.

One. Rolling is a compressive deformation process in which the thickness of a slab or plate is reduced by two opposing cylindrical tools called rolls. The rolls rotate so as to draw the work into the gap between them, and squeeze it.

Two. In forging, a workpiece is compressed between two opposing dies, so that the die shapes are imparted to the work. Forging is traditionally a hot working process, but nowadays many types of forging are performed cold.

Three. Extrusion is a compression process in which a work metal is forced to flow though a die opening, thereby taking the shape of the opening as its own cross section.

Four. Drawing is a forming process in which the diameter of a round wire or bar is reduced by pulling it though a die opening.

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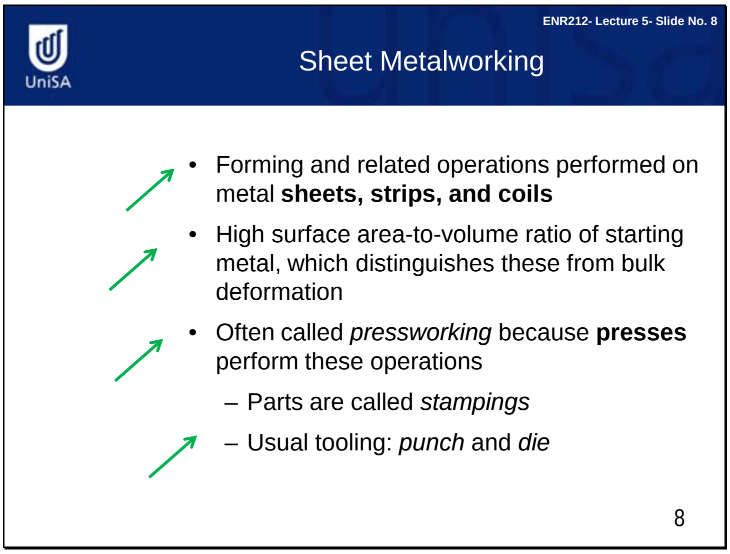

Sheet metalworking processes are deformation operations performed on metal sheets, strips, and coils. They are characterized by the high surface area-to-volume ratio of starting metal.Sheet metalworking is often called pressworking because the machines used to perform these operations are presses.
Sheet metal operations are accomplished using a set of tools called punch and die.

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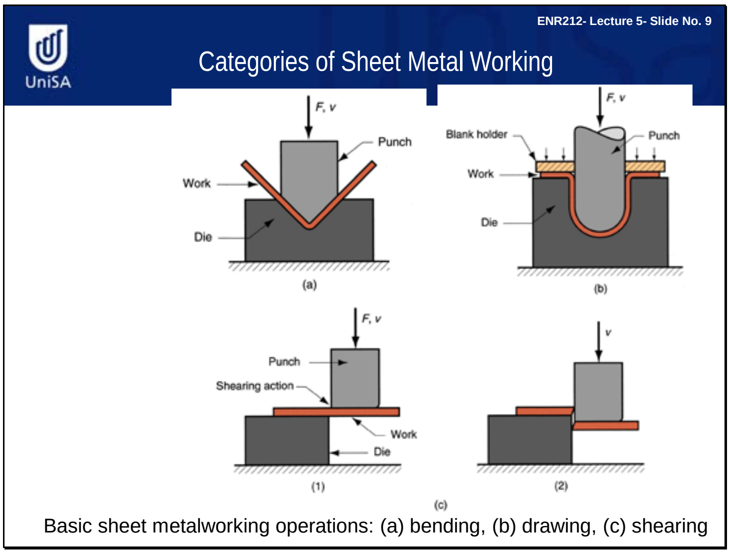

Sheet metal working includes bending, drawing and shearing. In Bending (figure a), a metal sheet or plate takes an angle along a straight axis by straining. Deep or cup drawing (figure b) refers to the forming of a flat metal sheet into a hollow or concave shape, such as a cup, by stretching the metal. A blankholder is used to hold down the blank while the punch pushes into the sheet metal. A shearing operation (figure c 1 and 2) cuts the work using a punch and a die. Although it is not a forming process, it is included here because it is a necessary and very common operation in sheet metal working.

