**Defects in Crystalline Solids (Part-I)**
Prof. Shashank Shekhar
Department of Materials Science and Engineering
Indian Institute of Technology, Kanpur

Lecture - 19
Mixed Dislocations+Dislocation Loops

So, we have already discussed individual dislocation properties we have seen a overall dislocation property, but so there are two different dislocations edge and screw. But we also said that in reality you will not have a true edge or a true screw dislocation. What you really have is most of the time like this. So, let us say that and we also said that it cannot the dislocation cannot start and in inside a crystal, it must either form a loop or must terminate at a grain boundary or a surface.

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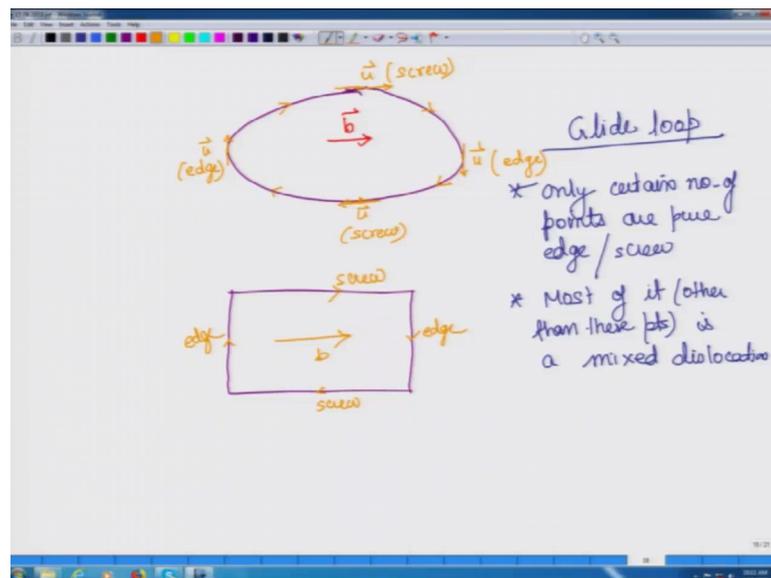
So, let us assume that we have a loop like this ok. And this if it is a loop it is one dislocation, let me so we are assuming that this is one dislocation, there is no start and end just the weight it has been drawn then will look like starting in, but that is just artifact of our drawing. So, there is loop like this. And since it is one dislocation you remember one of the general characteristics that we described is that the burger vector must remain constant. So, for this whole dislocation, there will be one burger vector. And it must lie in this particular plane if we are talking about a dislocation, glide dislocation

loop. So, the burger vector would be like this, so this is the burger vector in the plane. And this type of dislocation loop is called glide loop.

We will see that there can be another kind of dislocation, but for the time being let us stick with this let us try to understand more details about this. So, let us look at different aspects. This is the burger vector, and the line vector is how line vector is continuously changing along this line. So, somewhere around here, the line vector would be let us say we are we have taken a convention that line vector is going like this. So, it cannot change since arbitrarily. So, it is continuously going like this now at this point somewhere around this point, the line vector as you would see u, it is parallel or in fact anti parallel to v.

Similarly, somewhere over here the line vector would be parallel to b somewhere over here you would see that the line vector is exactly perpendicular to b; and somewhere over here again it is exactly perpendicular to b. So remember what does; that mean, what does the parallel and antiparallel mean when is the v parallel or antiparallel to you when it is a screw dislocation. So it is a, this particular point is a screw dislocation, pure screw dislocation. This particular point is a pure screw dislocation. This particular point, this particular point is a pure edge dislocation.

Now, this one similar to that one is also a pure edge dislocation meaning you know loop like this if it has continuous without lots of minimize and maximize, then there are only certain number of points, only certain number of points are pure edge or screw, so that I hope that you can now realize from this. And most of it is actually what is it most of it other than these points. So, everything other than these points is a mixed dislocation. Can you imagine a loop where you have only edge and screw dislocations? Think about it. So, you have to have the u vector either parallel or perpendicular.

So, let us say I have already given you that the b vector is like this. Now, you have to imagine dislocation loop which has only lines which can either be parallel to b or perpendicular to b. So, if you say it will not take much of imagination that you can actually have a dislocation loop like this. So, in a theory, you can have, so these will be edge, this will be screw and all of it, not just point. So, in theory you can have a pure edge and pure screw dislocation even if it is forming a loop, but in reality this is not what you would see; in reality you would have more something more like this. So, there will

be only fixed number of lower edge and pure screw and remaining of it will be mixed dislocation.

