Defects in Crystalline Solids (Part-I)

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Lecture – 28
Dislocations and Slips + Examples

So, I hope you have tried on your own because it will be important for solving some assignments and also for the final exam, because there may be some problems related to this.

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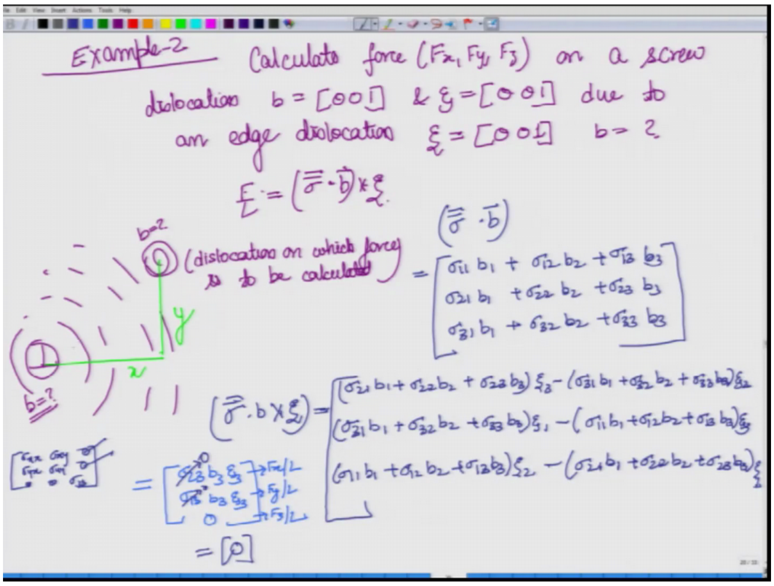

And, as you would have if you tried it out you would have realize that it is really straight forward and simple problem I have already mentioned it earlier also. So, now, let us see if in case you are not tried it out what goes on here. So, if we have something like this we know that this b and e are for the dislocation onto which the stress has to be calculated sorry, the force has to be calculated. So, this is 0 0 1, meaning epsilon 1 and 2 terms will go away. So, this term will go away, this term will go away, this will go away, this will go away, what we will remain with is this? This one and this one.

So, F z is automatically 0 here. What more? We will have b burger vector equal to 0 0 1. Now, here b 1, b 2; here b 1, b 2 these two terms will go to 0. So, what we are remained with is sigma 2 3 b 3 and assuming there is a line vector eps. So, I will write it 3 and sigma 1 3 b 3 epsilon 3 and 0, which means this is F x by L, this is F y by L, this is F z by L and what we see is that F z by L is 0 which not be surprising because this dislocation is a line and there cannot be any force in the normal direction. So, the z direction force is 0; what we have are only F x by L and F y by L.

So, we can see these are the quantities, but that is not still a complete picture. Let us now look more closely. We have said that this particular dislocation is a edge dislocation. Now, if you remember what is the form of stress for a screw for a edge dislocation? So, that stress dislocation is sigma x x sigma x y 0 sigma y x sigma y y 0 0 0 sigma z z. Now, where is the sigma 2 3 component here? This should have been sigma 2 3, this should have been sigma 1 3 and these are 0; which means that this is also 0, this is also 0. So, the overall force is 0.

So, all this exercise is telling us that the force because of edge dislocation onto a screw dislocation is 0 and again this should not be surprising because if you remember the components stress components of edge dislocation matrix are in effect in a way inverse of the stress components present in the screw dislocation. So, these stress components do not influence the screw dislocation and therefore, what we have obtained is what should we should have expected from the very beginning that edge dislocation cannot apply any stress on to a screw dislocation.

And, in fact, we can now extend this to find out what will be the forces because of a screw dislocation onto a screw dislocation, but ok. But, before that this is the standard way to solve it we could have also solve it in a more compact manner because you already know sigma and b.