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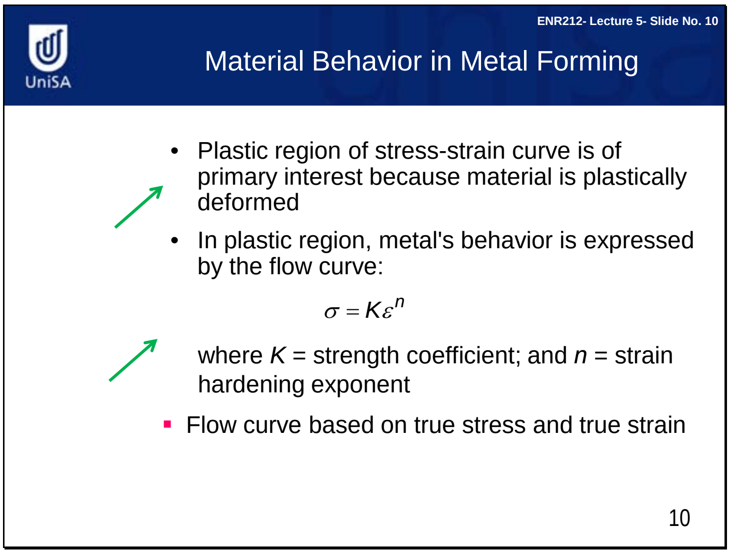

In metal forming, the plastic region of true stress-strain curve is of primary interest because material is plastically and permanently deformed in this region. The true stress-strain relation in the plastic region is given in the equation on this slide, where K equals the strength coefficient and n equals the strain hardening exponent.

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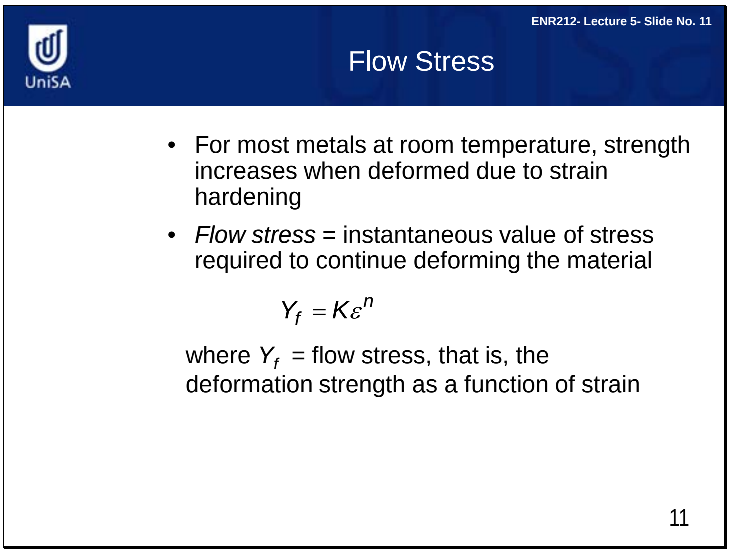

Since metal flow is the nature of metal forming, true stress in the plastic region is called flow stress in metal forming.

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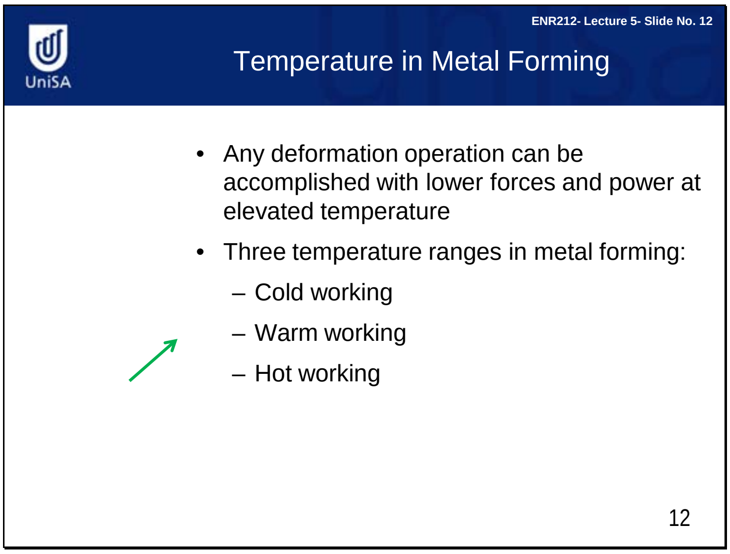

We have learnt about the effect of temperature on the mechanical properties of materials. With increases in temperature, strength reduces but ductility increases. Therefore, there are three temperature ranges used in metal forming: cold working, warm working and hot working.

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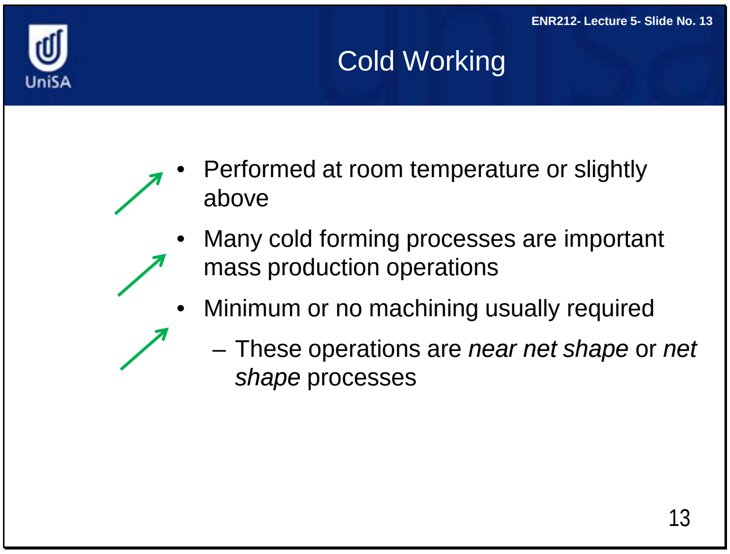