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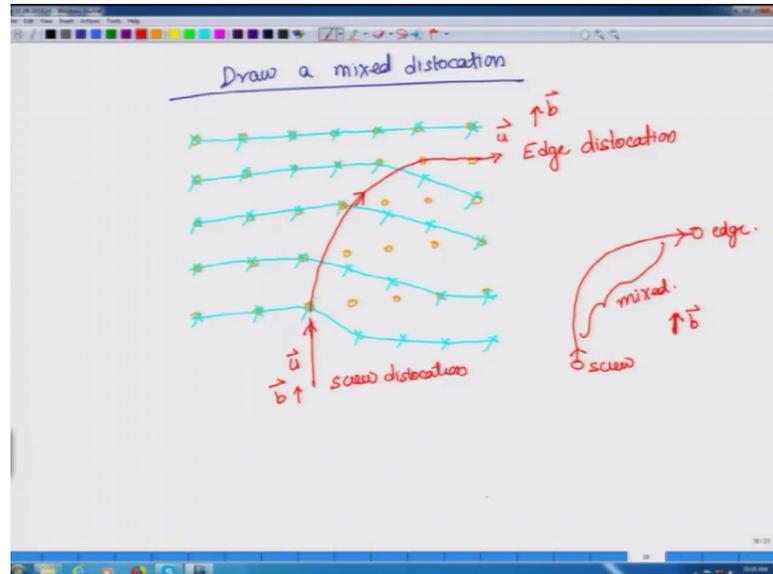
So, now we have termed mixed dislocation, mixed dislocation so many times. It is time that we draw a mixed dislocation; how should a mixed dislocation look like we cannot draw all the planes I mean we have seen it in the three dimension, but what I am talking about is inside it, what we were that we were able to look at in the three dimension refer only from the outside. How would it look like in the inside, how are the atoms arranged when you have when you have a mixed dislocation. So, we will try to draw it over here.

So, let us say this is the set of atoms just below the plane which has slipped. So, these are arranged in a well coordinated or a well periodic manner, there is no displacement in this plane of atoms. So, these are the we are drawing only a very small number of atoms; in reality what I have drawn here would be actually extended to a much larger set of atoms that as you would see what we will call as transition from h to mixed, mix to screw would be taking place over hundreds and thousands of atoms, but we are just trying to draw a schematic or understand what exactly goes on inside the atomic layers.

Now, next what I will do is, I will draw line to this to show where the atoms on the layer above it would like. So, let us say the first this layer of atom this lies perfectly matches perfectly. Now, let us say the second layer of atom this has. So, there is already you can see some displacement over here. So, there is another displacement over here, and yet

another and yet another. So, if I were to draw atoms onto this the atoms on the top layer are lying something like this. So, this one I lies just above it over here some of it are mega matching others are getting displaced.

Similarly, the atoms over here are getting are matching, but some others are still getting displaced. And as you shift you see that there is a certain kind of pattern to it, what is the pattern, here on this side as you would see what would you call this. If you look at it there is a extra half plane on the bottom and there is a missing plane on the top. So, this is nothing but a edge dislocation at the outset here. So, this is a edge dislodge, then we are talking about just the end not the inside part.

Now, when you look over here what you see is that there is a screw kind of character meaning that when you rotate when you go clockwise you see that you are coming out. So, this is a screw dislocation. And to be fair to draw it along or to be accurate in the line vector would let us draw something which would make sense. So, here we have this edge screw dislocation, here we have the edge dislocation; so the two dislocations at the extreme end.

But inside if we look at it somewhere over here; can you define any particular characteristics? It is not really, there is you can if you look at it one way, it would look like there is extra half plane; if you look at it other way it would look like it has shifted to give it as screw like character. So, in somewhere in between these in what you would see is that it is a mixed character. And this is what we are referring to as our mixed dislocation.

So, your core line would go something like this. So, this is how your mixed dislocation would look like from if we had drawn only a line in the not without the atoms, then it would look something like this. We have drawn a quarter of the loop of what we had drawn earlier. And at this particular point, we had we have here screw; and at this particular point we have edge. And here everything in between is mixed dislocation.

So, now you can realize that what kind of atom arrangement is there in the mixed dislocation. And it would be better if you can draw some of these to actually get a feel of it because most of the time in the books what you will see is from how it will look from outside. So, from the outside of course, on one side it is edge; on the other side it is

screw, but is it actually feasible to draw a structure like that is what you would get to know when you draw something like this.