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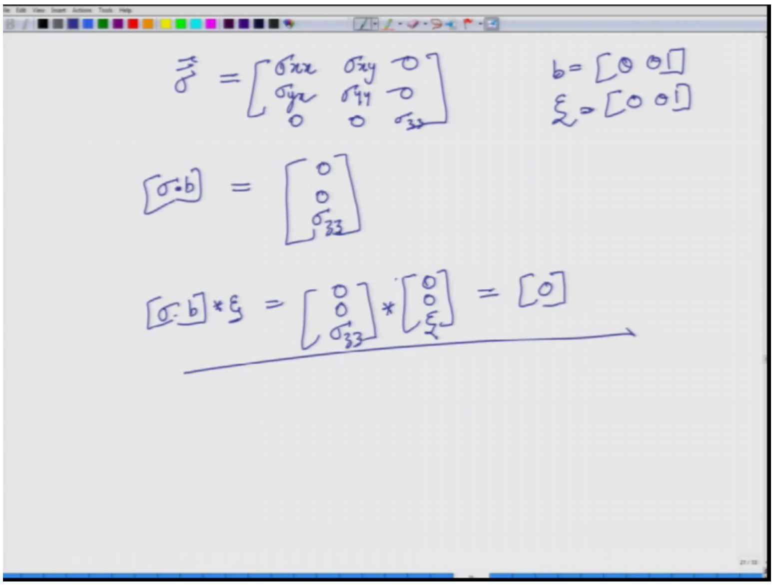

So, you can have said that ok. So, sigma here is sigma x x, sigma x y and 0 sigma y x, sigma y y, 0, 0, 0, sigma z z. So, sigma dot b where b is equal to 0 0 1 if you remember. So, sigma dot b will come out to be 0 0 sigma z z and when you multiply it with sigma dot b cross e, what is e; e is also equal to 0 0 1. So, we have 0 0 1 cross multiplied with 0 0 1 kind of vector and what should be the result yes that should be equal to 0.

So, the previous method was where you use the expanded form and you looked at the all the parameters. This is a more compact way to solve it because you already know the sigma is arising because of which particular dislocation. So, you write it in this form then you know that what is the burger vector. So, this is 0 0 1 and you can quickly get to this form of the equation sorry sigma dot b will condense to this form and then sigma dot b cross e you will say. So, this is sigma dot b cross e is equal to 0, ok.

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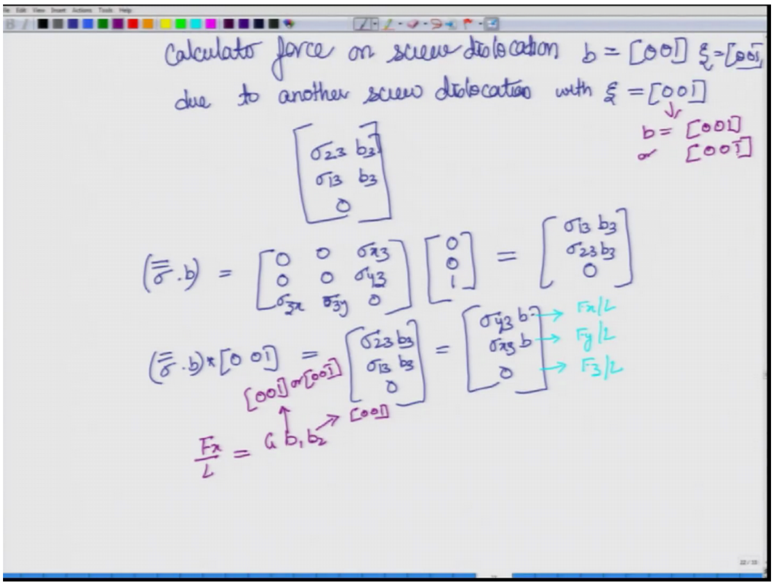

So, now, coming to the next part of the question which I said was to calculate force on screw dislocation and will assume again the same burger vectors and line vector due to another screw dislocation. So, this is completely new thing. So, now, we are trying to calculate force and screw dislocation because of screw dislocation. So, see what all we have done. We have looked at force on a dislocation because of edge dislocation. In the example we look that force on a screw dislocation because of edge dislocation and now, third we are looking at force on a screw dislocation because of another screw dislocation.

