Indian Institute of Technology Kanpur

National Programme on Technology Enhanced Learning (NPTEL)

Course Title
Manufacturing Process Technology –part-1

Module 07

by
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Hello and welcome to this manufacturing process technology part 1 module 7.

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And in the last section we were talking about the different crystal defect which could be point defect which line defect or surface defect and then in the context of that and observed how the presence or the absence or the particular lattice side and filled with the particular atom of the either the same species or the different species are different in the terms of the crystal defect we also saw in the several atomic spacing and the continued over the long line together able to move together and in the more and in the line in the dislocation we further observed if there is the sudden change in the direction and the crystal and in the continuity and in the way was proceeding.

This normally happen because zone one and zone two observed by two different lines called the twin planes. it is normally known as surface defect in the context of that we also saw the how for a multigrain structure you can visualize these surface defect are the what we call twin defect formula in the defect and then today we are just going to investigate in the numerical values for the material property really get influenced because of these dislocation.

And in the moving in the lattice matrix and see in there would be a heavy influence of the defect on the material properties. Let us look at the first the elastic and the plastic deformation.

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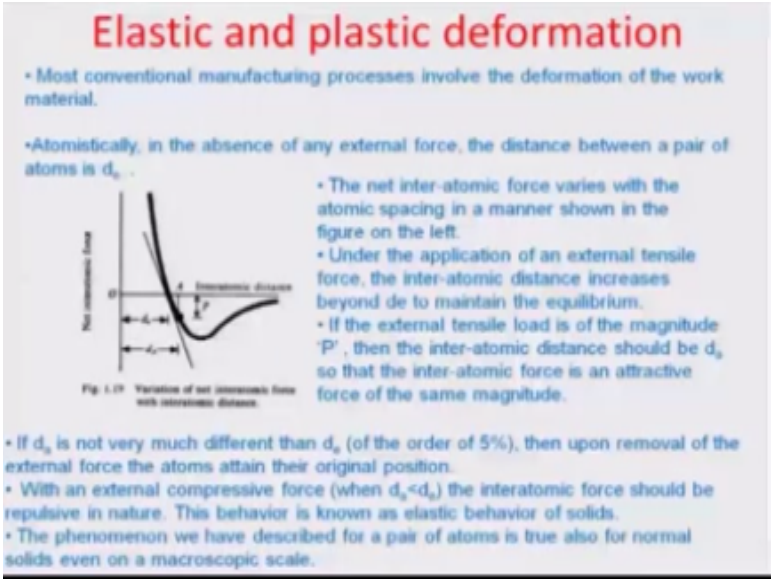

And within the crystal sand you know that the most of the conventional manufacturing process particularly the secondary level processes like machining etc. involve the deformation of the work material. So let look atomatically what happens so the absence of the any external force the distance between there are the pair of the atoms which are there and there are separated by the distance *d* equilibrium distance and the called in the d_e for example and in the atomestically the absence of the any external force the this *de* is because the balance of all the forces acting on the atomic system which as spaced in the distance d is 0, so there are the obviously going to be the forces of the attraction between the electrons and the nuclei and there are going to be forces of the repulsion between the two different nuclei.

And so you all these forces acting in there balanced manner would create an equilibrium situation where the lattice spacing is consider to be d. So let us look at the inter atomic force

obviously in order to the hold these atoms together at the distance d and you need some amount of forces for doing that and net interatomic force here and non zero as you can see at the distance d and supposing under the application of the external tensile force and in the interatomic distance increases beyond d to maintain the equilibrium.

So we apply and the external tensile load P and the interatomic distance should be the let say some value d_a because of the external applied force, there is going to be a change in the lattice spacing between the atomic systems. I am only talking about diatomic system this time. I am not concerned with how the atoms are arranged in crystal. So then the interatomic distance should be d_a so that interatomic forces become an attractive forces of the same magnitude so that it can take the configuration back to the equilibrium distance de, once the force P is removed i.e. the tensile load is removed so it should just go back are take back the distance of the separation between these atoms and the atomic system should the *de* from *da*. So the question is does it happen for all the different spacing *da* or is it governed by the some limitation where there is a finishing of the you know the effect of one atom on another beyond a certain cutoff distance, etc. which would not lead as such *da* would converted into *de*.

