Mechanical Behaviour of Materials - 1
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Lecture – 22
Cross-Slip of Dislocations

So, we have talked about glide of the dislocations, glide is basically when the motion is in the same plane. Now, we asked a question about how the dislocations would move if there is an obstacle. So, to begin with we will look at the obstacles present in the path of a screw dislocations, for them this out of plane motion is relatively easier and it is also a form of glide. So, first we will look at how the screw dislocations will move when there is obstacle and how they will move out of plane.

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So, we know that for a screw dislocation the Burgers vector and the line vectors are in the same direction or parallel or anti-parallel. So, the Burgers vector is parallel or anti-parallel to line vector which implies that there is no unique plane defined by the b cross u as is in the case of edge dislocations, which means that there is theoretically speaking large number of possibilities for the planes on which the screw dislocation can arrive.

However, there are other constraints, as we have already discussed there are other constraints for example, we have said that there is a slip system. So, first let me say that so theoretically infinite number of planes are available. But then we have also said that there are constraints and what we mean by constraint is that every material system has a slip system. So, constraints defined by slip system.

So, cross slip is what is the main name of the mechanism where the dislocation can move from one plane to another. So, even though there are constraints for the slip system, but there are always more than one plane available for screw dislocation. And the mechanism by which it moves out of the plane is called cross-slip. So, what is this cross-slip? To put in simple words let me say there is a plane on which a dislocation exists.

So let us say this is the screw dislocation that is there. Given the symbol of a screw dislocation, now it is moving let us say in this direction and it is able to move. Let us say there is some hindrance further in its path. So, let us say there is an obstacle over here, which it cannot circumvent. However, what it can do is that it has more than one slip planes available. So, let us say this is the other slip plane available to it.

So, at some point when the dislocation reaches this place, and it forces which do not allow it to move in this direction. But there is a component of force which can allow it to move in this direction, then it will start to move along this plane. And eventually let us say the original direction has larger component and therefore once it has passed on or moved away from the dislocation, then this screw dislocation can come back to this plane.

So, this particular case is the example of double cross-slip. So, this was the first cross-slip and then it is the second cross-slip. We are not saying that it is always the cross-slip has to take place in pairs, where this is just an example and just moving from one guide plane to another plane is what is termed as cross-slip of the dislocations and this screw dislocations are just able to move out of the plane. So, you can see this was the plane 1.

So, let us call this plane 1, this was plane 2, and then it is another plane which is also parallel to plane 1. So, it moved away from plane 1 to plane 2 and this is what is called as cross-slip and then again from plane 2 back to plane 1, although in a parallel one, not in the original one. So, this is again another cross-slip.

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And this is shown schematically in here also. So, this is the screw dislocation, and it is moving along this direction because there is a hindrance any precipitate or some other resistance maybe other dislocations are present there. There is something called as dislocation locks because of which there are a lot of dislocations present there and therefore, it is not able to circumvent that, so it will move on to another plane.

And if the stresses in the original direction are still high enough, then once it is away from the influence of that obstacle, it can come back to the original plane. So, this is the overall mechanism of cross-slip and now let us look at what are the possibilities for this plane 1 and 2? So, for example if you remember we talked about FCC and we said we are given a Burgers vector a by 2 110 which was done in our previous lecture.

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Screw Dislocation with $\vec{b} = \frac{a}{2}[10\bar{1}] \rightarrow \{111\}$

So, here we had given that actually it was 1 0 bar 1 and for this the possible slip planes came out to 111 and 1 bar 11. So, we can come back here and say that if for example in this particular case, it is 1 bar 10, then the possible places 111 and 111 bar. So, these are the two possible planes. So, perhaps this is 111 and this is 111 bar and since there are only two possibilities, so when it moves back to another one this has to be 1 1 1.

However, in case of BCC, you will see that there is a lot more possibilities, more than two possible plays are available and in that case the screw dislocations are able to move into variety of planes and it leads to a movement which is called tensile glide., meaning the screw dislocation is able to when you look at the trace from the side view it will look like as if it is free and it is drawn by a pencil. So, it is as smooth as a pencil from where comes the name pencil glide.

Now that we have looked at the cross-slip for screw dislocations, next comes the question of what will happen to mixed dislocations. So, we know that cross-slip cannot take place for at this location. So, clearly cross-slip we have mentioned this that is not possible, but the question is what about mixed dislocations, will the screw character dominate or would the edge character dominate?