Cold working is metal forming performed at room temperature. Many cold forming processes have developed into important mass production operations. They provide close tolerances and good surfaces, minimizing the amount of machining required. Therefore, these operations are classified as near net shape or net shape processes.

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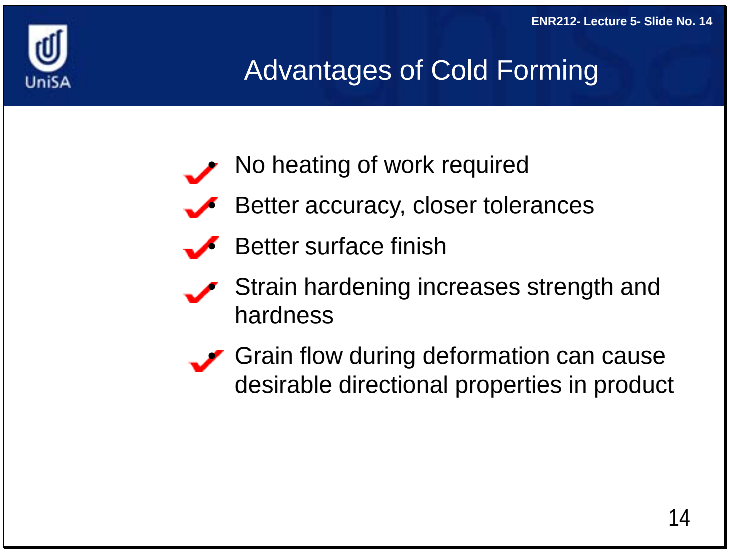

Cold forming has the following advantages:
No heating of the work piece is required.
It has better accuracy, and closer tolerances.
It gives a better surface finish.
The strain hardening increases the strength and hardness.
The grain flow during deformation can cause desirable directional properties in the product.

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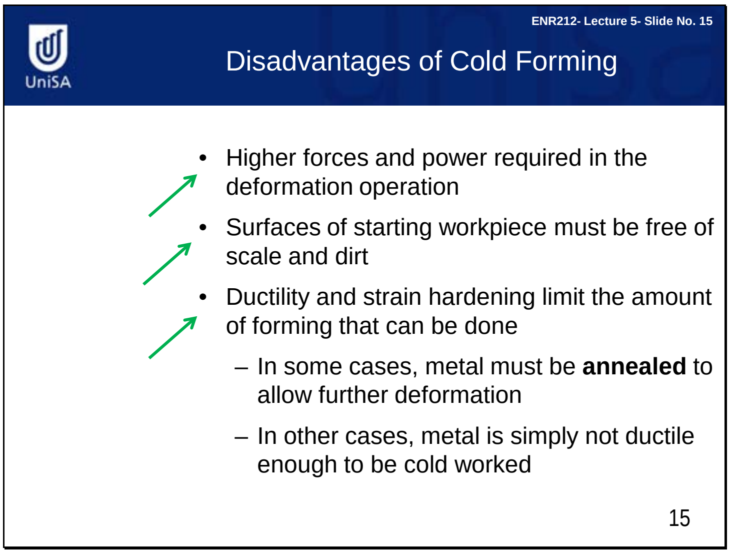

There are certain disadvantages or limitations associated with cold forming operations, as follows:

1. Higher forces and power are required in the deformation operation.
2. The surfaces of the starting workpiece must be free of scale and dirt.
3. The ductility and strain hardening limit the amount of forming that can be done. In some cases, metal must be annealed to allow further deformation. In other cases, metal is simply not ductile enough to be cold worked.

Note: Annealing consists of heating the metal to a suitable temperature, holding at that temperature for a certain time (soaking), and slowly cooling. This process reduces hardness and brittleness.