So if da is not very much different than de, let say order of the 5% then upon the removal of the external force atoms would attain more or less in original position but similar thing happen for the compressive force (da) obviously. The actual distance because of the application of the external force would be lesser than de and so when you remove that force then there has to be repulsive force generated in the system which will take the system backto its equilibrium distance de but this is only limited to about in the 5 %in the change in the d but beyond 5 % the distance is so much that the influence of the primary atom finishes and then the system may not restore back to normal condition. So this is 5 % da increases distance is something which you can probably recall as the elastic region of the material but beyond this d if the atoms displacement is more than the distance 1.05d let say then you have plastic range flow deformation. So having said that let us look at the you know in the very primary model where consider a crystal lattice with regularly space atom as shown in the figure below right here and

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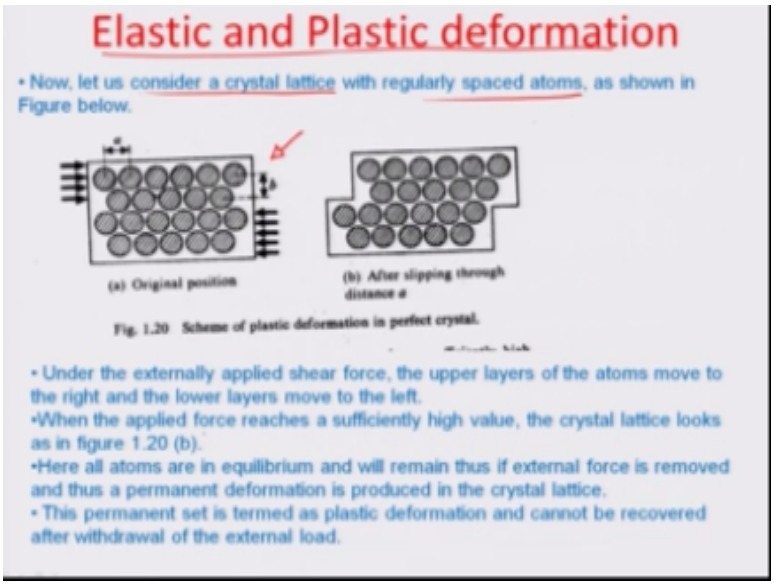

you having the external force influencing just in the shear force as you can see and the shear comes probably along right here and in the upper portion being moved by the force towards the right and the lower portion towards the left and. So when the applied forces reaches sufficiently high value the crystal lattice look something like this in the figure 1.2 b. here all the atoms are in the equilibrium and it will be remain thus if the external forces removed and thus a permanent deformation is produced in the crystal lattice. All the atoms are in quilibrium will be remain thus if the external forces removed and thus a permanent deformation is produced in the crystal lattice.

