ENR212 Lecture 10 Slides and Notes

Slide 1

Hello everyone，and welcome to Lecture Summary 10. (This lecture covers material from chapters 24 and 25 of the textbook.) This lecture is in two parts. In this first part, we will introduce the seven design guidelines for conventional machining operations.

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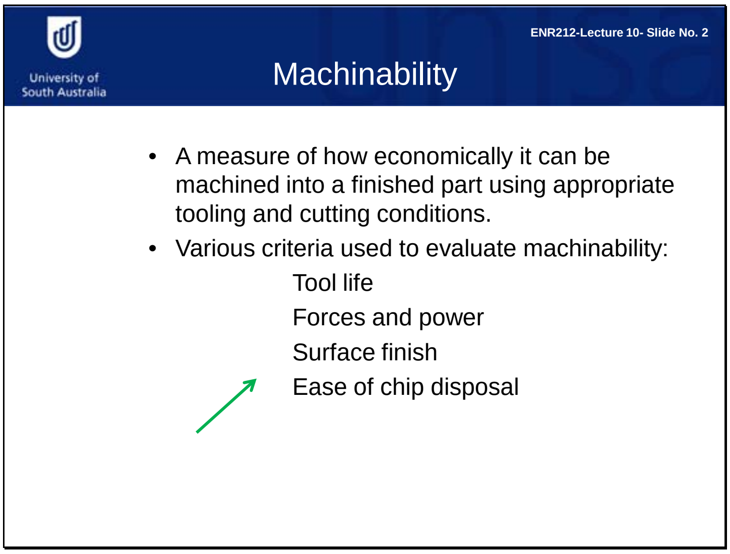

The properties of a work material have a significant influence on the machining operation of that material. These properties and other characteristics of the work material are often summarized in the term “machinability”. The machinability of a material is a measure of how economically it can be machined into a part. Machinability is evaluated by the four criteria: tool life, forces and power, surface finish and ease of chip disposal.

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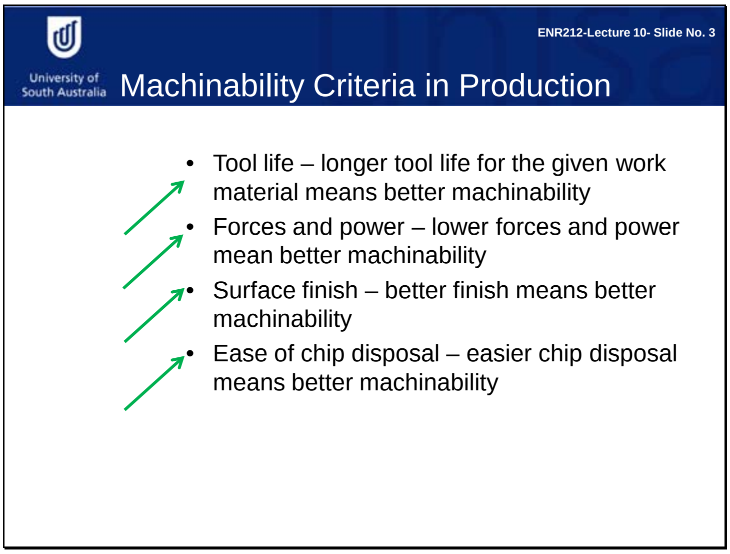

This slide shows how the four criteria affect machinability. Firstly, longer tool life and lower forces and power mean better machinability. For example, let's look at aluminium and copper. Aluminium has a lower modulus and a lower yield strength than copper, so it has a longer tool life and uses lower forces and power than copper. This means that aluminium has a higher and better machinability than copper. Therefore, if we have two parts, one aluminium and one copper, and both have an identical geometry, and are processed with the same forces and power, which will have a better surface finish? The aluminium part will have a better surface finish, because the material has a lower modulus and lower yield strength. Better surface finish means better machinability. Finally, easier chip disposal means better machinability.

Of all these characteristics, tool life is the most important.

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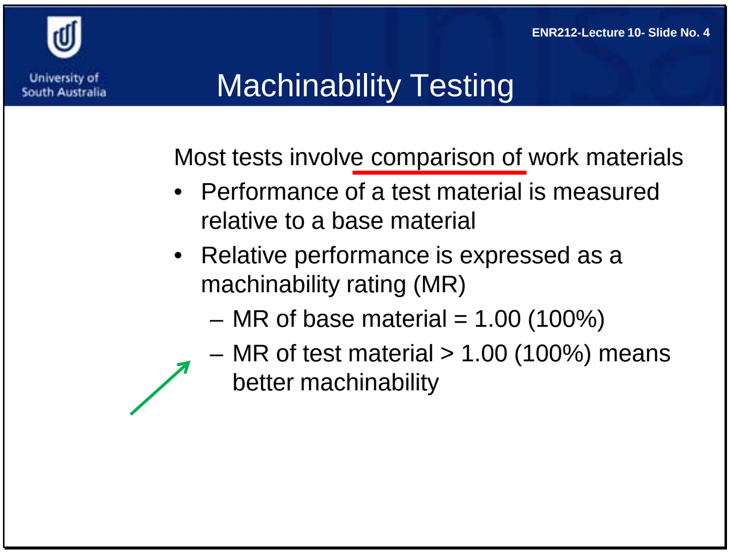

The machinability of a material is expressed relative to a base material, so selecting a base material is very important in determining machinability. For example, let's look at three materials: aluminium, copper and steel. Of these three materials, which one has the highest machinability? The answer is aluminium, because it has the lowest modulus and strength. The steel has the lowest machinability, because steel has the highest modulus and strength. If aluminium is set as the base material, then the copper and steel should have machinability lower than 1.0. If copper is set as the base material, aluminium should have a machinability higher than 1.0. Steel has a machinability lower than 1.0.

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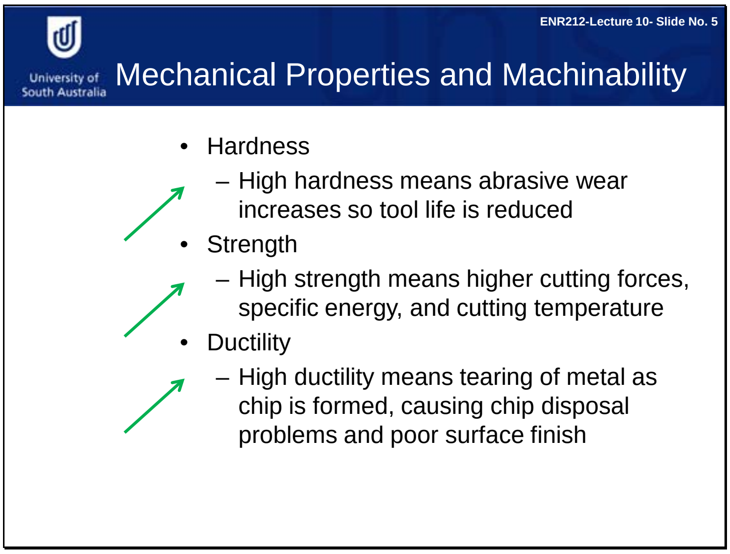

We know that the machinability of a material is determined by the mechanical properties of this material. To demonstrate good machinability, a material must possess moderate mechanical properties.

