Mechanical Behaviour of Materials
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Lecture - 19
Introduction to Dislocations - VII

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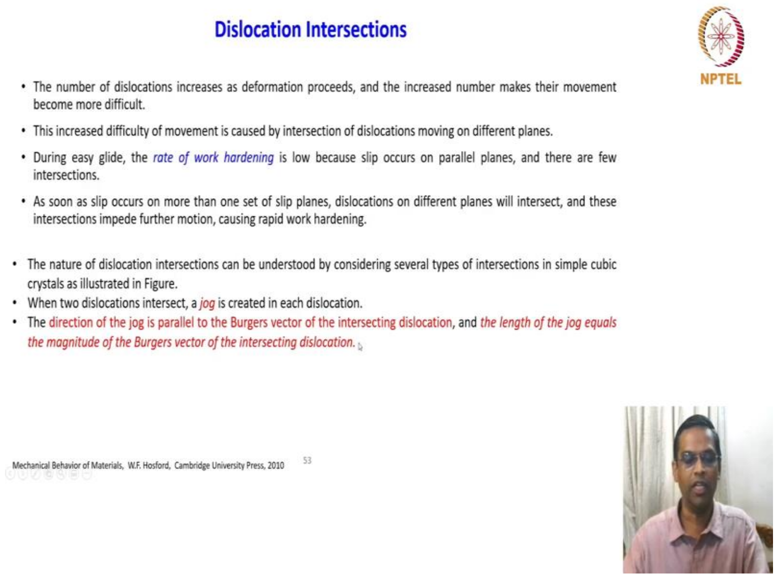

Hello I am Professor S. Sankaran in the Department of Metallurgical and Materials Engineering. Let us continue our discussion on dislocations. In the last class we looked at again different kinds of interactions between the dislocations and also kind of you know mechanics of dislocations I would say in terms of dislocation generation and its interaction with obstacles and so on.

In that connection we are going to continue our discussion on the dislocation intersections. We have looked at interactions and now these are intersections between two line dislocations. So, the number of dislocations increases as the deformation proceeds and the increased number make their movement become more difficult. As I mentioned in the previous class we are now getting into details of the deformation.

So, though we are yet to address that but in the context of dislocation and its multiplication we are indirectly discussing the flashing deformations. So, the number of dislocation increases the deformation proceeds that means as you continue to deform the material in a I mean below recrystallization or cold deformation they increased number makes each dislocation to move further become difficult.

Because of the interaction between other or neighboring dislocations this increased difficulty of movement is caused by the intersection of dislocations moving on different planes. So, we were talking about dislocation cross level dislocation you know aim interaction with the one dislocation with other. So, all these things will have some impact on the dislocation density for example I also mentioned about the wavy slip and planar slip and so on.

Where when we talk about a wavy slip material we are connecting the mobility of dislocation in three dimensions that means the dislocation motion is not restricted or confined to a given plane for example that is what happens in the planar material planar slip material but in a wavy slip material the dislocation moves freely all over the place but three dimensional motion is not restricted in such cases when the density of the dislocation increases.

Obviously they will encounter the other dislocations and as the number of dislocation lines per unit area increases then the difficulty arises the in terms of motion. So, during easy glide the rate of work hardening is low because slip occurs on a parallel planes and there are few intersections we are now bringing another term work hardening we will in fact we have to address this terminology this term will surface when we discuss the you know cold work of material.

And one of the strengthening mechanisms this will come as a part of the content but here as it is closely related to the room temperature deformation or cold deformation. So, here the rate of work hardening so that means it is also related to that dislocation density and its interaction. So that is why it is here so during easy glide the rate of work hardening is low that means when there is no high density of dislocation the glide is enabled without any problem in a glide plane.

Then the work hardening rate will be slow, low sorry not slow low because the slip occurs in a parallel planes slip. We have all the possible planes which are favourably oriented here in this case all the parallel planes we are assuming that there are favorably oriented. So, the dislocations will try to move in those parallel planes and then the intersection will be minimal that is what it is. As soon as the slip occurs on more than one set of slip planes dislocations on different planes will intersect.

And these intersections impede further motion causing rapid work hardening. So, a slip occurring at few slip planes possibly a parallel of planes then they glide is easy not impeded by any other dislocation. But when we are talking about multiple slip that means several slip planes are activated where all the slip planes will move in different, different direction depending upon the easy glide orientation and so on.

We will see which orientation will enable easy glide off dislocation and so on. So, once those slip additional slip planes are activated the dislocation motion takes place in all the randomly oriented planes. Then obviously one would expect that these dislocations will try to interact with each other and then it will impede the motion of the other. So that is where the restriction comes into play and that is an indication of work hardening.