This permanent set deformation the fact that the crystal doesn't come back to the normal regime. This is known as the plastic deformation and it can't be recovered even after the withdrawal of the external load. so this is like supposing this slip happens one plane over the other by some distance you know. And it is no recoverable and this is known as the plastic deformation.
That's how you can understand what atomistacally happening when referred to different region. so let us look at the some of the associated value related to the amount of the that in the shear stress which is needed.
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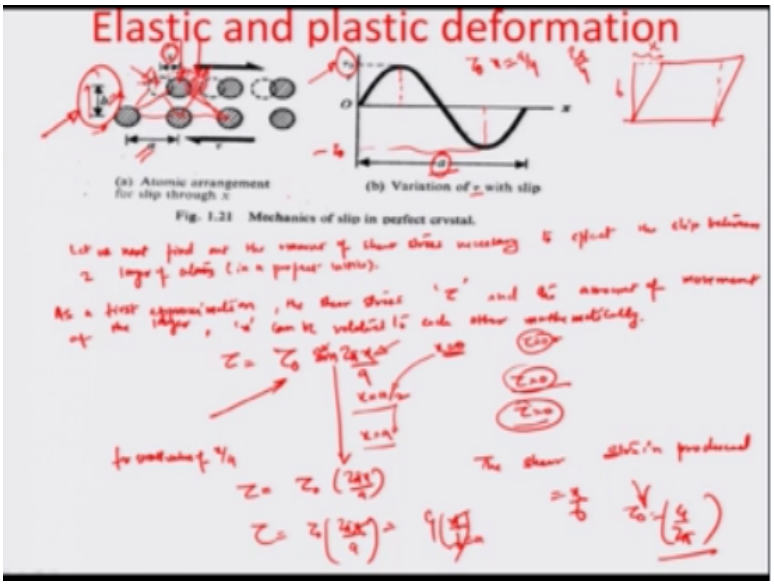

$$\tau = \tau_0 \sin\frac{2\pi x}{a}$$

$$\rightarrow \tau \approx \tau_0 \frac{2\pi x}{a} = G\frac{x}{b}$$

$$\rightarrow \tau_0 = \frac{G}{2\pi}\frac{a}{b}$$

$$\rightarrow \tau_0 = \frac{G}{2\pi}$$

The amount of deformation which would the executed because of the shear stress. Shear stress obviously is the force unit per area. so let us next find out the amount of the shear stress necessary to effect the slip between the two layers of the atom and this is across the shear plane which actually moves the upper half of lattice with respect to the lower half of lattice and the let us see in the last figure and this is a perfect lattice which doesn't have any defect, point deffect and so on so.

So this is just sort of the level of the what may happen. As a first the approximation, the shear stress τ and the amount of the movement of the layer X can be related to the each other mathematically. Let us look at how, so think of it that this is the atomic system that we are talking about the X is the distance which is being moved from a position which was in the equilibrium position and because of the movement and the movement is executed basically because of the sheer force obviously.

Let us say this was the old position the dotted one is the old position and this is the new position and moving at the X distances. if you look at the really at the crystal structure earlier this is the

equilibrium position and. so this is the basically the atom lattice the over the shear plane is exactly at the equal distance from the atomic pair which is below the shear plane in the particular case. so this is the 0 condition where all the forces are 0 because of which the atom stay in the equilibrium distance with the respect to the each other and analogically.
Last to the last slide. here when we move it from the equilibrium position by the distance X and that is obviously going to be some forces which goes into interplay and the this forces would the cycle of the forces would continue And the net force will continued and the unless and the until the dotted portion comes to the let say the other kind of the position And this atom comes to position where exactly at the centre between this particular you know the distance between this atom pair. so that it can formulate similar part of the equilibrium as you saw before okay.

At so the position here again has zero forces, the position in the centre which is started at the zero forces in between the some forces were you know atleast half way the through this whole atomic moment by a lattice spacing A. their should be a sort of the force so the getting in the back to the previous position and for the latter half of the A, there should be the forces would get this atomic system to the later position means. you know the later position is that this atom is really comes all the way to the centre place here in this particular figure as shown here where the equilibrium forces or where the with the net forces are 0 and it is another equilibrium position.

So how will you describe the mathematically so if I say that the variation of the τ that is the shear stress which the crystal is giving out in opposition to what is been given to it from outside is actually equal to $\tau = \tau_0 \sin \frac{2\pi x}{a}$ then is the purpose let us look at it when x=0, obviously the τ is going to be 0 so therefore there is no shear expression is given back by the crystal if τ=Fx=a/2 in that even the amount of τ is again equal to 0 because now it is in a position where again in the central position where it would really have equal amount of the positive and the negative forces.