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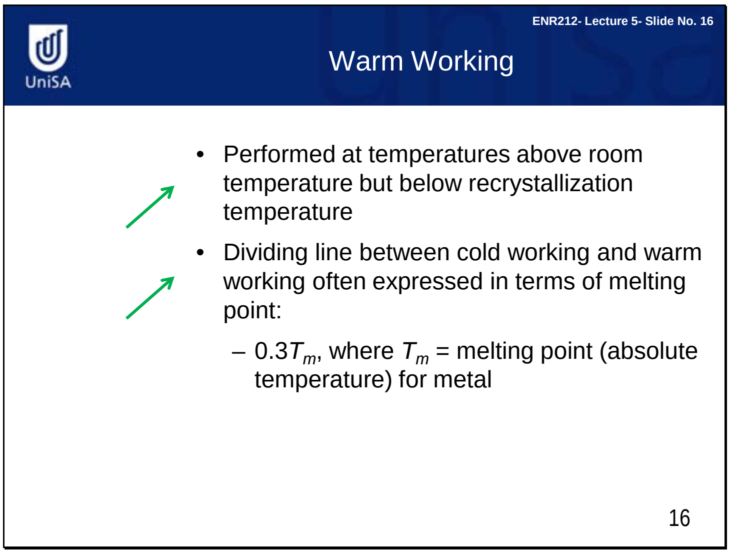

Because increasing the workpiece temperature reduces the yield strength and increases the ductility of metals, forming operations are sometimes performed at temperatures above room temperature but below recrystallization temperature. This is called warm working. The dividing line between cold working and warm working is often expressed in terms of melting point: 0.3Tm, where Tm equals melting point (absolute temperature) for metal.

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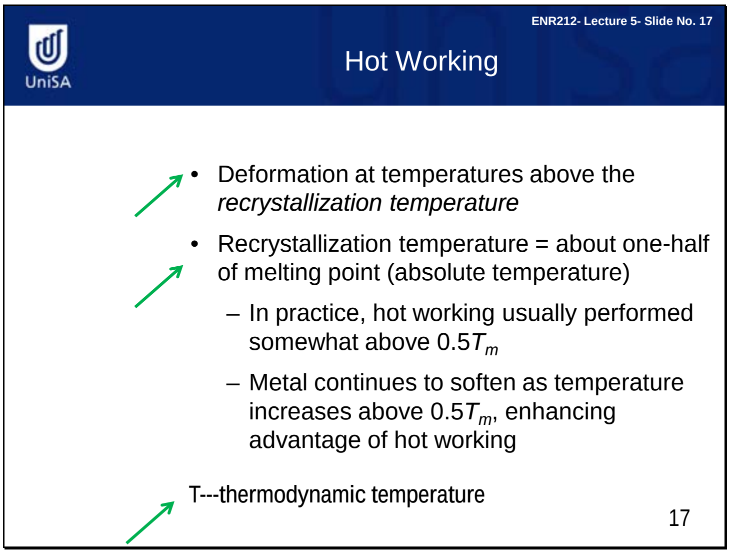

Hot working (hot forming) involves deformation at temperatures above the recrystallization temperature. The Recrystallization temperature for a given metal is about one-half of melting point. The work metal softens further as the temperature is increased beyond 0.5Tm, thus enhancing the advantage of hot working.

Thermodynamic temperature is an "absolute" scale because it is the measure of the fundamental property underlying temperature: its zero point, absolute zero, is the temperature at which the particle constituents of matter have minimal motion and can be no colder. Absolute zero is defined as 0 K on the Kelvin scale and as minus 273.15°C on the Celsius scale

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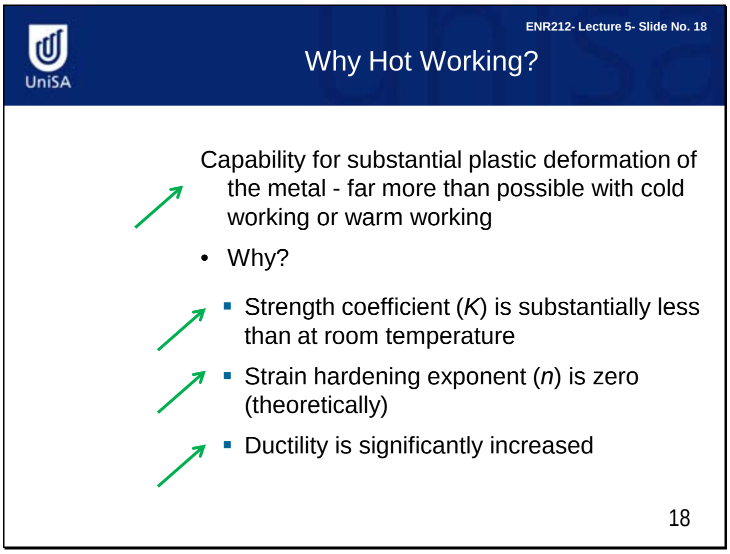

The most significant advantage of hot working is the capability for substantial plastic deformation of the metal - far more than possible with cold working or warm working. This is because the Strength coefficient (K) is substantially less than at room temperature, the Strain hardening exponent (n) is close to zero and the Ductility is significantly increased.

