Mechanical Behavior of Materials-1
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Lecture - 28
Dislocation Interactions

Welcome back students. So today we will now look at another important aspect about dislocation and particularly, which gives rise to various phenomena in materials. For example, strain hardening, strengthening effect and all these things. These arise because dislocations interact amongst themselves. So we will look at the relation which defines this relation.

And we will look at some special cases on how these dislocations interact to give you some idea and feel about the interaction of dislocations from which you can build up. In fact, Taylor hardening can also be deduced from this relation. So let us move on.

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So interaction between dislocations. And when we are talking about interaction, it can be like you may have one dislocation, which has its own stress field. So it has its own stress field and because of it, it may be causing some effect on another dislocation. So it may be causing forces in these direction or also in the Z direction. So this will become F x F y or F z.

And when I say F, remember that it is per unit length. So although I will not explicitly write it as per unit length, but we have to understand that for dislocation which is you can say not of any finite length or at least we are not considering any finite length, it can have any amount of length. Basically what I mean to say is that it is not any given length from the beginning of the problem.

So it can have a finite length but not any known quantity. So we will call always calculate forces per unit length. So it could be, so this is what is what we can term as dislocation interaction effect of one dislocation onto this. And for our purpose that is in our written work in our theories, what we will do is we will always treat this as dislocation 1. The first this one will be treated as dislocation 1.

This is because when we use the notation 1 and 2 so that you are clear on which particular dislocation we are talking about. So this will be treated as 1, meaning the 1 is the, dislocation 1 would be the one which, due to which effect is being created onto another dislocation, which will be treated as dislocation 2. So it need not be just one dislocation, it could be bunch of dislocations, which are together at some distance.

And together they have probably some stress field which is causing forces on this dislocation. So again there will be F x, F y and F z. And again in this context this would be treated as 1. So overall this effect this bunch would be called 1 and this dislocation, so if we are defining Burger vector and line vectors then it, we will call the Burger vector and line vector for this one as 2.

And overall whatever quantities we define for this one would be defined as 1. This overall treatment can also help us understand how much for example, if this is dislocation forest or some configuration of dislocation and you want this dislocation to move, then you know this the, this overall formalism would help us understand how much force it needs to overcome.

How much or how much external force is needed to overcome this internal forces, internal resistance. So this formalism would also help us understand how much external force is needed for dislocation 2 to overcome internal resistance.

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In this context we have the relation which is called as Peach Koehler relation. So here it is given force, again do you remember this is per unit length. Sigma it is the stress field being generated. So here this sigma for this case it would be generated by one dislocation 1 or in this case it can be stress being generated because of bunch of dislocation.

So you may be able to calculate the overall stress because of this bunch of dislocation and based on that you would find out what will be the force acting on this. And the line vector that is given is for dislocation 2. So we are calculating the force on 2, on dislocation 2 whose Burger vector and line vector are given here. And now I will say that, explicitly mention what is F.

F is the force per unit length at any point on dislocation 2. Sigma is the stress experienced by dislocation 2. But it may be generated by this bunch of dislocation or it may be generated by dislocation 1. But it is being experienced by dislocation 2 and Burger vector b is the Burgers vector for dislocation 2. And line vector is e is the line for dislocation 2.

So you can see that based on this what we get, if we put in the sigma in the tensor form, so it has nine quantities. B is a vector so it is b x, b y, b z. And line vector is again a vector. So epsilon x eta actually, eta e. I do not know, it is not eta. Sigma dot b cross e. So let us call it e. So it is e x, e y, e z. And sigma has the nine quantities.

And this is how it will be written when you want to calculate the forces acting per unit length on dislocation 2. When the dislocation density increases in the material, then this stress increases and in turn the force acting on the dislocation 2 would increase. So this is you can see the origin of strengthening when you have higher dislocation density and if one needs to deform the material one needs to apply external stress.

And that must overcome these internal stresses. So it also means that if you want to deform a material further and further as its dislocation density increases, you need to apply higher and higher stresses which is also called as the strain hardening.

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Hence, a larger stress is required to cause similar strain within dislocation density has increased. So this is something we can qualitatively see right now and we would be also able to establish this quantitatively in few minutes. So when you have sigma dot b, then we can basically this becomes, so it is a dot product. So we can as well write it as i sigma j sigma i j into b k.