First, it must have moderate hardness. If it is too hard (for example, diamond), then the processing will be extremely difficult. For example, a diamond knife, can be used to cut polymer nanocomposites samples, costs $5000 dollars. If the knife becomes blunt, it costs $2500 to sharpen it – which is quite expensive! The reason is that diamond is just too hard to sharpen easily.

Second, it should have moderate strength. High strength requires higher cutting forces, specific energy, and cutting temperature. Some alloys, such as titanium alloy, are very difficult to machine.

Third, it must be ductile. If the material is brittle, like epoxy, it is hard to machine, because brittleness often causes catastrophic failure. Material which is too ductile (for example, rubber) is also difficult to machine.

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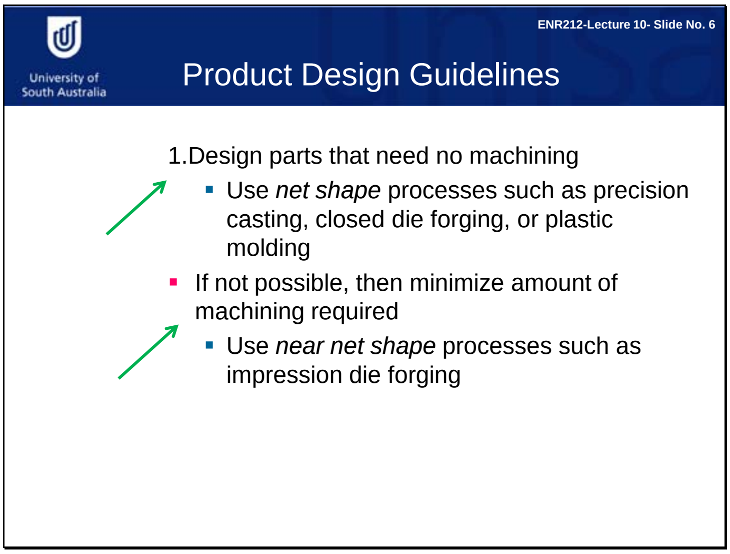

There are seven product design guidelines for conventional machining operations.
First guideline. If possible, parts should be designed in a way that doesn't need machining. In general, products produced by using net shape processes such as precision casting, closed die forging, etc, cost less to produce. If machining cannot be avoided, then minimize the amount of machining required on the parts.

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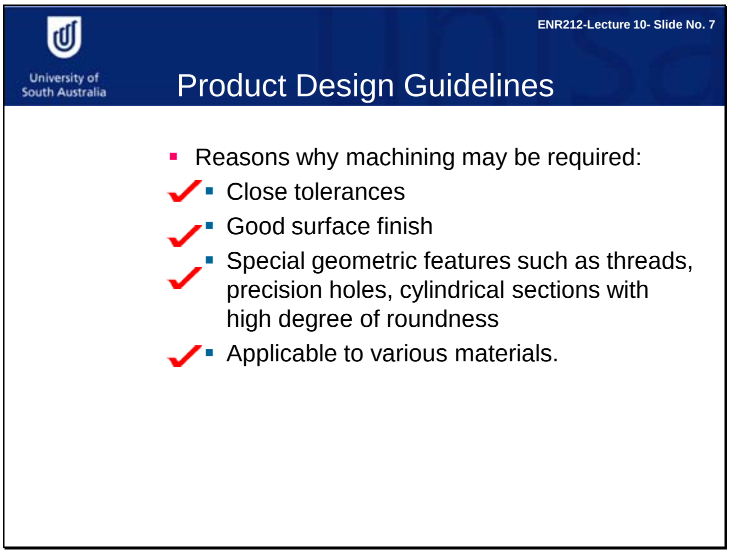

In fact, machining is desirable in a great many manufacturing operations because it can produce close tolerances and a good surface finish, and it can produce a variety of geometries. Machining is also applicable to various materials.

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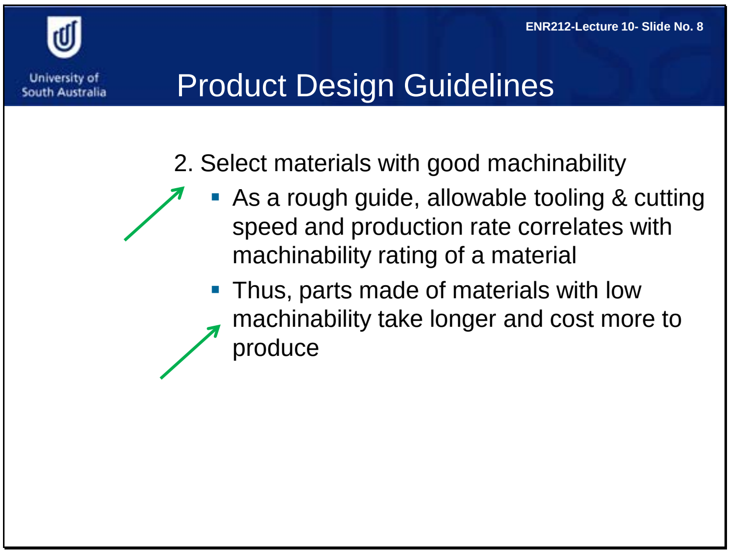

Second guideline. Select materials with good machinability, because the tooling and cutting conditions and production rate of a material correlate with the material's machinability. Parts made of materials with low machinability take longer and cost more to produce.

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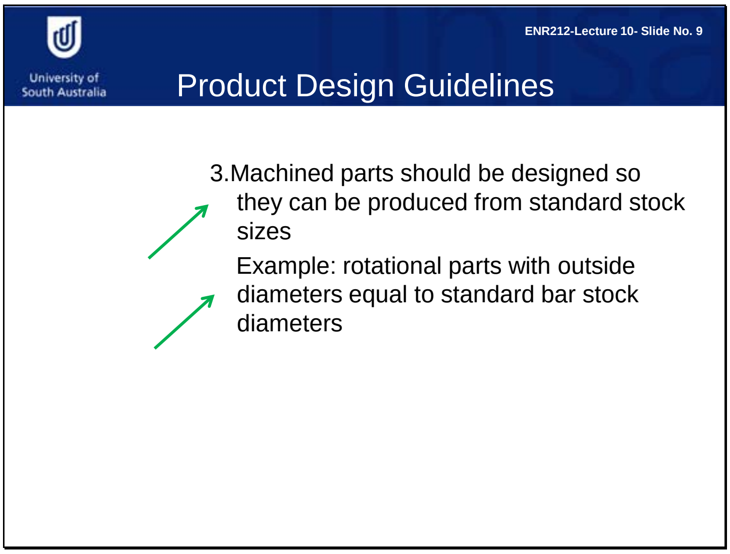

Third guideline. In order to minimize the amount of machining, the exterior dimensions of a part should be chosen to equal the standard stock size. For example, choose rotational parts with outside diameters that are equal to standard bar stock diameters.

