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

Lecture – 114
Why is experimental CRSS less than theoretical CRSS

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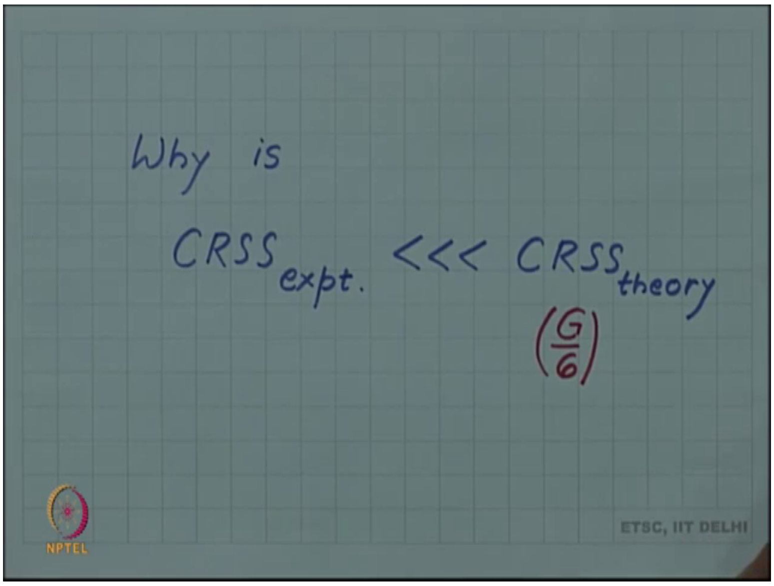

So, we raise an important question in the last video that why is the experimentally determined critical resolved shear stress is far, far, far less than what the theory is predicting for them. Theory was predicting a value which is shear modulus by 6, but the actual experimental value we saw is 1000, 10000 times smaller than this value. So, there is no real match between the theory and experiment.

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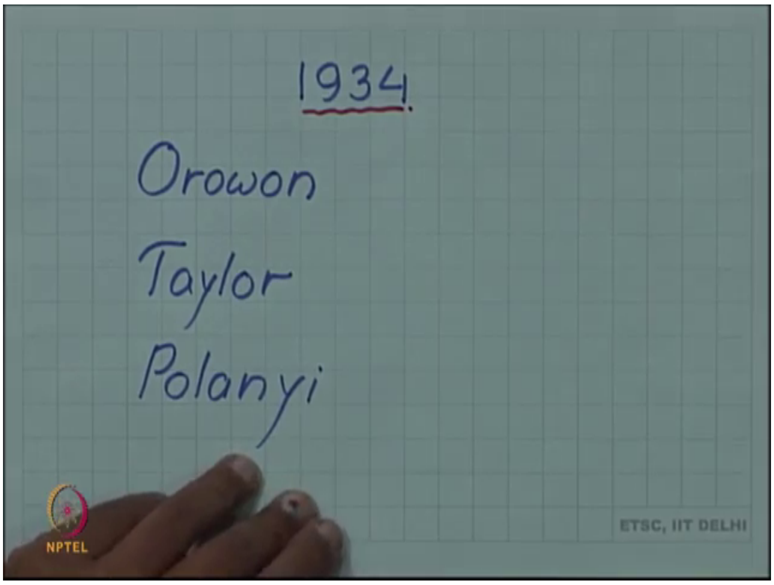

So, what was the solution? So, the solution came in 1934 independently by 3 different scientists; Orowan, Taylor, and Polanyi.

