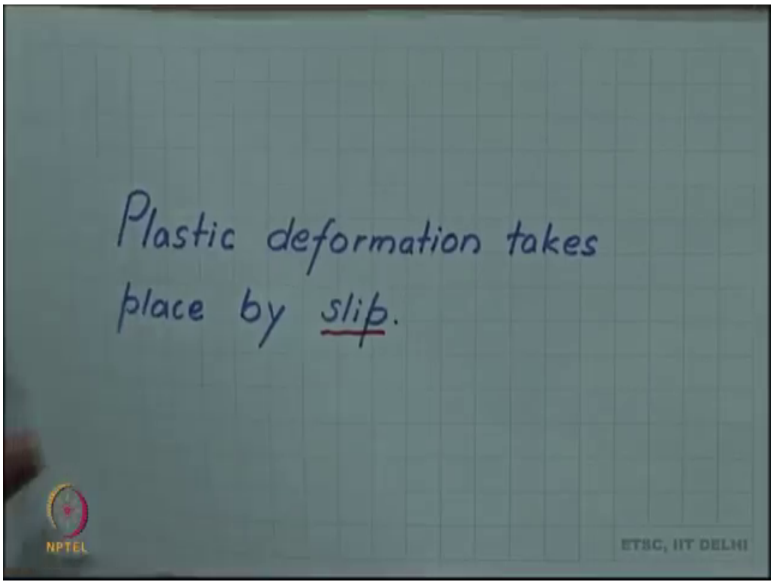
Introduction to Materials Science and Engineering
Prof. Rajesh Prasad
Department of Applied Mechanics
Indian Institute of Technology, Delhi

Lecture – 110
Resolved shear stress

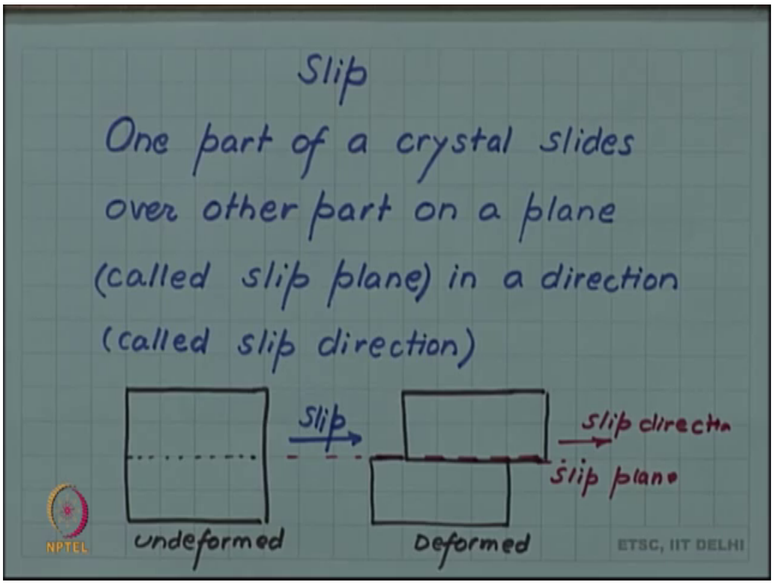
Let us discuss an important concept called Resolved Shear Stress, which will help us in understanding the plastic deformation.

(Refer Slide Time: 00:17)



So, we have already seen that plastic deformation takes place by slip, this was to explain that why there is no change in the crystal structure of the material, during plastic deformation. So, although there is a macroscopic shape change the external shape changes, but internally the unit cell does not deform, the unit cell remains the same the crystal structure remains the same so, to explain that the plastic deformation take was understood to take place by slip.

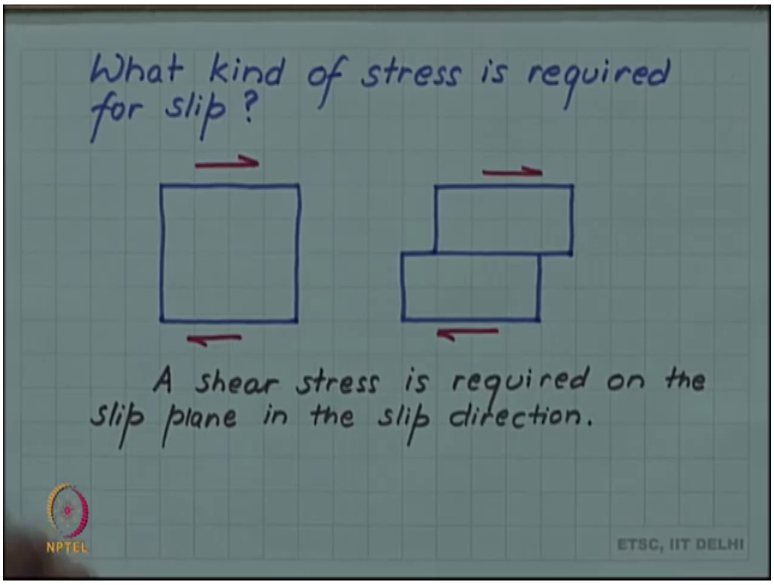
(Refer Slide Time: 00:56)



And by slip we meant that one part of the crystal slides over the other part, on a plane called slip plane in a direction called slip direction.