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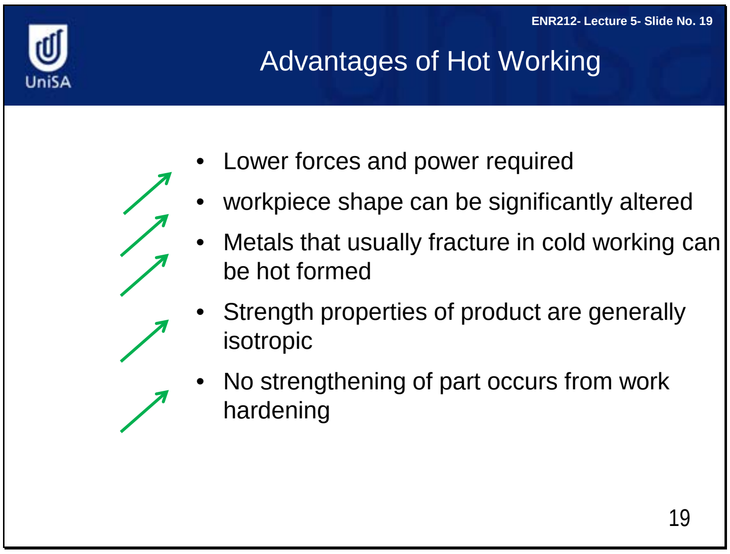

The advantages of hot working are as follows:

1. Lower forces and power are required to deform the metal.
2. The shape of the workpiece can be significantly altered.
3. Metals that usually fracture in cold working can be hot formed.
4. The strength properties are generally isotropic because of the absence of the oriented grain structure typically created in cold working.
5. No strengthening of the part occurs from work hardening.

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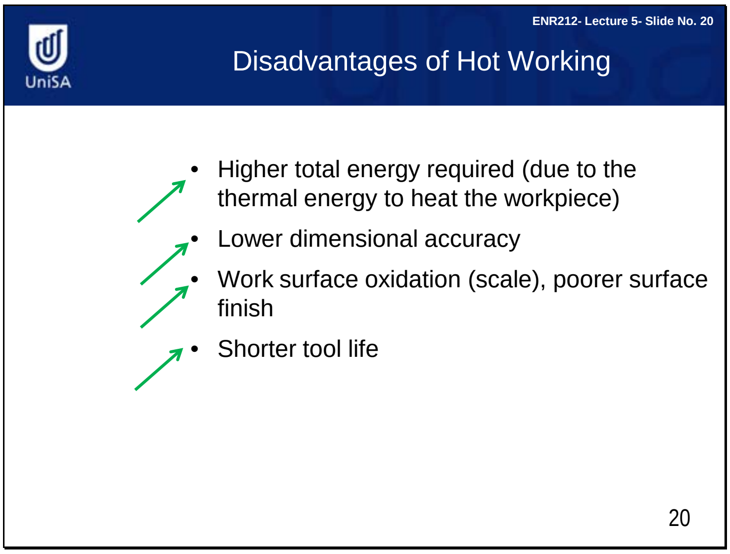

The disadvantages of hot working are as follows:

1. Higher total energy is required (due to the thermal energy to heat the workpiece).
2. The dimensional accuracy is not good.
3. It produces work surface oxidation (scale), resulting in poorer surface finish.
4. Tool life is reduced.

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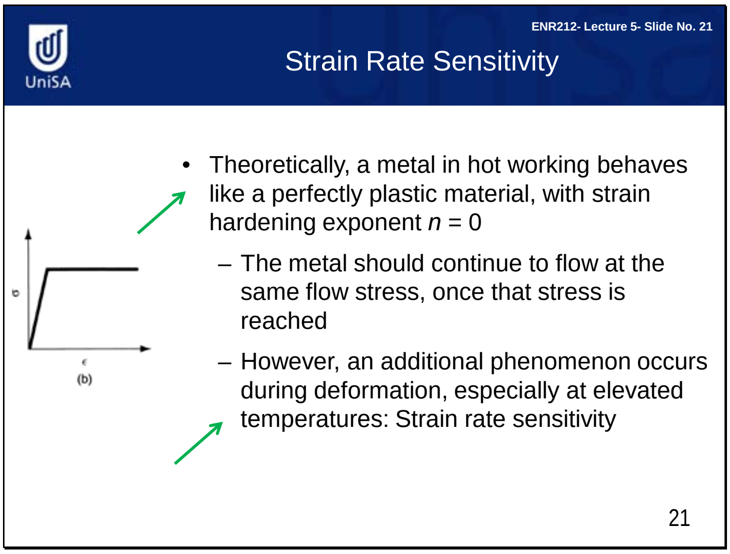

Let’s review and compare the three types of Stress-Strain curves. Theoretically, a metal in hot working behaves like a perfectly plastic material, with strain hardening exponent n = 0. This means that the metal should continue to flow under the same level of flow stress, once that stress is reached. However, the flow stress increases with strain in the plastic region, especially at elevated temperatures. That phenomenon is called strain rate sensitivity.