So, which is here we are talking about the rapid work hardening that means as I said that the dislocation moves with the velocity very high velocity that is what we discussed in the previous the velocity is very high. So that is why the interaction also will be very rapid and results in rapid work hardening that. The nature of dislocation intersections can be understood by considering several types of intersection in simple cubic crystals as illustrated in figure.

So, this is one set of schematic we are going to look at it very simple case we are going to assume and try to understand what kind of I mean impact it will create when two dislocations intersect a jog is created in each dislocation. So, we are now getting into a new term jog in a dislocation two in a line I mean in a two dislocations intersect a jog is created so jog is a typical name given when I mean the jog results only by the as the consequence of intersection of two dislocation lines.

So that way we can remember this. So, the direction of the jog is parallel to Burgers vector of intersecting dislocation and the length of the jog equals to the magnitude of the Burgers vector of the intersecting dislocation. So, this is some characteristic of a jog.

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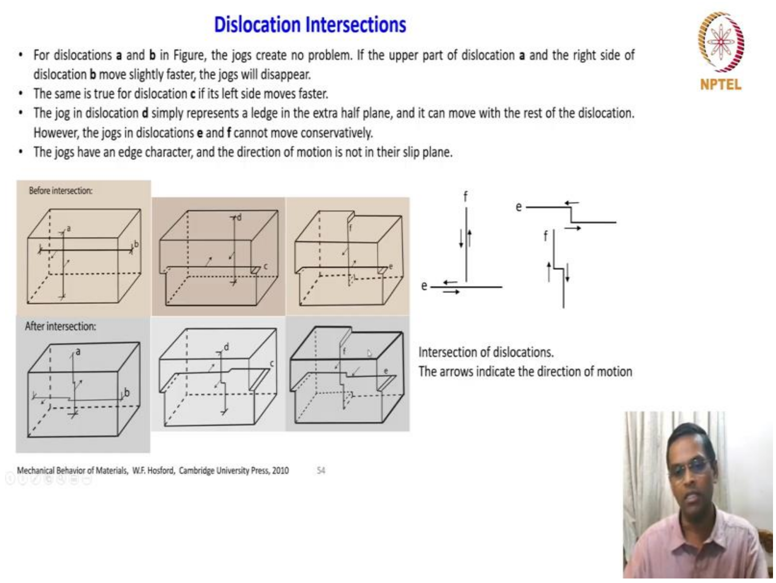

So, this is the figure we were referring in the previous slide. So, we will concentrate one by one there are too many figures at one time. So, it is better to spend some time to understand the figure first and then we will get into the concept the unit cell which is drawn here this is before intersection. There are two dislocation lines are drawn a and b if you look at the a the edge you can clearly see that edge dislocation side.

This is edge dislocation and side the b also can see that the edge dislocation is there in the positive edge dislocation and a top as well as bottom it is positive edge dislocations. Now these two arrows indicate the direction of the motion that is trying to respond to the stress external stress or whatever it is. It is direction of two dislocations like they move in these directions on b is moving coming out of the unit cell and it is going inside the unit cell.

So, this is before intersection and this is after the intersection what you are seeing here is the dislocation has surpassed that means the intersection takes place and then it produces a jog here the b dislocation here and a dislocation here and then they just surpass each other and create a jog and then start moving further. But if you look at the next figure here so if you look at this second figure where already a screw dislocation is generated.

And then you see the dislocation line c and d and then look at their direction and if these two dislocations are trying to move in the presence of screw dislocation like this then after they intersect what happens you see that it produces a jog here and there again there is no problem the jog will move in this direction or this jog will move in this direction depending upon the force but how what resulted of the intersection is shown here.

So, still that line is moving in that direction this line is moving in this direction. But third case is quite different you see that the screw dislocation is created here and there is another screw dislocation perpendicular to this unit. Now the dislocation line e and f are in a very different situation as compared to a, b, c, d these two cases so this is a before intersection after intersection. So, you see that as the intersection proceeds.

Then you see that the jog which is created here on e and f are shown here they are not similar jogs or their motion is not similar to the previous jog motion because we will see y. So, for dislocation a and b in figure the jogs create no problem if the upper part of the dislocation a and the right side of the dislocation b moves slightly faster the jobs will disappear. The same is true for dislocation c if it is the left side moves faster it will disappear.

The jog in dislocation d simply represents a ledge in the extra half plane and it can move with the rest of the dislocation here we are talking about the d. However the jogs in dislocations e and f cannot move conservatively. We are talking about e and f these two jogs will not move conservatively because you see that enlarged view of this e and f is given there the shear stress which is acting on these two lines also shown here and the enlarged view of this ledge here.

So, this is going to move this direction or this direction this is this ledge is going to move this direction or this direction depending on the direction of force. These jogs have an edge character and the direction of the motion is not in their slip plane. This is a problem with the direction of the motion is not in the slip plane and they are going to encounter each other because you see that this plane that shear I mean screw dislocation on this direction is going to come this direction or moving this upward.