So, I will suggest that you draw a couple of these drawings with different orientation of edge and screw sometimes RH is right handed screw, sometimes left handed screw, sometime the edge dislocation with the extra plane on the bottom and sometimes with the extra plane on the top side, so that will give you a good understanding.

And over here, so if this is the direction the burger vector is like this and burger remains constant. So, burger vector here is like this. So, this is again as you would expect burger vector is perpendicular to u here, burger vector is parallel to u here. So, b is like this, so no surprises here. Of course, this is what you expect the burger vector to lie parallel at the screw dislocation side and perpendicular to the line direction at the edge dislocation side. And everywhere in between what you have is mixed.

So, how would it look like or how would it work when you have a mixed dislocation meaning in terms of finding the character can be resolved, there are two methods to resolving.

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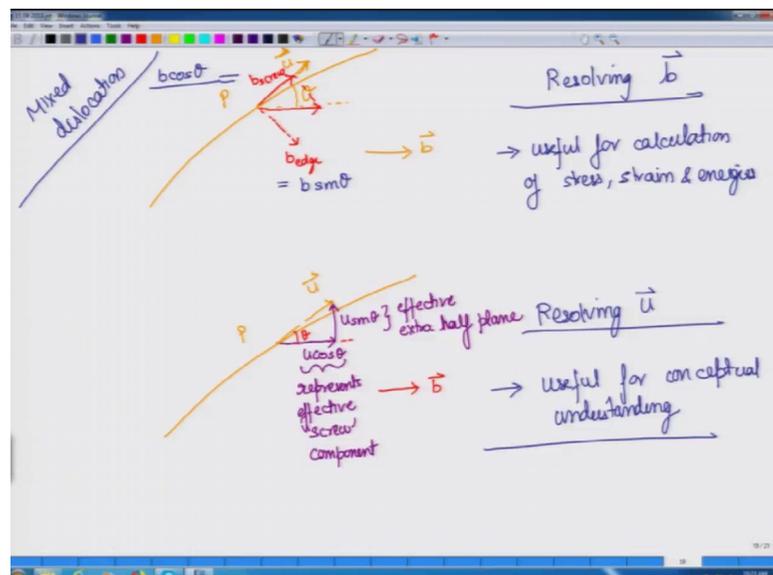
So, let us say this is a dislocation line we are looking at a very small segment, but what we know is that the burger vector is going something like this. Now, the line direction at each point is where nothing but tangent of it. So, if let us say we talk about this particular

point. So, at this particular point, there is angle theta between so let us say this is the tangent to this point p. So, what we are trying to do here is resolving there are two methods to resolve a dislocation into edge and screw. One is resolving burger vector b. And we will see the other method is resolving line direction u.

So, first let us look at what we do in resolving b, it is very simple you have to just take component of b in parallel and perpendicular to u direction. So, this is your burger vector b. So, we will draw it now the orange one that I have drawn earlier is the perpendicular it is the tangent to the line which is u vector u, line vector u for the point p. And the red ones that I have drawn, so this red is the total burger vector this red is perpendicular to u. So, it means this represents b edge; this is parallel to b, so this means b screw. And it is not very difficult to see that the b edge if here the theta is given like this b edge is equal to b sin theta; and b screw is equal to b cos theta.

So, if anywhere you have to say or do take into account calculations of edge of edge and screw, then you can now see you can just put b cos theta for this particular dislocation which is a mixed dislocation. And, simultaneously take b sin theta as the burger vector for edge dislocation. So, this would be useful for as you would see later for calculation of stress, strain and energies.

The other method that we said which is not you can say used more mathematically, but it is more from the point of understanding or conceptual is resolving line vector u. So, we will take the same dislocation line like this. We are talking about the same point p. And this is our line vector u and we already know that the burger vector is like this.

So, now what we need to do is just and ok. So, we are also aware of this angle theta. So, what we need to do now is just take components of this u parallel and perpendicular to b. So, this is u cos theta, this is u sin theta. So now, you have you have basically divided or a dissolved line dislocation component a small component into parts which are parallel to burger vector and perpendicular to the burger vector.

Now, when the part which is u cos theta which is perpendicular to the burger vector, this part represents effective extra half plane. And this part u cos theta this represents effective screw component. This is as I said useful for conceptual understanding. You will at least in our work, we will not be using resolving u method, but resolving b method. So, this is a mixed dislocation.