And this is for the sigma dot b part. And when you put it together you will see this will come out like this, which is if I write it, so what I will do is also write it in terms of x, y, z and also write it in terms of 1, 2, 3. Because at many a places it will be easier to handle this quantity in terms of 1, 2, 3. So it will be sigma 11 b 1, sigma 12 b 2, sigma 13 b 3, sigma 21 b 1, sigma 22 b 2, sigma 23 b 3.

Sigma 31 b 1, sigma 32 b 2, sigma 33 b 3. So this is sigma dot b and in terms of 1, 2, 3 and this is sigma dot b in terms of x, y, z. And then we take a cross product with line vector e x, e y, e z are the vectors. And this is the overall form in terms of x, y, z and again I will write it also in terms of 1, 2, 3.

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Sigma 21 b 1 plus sigma 22 b 2 plus sigma 23 b 3. Sigma 31 b 1 plus sigma 32 b 2 plus sigma 33 b 3. Sigma 11 b 1 plus sigma 12 b 2 plus sigma 13 b 3. And this is 3, 1, 2 and then there is a second term over here. So you see this is a vector. Keep in mind this is not, no more a determinant or a tensor quantity, it has only three values. Because force which is the vector affects F y, F z.

And over here we have sigma 31 b 1 plus sigma 32 b 2. Sigma 11 b 1 plus sigma 12 b 2 plus sigma 13 b 3. And this last one is sigma 21 b 1 plus sigma 22 b 2 plus sigma 23 b 3. So this is the overall quantity. And like I mentioned, now we can look at this equation in two different forms. So this is x, y, z and this is in 1, 2, 3. So 1, 2, 3 basically represents x, y, z respectively.

But at many places this one will become much easier or to look at and also in terms of writing. So both of them are one and the same quantity and it will give you the value of forces acting on dislocation 2 because of stress field which may be generated because of this is the stress field quantities which may be generated because of single dislocation or group of dislocation or maybe even external forces.

So whatever be the source of this sigma this is affecting the dislocation 2 whose Burger vector are given b 1, b 2, b 3 and e 1, e 2, e 3 or b x, b y, b z and e x, e y, e z are the nine vectors. So to be able to appreciate this better, what we will do is we will go through some case studies. So let us look at case study number 1.

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What is this case study? Here we are looking at interaction between two positive edge dislocations. So what do we mean by this? So let us say we have dislocation 1 here, another dislocation over here. So if we have, so this is 1 and dislocation, so let us say this is affecting the dislocation 2. So this is one and here we have epsilon and I will write as 1 over here on the superscript. 1 equal to 001.

And sorry line vector. Again I will put the superscript 1, which will be which has to be perpendicular to this. So it could be anywhere on this 2, but to make things simple, we will take it as 100. And this is this dislocation 2. So this one is also parallel. So epsilon e 2 is equal to 001 and again to make things, keep things simple we will keep the Burger vector 100.

So what we are seeing is b 2 x is equal to 1, b 1 x is equal to 1. And b 1 y, b 1 z are 0. Similarly, here e 1 z is equal to 1 and e 1 x is equal to e 1 y is equal to 0. Similarly, e 2 x is equal to 0, e 2 y is equal to 0, e 2 z is equal to 1. Now that we have to keep in mind when we are solving this. Now we will put this. So we know that in this equation what we get in terms of Burger vector is for dislocation 2.

So the only two quantities which are nonzero are e z and b z. So only those quantities will remain and that would mean that this would be here, this would be here. But this is 0. So the whole quantity goes to 0. This whole quantity goes to 0. This whole quantity goes to 0 and this whole goes to 0. And even in this only b x is nonzero, b y is 0, b z is 0. Here also b x is there, b y is nonzero, b z is nonzero.

So what we get is F is equal to sigma yx b x and to be sure I will now put the superscript 2. And the second quantity is minus sigma xx and then again, I am sorry there is also this e component which is e z which is also for 2. And here similarly, sigma xx and b x which is again superscript 2. So keep in mind this is not square, this is superscript 2 to define that, to inform us that this is for dislocation 2.

And this is e z again 2. And the third one there is no nothing left, so it is 0. Now this is F x, this is F y, this is F z and also per unit length. Okay, I am not explicitly mentioning it again and again but that you have to keep in mind. So if that is so then this is equal to F x, this is F y and this is F z.

So this is glide force acting on it because if this is the force acting in the x direction, whichever direction positive or negative this is called the glide force. So this is glide force acting here. F y is acting in this direction, which we can call climb force acting on this. But we will not consider at this time about the or not worry much about the climb force because one that time force will also be dependent on temperature.