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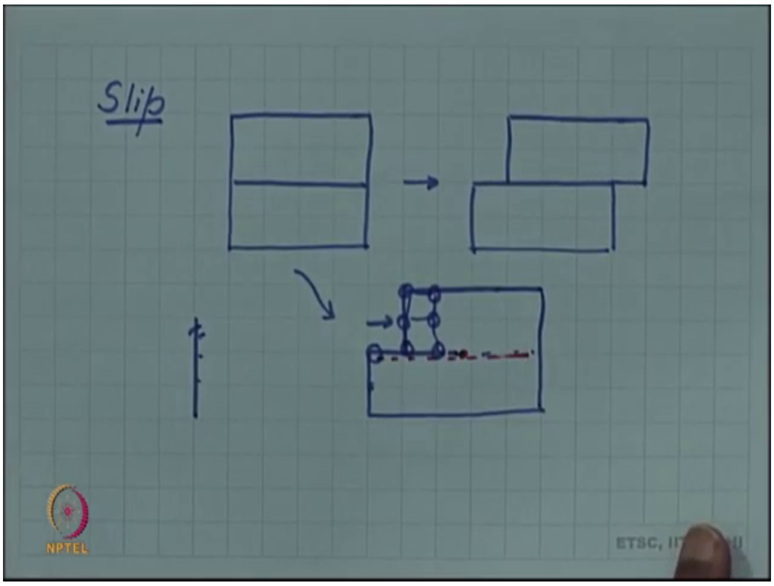

And all of them finally, proposed that the slip which is happening we decided this was agreed upon that the deformation is happening by a slip. And the picture of slip was that one part of the crystal slides over the other part.

So, we have seen this model of plastic deformation that one half of the crystal slides over the other half on a slip plane in the slip direction. However, what they realized the proposal the new proposal was that this sliding need not happen in one go it may happen that one side of the crystal has slipped whereas, the other side has not slipped. So, maybe in the intermediate stage the deformation is something something like this.

So, if I look at this plane, on this plane up to some point up to some point sliding has happened from the left side I have this step, but on the right side I do not have this step. This is possible because the entire crystal is not really a continuum rigid body, but is made up of atoms and it is possible for atoms and the atomic bonds to distort and deform in a way that sliding happens on one part, but the other part has not yet fled. So, this was the proposal.

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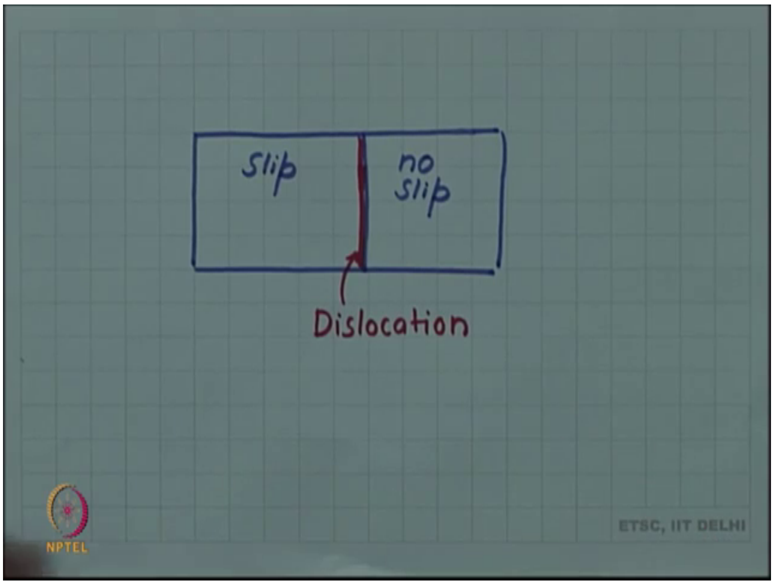

So, essentially what is being proposed is that on the slip plane if you think of the slip plane slip has not taken place over the entire slip plane. But part of the slip plane has slipped and on the other part there is no slip and if you recall from your defect chapter this was what we considered as a dislocation line.

So, what is really being proposed that a dislocation is present during deformation a boundary between slip and not slip line we called dislocation. But why should dislocation lead to an easy deformation of the material? So, let us look at that in this picture.