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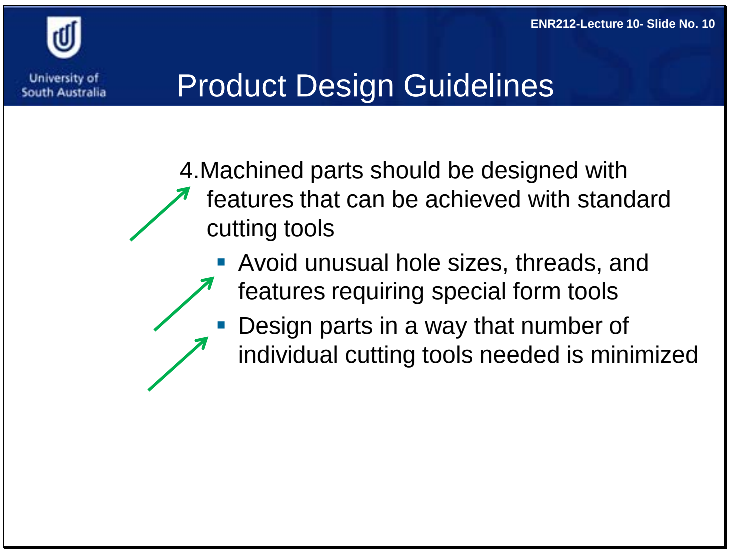

Fourth guideline. Machined parts should be designed with features that can be achieved with standard cutting tools. This means avoiding unusual hole sizes, threads, and features requiring special form tools. It is helpful to design a part in a way that minimizes the number of individual cutting tools. This often allows the part to be completed in one setup on a machining center with limited tool storage capacity.

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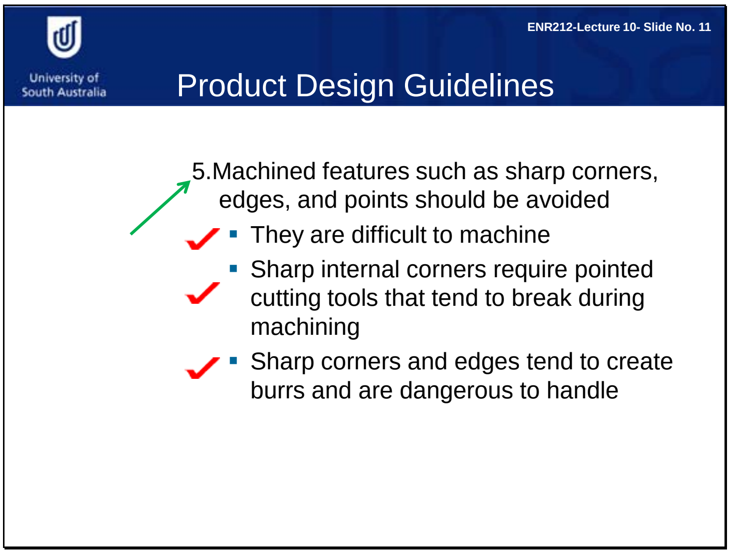

Fifth guideline. Machined features such as sharp corners, edges, and points should be avoided. There are three reasons for this: they are difficult to machine, they tend to break during machining, and they are a safety hazard.

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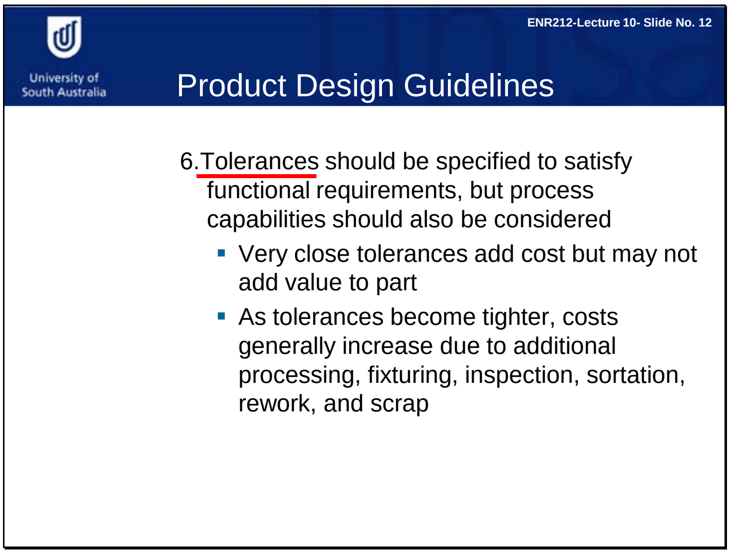

Sixth guideline. Machining is time consuming, but it provides good surface finish and close tolerances. We know that good surface finish and close tolerances are desirable in design, but that means a high manufacturing cost. Therefore, we need to evaluate the level of tolerance and surface finish needed by taking into account the end application of the product, the machining time and tool life.

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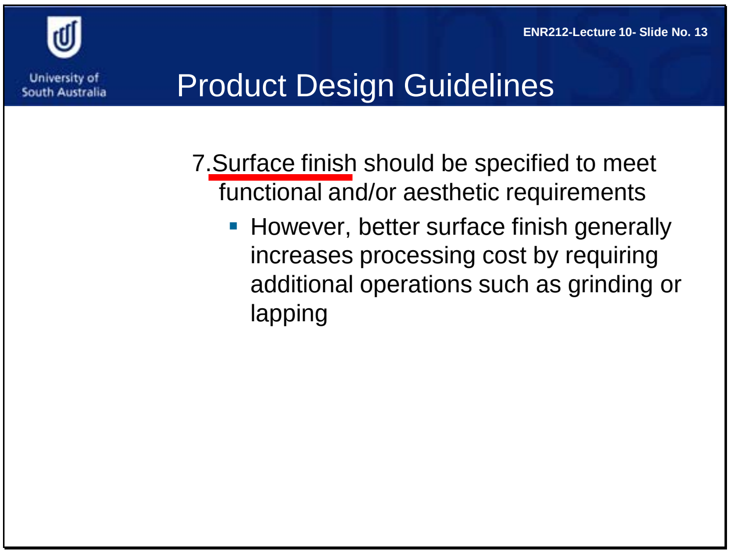

Seventh guideline. As we discussed in the previous guideline, surface finish should be specified to meet functional or aesthetic requirements.

