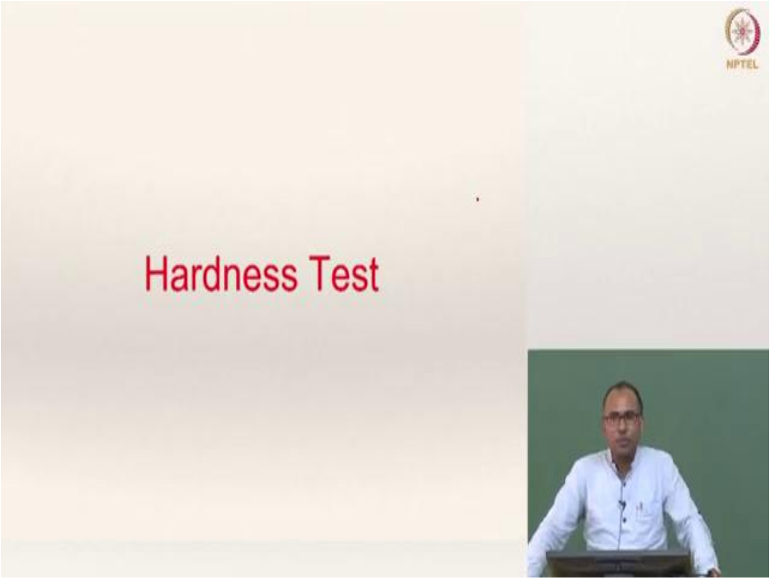
**Basics of Materials Engineering**
**Prof. Ratna Kumar Annabattula**
**Department of Mechanical Engineering**
**Indian Institute of Technology, Madras**

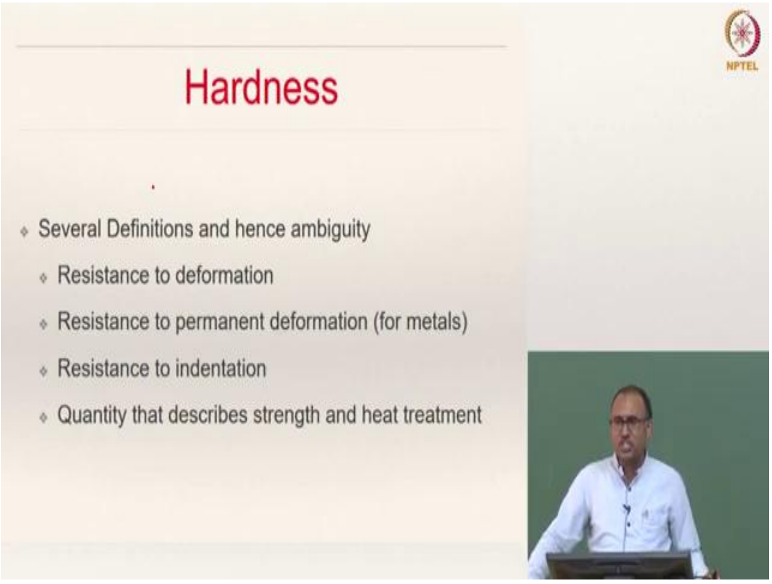
**Lecture – 29**
**Mechanical Properties (Hardness Test)**

(Refer Slide Time: 00:13)




The next property that whose measurement we are going to discuss is hardness.

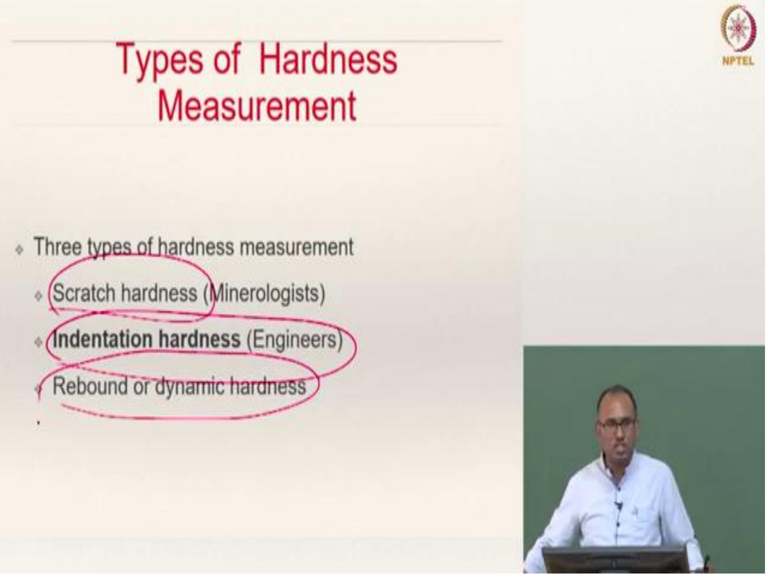
(Refer Slide Time: 01:07)



So, there are several definitions available in the literature for hardness and hence, it is quite ambiguous alright. People define hardness as resistance to deformation; some people define as resistance to permanent deformation for metals and some people define it as resistance to indentation and somebody says that the quantity is that hardness is a quantity gives that describes strength and heat treatment.