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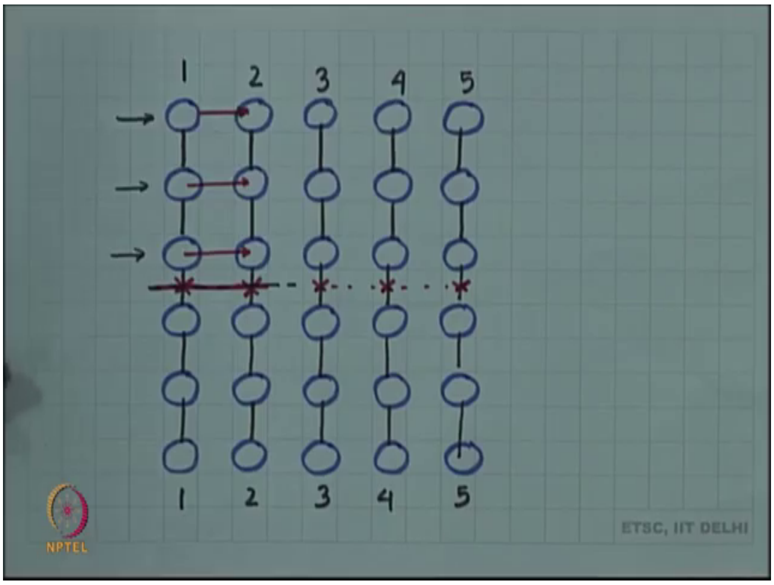

So, suppose this is a crystal this is a crystal, and suppose we cut this crystal on some slip plane and after this cut I try to push this upper half above the slip plane with respect to the lower half. And suppose I have made the cut only up to the second plane then what will happen and I am pushing let me label the planes. So, I call this plane 1, plane 2, plane 3, plane 4, and plane 5, I am labeling the vertical planes think of these as a vertical planes.

So, I have these vertical planes and I have cut these bonds here, Ii cut these bonds and trying to slide the crystal in a way such that the first plane shifts to the position of two to the second plane. So, second plane has to move to accommodate the first plane, but it cannot join the third plane because I have not cut any further bonds there. So, what will be the configuration which will be generated by this process?

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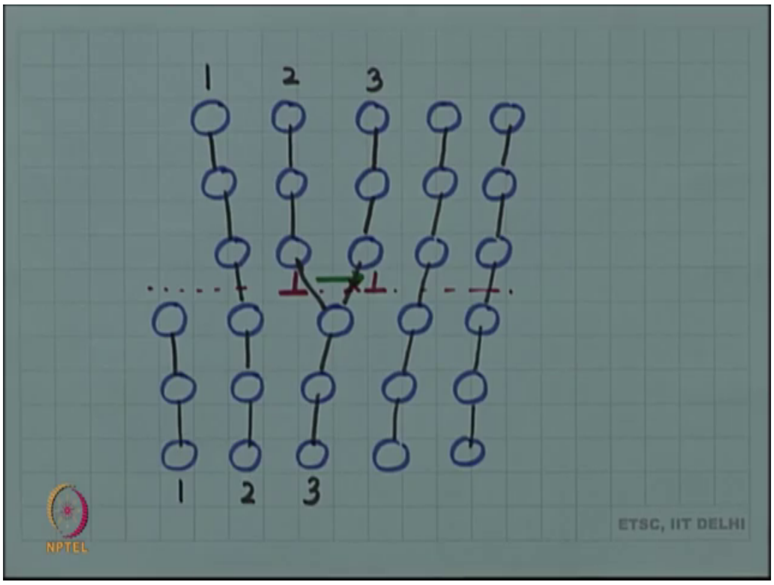

So, you have already seen in your study of dislocation that then since you have the first plane joining with the second plane. The first plane from the top is joining the second plane from the bottom, but the second plane from the top is not able to join the third plane because third plane is continuous remember I have not cut the bond there.

So, the third plane just deforms to accommodate the second half plane from top. So, we have created a half plane and we have seen that there is a dislocation which has appeared now. So I am using the symbol of dislocation as dislocation which we have introduced in our defect chapters.