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So, let us look over here. Remember that a mix dislocation has both edge and screw character and that is why this question becomes so interesting. So, is it yes, no or maybe? And the answer is all of it. It is yes, it is no and it is we can say complicated. Let us see why. So, let us look at mix dislocation, meaning let us look at screw dislocation line which is curved in nature which means it has mixed dislocation character. So, let us draw a plane here.

So, let us say this is a plane on which dislocation is lying. So, let us say this is the dislocation and for this particular case we will say that the Burgers vector is like this parallel to this line. So, at this particular point it has screw character and somewhere over here it may have an edge character, over here also it may have edge character and rest of it is mixed dislocation. Now, what happens if we bring this line just near the edge?

So, let us say this is the edge from where the dislocation would have liked to move and we will explain why we have chosen this line which is parallel to Burgers vector. So, let us say now bring this dislocation all the way. So, it moved, moved on all the way it is now over here. So, this is where the screw character is, but now we know that screw dislocations can cross-slip. So, let us say there is a possible plane which is like this.

So, screw dislocation component which is pure screw which will be a very infinitesimally small component of it is able to move into the other plane. However, the rest of the component cannot move on to this one because it will have edge dislocation and edge dislocation has to be confined to its original plane. Therefore, this will remain a just a pure screw dislocation which has moved to this new plane.

So, this is plane 1, plane 2. But there is something else that can happen and what is that? It is that this new dislocation that has come here it can actually elongate, meaning the screw dislocation can move and at the same time the edge character can keep on getting generated and therefore the new dislocation would look; so I will now use a different one. So, at some point it would look like. So, here what happened is that only the screw dislocation moved and rest of the dislocation character were created or generated onto this plane.

It did not move on from there, it is like you take a dough and you are preparing chapati. So, this part of the chapati is getting just elongated over here. So, the first part rolled over here and the rest of it is getting stretched. So, in some ways this is a newly generated dislocation, not in some way, but it is actually the newly generated dislocation except for the screw dislocation part which keeps coming over here and that can get rolled onto this part.

And that is why you we have selected this line because the at this particular point, the line vector and the Burgers vector they are parallel and therefore this is where it can it has the possibility of moving from plane 1 to plane 2. if it is at some other angle, let us say if it is at this angle, then it is not in a position to move, meaning it does not have a pure screw character, only when it is oriented like this that it has a pure screw character and hence it can move on to another plane.

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And this is very nicely shown in this schematic. So, you can see this was the original dislocation and we are assuming FCC type of material. So, the Burgers vector is along bar 101. So, this line will have to be bar 101 where that dislocation moves on to another plane and since it is bar 101, so the two possible planes are 111 and 1 bar 11 or it could have been the other way around.

And now, once this dislocation reaches this point or even if you can talk about this one, this particular point has pure screw character, and it can move on to another plane and so it moves on to another plane and the rest of it gets generated. And then again just like in the previous example where we get double cross-slip so here also it can get a double cross-slip and in effect the screw dislocation is what is double cross slipping and rest of it is getting regenerated.

So, a couple of things that we can clearly make out from here the line where this folding will occur or where this transfer across it will occur from one plane to another. The line vector for this would be the Burgers, it has to be because it will be the only place where line vector will be equal to Burger’s vector which means that is where you will have the pure screw character. So, with that in mind, we you can look at some YouTube videos.

And one of these YouTube videos I would like to show you over here you can just search Google search and you will be able to see here. **(Video Starts: 17:28)**.

So, what you see here is that dislocations are moving here and then suddenly they are changing direction over here. From here you can clearly say that this particular direction is the Burgers vector. So, the Burgers vector must lie along this direction. **(Video Ends: 17:48)**

So, just by looking at this image, we are in a position to define the direction of the Burgers vector. And this is done by Kacher Group, which have uploaded this video on YouTube and this is in situ TM imaging meaning inside the TM you can take video by applying very minute forces and you can see the movement of the dislocations which is what they are able to see over here.

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So, let me just summarize what we have just gathered here. For the mixed dislocations only screw dislocation cross slips. Rest of the component gets regenerated on the new plane and we also saw that the intersection line will be along Burgers vector because that is where it will be pure screw dislocation and once you have the Burgers vector you can find out what are the possible planes that you are seeing where the dislocations are moving.

So, we have now shown that mixed dislocations can also cross-slip and it is not as simple as for a screw dislocation because here mixed dislocation is composed of both edge and screw and only the screw dislocation actually cross slips and rest of it gets regenerated. And we also found that the intersection line is along the Burgers vector. So, we will end this cross-slip chapter over here and move on to another motion of the dislocation, which is climb motion. Thank you.