And now this will also help you understand why we are always talking about screw dislocation, edge dislocation. When in reality what we have is a mixed dislocation because now you can see that we can easily resolve at any time any mixed dislocation into edge character and screw character. And even do mathematical manipulations are basically trying to understand the stress-strain, we can resolve it into a stress component into edge component and the screw component get the stress, strain, energy all everything. And just we need to add them in a proper fashion and we will be able to get every information about that mixed dislocation.

So, it is nothing to be intimidated about that we have what we have is a mixed dislocation and not a pure edge or screw dislocation. And we can still continue our understanding about pure edge and pure screw dislocation.

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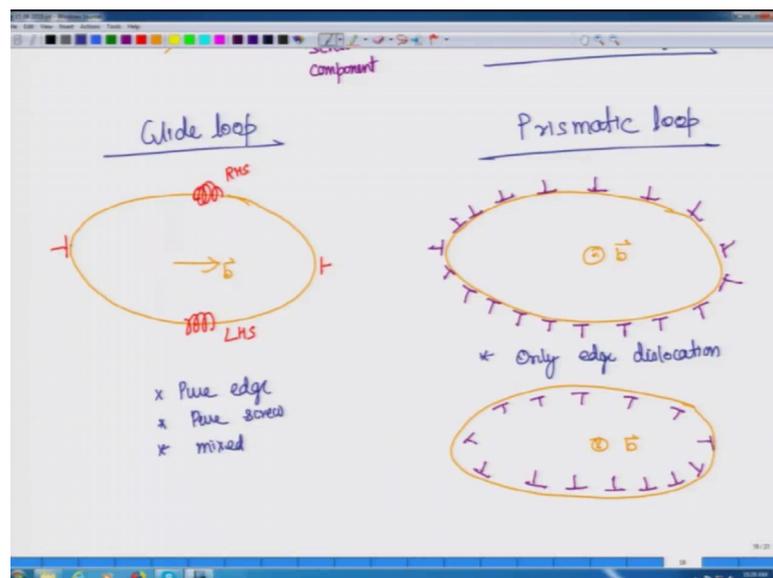
So, before I move onto understanding more of the pure edge and pure screw dislocation, we said there was something called as glide loop. So, we said glide loop is when you have, so we said when the glide loop is the one, where you have burger vector in the plane of the loop. So, over here like I said this is a perpendicular, so there is you can imagine there is a there is a edge dislocation. On the other side also there is the edge dislocation of opposite character. And since you are rotating you are over here there will be some screw dislocation which will be either let us say it is right handed side. And if you go to this side there is a pure screw dislocation, there is at one point and it will be

left handed side. So, the edge character is continuously changing or as and the drawing of how the atoms are arranged is something we have already seen.

Now, the other one is what is called as prismatic loop. And by now you should have realized what it will be how it will be different from the glide loop is that the burger vector would be perpendicular. So, it is perpendicular going in or out of the plane. It is not in the same plane it is either going in or going out of the plane. So, the burger vector is like this.

Now, what does that mean, can you imagine how the dislocation here should look like if you have the burger vector over here? First of all you realize that this is burger vector and the line vector is like this. So, line vector is moving on this particular plane it is rotating somewhere over like this, like this, like this like this in a different points, but burger vector is always like this. So, what does this mean that the burger vector is always perpendicular to line vector. Now, that is very surprising. So, in a loop we have a completely edge dislocation because the burger vector is lying always perpendicular to the line vector. So, this is a very interesting loop.

Now, how does it look like or what is how does it the atoms how are the atoms arranged here. It is not very difficult if you think about a little bit. What you will realize is that what it is that either you have a extra set or extra loop of atoms present or there is a extra loop of atom or atoms missing over here. So, it is more like vacancies which have condensed in this region. So, this is the condensed vacancies and there is extra plane all around. So, you can draw it something like this. So, there is extra half plane, extra plane.

And as I said the other way in this particular case what you have is extra half plane is outside this loop. The other configuration for the prismatic loop is when you have the extra half plane inside this. So, it is the extra set of atoms which have condensed over here. And in this particular case you will draw it like this. So, one of them will be positive b; other will be negative b.