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In the second part of this lecture summary, we will introduce abrasive machining processes. Let's start by reviewing the classifications of manufacturing processes. Manufacturing processes include processing operations and assembling operations. Processing operations consist of shaping processes, property enhancing processes, and surface treatment processes. There are four categories of shaping processes: solidification processes, particulate processes, deformation processes and material removal processes. The topic we are going to talk about now, abrasive machining processes, is one of the material removal processes.

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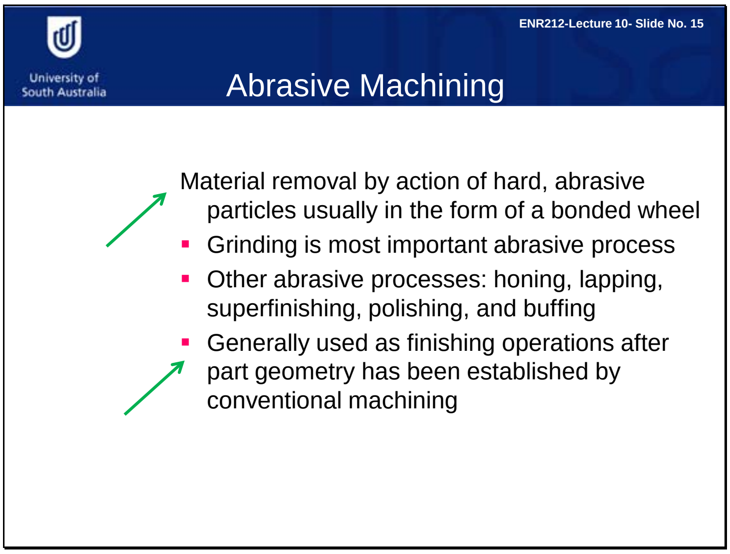

Abrasive machining processes use hard, abrasive particles (usually in the form of a bonded wheel) for material removal operations. Abrasive machining processes are generally used as finishing operations after the part geometry has been established by conventional machining operations.

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Why Abrasive Processes are Important

- Can be used on all types of materials
- Some can produce extremely fine surface finishes, to 0.025 μm (1 μ-in)
- Some can hold dimensions to extremely close tolerances

Process	Tolerance (mm)	Surface Roughness (μm)
Sand Casting	± 0.5-2.0	6
Milling/turning	± 0.025	0.4/0.8
Grinding	± 0.008	0.025

Conventional machining operations can produce close tolerances and good surface finish. However, abrasive processes can produce even closer tolerances and better surface finishes. This table compares the tolerance and surface finish produced by conventional machining processes and abrasive processes.

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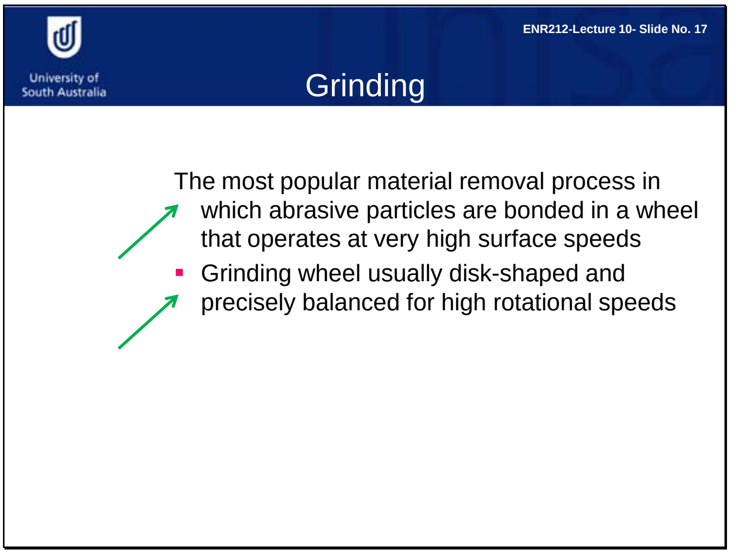

Grinding is the most popular abrasive machining process. In grinding, abrasive particles are bonded in a wheel that operates at very high surface speeds. Most grinding wheels have a disk-like shape and are precisely balanced for high rotational speed.

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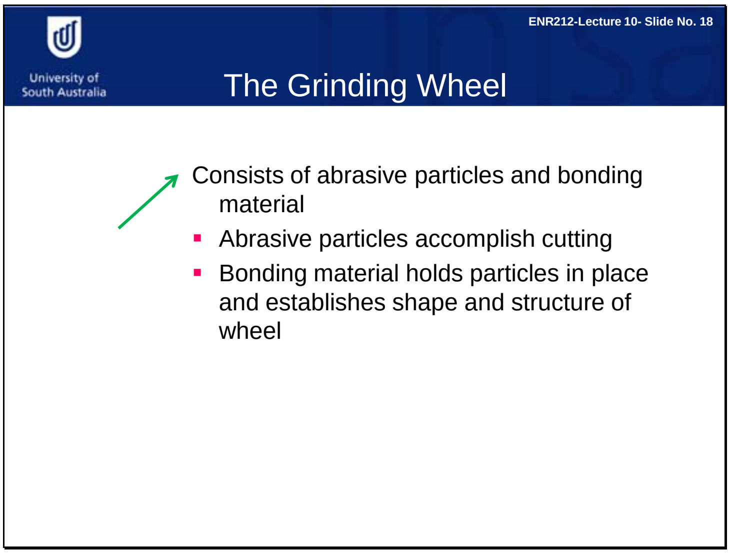

A grinding wheel consists of abrasive particles and bonding material. The role of the abrasive particles is to accomplish cutting, and the role of the bonding material is to hold the particles in place and to establish the shape and structure of the wheel.