So, which one to follow, you do not know, right. So, because there is a lot of ambiguity; in this class, we will try to fix to one definition that is more suitable for mechanical engineers ok.

(Refer Slide Time: 01:51)

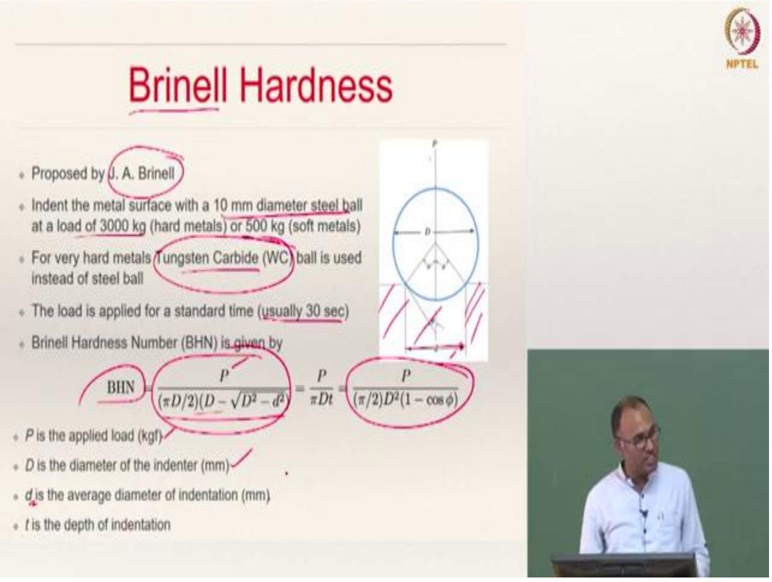



So, there are several definitions available in the literature for hardness and hence, it is quite ambiguous. Some define hardness as resistance to permanent deformation for metals. Others define it as resistance to indentation. In this class, we shall fix a definition suited for Mechanical Engineers. The definition that is more suitable for us is indentation hardness. Indentation hardness is measured by making an indent using an indenter and looking at its depth; a harder material will have a smaller depth of indent.

A mineralogist may prefer to use scratch hardness wherein they measure the ease with which material can be dislodged by scratching. Others may also use rebound hardness which is measured by bouncing a ball on the surface and measuring the height of bounce.

.

(Refer Slide Time: 04:03)




One of the earlier methods of measuring hardness is what is called Brinell hardness; it was proposed by a person called J. A. Brinell. In this test, you use an indenter and apply a load onto the surface and measure the depth of the indentation. Depending on the shape of the indenter, you will have different tests. A Brinell hardness test uses a spherical indenter; it uses a spherical ball as an indenter. This is a schematic of the test (shown). So, this blue color one is your indenter and the material to be tested is at the bottom. Then, you apply a load P and then measure the indentation depth.

So, the procedure is you indent the metal surface with a 10 mm diameter steel ball. This is the standard. The diameter of the steel ball is 10 mm for Brinell hardness; but if you want to change it, you can change it by following certain rules. Futher, if it is a hard metal, you apply a load of 3000 kg. If it is a soft metal, you apply a load of a 500 kg. If you are going to measure extremely hard surfaces, then tungsten carbide ball will be used instead of a steel ball. The time of application is usually 30 seconds.