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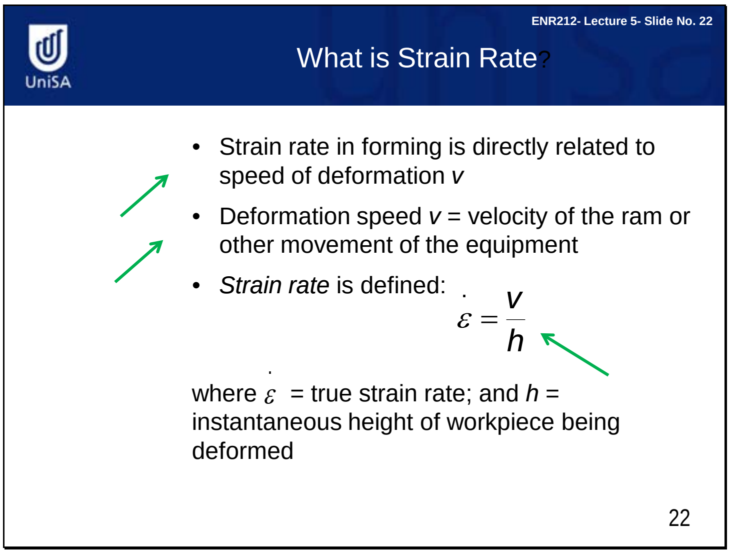

Strain rate is the rate at which a metal is strained in a forming process. The rate is directly related to speed of deformation v. In many forming operations, the deformation speed v is equal to the velocity of the ram or other moving parts .

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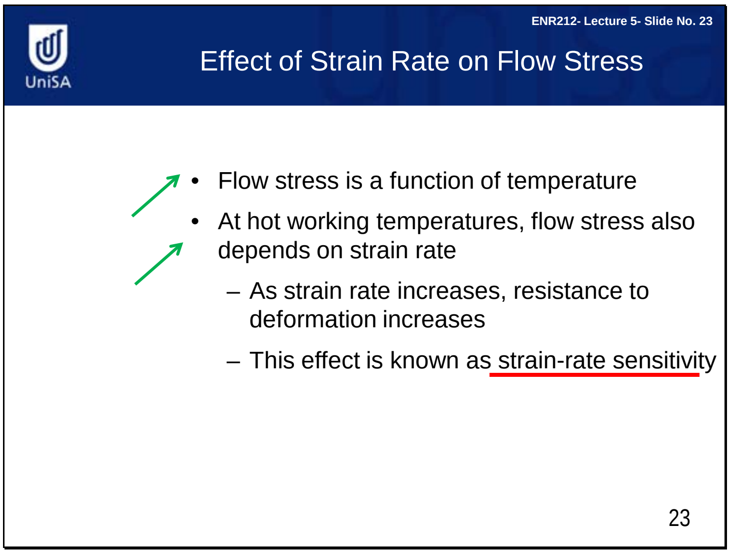

Flow stress of a metal is a function of temperature. At hot working temperatures, flow stress also depends on strain rate. This effect of strain rate on strength properties is known as strain-rate sensitivity.

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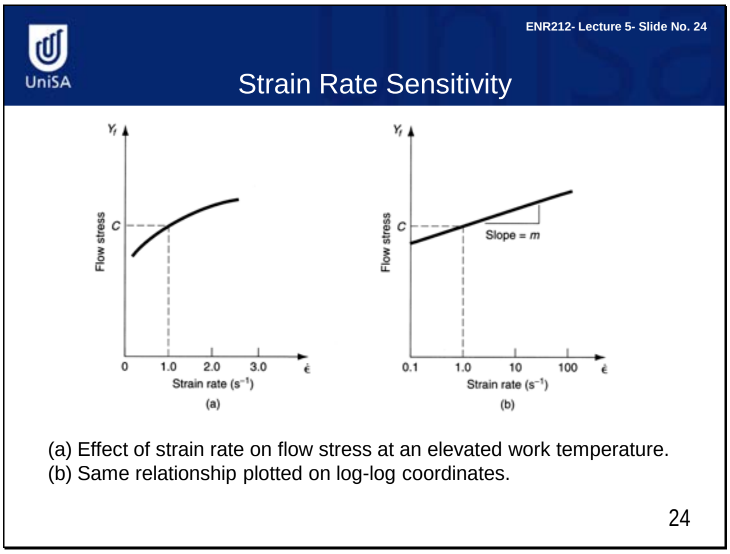

This effect can be seen in the figure. As the strain rate is increased, flow stress increases. This usually plots approximately as a straight line on a log-log graph. So there is a linear relation between log flow stress and log strain rate.