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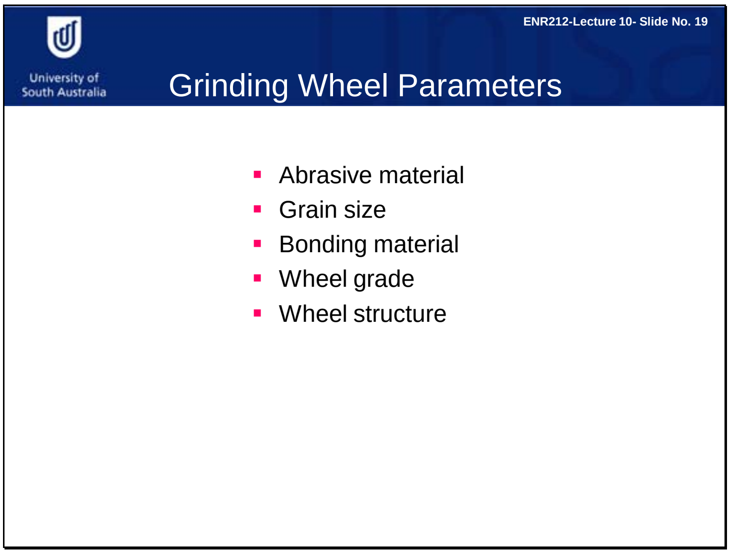

These abrasive particles and bonding material are the two ingredients, and the way they are fabricated determines the five basic parameters of a grinding wheel: abrasive material, grain size, bonding material, wheel grade, and wheel structure. Each of the parameters must be carefully selected to achieve the desired performance in an application.

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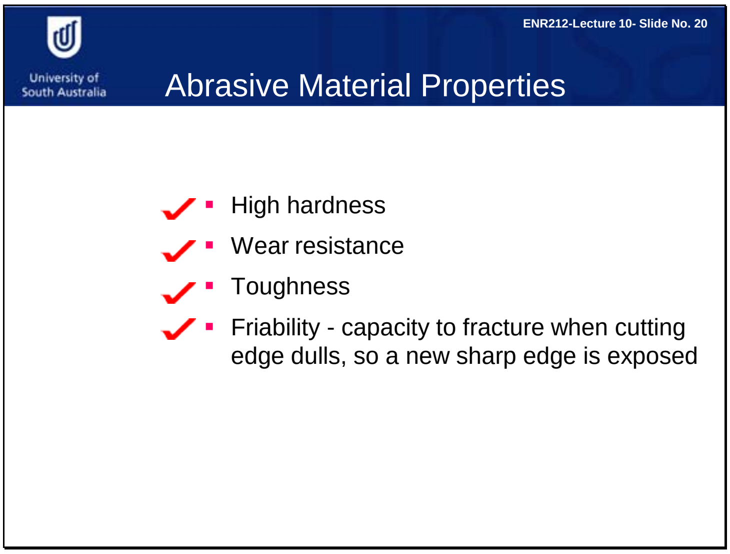

A grinding wheel consists of abrasive particles and bonding material. The desirable properties of the abrasive materials include high hardness, wear resistance, toughness and friability.
Hardness refers to the resistance of a material to permanent deformation. Stiffness is the resistance of an elastic material to deformation. (In solid mechanics, Young's modulus is a measure of the stiffness of a material.) The wear resistance refers to how resistant the material is to wear. The toughness refers to how resistant the material is to the propagation of a sufficiently sharp crack. Finally, friability refers to the capacity of the abrasive particles to fracture when the cutting edge of the grain becomes dull, thereby exposing a new sharp edge.

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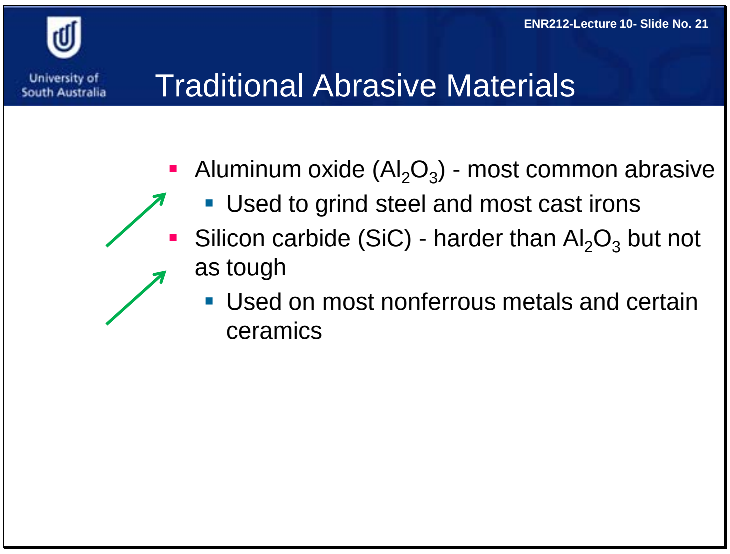

There are four important materials used for abrasion. The two traditional materials are aluminium oxide and silicon carbide. Aluminium oxide is the most commonly used. It is used for grinding steel and for most cast irons. Silicon carbide is harder than aluminium oxide but not as tough. Silicon carbide is used on most nonferrous metals and certain ceramics.

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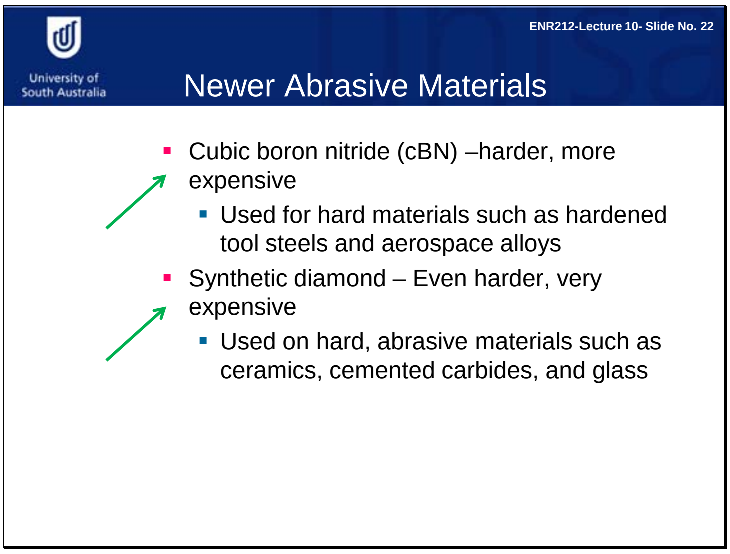

Cubic boron nitride is harder and more expensive than the first two materials. It is used for hard materials, such as hardened tool steels and aerospace alloys. The last abrasion material is synthetic diamond. It is the hardest and the most expensive of the four materials. It is used on hard, abrasive materials such as ceramics, cemented carbides, and glass.

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Hardness of Abrasive Materials

Abrasive material	Knoop hardness
Aluminum oxide	2100
Silicon carbide	2500
Cubic boron nitride	5000
Diamond (synthetic)	7000

This table shows you the hardness of these four commonly used abrasive materials.