And, for this also we are given line vector is equal to 0 0 1 the burger vector I am not giving, but if the line vector is given like this then the burger vector will be either 0 0 1 or 0 0 1 bar. So, it can be one of the two, meaning it will be b b or minus b. So, again the expanded form it you can look at this relation and say I have, it will be something similar to this because here I have assumed all the sigma components and only thing that I am assuming is that epsilon 3 is 0 0 1 and b is 0 0 1 form and therefore, it will come out to something like this.

So, you can directly come and say it will be sigma 2 3 b 3 sigma 1 3 b 3 0. So, that is the advantage of using the expanded form, you can directly arrive at the solution or if you do not remember the expanded form then you know that sigma dot b sigma over here this is because of screw dislocation. So, this is like this. So, I am interchangeably using 1 2, 2 3 kind of subscripts and x y, y z. So, you will have to bear with me on that, but you must you should be able to directly relate when I say 3 it means z, 2 means y and 1 means x.

So, this is sigma and when you multiply it with b which is 0 0 1 what you get and then you multiply it with then you will get sigma 2 3, b 3, sigma 1 3, b 3, 0 which is same as saying sigma y z b because b is the burger vector we have sigma x z b and z. So, we know this is F x by L this is F y by L this is F z by L. So, again we know that we can see that F z quantity has come down to come out to be 0 which is expected F x and F y have come out with this form.

Now, we can use the sigma y z that we already know for a screw dislocation. So, we can write here I will write b 1 b 2 where b 2 is 0 0 1 and b 1 is either 0 0 1 or 0 0 1 bar. Why because we know this is arising from the from the burger vector because of which stress is being created and that for which we are only given line vector 0 0 1. So, here only we know that b is either 0 0 1 or 0 0 1 bar. So, you have to be clear about this part. And, then you can write 2 pi by x square plus y square.

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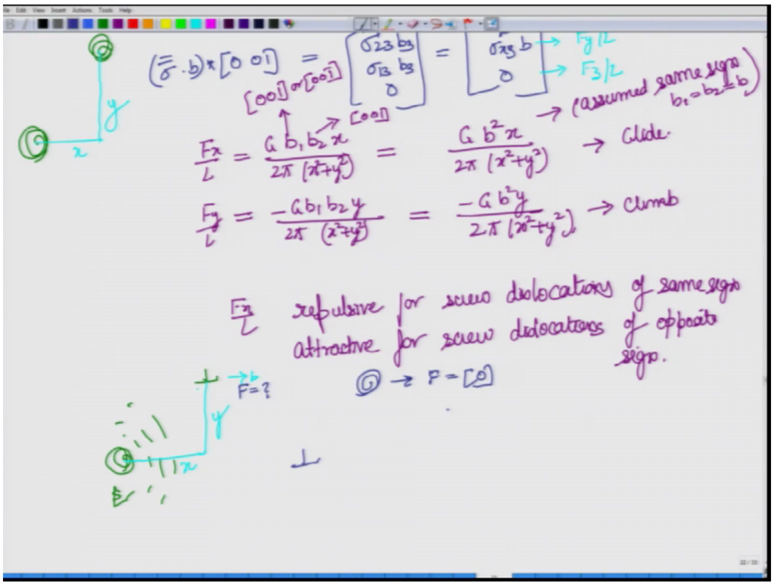

Now, assuming that both of them are of same sign meaning what we are saying if you are saying that both of them are right handed screw. So, here assuming that both of them are same of the same sign then this relation would become G b square, where b we have already taken to be 1. So, it becomes 1, but let us put it G b square by x by 2 pi x square plus y square and F y by L is equal to. So, this is the climb because it is F y this is the glide, but only in terms of edge dislocation. This climb is a does really having any meaning.