And beyond this so basically τ is 0 again if x is a then again the τ become equal to 0 so these are probably the position over which the atomic system is going to be happy. So obviously between the x=0 to x=a the force would be as if the crystal can come back to the initial position and between a/2 to a ,the force would change directions and it will be the crystal can go back go to the final position where as I told you this dotted circle right about here moves to this center position here.

Where there is again equilibrium condition. in between obviously there is a condition which is stone here by the solid line where the forces between these atomic systems should be equal to 0 and it will also be equilibrium. But a/2 also is going to a net stress given out by the crystal which is equal to 0 and it is going to be in equilibrium. So this is actually represented by this condition obviously as you see here x=0, τ=0, x=a/2, τ=0 and is going to x= a τ=0 again.

So basically talk about sine wave of wave length a, where a is actually lattice spacing. so once we have done that we are in enable a sort of c what is going to be the you know the stress strain relationship given this shear stress value with respect to the position x of the layer above this shear plane respective layer below the shear plane. So we are going to for small value of x/a make a small assumption here make a τ is τ_0 2πx/a okay the sine is converged to 2πx/ a and therefore the shear strain produced in such circumstance.

If we assume the total vertical spacing in the lattice to be equal to b at this time let us unequal lattice spacing which seldom happens which is the crystal you have more or less regular orientation of the atomic planes with respect to the each other whether you go in the each other vertical or horizontal is does not matter and the lattice spacing is one constant a so these actually 2a for the regular kind of the crystals. But here for the models sake we are assuming this to be different value.

So shear strain is produced there would actually be equal to x/b because x is the movement and the original distance that was there was b. so basically if you are moving this lattice from a you know cubic position or let us of straight position to some angular position the distance of movement is x here this being b. so shear strain obviously x/b and so stress strain related to each other and therefore we can say that the total amount of shear stress is τ, which is $\tau \approx \tau_0 \frac{2\pi x}{a}$.

And it related to the modulus of rigidity shear modulus times of the shear strain by simple Hooks law and we could say that the τ_0 in this particular case in assuming b=a for the lattice comes out to be equal to g/2π. So that is going to be the amount of stress required in order to execute. you know any kind of motion. so this is going to be actually say the ultimate shear yield stress value which would be needed for creating the motion which is in question you know between the atomic plane.

You can see that τ_0 is corresponding to the maximum value when probably the x= a/4 or will 3a/4 so in that situation the value here for the a/4 would be actually sin π /2 which become equal to 1 and therefore 3 /4 would be 3π/2 is again sin π/2 and this also going to be -1. So in one case the maximum value of the τ, the τ is actually 0 in other case this is – τ0 it can be seen from this plot here so having said that.

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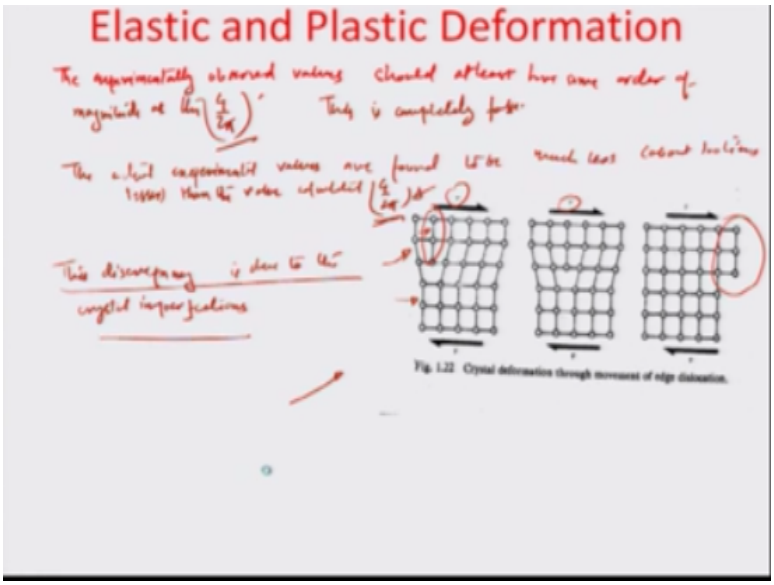

It means that the experimentally observed values should at least have same order of magnitude as the $\frac{G}{2\pi}$ that I have formulated the last step. This is completely untrue. the actual experimental values has been recorded or found to be much less about 100 times lesser than the value calculated $\frac{G}{2\pi}$. so this discrepancy is due to the crystal imperfections. You can see for example here and extra plane the line dislocation is available in upper half of the crystal.