So it is not only this force that has to be taken into account, but also the temperature. And moreover in room temperature deformation this would anyways be of non-significant unless we are applying temperature also or unless we are applying doing that deformation at high temperature, okay. So with that what we see is that we have this quantity glide, which is sigma yx and just for the sake of completion, we will look at the whole equation how it looks like, so which is sigma xx.

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$$\boldsymbol{F_x = \frac{G b_x^1 x(x^2 - y^2) b_x^2}{2\pi(1-\nu)(x^2+y^2)^2}}$$

$$\boldsymbol{F_y = \frac{-G b_x^1 y(3x^2 + y^2) b_x^2}{2\pi(1-\nu)(x^2+y^2)^2}}$$

And therefore F x is equal to now sigma yx. Sigma yx we will remember is equal to G and since it is Burger vector has only one quantity which is x, but this time this x is for first dislocation. So it is superscript 1 and it is x square minus y square and into this b 2 which is and epsilon z, e z but we know that it is equal to 1.

So we will just multiply with 1 and on the denominator we have 2 pi 1 minus nu x square plus y square whole square. And F y again is sigma xx, but with a minus sign. So it is G b x again superscript. Then we have y, then 3x square plus y square and there is 2 pi 1 minus nu x square plus y square whole square. And also this is a negative quantity in itself. So overall it will become a positive quantity.

And it has again b x superscript 2 into 1. And yes something I am missing here and it has to be x. There is a factor x here. So this is the glide force, this is the climb force acting on the dislocation. Now we will concentrate on this particular equation, which is for the glide. Because, this one will give us lot more information about interaction between dislocations.

So we are looking at the interaction between two positive edge dislocation and we know that these are the two forces and now we have said that climb is something that we can, we are not really interested in because it is a high temperature phenomena.

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$\boldsymbol{F_x = \frac{Gb^2x(x^2-y^2)}{2\pi(1-\nu)(x^2+y^2)^2}}$ **when both dislocations have same sign**

$\boldsymbol{F_x = \frac{-Gb^2x(x^2-y^2)}{2\pi(1-\nu)(x^2+y^2)^2}}$ **when both dislocations are of opp. Sign**

Now bringing this equation over here and assuming that both the Burger vectors are equal in magnitude, so if we have the two Burger vectors in the same with the same sign then F x will be equal to G b square x x square minus y square by 2 pi 1 minus nu x square plus y square whole square, when both dislocations have same sign.

And if both the dislocations happen to be of opposite sign then we know that this will be and there will be a negative, sorry here it is it will be, one will be negative and therefore, the F x will be equal to minus G b square x x square minus y square by 2 pi 1 minus nu x square plus y square whole square, when both dislocations are of opposite sign.

Now here if we assume that the two dislocations are on the same plane which means y is equal to 0, so now let us go to the condition where okay when dislocations on same glide plane, meaning y is equal to 0. So if you put y equal to 0 in all this, what we get is F x is equal to G b square and this one will become x cube and this will be x 4. So this will get cancelled and there will be only x remaining in the denominator.

So it will become 2 pi 1 minus nu into x. But I can write it like this, which will have plus when dislocations are of same sign minus when dislocations of opposite sign. So what is the meaning or significance of having a plus and a minus? So plus implies that the dislocations would try to move in opposite direction.

And minus implies that the dislocations would try to move in the, towards each other. So it would look something like this.

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$\boldsymbol{F_x = \frac{Gb^2}{2\pi(1-\nu)x}}$ **when dislocations on same glide plane (y=0)**

So if the dislocations are like this, then the forces acting on them would be like this, repel. So now you can see I have drawn it on the same plane and if the dislocations happen to be of opposite sign, so this is how it would look like. In this case the dislocations would attract each other. So dislocations of same sign will repel and that of opposite sign will attract. This is the main message that we get from this relation.

But then we could have also obtained this relation in a slightly different way. Let us look at it in a more without going through these equations. But then there will be some meaning for these equations which I will show you again after this.

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So interaction attraction and repulsion can also be predicted on the basis of energy. So when two dislocations of same sign are sitting next to each other, so let us first consider the case of when two dislocations of same sign are sitting next to each other. What is the implication? The implication is the equivalent Burger vector would become 2b because those two are sitting very close to each other.