Now, here looking at this we are looking only at numbers and, but if you want to put it qualitatively; qualitatively what it means is that F x by L is repulsive. So, this comes out to be positive which means that the two the two dislocations are trying to move apart. So, the F x by L is repulsive for screw dislocations of same sign. So, here I have not mentioned, but we assumed same sign. What does it mean? Same sign meaning b 1 equal to b 2 equal to b and if one of them were opposite sign then it will become minus b square. So, F x is now minus meaning it is trying to move closer to each other. So, F x by L will become attractive for screw dislocations of opposite sign.

So, we have looked at various combinations of stresses arising from different sources edge dislocation, screw dislocation acting on edge dislocation and a screw dislocation. One combination that you can try and solve it using this is what will be the effect when you have stress field being generated because of a screw dislocation and its effect on edge dislocation. So, this is one example that we did not solve and I leave it to you to solve it. What you need to do is again calculate the stresses because of the screw dislocation you are given x and y you just look at the sigma dot b cross e form. So, here you can again take e along 0 0 1 for both of them the burger vector for this for the screw dislocation is along the line direction which will be 0 0 1 or 1 0 0 and for this you can take it along the perpendicular direction, so, the burger vector would be like this.

So, to simplify which would mean that if it the line direction 0 0 1 the burger vector has to be x y 0 form and to simplify it you can make it either x 0 0 or 0 y 0. So, that is something you can do without loss of generality and find what should be the F x by L and F y by L on to the screw dislocation and remember that what we earlier found was that for this configuration F x in fact, all the F was equal to 0. So, compare this force with the force value that you obtain over here do we still get 0 or do we get something different. So, I will leave it leave that to you and will go on to solve still another example.

Now, this time it will not be related to action of forces, this time we will be looking at the slip planes. So, you saw that we found that there are certain kind of slip planes that are possible. So, the next example.

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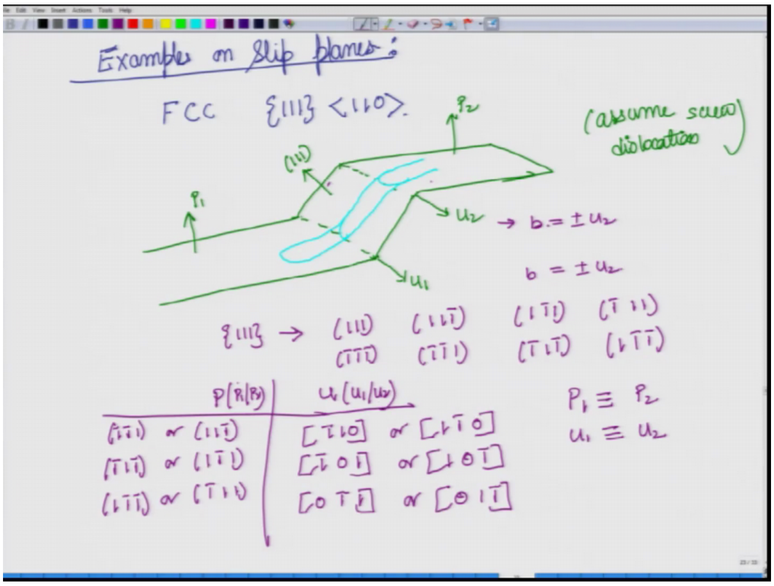

And, one of the system which is simplest to begin with for understanding this slip planes we have already talked about is FCC. Why it is simpler because there are unique not unique, but only 1 set of directions sorry one set of planes and one set of direction ok. So, in this particular problem you are given that the given that a dislocation moves it is originally like this then it moves like this will talk more about this what is called as cross slip, but right now just to understand different planes I am giving you this problem and then it moves into this plane.

Although the picture may show that these two are parallel, but you do not I need to assume that, and what you are given additionally is that this is 1 1 1 plane. Now, this is 1 1 1 plane you are asked what are the possible planes this one P 1 what are the possible planes P 2 and simultaneously if this is P 1 what will be u 1 which is the line vector and if this is P 1 this is what will be this one u 2.

