Properties of Materials (Nature and Properties of Materials: III)
Professor. Ashish Garg
Department of Material Science & Engineering
Indian Institute of Technology, Kanpur
Lecture 25
Dislocation and Slip 1

So, welcome again to the new lecture of the course, properties of materials. So, let us just briefly see what we did in the last lecture.

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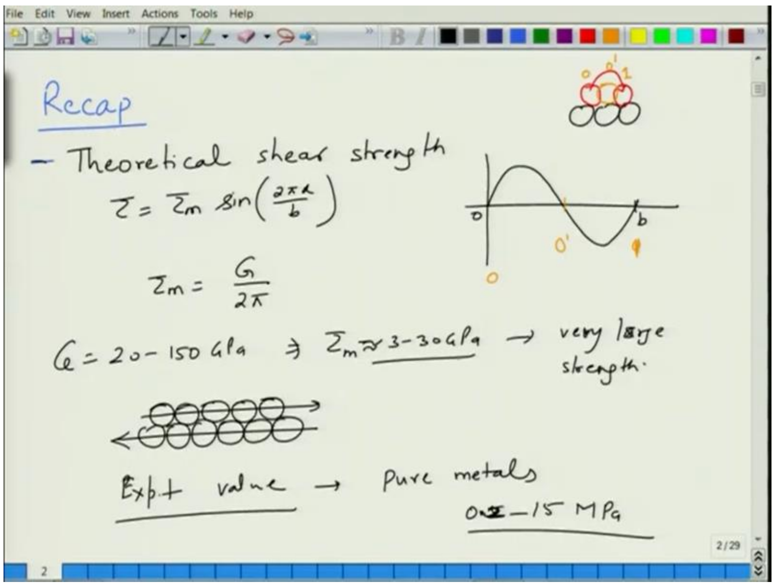

So, in the last lecture, basically we looked at theoretically shear strength. So, a simple derivation, so assuming that stress is varies as sinusoidal, in a sinusoidal manner. So this fashion, so basically, stress in the crystal when you move the atom, varies like this. So, this is the distance that atom has to go. So, if the atom was let us say we draw three atoms. So, atom was sitting here, it has to go to then this position. So, it has to migrate through, intermediate position which is this.

So 0, 0 to 1 it has to migrate through a position let us say 0 prime. So, this will correspond to 0. This will correspond to 0 prime and this will correspond to 1. So, stress varies sinusoidally, using this expression and then by equality of shear stress with shear modulus and shear strain, we can find out that the maximum shear stress required to move the atom will be G divided by 2 pi and this G divided by 2 pi and G, the magnitude of G crystals varies from 20 to metals, 150 GPa.

So as result the value of tau m is also between 3 to 30 GPa, which is a very large stress. So, theoretical strength is extremely large, you would require strength to move atoms by the order of 3 to 30 GPa, but what basically assumes is that when you have this row of atoms and when you have another row of atoms on top and when you are sliding them past one another, this whole row moves with respect to this row. So, which means every atom has to break its bond with the neighbor and then go to the new position, reestablish that bond. So, as a result, lot of energy has to be spent.

However practical values, the experimentally, experimental values of strength to cause deformation are of the order of few MPas. So, for example for pure metals they vary anywhere form 0.5 to 15 mega Pascal or maybe 0.2 to, 0.2 to 15 mega Pascal. So, they are orders of magnitude smaller than the values that you calculate using theoretical shear strength.