Now, why should this process be easier than deforming like a rigid body, deforming like this like a rigid body over the entire plane. You can see that here we have to cut only the 2 bonds, to introduce this step I have cut only these 2 bonds.

And then I am able to deform and create this extra half plane if I wanted a complete step then I will have to cut all these bonds in one go so that will require a higher energy and correspondingly a higher stress to achieve it. Whereas in this case for each unit step from now onwards I have to cut only one set of bonds, so, what I will do now to create further deformation I will just cut this bond such that this bond now rejoins here.

So, I have now the second plane joining with a third plane from the bottom whereas, third upper plane is hanging. So, the dislocation line dislocation line moves one step this is what we show in the next picture.

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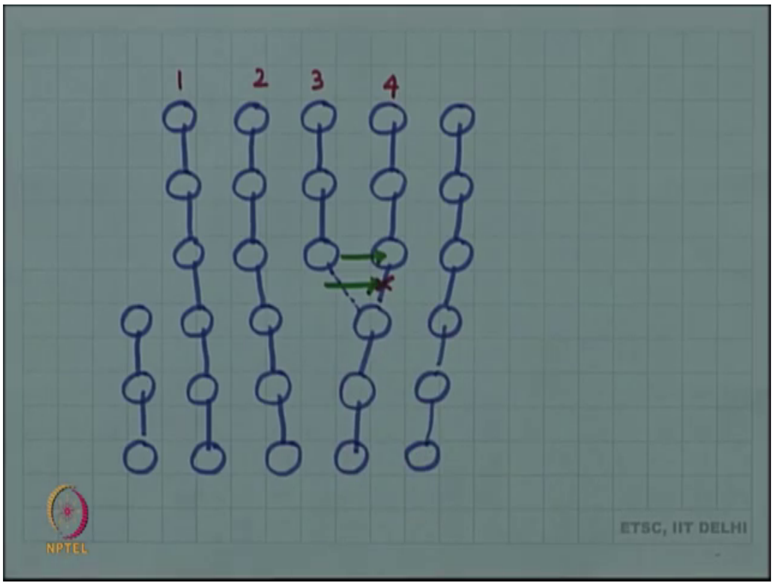

So, now dislocation line has moved one further step. So, it has come to the third plane from the top now. So, gradually if we keep moving it this way each time now for yet another step I have to just break this bond and connected this way. So, it will go to the fourth plane instead of currently 1, 2, 3, and it is on the fourth plane it is in the third plane. So, from third plane it will move to the fourth plane a dislocation will move from here to here. So, that is shown in this picture.

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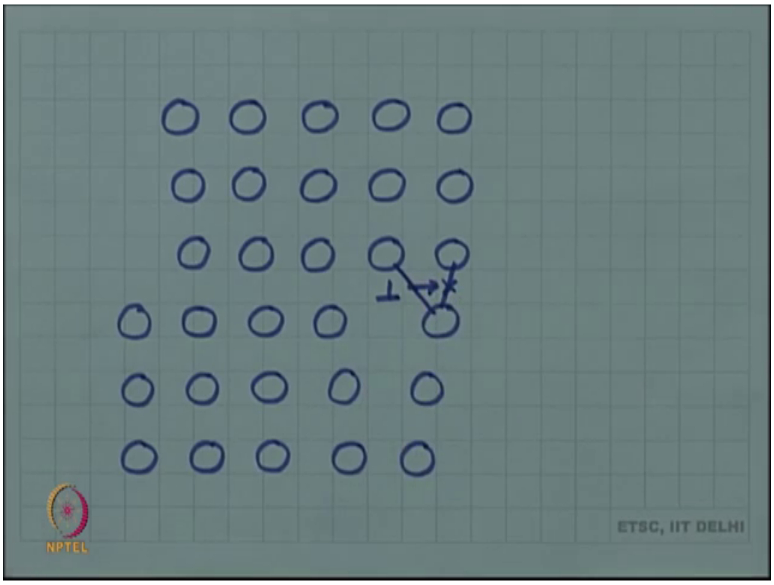

Let us now moved to the fourth plane now there is only one external plane left outside and once I break this bond and connect it here, then there will be this half plane moving out, a dislocation will be moving out of the crystal and we will create a unit step in the crystal.