So assume that if I put shear stress the use of this movement of this already you know prestressed plane would much more or much easier in comparison to generating an additional plane movement for the example in the lower half plane. So that is you can easily apply a small stress and get this misfit plane already in corner more easily to comparison to or otherwise it will take for a regular lattice without any imperfection so in order to just explain this from a real life example

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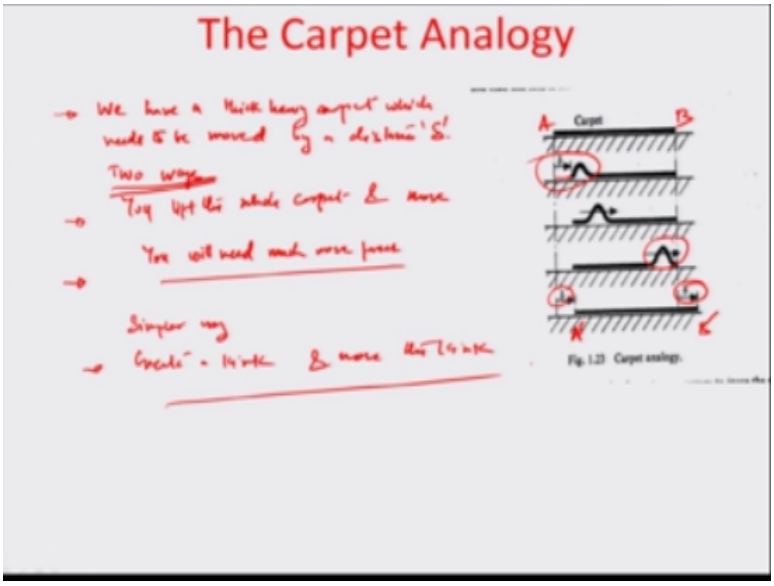

Let us see what happens a thick heavy carpet how move it right so let say we have of thick heavy carpet which know needs to be moved by a distance δ .let say in this direction you want to move this carpet from the point AB to the point to A' B' where the A' is should be δ. Two ways to do it one is that lift to the whole carpet. So in this particular method you will need much more forces obviously the carpet is very heavy being thick and very you know heavy high density material. So it is very difficult for you to move by lifting the whole thing and move.

So there is a simpler way which is there that you create a kink created in a way that exactly moves δ and whatever left over portion you create a kink. So create a kink and move the kink so here probably you can only a single person you can do the job so you can see the kink is moving here and so the kink moves all the way to the end of the carpet so that now carpet has moved by distance δ from AB $\delta\beta$. so this actually the locations the kink is basically a dislocation is create a kink in a particular crystal is otherwise a regular crystal is always easier to move the crystal plane will respect to each other.

So obviously there are lot more to this because so far been considering on the single crystalline orientation. But supposing to there is a polycrystalline grain, you already you know what is polycrystalline grain is. Obviously all these locations multifarious in nature and there are many dislocations per unit volume and whenever you apply a stress they start moving towards each other or away from each other. So basically there may be a situation where such dislocations are

unable to move because there are so densely jamming or packing the way of each other so it is like a traffic jam.

This also this phenomenon crystal particularly polycrystalline material is known as strain hardening. whenever we have too much of stress induced in to the crystals because of the this dislocations starts moving in all different direction. they pileup ,the jam each other path and they are not able to move anymore okay. So obviously the ultimate yield strength will increase because of that. So this phenomenon of strain hardening etc we would consider in great details. In next module as if now would like to close this module thank you.

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