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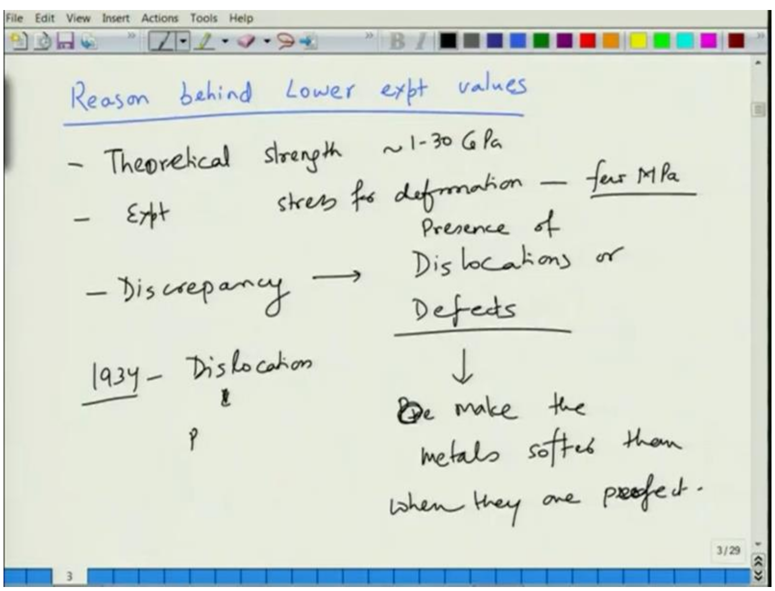

So, what is a reason behind that? The reason, so we are saying theoretical strength is, is of the order of GPas, may be 1 to 30 GPa, experimental strength, stress that is required for deformation is you know few MPas. So, discrepancy has to have a reason and this reason is presence of dislocations or defects inside the metals. So, these defects or dislocations make the material much more softer.

So these, presence of these defects make the metals softer, then when they are prefect. So, obviously when you have a material which is perfect, which does not have any defects it is got to be very strong. But that is not the case experimentally and we saw various values. So, in 1934 was the time when this dislocation theory, dislocation and plastic deformation was explained. The role of dislocation.

How dislocations assist in lowering the stress to cause the deformation which means, real crystals are weaker than, the, and have lower stresses for causing plastic formation or yielding, then the strength values which are predicted from theory. So, so essentially what happens is that. So, let us first look at what dislocations are.

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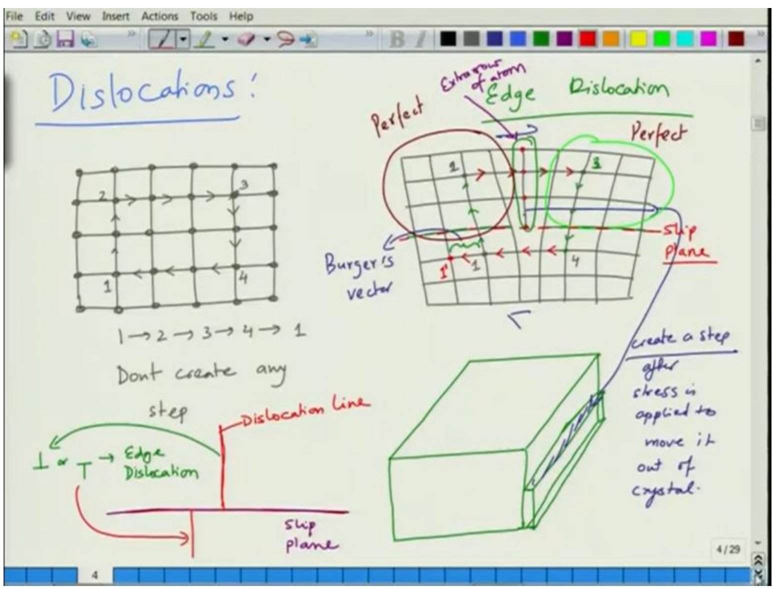

So, we have seen that in little detail earlier in another course Structure of Materials. But let just for the sake of introduction let just see what the dislocations are. So basically we are saying, dislocations as we have seen in a perfect crystal if you take a perfect crystal like this. Let us say this is a perfect crystal and in this perfect crystal let us make a few grids.

So, you have atoms at various positions. So, these are atoms sitting in a. So, let us say we choose position 1, we go two step up, so position 2, two step up, then let us say we go three step to the right to position 3 and then we come back by two steps to position down that is to downward position 4.