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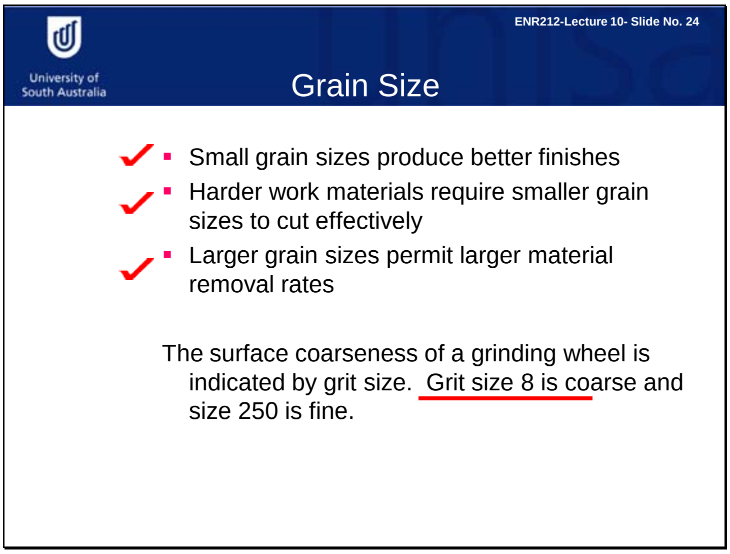

These materials are in the form of particles, and the grain size is the actual size of the materials. A smaller grain size produces better finish, and is more suitable for harder material, when it corresponds to lower removal rates. Grit size is a grinding product indicator. It is the opposite to grain size.

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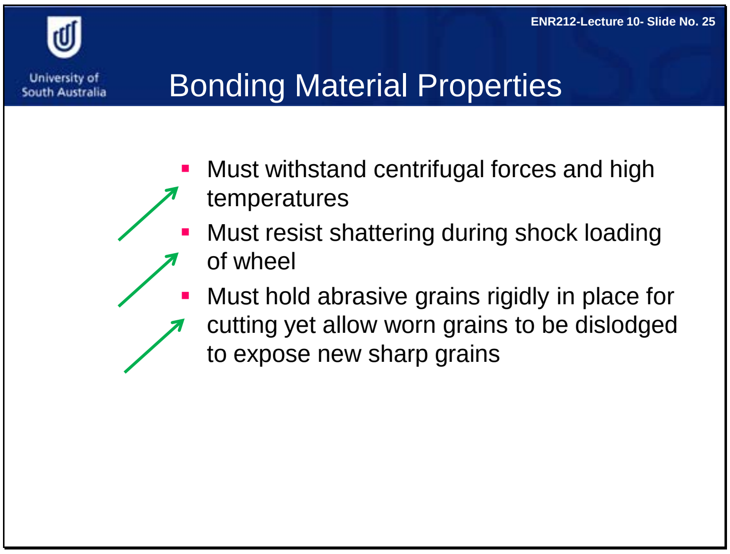

The bonding material holds the abrasive grains and establishes the shape and structural integrity of the grinding wheel. The bonding material must be able to withstand the centrifugal forces and high temperatures experienced by the grinding wheel. It must resist shattering in shock loading of the wheel. It must hold the abrasive grains rigidly in place to accomplish the cutting action while allowing worn grains to be dislodged so that new grains can be exposed. That is what we called friability.

There are three types of bonding materials: ceramics, metal(bronze), and rubber or resin.

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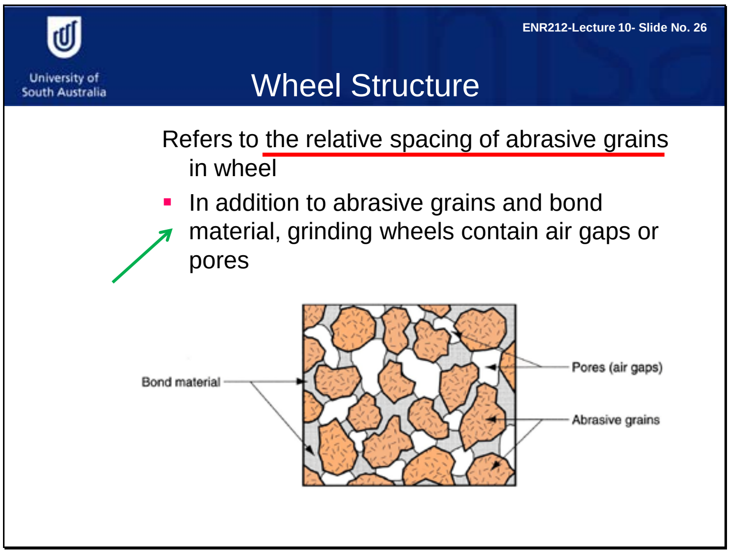

Wheel structure refers to the relative spacing of the abrasive grains in the wheel. This figure shows that a wheel structure includes bond material, pores and abrasive grains.

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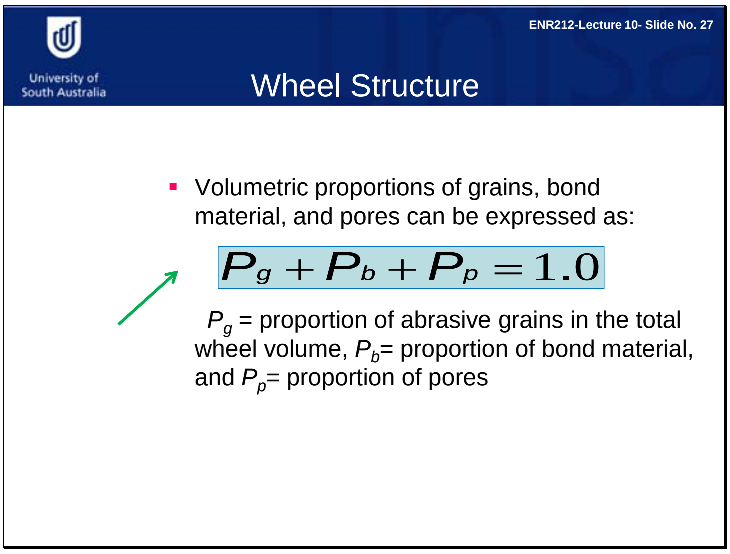

The volumetric proportions of grains, bond material, and pores can be expressed in this equation.