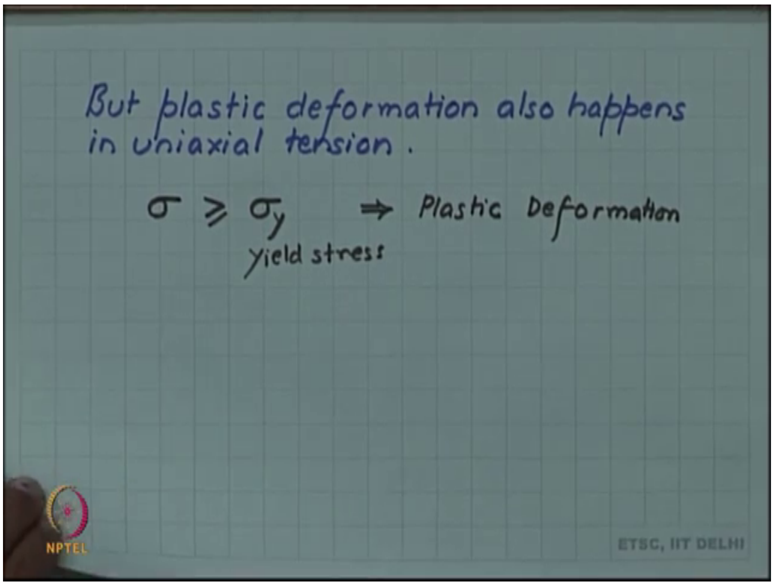
Recall that we had something like. So, we say that if ever if we have a block of material and, if we if this is deforming one way of deforming is that on a plane like this, if the upper half slides with respect to the lower half, then we have obtained deformation. So, this is what we are calling slip; this was undeformed and this is deformed. And we will call this plane the slip plane, this plane is the slip plane and this direction will be the slip direction. Plane is the slip plane in the material. So, this is the basic mechanism we are accepting for plastic deformation.

(Refer Slide Time: 02:36)



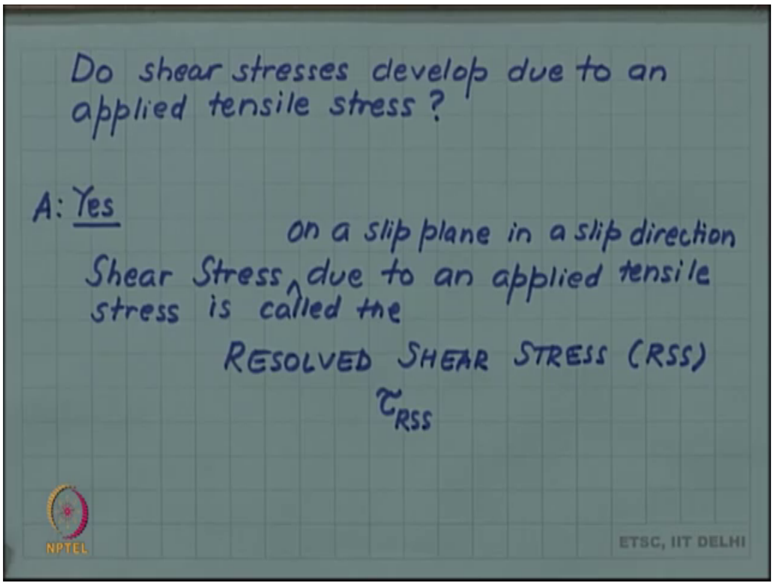
Now, the question is what kind of a stress will be required, if this is the basic mechanism, what kind of a stress will cause this deformation to happen and we can see that for slip to happen the required stress will be a shear stress you have to apply a shear stress on the slip plane in the slip direction; for slip to happen. So, a shear stress is required on the slip plane, in the slip direction.