Then again we walk back to position 1 by taking three steps to left. So, essentially if you complete whole circuit from 1 to 2 to 3 to 4 to 1. So, 1 to 2 to 3 to 4 to 1, you do not create any extra step, that is perfect crystal. So, you do not have any atom missing or any extra atom over (())(7:04) in the whole thing.

But let us say if you have scenario like this, so we have. So, what we have here is let us say if I start now at 1 let us say at this point. So, we can see that there is an extra row of atom here, in a otherwise perfect crystal. So, this is the extra row of atoms, otherwise perfect crystal. So, if this is the case, let us say if we go from 1 to some position.

So, let us say 1 step, 2 step, 3 step, 4 step, we go to position 2. Let us say we start form here, I think it is convenient to do it form here. So, we start form position 1. Let us take 1 step, 2 step, 3 step to go to position 2 which is here and then we take 4 steps to go to position 2, 3. So, this is position 3, then we again take 3 steps to position, to position 4, to come down.

So, we went from 1 to 2 in one plane by taking 3 steps, we took 4 steps to go to right in the same plane to the right to the position 3, we comeback to positon 4, which is same as position 1, which is same as in the plane in position 1. But now when we want to go back to positon 2 by taking 4 steps. So, we take 1 step, we take 2 step, we take another step. We have to go to another step here to go to, to take equal number of steps. Which means I have created an extra step and this is what to concept of edge dislocation. You insert in extra plane of atoms.

This extra plane of atoms basically causes a step. So, how does it look like basically, it looks like as if you have perfect crystal like this. So, this is a perfect crystal and the perfect crystal will look like this. But if you wanted to create step out of it, the step will look something like this. So, you have a step here and there is this little extra step which is created. So, basically it looks as if you have it is when you move it out but when it is inside, it may look like that the crystal is sort of little deformed, you have an, because you have an extra row of atoms.

So, this is known as edge dislocation. So, when you have this extra row of atoms, then this is called as edge dislocation and this extra step that we create is called as Burger’s vector. So, of course when you apply stress to it, the stress to it will move this out of the crystal, leading to the formation of this step. So, this will happen when you create a step. After stress is applied to move it out of crystal, this is what will happen. So, this is basically you can say the, the dislocation. So, now if I define it, this part of crystal is perfect crystal.

So, this region will be basically you can say perfect. This region is perfect in terms of at least atomic arrangement. Shape will be slightly different because of the deformation in this lattice because of extra row and this extra row of atoms which is present here. This is you can say is the extra row of atoms.

So, the plan in which dislocation is going to move. So, you can see that this extra row, as you apply stress will either move to right or to the left. Let us say if it moves to the right, then basically you can see that it is going to move. So, the bottom 3 layers are perfect, it is going to move in this plane where it terminates.

So, this plane in which it is going to moved it will be called as slip plane in the direction in which it will move will be basically slip direction. So, dislocation line basically is into the slip planes. So, this is your slip plain and this is the dislocation line. So, let us say this is the slip plane and this is the dislocation line and that is why edge dislocation are represented as either this or that. So basically these are basically edge dislocations. So, if it is from the top it will look like this, if it is from the bottom then it will look like this. So, this is the representation for edge dislocations in crystals.