So, this was coming out. Now this is going in. So, this is a prismatic loop. And it has only in this particular case when we look at glide loop, it has pure edge, pure screw and mixed. But over here if you come what we have is only edge dislocation though it is only this it is only that it is oriented different from what you see over here. So, the prismatic loop have is very different from a glide loop. And even its characteristics when it comes

to moving is very different from the glide loop and we will discuss those when we come to movement of dislocations.

So, now, that we have understood the dislocation in a general way we have looked at edge dislocation and screw dislocation, their individual characteristics and some of the other properties. For example, that what is the relation between b and u and all those additional parameters. We have also looked at there is nothing called as pure edge and pure screw in most of the time and it is only mixed dislocation, but we can still understand pure edge and pure screw.

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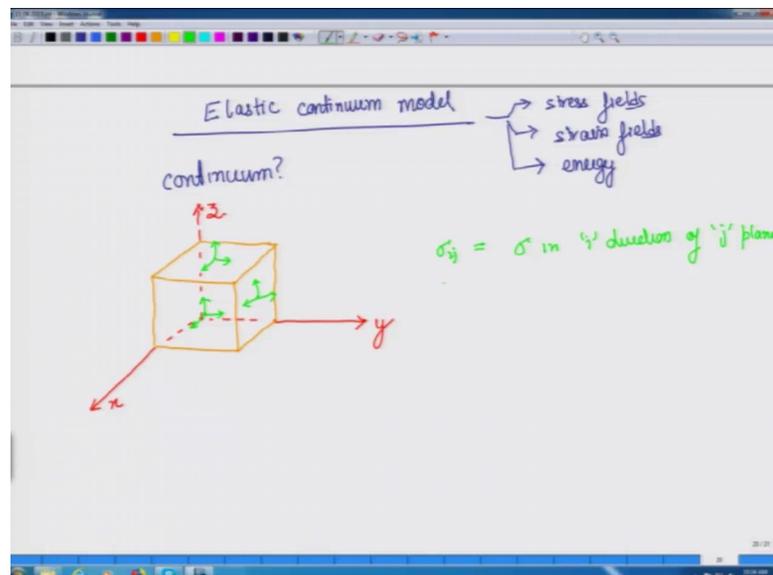
So, with those understanding now we will move on to develop our understanding of the elastic continuum model which is used to understand energy as stress, stress field, strain field and the energy stored around the dislocation. So, next what we need to do is develop our understanding of elastic continuum model which is used. What is it used for we use to understand the stress fields, strain fields and energy stored in this dislocation.

So, as you will see it is kind of irony that when you do the formation on a material plastic deformation it leads to generation of dislocation. And the energy that you have put in the work that you have done gets stored fraction of it in the form of elastic energy around these dislocations. So, these this energy that we are talking about these are elastic energy in a in and around the dislocations. And to understand this, we will need this

elastic continuum model well just explain briefly we will just go through the concept basic concepts of elastic continuum model.

What first of all you know the term elastic meaning, it can release, it can come back. What is continuum? Continuum means that it is continuous there is no you know when we are developing these models we are ignoring that these solids are present as individual atoms in instead we assume that it is a uniform then a uniformly distributed uniform with uniform density of material. So, the properties are you can say isotropic and it does not change from one point to another.

For example, if we were to really go in depth what we realize is that the masses are stored in atoms. So, in between the two atoms, there is no mass and therefore, the properties are very different when you go from one atom to in the space in between these two, but in the continuum model, we are assuming it is a one uniform material with uniform density. And there is no discrete there is no discrete object inside it there is continuous distribution of the material, so no discontinuity.

And hence as the model we are assuming no items etcetera, but of course there are limitations when you go very close to a dislocation this model breaks down and we have to resolve to you can say empirical understanding at that end. So, now having said that what are the stress and strains, how do we define the stress and strain in our system like this. So, there are stress and strain is actually as you would know that not a vector or not a scalar quantity, it has a tensor quantity. So, it has nine and it has nine different components.

So, if you look at a small component of the material which has which is in a cubic form because we have because let us say we are taking a x, y and z coordinate system. So, this is y; this is x; and this is z. So, we have x, y and z components. And for this particular small element from the material, we have taken a small element with x, y, z coordinate, we can define stresses along different directions. The usual ways when we say sigma ij, it means sigma in i direction of j plane. So, you will have stresses along all the three different directions.

I will leave you with this drawing, you will have to tell me what will where will be the sigma x y, sigma y z, sigma z x in all this. And in the next class we will continue with

this and you will see where to fill in sigma x y, sigma y z using the understanding that is already given over there.

So, we will meet in the next class.