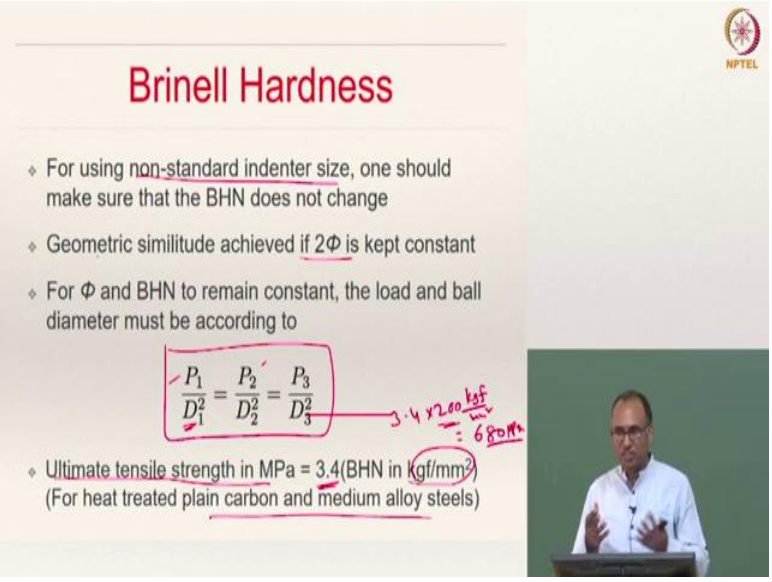
The Brinell hardness number; that is, the number that represents the hardness of this material is some sort of stress measure. The formula is given by

$$BHN = \frac{P}{\left(\frac{\pi D}{2}\right)\left(D - \sqrt{(D^2 - d^2)}\right)} = \frac{P}{\pi D\ t} = \frac{P}{\left(\frac{\pi}{2}\right) D^2 (1 - \cos\phi)}$$

Where,

P is the applied load in kgf, D is the diameter of the indenter (mm), d is the average diameter of indentations (mm), and t is the depth

. (Refer Slide Time: 08:12)

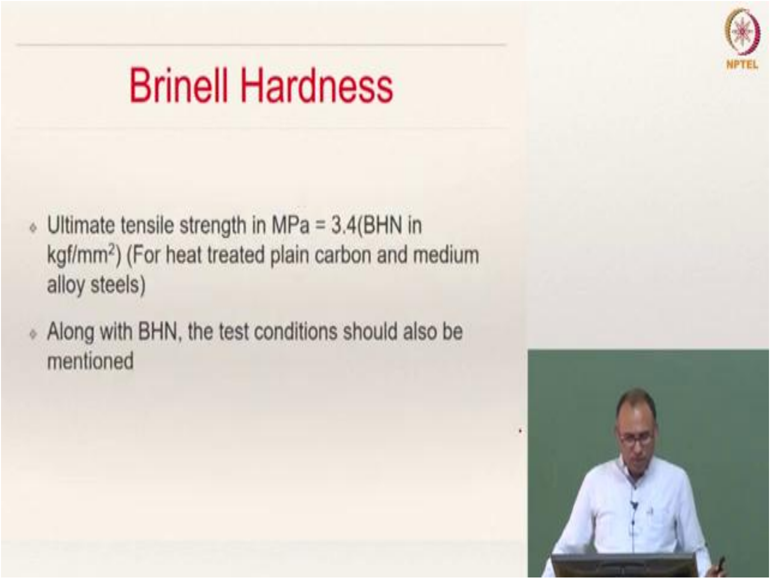



To use a non-standard size indenter, one should ensure that the load should be changed correspondingly so that the BHN of a material is not changed. You have to change the load that you apply according to this similitude formula

$$\frac{P_1}{D_1^2} = \frac{P_2}{D_2^2} = \frac{P_3}{D_3^2}$$

Geometric similitude is achieved if $2\phi$ is kept constant.

(Refer Slide Time: 10:45)