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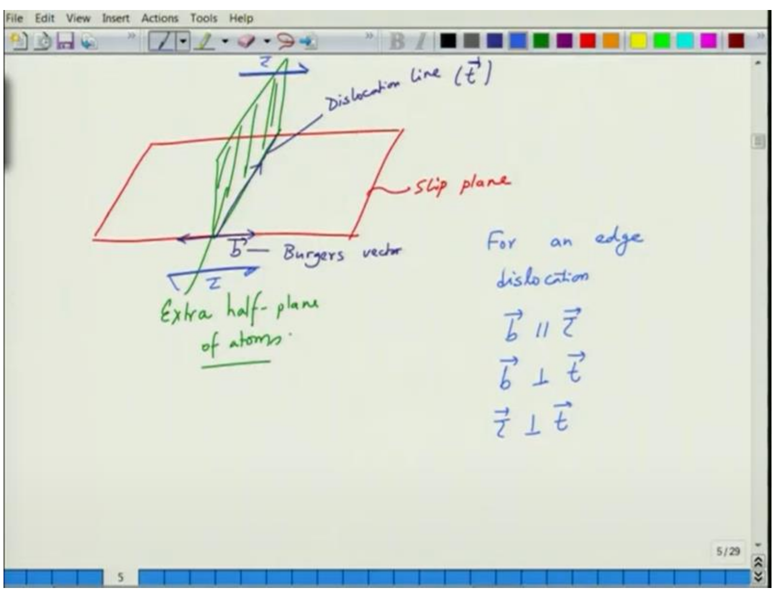

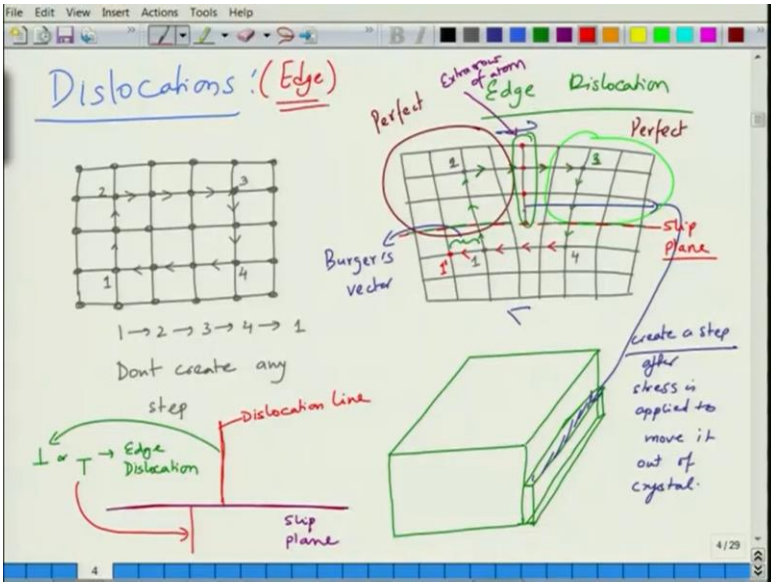

So, essentially what will happen is, this is let us say your slip plane and you have created an extra row of atoms which is like this, extra let us say half plane of atoms, in 2D it will become plane extra half plane of atoms and the Burgers vector would be ether in this direction or in this directions. So, this will be Burgers vector, which is that extra step that you need to take and the dislocation line is, this line which is represented by a vector t. So, for a dislocation so and the stress that is applied is this is. So stress I can, so this is stress tau.

So, the following characteristics is you can see, so this basically is the dislocation line. So, for a edge dislocation, one can write b is parallel to tau and b is perpendicular to t and so by this token tau is perpendicular to t. So, Burgers vector is parallel to applied stress, burgers vectors moves in the same direction in which. So, the extra row of basically the extra step you create is in the direction of applied stress, the Burgers vector is perpendicular to the dislocation line.

So, dislocation line moves in the slip plane. But the movement is along the direction perpendicular to itself. So, b is perpendicular to t and the, if you combine these two, what it means is that the shear step is also perpendicular to the, to the dislocation of the line. So, these are certain characteristics of edge dislocation. The screw dislocation on the other hand makes another kind of dislocation. So this is the first kind of dislocation which is edge dislocation. So we can say this is, first is edge dislocation.