So it is as good as saying that the two dislocations are, so this will have equivalent Burgers vector of 2b. And therefore, the energy for this new dislocation would be of the order of G into 2b whole square which would be of the order of 4Gb square. However, if the two dislocations were very far apart, very independent of each other. Then their energy would have been Gb square and Gb square.

Meaning total energy would have been 2Gb square. So this energy 4Gb square is certainly greater than 2Gb square when independent. And certainly any system does not like the energy to increase. Therefore, the dislocations will tend to stay away. Now let us move on to another case when the opposite extreme, when the two dislocations of opposite signs are sitting next to each other.

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So in this case what will happen? Now that the two Burgers vectors, the two dislocations are sitting like this, so this has b and this is minus b which means that total is equal to 0, 0b. So equivalent Burger vector is now equal to 0, which means that the energy is of the order of G into 0 square which is equal to 0 is less than 2G b square when the dislocations were independent.

So what is the message here? That the dislocations will attract each other. So dislocations with opposite b will attract and annihilate while dislocations with same or similar sign will repel each other. That is the message that we get when we look at this consideration of dislocations being, on that basis of the dislocation energy. So this is also the message that we obtained earlier when we were looking at the force.

So it is not that the force relation is useless or meaningless. We will look at still another example of force. So now we will again bring our equation F x equal to Gb square and look at more analysis.

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$$\boldsymbol{F_x = \frac{Gb^2 x(x^2 - y^2)}{2\pi(1-\nu)(x^2+y^2)^2}}$$

When dislocations not on same glide plane, meaning y is not equal to 0, okay. So earlier case was the simpler case where we said that y is equal to 0. But now let us say y is not equal to 0, then what happens? So we will go back to our equation which says that F x is equal to Gb square x and plus or minus would depend on whether we have the same sign or the opposite sign, which we will look at in a moment.

2 pi 1 minus nu x square plus y square whole square. Now so y is not equal to 0 and let us try to plot the relation. Okay, so I have drawn a x y plot, because what I want to do is I want to plot on the x axis distance. But I want to plot a distance in a way which will take into account both x and y. So what I will do is let us keep y fixed and I will write x in terms of y. And on the y axis I will have force, specifically F x.

So this is F x which will have, which will be drawn in the we can say this is a constant Gb 1, and b 2 by 2 pi 1 minus nu y. Now let us say we have the x as equal to 1y or 2 y or 3y or 4y. Or in the negative side we have -1y, -2y, -3y, -4y. What it means is that we have a configuration which looks like this. So this is the first dislocation. And the second dislocation, we keep the y fixed.

So the dislocation, second dislocation can be here. It can be here, it can be here. And this particular location would be of very big interest to us. So let me draw this. So this is 45 degrees. Now what happens at 45 degrees, if you which means at x equal to y. So when you put x equal to y we see that F x become equal to 0. And we are, for now we are considering positive dislocations or dislocations with same sign.

Therefore, we are only interested in or only the plus sign of the force comes into picture. So when we have x equal to y then force becomes 0. So let us say this is the point and when x is equal to 0, then also what we would see that this is there is a factor x here, therefore this whole thing goes to 0. So at these two points, we know that the forces are 0. What happens in between?

Now let us say at you are little less than x equal to y, meaning you are left of this position. So what will happen? So x is less than 1y. Therefore this is, this quantity is x square, this is y square. This whole thing is still positive, and this whole thing is positive, but then x square minus y square is a negative quantity. Therefore, this whole thing becomes negative.

So the force is acting in another direction, which means that the force is acting in this direction to the dislocation as soon as it moves away from the 45 degree position and the force is going somewhere over here. So assuming that there will be a minima somewhere over here, because it has to come back to this. So the force would, the force plot would look like this.

And if you go to the negative side, you would see a similar symmetric one where it will have a positive maxima and the dislocation would want to move in that direction. And if you keep plotting and taking the value various values, what you would see is that this will get a relation like this. What does, what do we obtain from this? What does this plot tell us?

This plot tells us that when you have a dislocation over here, then it is some sort of equilibrium. But as soon as you move a little bit less left to the left, then this whole quantity becomes negative and the force starts at in the negative direction. As soon as you make x greater than y, therefore everything becomes positive and the force acts in the opposite direction and therefore a positive force will act.

Now let us come to the position where x is equal to 0, which is right over here. So again, let me draw this. So at this position, it is equal to 0. Now as soon as you move a little to the right, so you have a little x positive, but it is still less than y, much actually much less than y. Therefore, the force is still negative. So if you move a little bit over here, then it is still has force acting in this direction.