And this direction that means two screw dislocations move in a perpendicular direction then this jog will get I mean we will get into a very special situation what is that situation?

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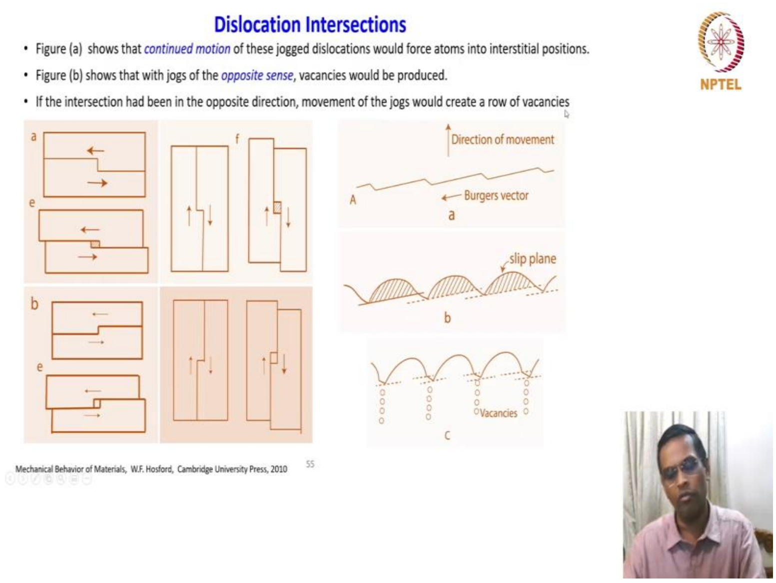

So, this is the continuation of those jogs so this is a jog this figure shows that a continued motion of this jog this rotation would force atom into the interstitial positions suppose if the jog goes like this and then another jog comes in the opposite direction they will force interstitial atoms to get into this y. And there is another possibility it can also produce something different like what is shown in figure b that jogs of opposite sign they produce vacancies.

So, here it is shown we can see here so here it is an interstitial and here it is a vacancy. So, there are two possibilities either they can get locked on in interstitials solute atoms or they just can create markets and this is what is shown in both e type jogs and then f type jog which is shown in the previous slide. So, this is again an interstitial this is the vacancy just do continue that if the intersection had been in the opposite direction movement of jogs would have create to I mean create a row of vacancies.

Suppose in the line of dislocation we said that the opposite jogs will create a vacancies all of them would result in a line of vacancies if it this kind of ledge formation continue to move in the opposite direction. So, to give you an idea of what happens in a boundary like this and this is a ledge the dislocation boundary sponsor ledge which is similar to what is produced here jog.

And these positions will get either as I said either it get locked by interstitial or it will get created vacancy. So that means it will get pinned down by these points all these points. So, there will be a drag and then we know the line tension all this there is how the dislocation moves and so on. And then finally it will produce vacancies like this and there in as it moves that is what is written here the intersection had been in opposite direction moment of jogs would create a row of vacancies. But it is not going to happen so easily.

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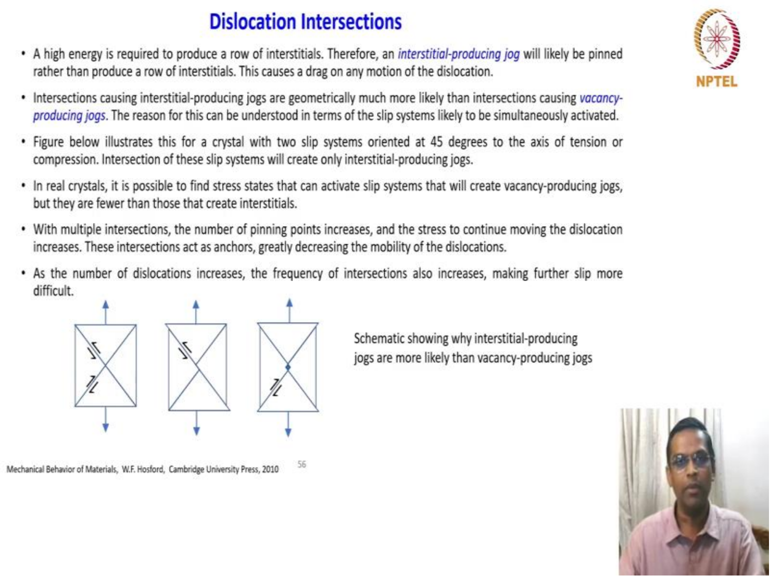

Because energy consideration if you discuss that a high energy is required to produce a row of interstitials therefore an interstitial producing jog will likely to be pinned rather than produce a row of interstitial. So, this causes a drag on any motion of the dislocation like what we have seen in this previous image. So, we are now talking about two types of jog interstitial producing jog or vacancy producing jog causing interstitial producing jogs are geometrically much more likely.

