Dynamic Behaviour of Materials
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Lecture - 42
Shear Band I

Hello everyone. So we have discussed about plastic deformation mechanisms under shock wave propagation. So today, we will discuss about shear bands so which is a failure mechanism or rather we should call this a precursor to failure, because the failure mechanisms actually eventually lead to crack formation and that will actually fail the material.

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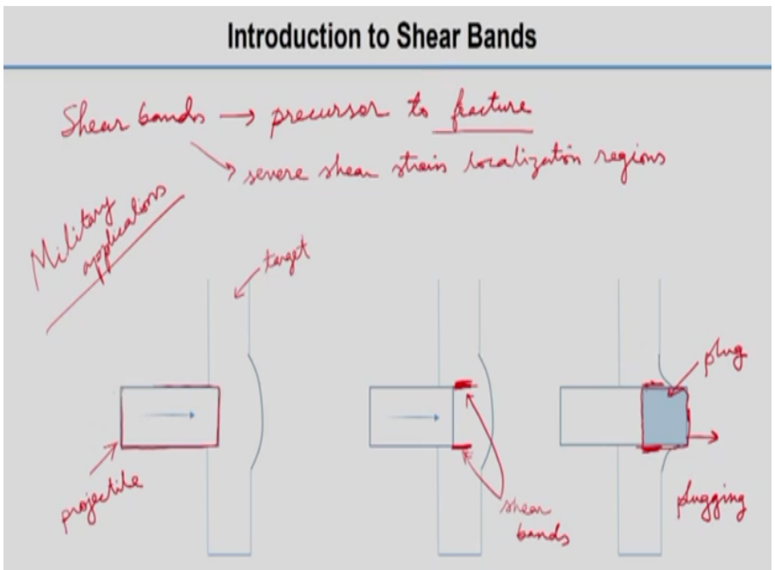

So we can call it as a failure mechanism or better probably we will call shear band, sorry we will call shear bands, you know as a precursor to of failure or actually we can call precursor to fracture. So the complete failure may not happen when the shear bands form, but it will eventually lead to fracture. So what we will see now is some applications. So we will first start with some military applications armour or yeah I mean basically armour application.

Military applications, here we can see a projectile hitting a target. So this is the projectile and this is the target. Here is projectile. So after some time the shear band will form. So these are the shear bands in these areas. So it is called shear bands. So we are not going to discuss the basics of shear bands, because we already discussed in the introduction chapters, probably the first or the second lecture. So we have discussed about shear bands.

So shear band is basically severe shear strain localization zone or shear strain localization regions. So now here these portions, as I have shown these portions will form a shear band and that will help to form a plug. So this is called the plug and eventually the plug will go out. So this is called plugging that failure is called plugging and this is plug formation and that happens due to the shear bands.

So shear bands helped to form the plug or the plug will go out of you know that target forming a, you know, that is penetration, complete penetration by the projectile.

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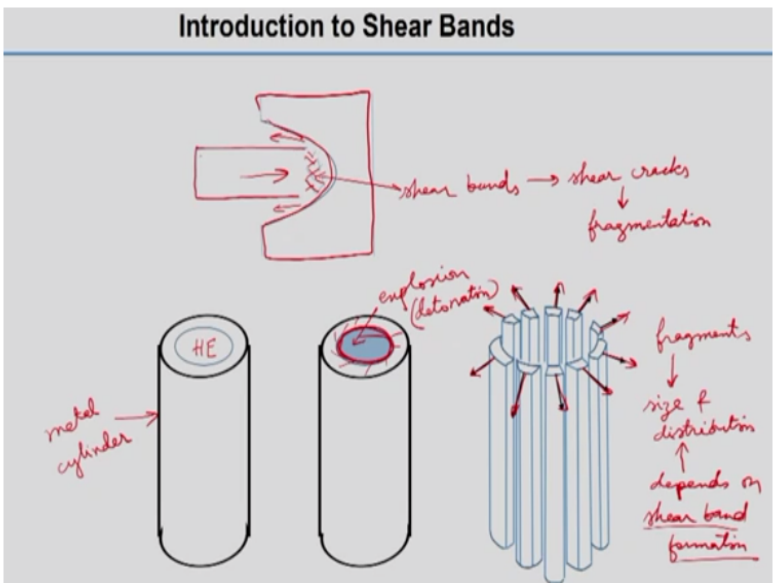

And another case, this case the diagram may not be very correct, but what happens is the target. This is the target. Target is already deformed by the projectile. So this is the projectile and so this projectile will move in the velocity of this way and then there will be shear band will form in the front of the projectile. So these will form shear band and so these shear bands, what will happen is, so we will draw this as shear bands.