(Refer Slide Time: 03:46)



But then we have also seen that plastic deformation also happens in uniaxial tension, in the beginning of this chapter, we discussed uniaxial tensile test as an important test for deriving mechanical behavior of the material and there we saw that initially although the material deforms elastically, when the tensile stress reaches, a critical value of stress called the yield stress, sigma y which is the yield stress; then plastic deformation happens in uniaxial tension. But then this suggests that if slip is the mechanism, then this uniaxial tension should be leading to shear stress on the slip plane in the slip direction.

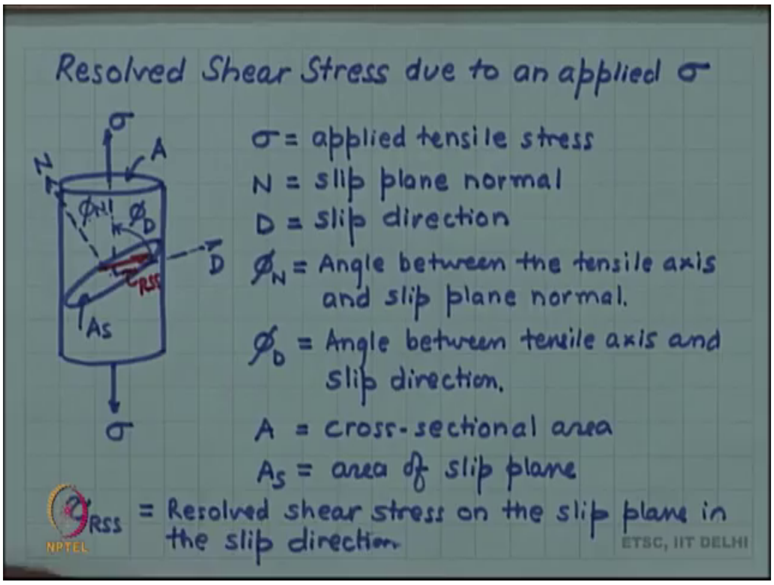
(Refer Slide Time: 04:57)



We have a question that do shear stresses develop due to an applied tensile stress because, your slip is the mechanism of plastic deformation and tensile stress is causing the plastic deformation. So, that tensile stress should be capable of generating shear stress on the slip plane in the slip direction. So, the answer to this question is yes and the stress generated the shear stress due to an applied tensile stress, sheer stress on a slip plane in a slip direction, due to an applied tensile stress is called is called the resolved shear stress.

Sometimes we will have reviate it to RSS and sometimes we will use the symbol tau for shear stress and put RSS as subscript. So, this is called the resolved shear stress.

(Refer Slide Time: 07:00)

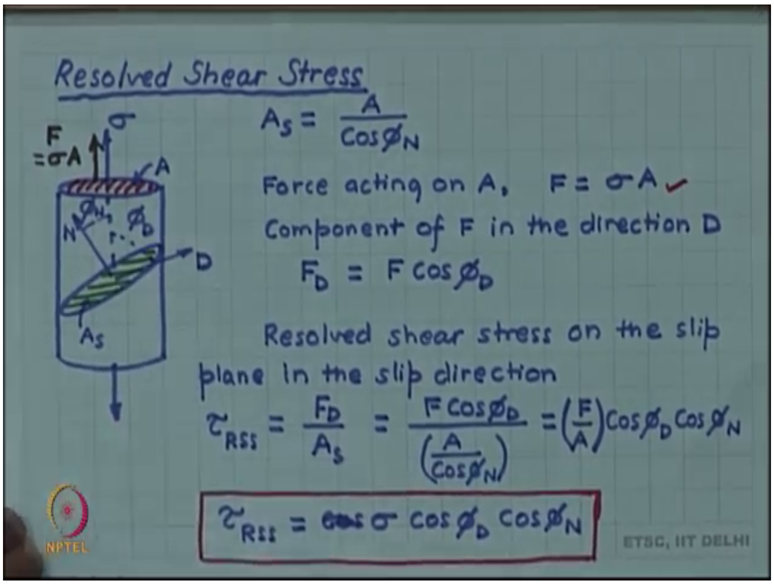


So, let us now try to find that a given applied tensile stress, how much resolved shear stress will be generated. So, resolved shear stress due to an applied tensile stress sigma as shown here, for this first we have to identify the slip plane. So, let us include a slip plane in this. So, I am including an inclined slip plane, such that the normal to the slip plane normal end to the slip plane makes an angle phi N and let us say D is the slip direction and the tensile stress makes an angle phi D with the slip direction.

So, let us write down our variable. So, sigma is the applied tensile stress, N is slip plane normal, D is slip direction, phi N is the angle between the tensile axis and slip plane normal, phi D the angle between axis and slip direction. So, with these variables we can try to find what is the resolved shear stress to; let us also define, we will need this the cross sectional area A and the area of the slip plane A S. So A is cross sectional area of the specimen, and A S is the area of slip plane. So, with these variables we can now try to find what is the resolved shear stress?