Than the intersection causing vacancy producing jogs the reason for this could be understood in terms of the slip systems likely to be simultaneously activated. So, to explain this whether the interstitial producing jog will get produced or the vacancy producing jogs will get produced. We have 1 schematic here what are the schematic shows? The schematic showing why interstitial producing jogs more likely than the vacancy producing jogs?

You will see figure below illustrates this for a crystal with two slip systems oriented at 45 degrees. So, this is one slip system this is a another slip system to the axes of tension or it could be compression in this case it is tension the intersection of this slip systems will create only interstitial producing jogs in real crystals it is possible to find the stress states that can activate slip system that will create vacancy producing jogs.

But they were fewer than those that create interstitial so what it means is when you have the real systems the interstitial producing jogs will be the most prominent case as compared to the vacancy producing jogs because of the again energy consideration. And what practically will happen is because most of the real systems we have some or the other impurities industrial atoms and so on.

So that is another reason why it is preferring to produce this. With the multiple intersections the number of pinning points increases and the stress to continue moving the dislocation increases. So, the intersection we talk about as the dislocation density is increasing and then when you have I mean the intersection causing pinning this second phase particle or a solute atoms or interstitials here we are talking about that increases they are all anchoring points.

That means whatever the jogs produce they are already locked up so that that means it will act as an obstacle for the other neighboring jogs or any other dislocation to move around these intersection act as anchors greatly decreasing the mobility of the dislocation as a number of dislocation increases the frequency of intersections also increases making further slip more difficult. So, this kind of mechanisms give you a perspective of why the dislocation density is directly promoting work hardening for whatever the mechanics we are just discussing it is completely related to the work hardening nature of any given material.

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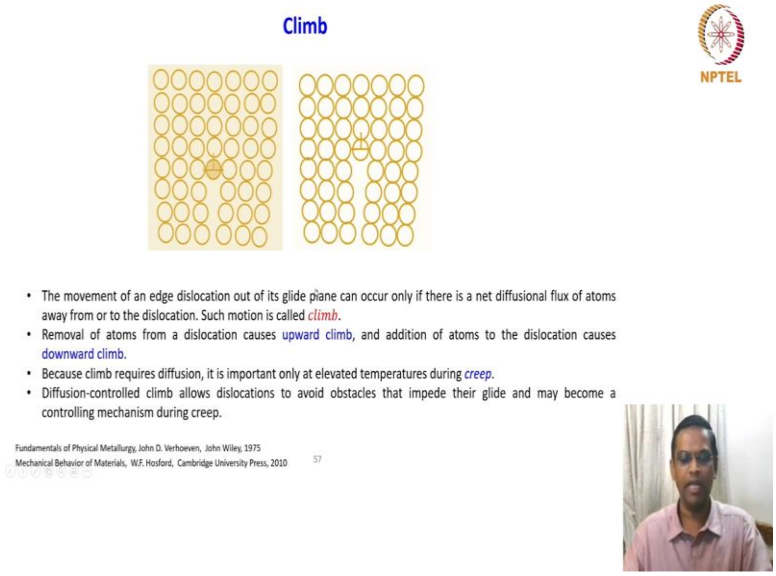

So, finally the we talk about climb we have already discussed this in terms of dislocation motion and here the schematic shows the extra half plane in one case it is extending downward the other case it is moving upward. So, there are two possibilities either it can come down or it can go up and we have seen that the movement of edge dislocation out of its glide plane can occur only if that is a net diffusional flux of atoms away from or to the dislocation such motion is called climb.

If you recall the previous climb slides we have shown some you know vacancies which is trying to get attracted towards this dislocation core and in that case the atom will go and occupy that vacancy see that means the extra off plane is going up that is climb that is a positive climb or the vacancy is started moving from away from this score and the atoms are coming here that means the dislocation climb is downward.

So, the removal of atoms from the dislocation causes upward climb and the addition of atoms to the dislocation causes a downward climb both are equally possible depending upon the characteristic of a material very important point is because climb requires diffusion it is important only at elevated temperature during creep. So, this particular mechanism of dislocation climb is quite relevant to the creep.

When we discuss the creep mechanisms we will use this terminology of or I mean the aspect of dislocation diffusion control claim allows dislocation to avoid obstacles that impede their glide and may become a controlling mechanism during creep. So, this is again very important point diffusion controlled claim is also a mechanism of a creep high temperature deformation we will use this or we will bring all these aspects when we discuss creep.

So, this is kind of a mechanics aspect of a dislocation that is why I got it now itself though it involves a lot of lacing deformation those things we can connect it later. But if you look at purely the mechanics part it is all this activities whatever we have of dislocation we have seen it was suitably I mean suitably illustrated the dislocation nature.