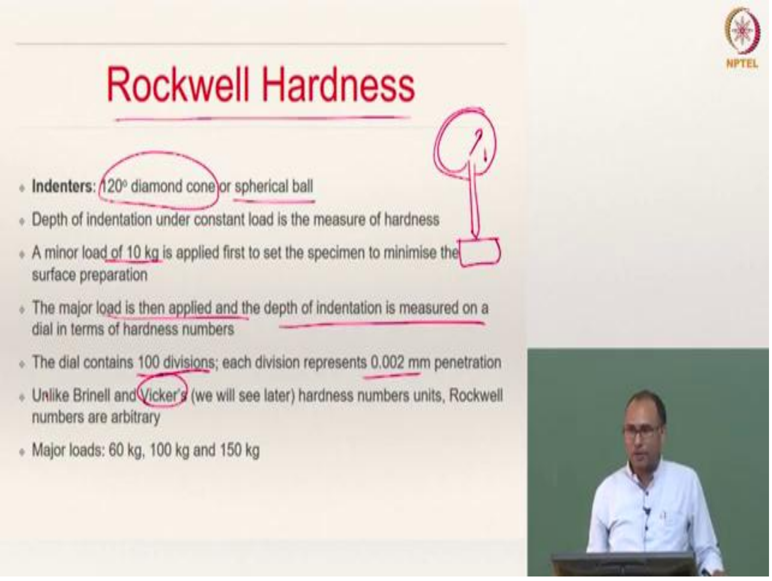

By measuring the Brinell hardness, you can also sort of estimate the tensile strength of the material; it is only an empirical formula suitable only for plain carbon and medium alloy steels. That means, if you know your Brinell hardness number in $kgf/mm^2$ from the previous formula, if you multiply that with the 3.4, the number that you get is approximately equal to the ultimate strength of the steel in MPa.

So, if your Brinell hardness number is 200, then the ultimate strength is

$$3.4 \times 200 = 680\ MPa$$

This is just an empirical formula.

(Refer Slide Time: 10:48)

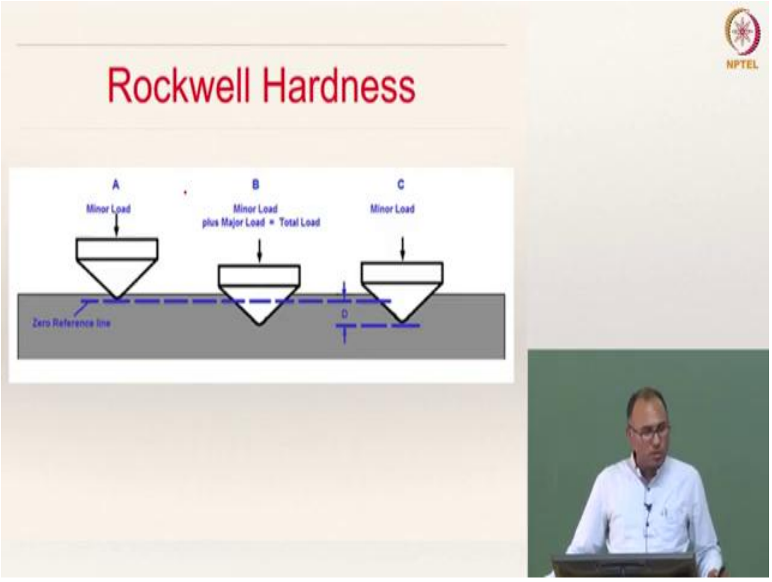



If you change the indenter from steel ball to some other indenter shape and if that indenter shape happens to be a 120 degrees diamond cone (or sometimes spherical ball), then, you will have something called Rockwell hardness indentation. As above, you apply a constant load and measure the depth of indentation.

You take the specimen and the indenter and firstly apply a minor load of 10 kg, just to prepare the specimen for the test. There may be some surface scales on the surface, so you want to get rid of them. So, this 10 kg is used to get rid of these surfaces. After this a major load is applied and the depth is measured on a dial in terms of hardness numbers.

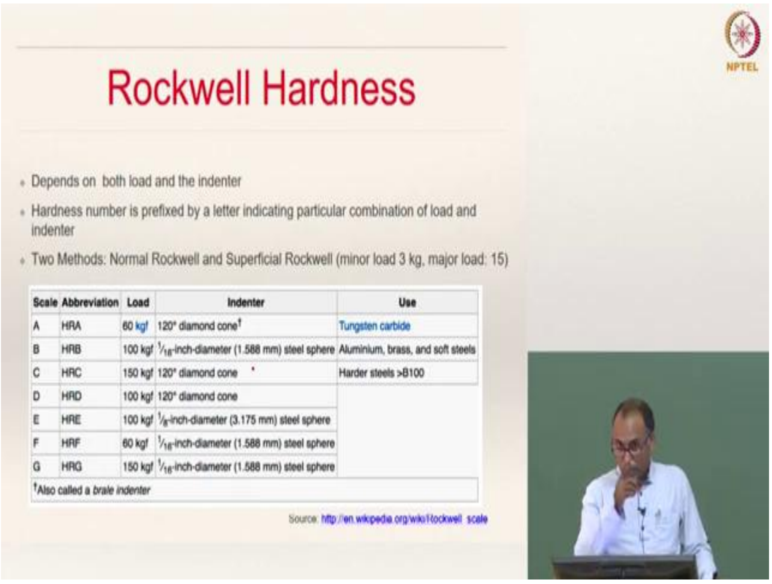
This dial contains a 100 divisions and each division represents 0.02 mm penetration. Unlike the BHN, the Rockwell hardness numbers do not have a unit. The major load applied depends on the material being tested. If it is a soft material, you will apply 60; a little bit hard, 100; and much harder, 150.