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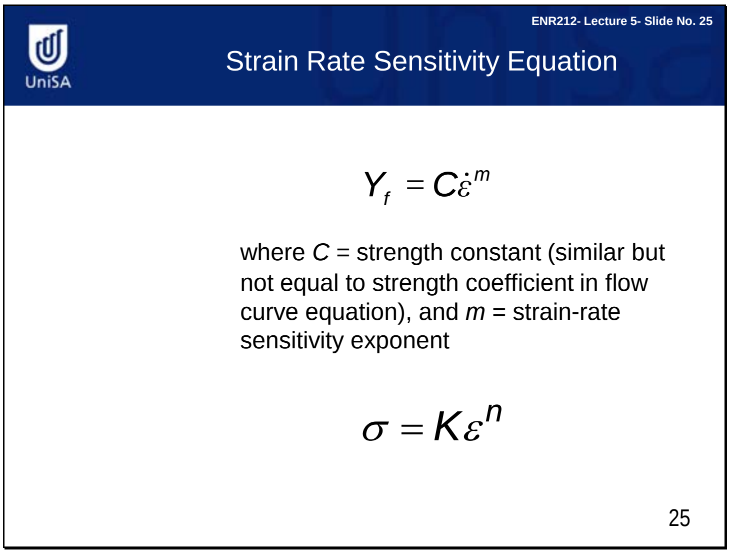

The strength constant is the flow stress when strain rate equals 1, while the strain rate sensitivity exponent is the slope of the straight portion.

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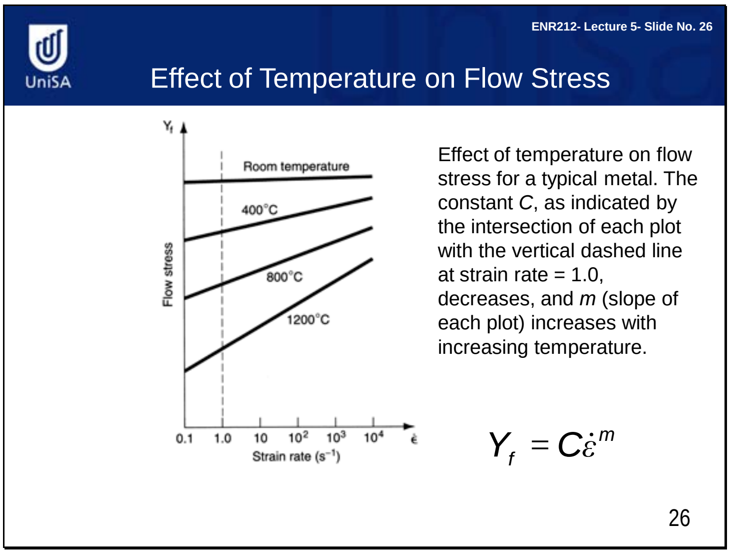

This plot indicates the effect of temperature on flow stress. With increasing temperature, these lines become steeper.
So we conclude the following:
Increasing temperature decreases strength constant C and increases strain-rate sensitivity exponent m .
At room temperature, therefore, the effect of strain-rate sensitivity exponent is almost negligible.
As temperature is increased, strain rate plays a more important role in determining flow stress.

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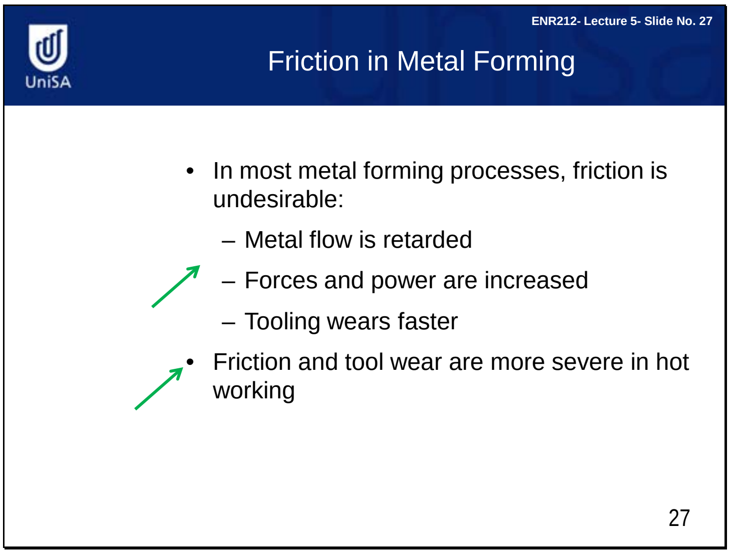

Friction in metal forming arises because of the close contact under high pressures between the tool and work surfaces. In most metal forming processes, friction is undesirable for the following reasons:

Firstly, metal flow is retarded, causing residual stresses and sometimes defects in the product. Forces and power needed to perform the operation are increased. Tooling wears faster, which leads to loss of dimensional accuracy, resulting in defective parts and requiring replacement of the tooling.