And if you move a little bit to the left, then it still has forces acting to the right, which means that the forces are trying to keep the dislocation aligned along this line, 0 degree line. And it is for this reason that we see low angle grain boundaries with dislocations aligned like this. So the dislocations have the tendency, because of the interaction between the dislocations they are being pulled back to this location.

But once it, dislocation moves out from 45 degree position then it will get thrown off, then it will not be considered anymore in the array, it will get pushed off. So there is a V shaped region within which, which is equal to 45 degree and 45 degree 90 degree region within which the second dislocation lies.

Then it is, then it has a force acting on it which tries to bring it back and bring it back to the alignment exactly in the line. And once it goes outside that V region then it is pushed off. Then you are no more my friend, you can go away. It is like that kind of condition between the two dislocations. And when you have more and more it gets aligned and forms an array like this.

So this is what happens when you have all positive dislocations. But then what will happen if I have dislocations, pairs of dislocations with opposite sign. Let us see, it will be very interesting. And what I will do is I will again plot this separately, I do not want this to get messy.

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And this time I will draw the dislocations in a different color. So again y distance is fixed and this is the distance x and at some angle which is equal to 45 which is of interest and here if you plot the graph you would see okay first let me put this 1y, 2y, 3y, 4y. And over here -1y, -2y, -3y, -4y. Now if I put it like this, then and use the equation here again but this time the dislocations are of opposite sign.

So the negative one will be picture and from this relation or from this you can see it will be symmetric of this, just inverted symmetry. So the plot we will get would look something like this. So it will be 0 here, it will be 0 here, it will be 0 here. Only it will have maxima over here and it will have a minima over here. And if you plot it further, you will have something like this and you will have something like this.

Now let us look at what is the meaning of this. So what it means is that if you are at 45 degrees, then of course it is equilibrium, although we will show it is, in the previous case we saw it was unstable equilibrium. Now if the dislocation moves a little bit to the left, say somewhere over here. What will happen? There is a positive force acting on it, positive meaning in this direction.

So the forces are trying to bring it to this position. And if the dislocation moves away from 1y or x is greater than 1y, then it is over here and the forces are acting in this direction. Meaning now they are trying to bring the dislocation into equilibrium in this position. So this 45 degree line becomes the stable equilibrium position. Earlier this was a unstable equilibrium position.

In this particular case, where we had positive dislocations, then dislocation would try to move away in this direction or in that direction and the stable equilibrium was over here. But now we have a stable equilibrium over here. And if you look closely, what you would see is that there is a unstable equilibrium over here.

From this plot, you can see that if the distribution moves a little to the positive x then it has forces acting in the positive direction. And if it moves a little to the left it has forces acting in the negative direction. And there will also be equilibrium, stable equilibrium direct position over here at -45 degrees. So this is a stable equilibrium, this is a stable equilibrium.

Meaning the forces want to bring the dislocation back to this position while this one is a unstable equilibrium. And now that we are talking in terms of stable equilibrium and unstable equilibrium let me also mentioned here that this one is stable equilibrium. And this one and there will also be some here at -45 degree these are unstable equilibrium.

This equation which is telling us the force acting on the dislocation can also be used to derive the Taylor hardening relation. But for now, it is showing us the forces required for, forces acting on this dislocation or in other words, how much force would be required for this dislocation to move in the presence of another dislocation.

So what we realize is that a positive dislocation would form an array like this and a negative dislocation would also form an array, but at 45 degrees. So this one if you look at it would form a array something like this. So this is just part of it, but next line would again be all positive at 45 degrees and so on.

So this is the condition we have looked at where dislocations two positive as dislocations are interacting. Next we will move on to another case study where two screw dislocations are acting.

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So for the two screw dislocations again we need to define what are the line vectors. So for dislocation 1 and dislocation 2 we know that here, I will put it as a superscript, is equal to 001 and Burger vector for this one is equal to, because it is a screw dislocation it has to be same as the line dislocation and again we are taking a case of two parallel screw dislocations, okay.

So parallel screw dislocation. And therefore, e 2 superscript 2 is equal to 001 and Burger vector superscript 2 is equal to 001 and the force acting on dislocation 2 would be, this is the general relation, so this is what would be the force acting on the dislocation 2. Over here the Burger vector and line vector are with respect to this dislocation 2, so it has only z component or basically epsilon 2 z is equal to 1, b superscript z is equal to 1.