So, if you remember which particular dislocation can really cross slip it is only screw dislocation, but we are showing a mixed dislocation here. So, do not worry about it will explain you the phenomenon later on, but just assuming that it is only the screw dislocation which has cross slip from plane P 2 onto 1 1 1 plane and then 1 1 1 plane to P 1 you have to tell us what will be the burger vectors or sorry the line vectors over here over here and what will be the corresponding planes. So, you can assume as I said screw dislocation it will make our job much more easier when you assume screw dislocation.

So, the first thing that you would realize now that I have already given you the hint that it is a screw dislocation you should realize that whatever be the u 2 that will also be the burger vector or at least then plus or minus of that burger vector. So, burger vector has to be plus minus u 2 burger vector has to be plus minus u 2. Next if this is a plane 1 1 1 and this is a plane 1 1 1 then sorry this is also another plane of this family 1 1 1 then another thing is that whatever is the burger vector this particular burger vector has to be common to both the planes.

So, first let us see what are the possible different 1 1 1 planes. So, 1 1 1 1 1 can be written as 1 1 1 it is negative 1 one 1 1 bar 1 or bar 1 bar 1 1. So, basically there are 4 different 1 1 1 planes. So, the P 1 and P 2 can either of these four different planes or its negative. So, the possibility for planes are like this now I will have to write it can be if it it cannot be 1 1 1 because 1 1 1 is this 1 and it is moving onto another plane. So, the other planes possible are 1 1 bar 1 or 1 bar 1 1 or bar 1 1 1. So, these are the three possibilities and corresponding to each of these you know there is also negative.

So, this which is not really unique, but for the sake of completeness we will list it out over here. So, either this or this this or this this or this; these are the three possibilities for plane. If this is the possibility for plane what will be the common direction? So, if this is 1 1 bar 1 and other 1 is 1 1 1 what is the common direction which is of the type 1 1 0 and as you will see as you will find out there is only one possibility here. So, in this particular case it will be you can see this particular one will lie on this because you can take a dot product it will come out to 0. If you take a dot product with this it will come out to 0 for this 1 it will come out. So, again dot product of these two will be 0, dot product of this with 1 1 1 will also be 0 third possibility of u is.

So, again if you take the dot product of 0 bar 1 1 with bar 1 1 1 is it is 0 0 bar 1 1 dot product with 1 1 1 which is the other plane will be 0. Why we are taking dot product again to remind you because dot product tells us that this lies in this plane 1 1 1 plane if this particular direction lies in this plane then this has to be dot the dot product must be 0 and we said that this is a common line which has on both of these. So, it should be dot product for both of these should be 0 and that is what we are getting and these are the only if P is 1 1 bar 1 this is the only possibility in this set of directions if P is 1 bar 1 one then the common line vector of this type 1 1 0 there is only 1 possibility bar 1 0 1 if bar 1

1 1 is the plane then this is the only possibility for this direction and therefore, we have these possible sets of P and u.

So, for corresponding to this P this is the only possible u, if this is the P 1 this is the only possible u 1, if this is P 1 this is the only possible u 1 and just like in this particular case there are negative. So, here are also you will have negative which we can write as these are not really additional planes, but just the negative of these. So, I have written over here. Similarly, so, now, this is corresponding to for each corresponding plane we have find one u direction, similarly for each P there will be one u direction. So, one of these it will not be anything outside this.

So, what we are saying is that P and u are related P P 1 and u 1 related P 2 and u 2 are related. Both of them can be same both of them can be different. If it is the same screw dislocation with the same burger vector then what do you think would happen then this will have to this u 2 will have to be equal to u 1 because the and we already know that the burger vector does not change. Therefore what it implies is that P 1 must be equal to P 2 it also implies that u 1 must be equal to u 2.

So, although began with the assumption that P 1 and P 2 need not be same, but we see that since burger vector same which would mean that this line vector has to be same and therefore, this remains constant and therefore, this again P 1 and u 2, P 1 combination will also be same as P 2 and u 2. So, this can be this P is now either P 1, P 2 u is u 1 u 2. Hence we are now in a position to describe the different two different planes and two different directions.

So, now we have looked at several examples and it is time that we come back to little bit more understanding about dislocations and slips.