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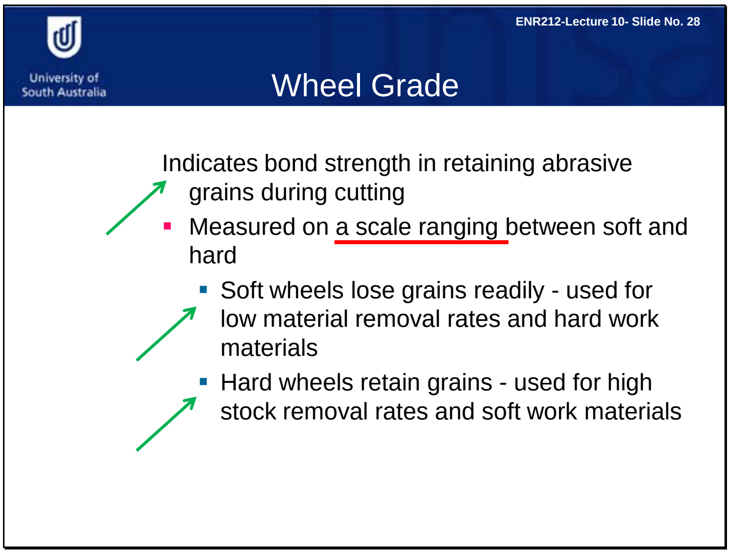

Wheel grade indicates the grinding wheel's bond strength in retaining the abrasive grains during cutting. The grade is measured on a scale that ranges between soft and hard. Soft wheels lose grains readily and are used for low material removal rates and hard work materials. Hard wheels retain grains and are used for high stock removal rates and soft work materials.

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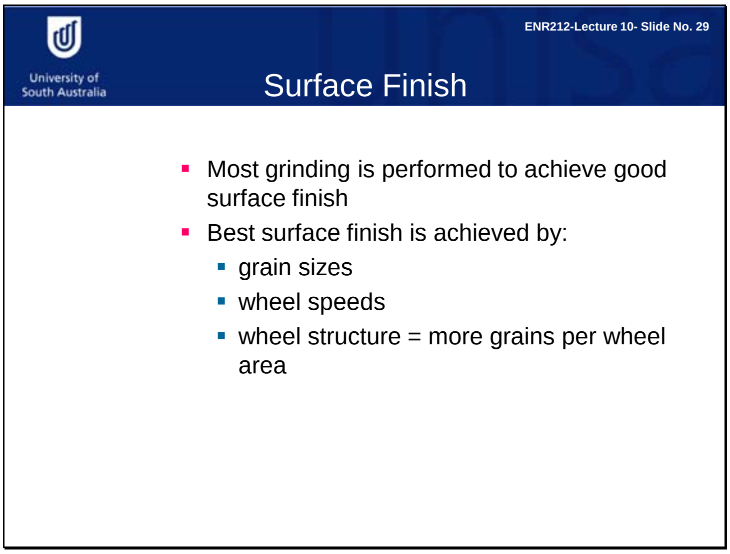

Most grinding is performed to achieve a surface finish that is superior to what can be accomplished with conventional machining.

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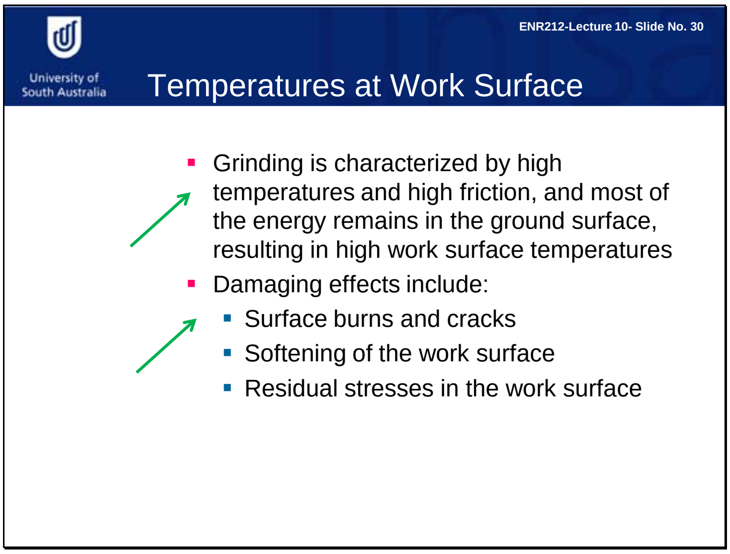

The grinding process is characterized by high temperatures and high friction. The high surface temperatures have several damaging effects: surface burns and cracks, softening of the work surface (like a polymer sample) and residual stresses in the work surface.

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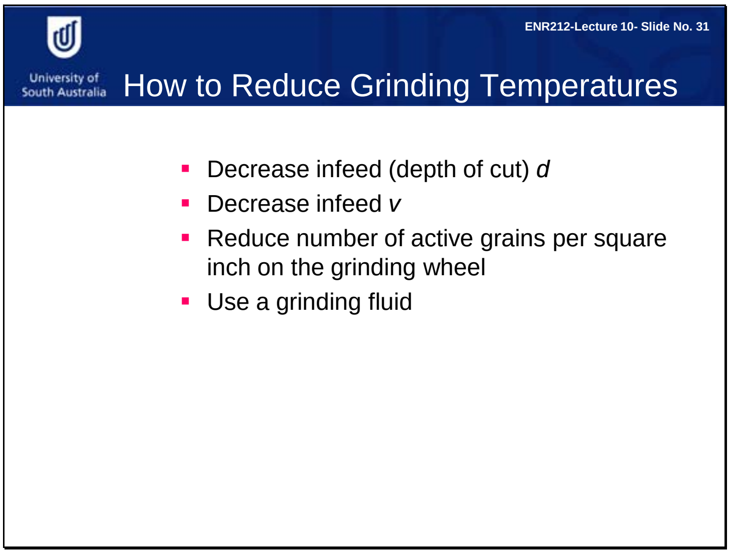

High grinding temperatures are harmful, but can be reduced. There are four ways to do this: decrease the infeed depth of cut, decrease the infeed, reduce the number of active grains per square inch on the grinding wheel, and use a grinding fluid. Of these methods, the most effective is using grinding fluid.

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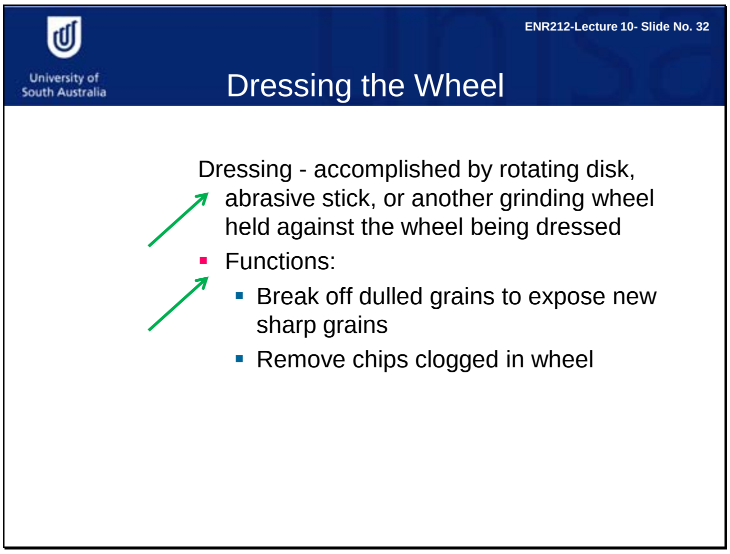

When a grinding wheel is worn, it is resharpened by dressing and truing. Dressing is accomplished by using a dressing tool. The tool can be a rotating disk or an abrasive stick, or another grinding wheel. Operating at high speed, the tool is held against the wheel to be dressed. The dressing breaks off dulled grains to expose new sharp grains and removes chips clogged in the wheel.