(Refer Slide Time: 13:28)



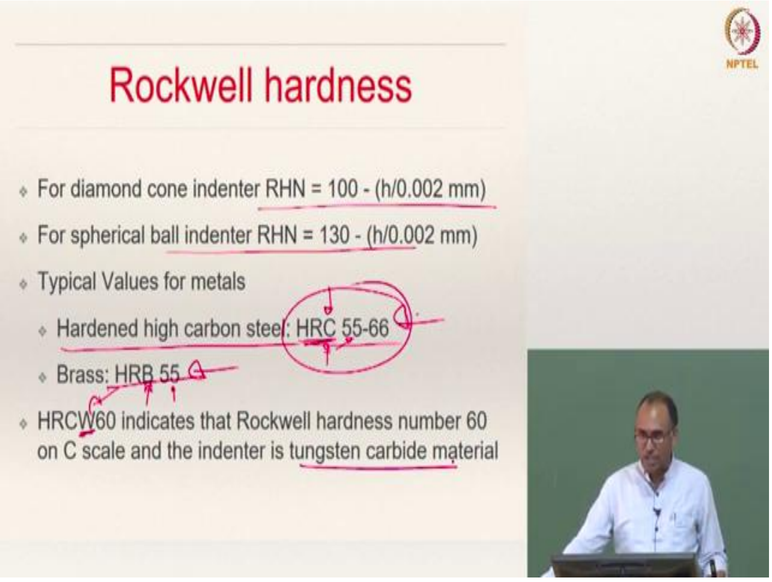

So, this is how you will apply you apply a minor load and then a major load and measure the depth of indentation. That depth of indentation is shown on the dial.

(Refer Slide Time: 13:45)




Also, different scales are available in the Rockwell Hardness depending on the shape of indenter used and the force applied. Therefore, when reporting the Rockwell Hardness number, one must also mention the scale being used. For example, HRA, HRB, HRC, etc. Also, there is Rockwell Hardness number to the Brinnel hardness number.

(Refer Slide Time: 15:08)




For a diamond cone indenter

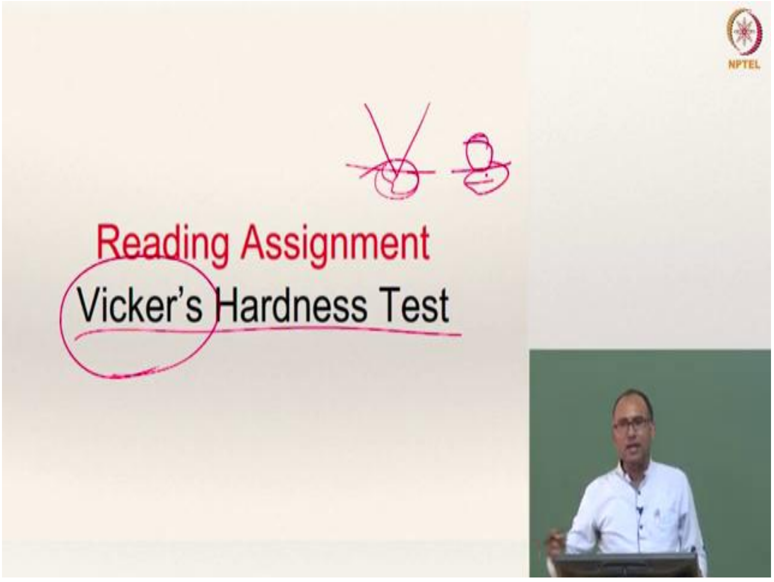
$$RHN = 100 - \left(\frac{h}{0.002\ mm}\right)$$

For spherical ball indenter,

$$RHN = 130 - \left(\frac{h}{0.002\ mm}\right)$$

High carbon steel has a Rockwell hardness of HRC 55-66 while brass has a HRB of 55. Note that the scales used are different. A ‘W’ indicates (eg. HRCW60) that the indenter material is tungsten carbide.

(Refer Slide Time: 17:32)




The indenter is different in Vicker's hardness test and the way the Vicker's hardness test works is similar to Brinell hardness test. It also reports the load by area unlike Rockwell hardness

(Refer Slide Time: 20:24)


The students are encouraged to read the chapter on tension test from the book by George E Dieter.