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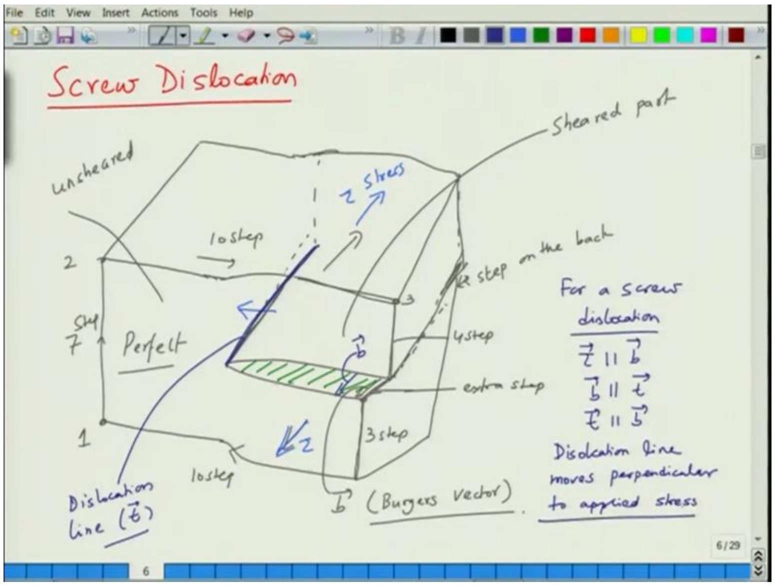

Now the second kind of dislocation is basically Screw Dislocation. So, essentially this is the dislocation which looks something like let me try to draw it well. So this is let us say, little exaggerated. So, you create a step here this is the step on one side. So, this is the step you created on front, front side. This is the step you create on the backside. So, basically what you have done is, you have moved this half of the crystal with this half of the crystal.

Along this, so this would be the basically you can say the dislocation line passing through the crystal. So, this is perfect crystal and this is where you have created the dislocation. So, if you start from this point, point 1, you would point 2 of the crystal, you come to point 3 of the crystal and then in order to go to let us say that, the easier one would be, you come to, you come from this point, you take few steps.

So, let us say 3 steps here, you 3 steps let us say you go there, you take 10 steps, you go up take, I do not know you take 7 steps, you come here you take 10 steps and then you come you have, you complete 4 steps and to come back to this point you have an extra step this the extra step and this is basically the you can say the Burgers vector and the, and the line that goes through is called as, this the line across which you have division between the perfect and the sheared crystal. So, this is the sheared part of the crystal and this is the unsheared part of the crystal.

So, basically stress is applied in this direction. So this stress and this would be stress here. So, tau would be in this fashion. So, this line when you, when you apply stress, this line will move in this direction. So, basically for a screw dislocation you can see. For a screw dislocation as we keep applying stress the line, dislocation line, this is dislocation line. So, let us say this is dislocation line t. So, for a screw dislocation, this is your Burgers vector v.

So, tau is parallel to b. b is perpendicular to t, b is parallel to t, I am sorry. B is parallel to t. So, this is t and this is b, both are parallel. So, by this token t is also parallel to b. But dislocation line moves perpendicular to applied stress. So, dislocation line moves perpendicular to applied stress, it will move in this direction. So, when the crystal is completely sheared.

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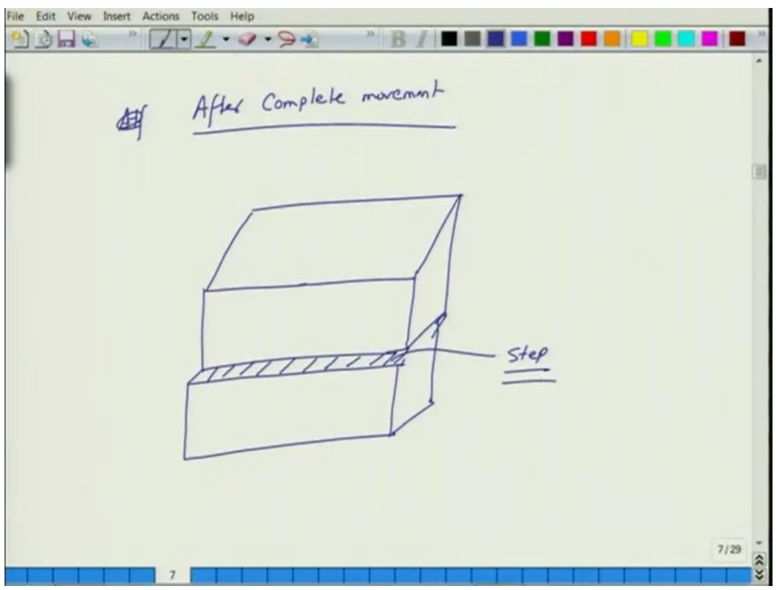