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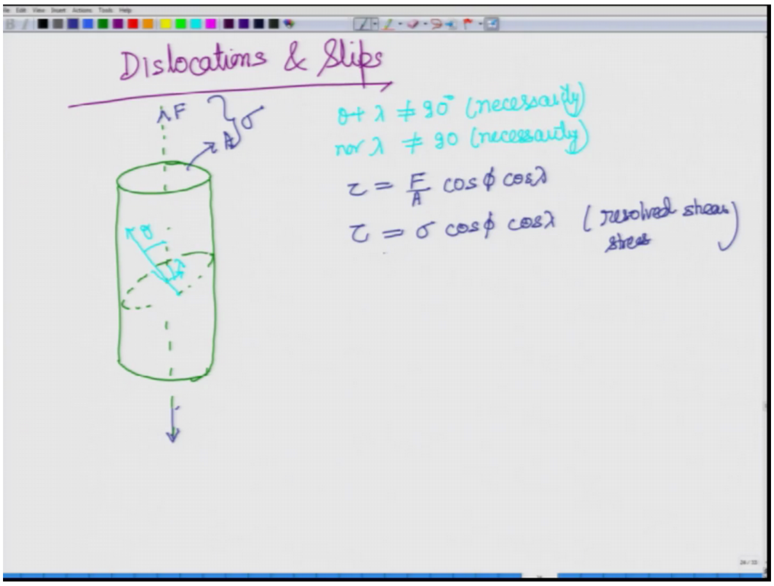

So, in this context let us come back to our some fundamental understanding what we studied in our mechanical behavior course if you have taken that and what is called as critical resolved shear stress. So, let us try to understand this concept critical resolved shear stress. So, this is let us say a single crystal and there must be a certain particular plane. So, let us say if this is FCC there will be certain 1 1 1 plane onto this. So, let us say this is one particular 1 1 1 plane, there will be more than one. If you remember, there four different planes.

So, there can be for different planes 1 1 1 planes over here. Let us say this is one particular plane that we are talking about and. In fact, you should be talking about all the plane, but for the sake of understanding will limit our self to one particular 1 1 1 plane and let us say we have a dislocation which is like this and for this dislocation this is the slip direction and for this particular plane this is the normal. So, this normal is oriented at some angle theta to the axis and the slip direction is oriented at some angle lambda. Now, what you need to understand here is that 1 at theta plus lambda is not equal to 90 degree necessarily meaning and some particular instance it can be possible, but it need not be theta plus theta plus lambda has to be 90 degree nor independently nor lambda has to be 90 degree necessarily.

So, these two are something which whenever we draw something like this we end up believing that theta plus lambda has a relation and similarly or lambda has a relation with this axis, but that is not true. Now, let us say that there is some force acting on to this in this particular direction which will cause the dislocation motion and the area is A because of which we can say the stress on to this is sigma. So, a stress sigma is applied or you can say a force F is applied on to a area A.

Now, this stress would should cause the motion of the dislocation and in affect this is what will lead to the strain the overall accumulation of such the movement of such dislocations would lead to strain will a which will again see later on. But, for now let us say this is the force acting on to it. Therefore, we can say that onto this particular plane which is the plane onto which the dislocation lies the resolved shear stress is equal to F by A cos phi cos lambda you would be able to you should be able to see that directly and there is it is not very difficult to come to this conclusion that the resolved shear stress acting on to this particular plane because of this acting force F by A F by A cos phi cos lambda and we have already said that F by A sigma cos phi cos lambda. So, the shear stress acting on to this plane is equal to sigma cos phi cos lambda.

So, earlier you remember we were able to relate the stresses to the forces and, but we never said how to resolve the external stresses to the stresses on to the plane. This is what this particular relation is telling us and as you can see that it is not so difficult, it is very easy to find out what will be the resolved shear stress. So, this is resolved shear stress. Now, what is this minimum resolved shear stress how much should be the the stress for it to be able to move, that is called a critical resolved shear stress.

We will come to that particular topic in the next class. You in the meantime try to prove that the resolved shear stress is equal to sigma cos phi cos lambda and will see you in the next class.