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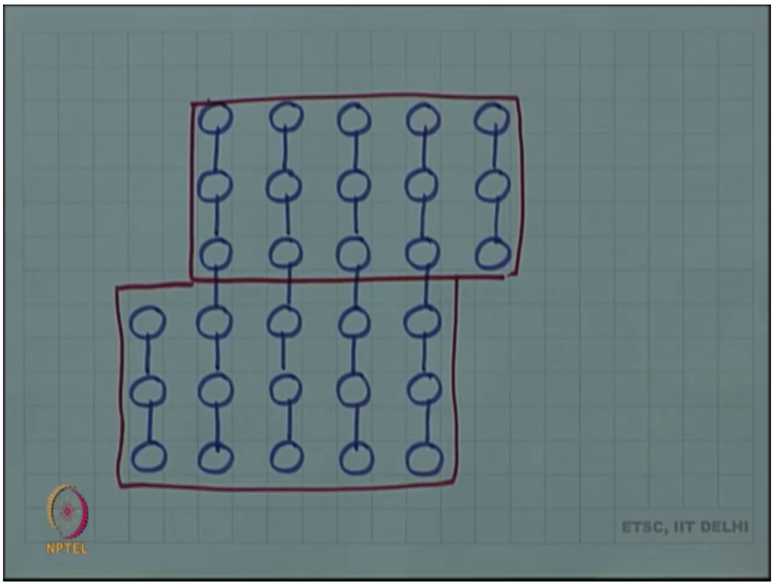

So, this is the final arrangement where the extra half plane has now come out of the crystal. You can see that final deformation in the end we have achieved the same configuration which we would have obtained by a complete single step rigid body deformation of the upper half of the crystal with respect to the lower half.

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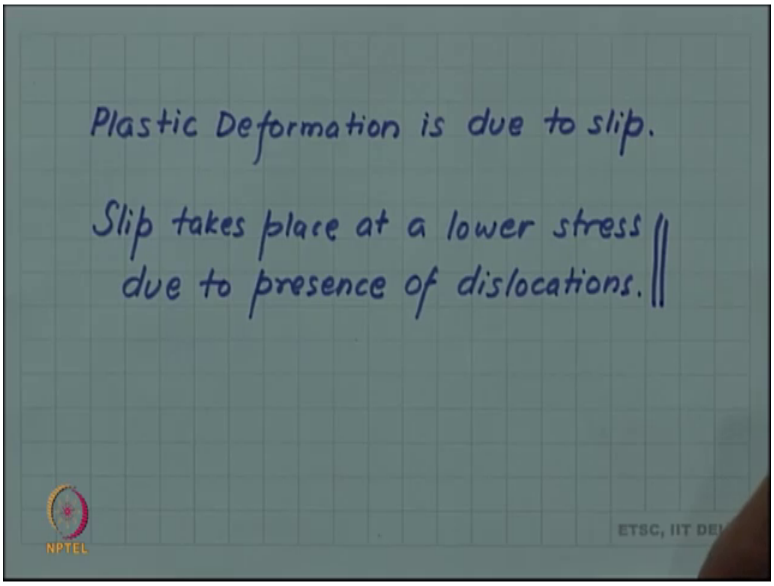

However to achieved in a steps such that in each step we were breaking only one set of bonds and that is why they required stress was much much lower. Plastic deformation requires slip; plastic deformation is due to slip. But slip is made easier by movement of dislocation slip at a lower stress due to presence of dislocations.

We are only giving a qualitative picture of this lowering we are not doing any calculation; however, we will accept this fact that slip takes place at a lower stress due to the presence of dislocation that it is easier to move the dislocation, and by movement of dislocation also we can create plastic deformation.