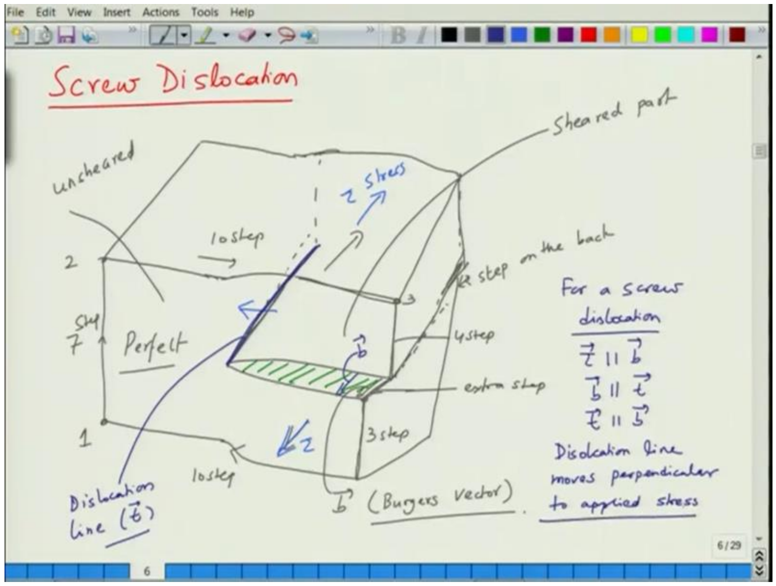

So, after, after complete movement of course it will look like you have, there is a top of the crystal and so basically when this line moves here you have created to step completely in this direction this is step you create. So, when the dislocation line would have completely moved of out of the crystal, applying the step, this would have been a situation.

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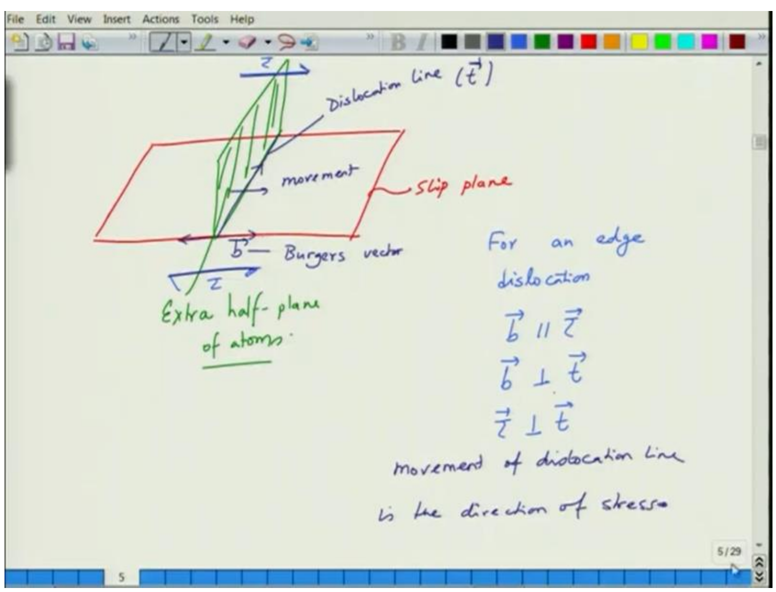

So this is in contrast to what we see in the edge dislocation, in the edge dislocation, the dislocation line. So you can see in the edge dislocation, Burgers vector is parallel to shear stress, but Burgers vector is perpendicular to dislocation line and as a result dislocation line is perpendicular to shear stress. However the dislocation line, the movement of dislocation line. So, movement of dislocation line is in the direction of stress.