Secondly, friction and tool wear are more severe in hot working because of the much harsher environment.

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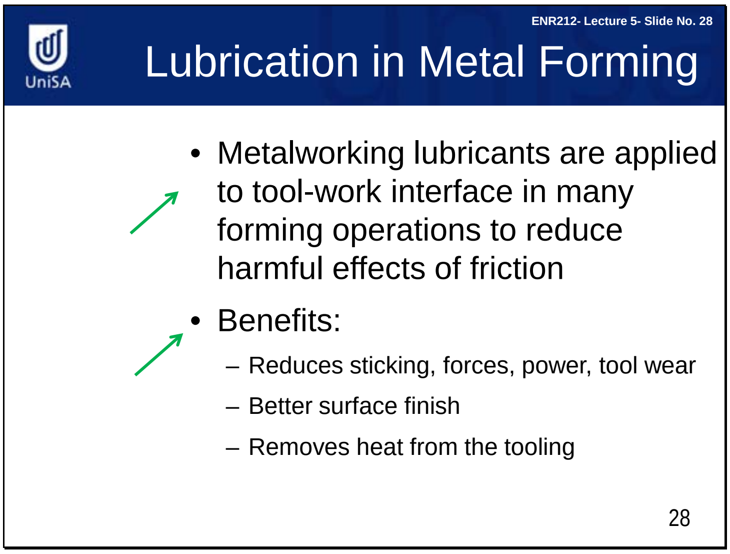

Metalworking lubricants are applied to tool-work interface in many forming operations to reduce the harmful effects of friction. Using lubricates reduces sticking, forces, power, and tool wear. It gives a better surface finish and removes heat from the tooling.

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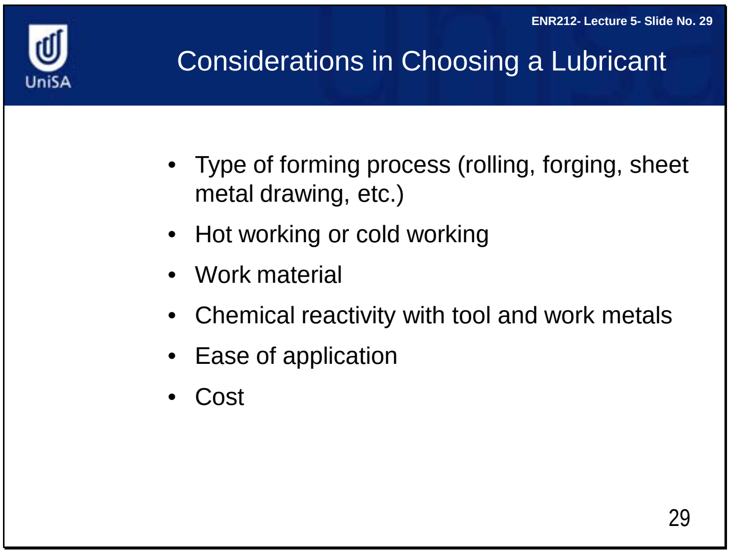

When choosing an appropriate metalworking lubricant, consider the points on this slide.

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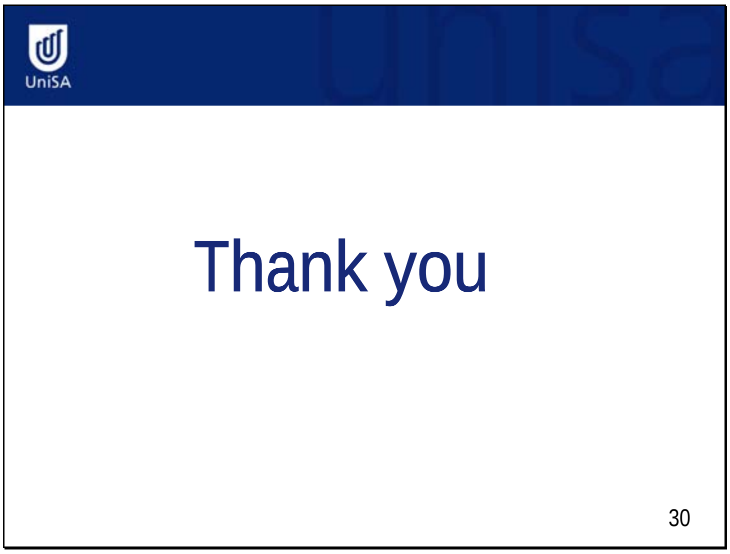

Thanks for your attention.