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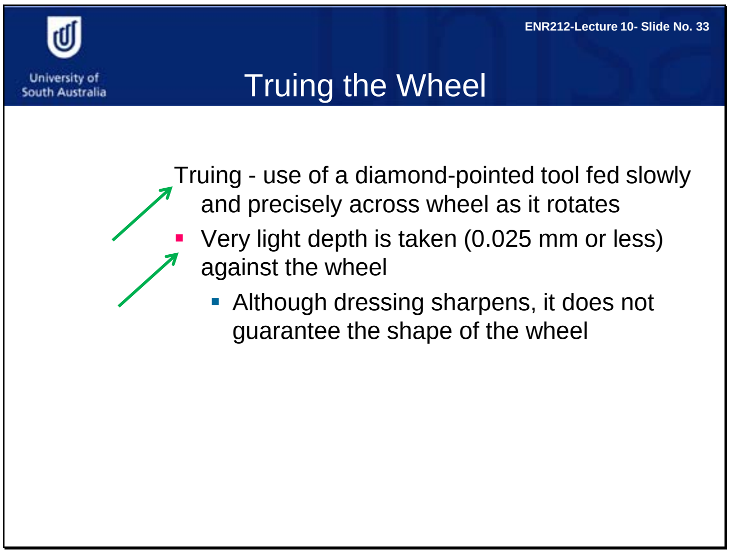

Dressing is a procedure to resharpen a worn grinding wheel. Truing is an alternative procedure. The procedure involves feeding a diamond-pointed tool slowly and precisely across the wheel as it rotates. Truing makes a very light depth (25um) against the wheel.

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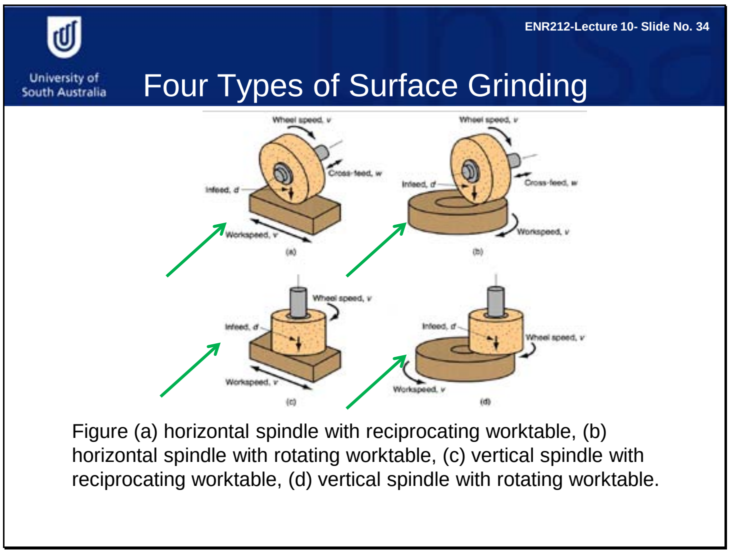

There are four types of surface grinding, depending on the relative motion between the worktable and the spindle of the grinding wheel. As you can see in figure a, this surface grinding machine has a horizontal spindle with a reciprocating worktable. In figure b, the grinding facility has a horizontal spindle with a rotating worktable. In figure c, the grinder has a vertical spindle with a reciprocating worktable. In figure d, the grinder has a vertical spindle with a rotating worktable.

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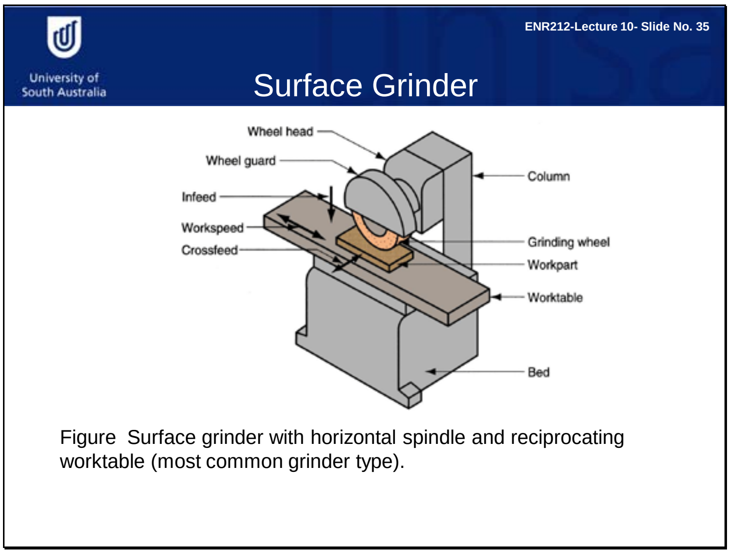

This figure shows you a surface grinder which has a reciprocating worktable and a horizontal spindle in the grinding wheel.

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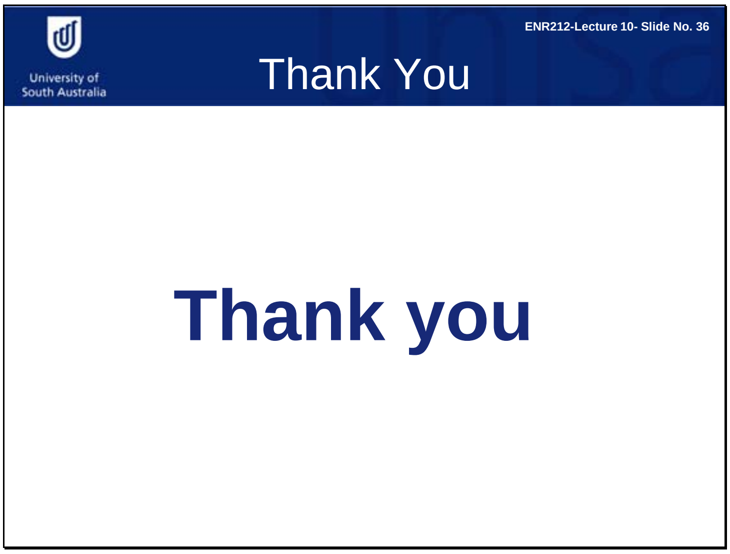

Thank you for your attention.