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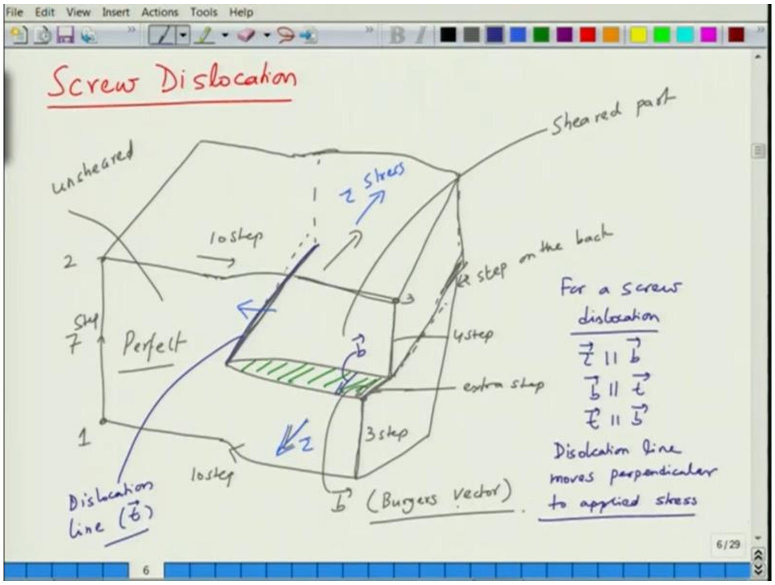

Similarly here, here the dislocation, now here on the other hand, the dislocation line moves perpendicular to the applied stress. So, these are the two fundamental difference between two kinds of dislocations. So, in reality what happen is that we do not have perfect edge or perfect screw dislocations.

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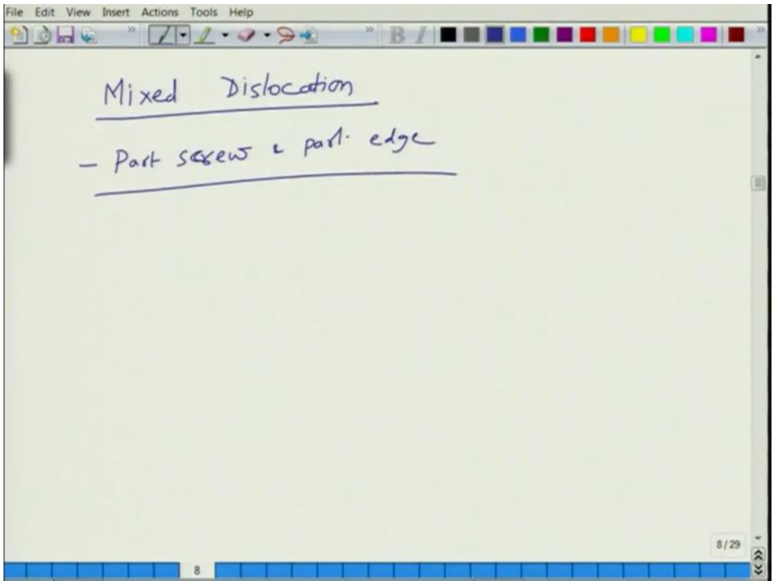

What we tend to have a mixed dislocations and these mixed dislocations basically are you can say the part of the crystal. So basically, part screw and part edge. So, we will do a detailed discussion on this in next class and what we have done in this class is, we have introduced the concept of dislocations and we have just stated the concept of dislocations are the once which take part in introducing the amount of stress that is necessary to carry out deformation.

We have not gone into mechanism. So, this we will see them little later. We have and what we have done is we have just taken a brief relook at dislocation, what are edge dislocations, what screw dislocation is and we will discuss this in details in the next lecture. Thank you.