And since only z and e z are there, so all other quantities would get cancelled out or basically they turn to 0. Then again b z is the only quantity here, all other go to 0, b x, b y, b x, b y, they all go to 0. And what we are left with is F and remember this is a vector. So there are 1, 2, 3 quantities here, sigma yz b z e z and I will put the superscript 2 to distinguish the fact that it is the Burger vector and line vector for dislocation 2.

Of course, in our case it happens to be same in magnitude, but we want to keep things distinguished. And here we will have sigma xz with a minus sign and again b z superscript 2, e z superscript 2 and line vector 0. So this is the force acting on the dislocation and like we mentioned earlier this is F x which is the glide force and F y which is the climb force. So again we are interested only in the glide force and here the yz.

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So if we go back we will see that G and there is Burger vector for and if we take the magnitude, we have to take only the magnitude of since it is only z, so b superscript 1 z by 2 pi into cos theta by r. And here into b which is equal to z superscript 2 and e we will take as 1. And cos theta we know can be, so I will now just write b 1 b 2 and cos theta can be written as, cos theta by r can be written as x by x square plus y square.

So this is the force acting on the, glide force acting on the screw dislocation 2. And here also what we see is that when dislocations of same sign then F x greater than 0, which means repel. When dislocations of opposite sign then F z is less than 0, attract. So this is the relation or the forces acting between two parallel screw dislocation. And here also we see that the same thing turns up.

The dislocations of same sign will repel and dislocations of opposite sign will attract. And again we could have used the same argument of energy also and we would have obtained the same relation. So overall we can say whenever dislocations are of same sign they will attract and whenever, sorry they will repel and whenever dislocations are of opposite sign they will attract and they can also annihilate each other.

In fact, this is also something that happens very often at high temperature where recovery is taking place, dislocations get annihilated. Next what we will look at is the interaction between a screw dislocation and a edge dislocation where the line direction is same.

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So this would be very interesting as you would see. So here we will write, so this is dislocation 1 which we will be calling as, so this is our edge and this is screw and line vector is same. So we will have e 1 equal to 001 and the line directions they are parallel. Again I have not mentioned it explicitly, but we are considering the case of parallel dislocation. So epsilon subscript 2 is also equal to 001.

And here it is edge dislocation. So Burger vector is equal to 100 and here the dislocation is screw dislocation. So the Burger vector will also be same as the line vector, okay. So now we have you know that in the, this is the force. We are basically calculating effect of edge dislocation on screw dislocation. And since we are talking only of two dislocation it will be the same force that will be acting on from the screw dislocation onto the edge dislocation.

So that will not change. Now that we have this relation we will look at what are the quantities that will go down to 0. So here we have only e z and here we have only b z, every other quantity must go to 0. Therefore, this whole quantity goes to 0, this whole goes to 0, this whole goes to 0, this whole goes to 0. And b z is the only nonzero elements of b x b y, would also go to 0 over here and over here.

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And therefore, the force that we obtained earlier is same here, but there will be one major difference as we will note. Sigma yz b z where b z is for the 2 e z for the 2. And then we have sigma x z b z 2 e z 2 and the third quantity is 0. Okay, so it looks like it is all same as the previous one and nothing is new, okay. Then let us try to find out what would be the sigma yz. Now remember this sigma yz it is because of edge dislocation.

Sigma xz is because of edge dislocation. But for an edge dislocation xz and yz and zx and zy are nonexistent quantities meaning they are 0, which means that the total force acting is equal to 0. There is no force acting on the screw dislocation because of the edge dislocation or vice versa. That is no force is acting on the edge dislocation because of the screw dislocation.

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So let me, no force or vice versa meaning no interaction. Now is that not very interesting? So why is it that a screw dislocation and an edge dislocation which are parallel to each other do not interact with each other? Okay, I will leave you with that thought, with that question. So look into that. Try to find a reason why there should be no interaction.

Only when we are talking about, so I have been, this calculation I have shown is when they are parallel. Need not be true when they are perpendicular to each other or at some other angle. Okay, so keep that in mind. Only when they are parallel to each other. Anywhere, that does not matter.

If they are parallel then we have shown that there is no interaction, there is no force acting on either of them because of the other one. So why is it so, it is for you to find out. So I will end this lecture over here. Thank you.