So, tau RSS is resolved shear stress on the slip plane in the slip direction. So, tau RSS is on this plane acting in that direction. So, what is the value of this tau RSS in terms of the variables.

(Refer Slide Time: 12:02)



So, first of all let us relate A and A S. So geometrically we can show the slip plane area A S will be the cross sectional area A divided by cos phi N. Also let us try to find how much force is acting on this cross sectional area. So tensile force acting on A; so this by definition since the definition of stress itself is force divided by cross sectional area. So, this force will be given by F is equal to this stress times A because, the stresses force divided by area. So, force acting on a is F A.

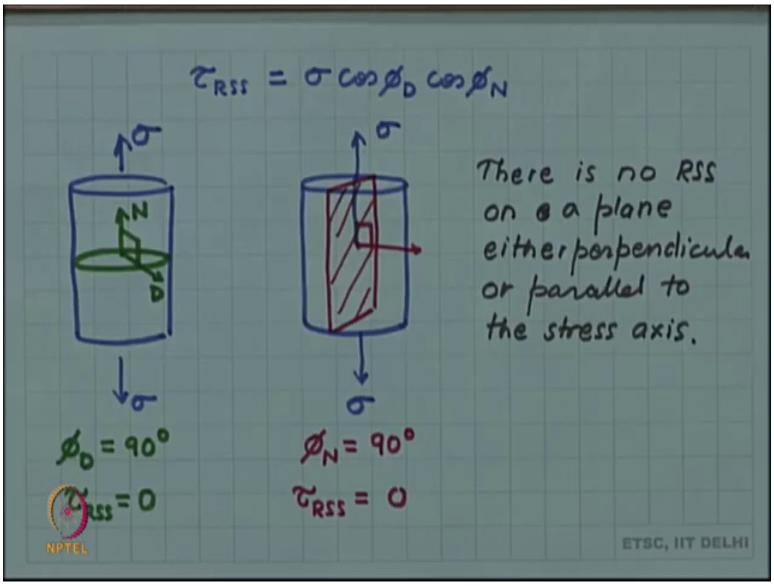
Let us take the component of this force in the direction D; component of F in the direction D that is in the slip direction. So, let us call that component F D. So, this will be simply F cos phi D because, phi D recall that this tensile force will also be acting in the same direction as the stress. So, this force this force F is equal to sigma A is acting in the same direction. So, it makes an angle phi D with the direction D and we know it to take the component of any given force, we multiplied by cosine of the angle between the direction and the force. So, F D is F cos phi D.

Now, this F D is what we will generate the shear stress. So, if we now think of this F D acting on the slip plane A S. So, the plane which on which it is acting is a slip plane A S. So, the shear stress resolved shear stress on the slip plane in the slip direction tau RSS will be the force is F D and it is acting on an area A S. So, F D we have already found is F cos phi D and A S, we have found as A by cos phi N.

So, we can see that we can write this as F by A cos phi D cos phi N, but note this F by A F is acting on the cross sectional area and we are dividing it by the area cross sectional area look at this relationship. So, F by A is simply F by A is sigma the applied stress sigma. So, we then get our final relationship, which we will be using sorry sigma cos phi D cos phi N. So this becomes our resolved shear stress.

So, we see the resolved shear stress depends not only on the applied stress, but also on the orientation of your slip system, orientation of the slip plane normal and the slip direction cos phi D cos phi N. So, we have established this relationship which we wanted of the resolved shear stress. Let us look at some of the con consequences of this relationship.

(Refer Slide Time: 17:50)



So, we have tau RSS is equal to sigma cos phi D cos phi N and this is our sample. Now, consider a plane which is normal to the stress axis. So, for this the slip plane normal is in the stress axis. So, which means the slip direction any slip direction which you will take will always make an angle 90 degree with the stress axis. So, phi D for this case phi D will be 90 degree and so resolved shear stress will be 0. So, no resolved shear stress can exist on a plane which is perpendicular to the stress axis. Now, let us consider another case, in which I now take a plane which is parallel to the stress axis. If I take a plane like this, you can you can see the plane normal will make an angle 90 degree with the stress axis.

So, now phi N irrespective of phi D phi N will be 90 degree and tau RSS will again be 0. So, we find that there will be no in fact, these are the only 2 planes for which the resolved shear stress has to be 0 all other inclined plane, there will be some resolved shear stress. So, let us note down this that there is no resolved shear stress. There is no RSS on a plane either perpendicular or parallel to the stress axis.