So these shear bands will eventually lead to shear cracks and these cracks will lead to fragmentation, fragmentation of the projectile fragmentation. So these fragmented parts will probably move out from there. So in the third case which is also have a defense application. So this is an explosive inside this metal casing, this higher heavy explosive, high explosive. So this is a metal cylinder.

So what is happening here is, it is with you know detonation, due to explosion or by explosion this fragmentation happens. So just the metal casing is, you know, fragmented, you know, made in to lead to fragmentation with the help of explosive. So rather I should write explosion here or you know it is the other way you have the detonation which lead to explosion. So here you can see that this is exploding and you can see that many fragments.

And that is these fragments if you can see the size and distribution of these fragments distribution depends on shear band formation. So basically what happens is, first the sheer band will form here, not exactly here sorry this is, this area has a high explosive right. This is a high explosive. So after the explosion what will happen, the shear bands will form in this metal casing or the cylinder. So these shear bands formation will decide.

So what is the level of sheer information that will decide the size and distribution of the fragments. I just want to let you know that there are several micrographs that means microscopic images in the (()) (07:27)) book, so that textbook. So you are requested to, you know, read that many at least study that part of those micrographs, microscopy measures. So we could not you know include it in the slides.

So if you can see this, you can study by yourself all those micrographs that will be good for understanding the shear bands. So here we only are showing the schematic diagrams.

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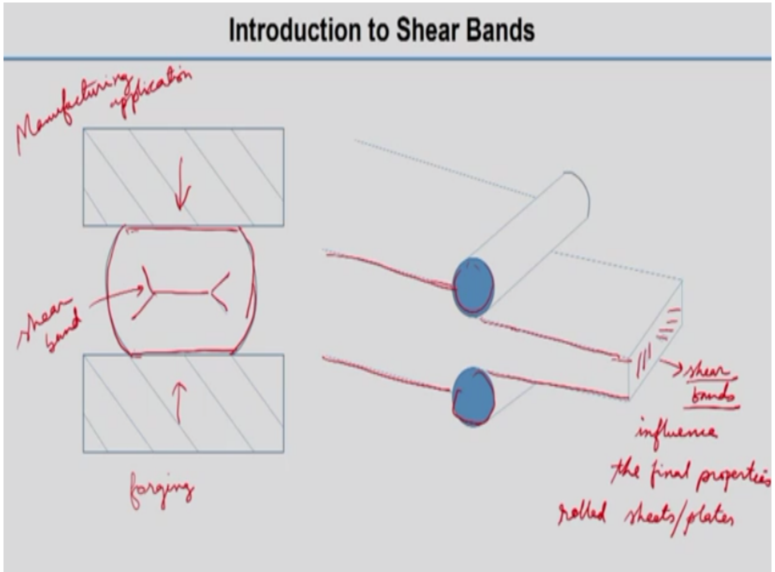

But here, what we will discuss, are different kind of applications and this is manufacturing applications. Earlier we discussed about defense or military applications. This is the forcing. Forcing you can see that this material will be forced here. This is the material. Let us say some metallic material. So this is the shear band. So shear band formation shape generally is like that for, you know, for this kind of forcing and then there is another example of rolling.

So these are the roll as you can see. These are the rollers. This is the work piece and then after rolling, it will come out of it thinner sheets, so sheets or plates. So there are some shear band formation here you can see. These are you know shear bands and then these shear bands influence the final properties of the sheets or plates you know rolled. I should write rolled plates. So the most important part is the shear bands are important here as well.

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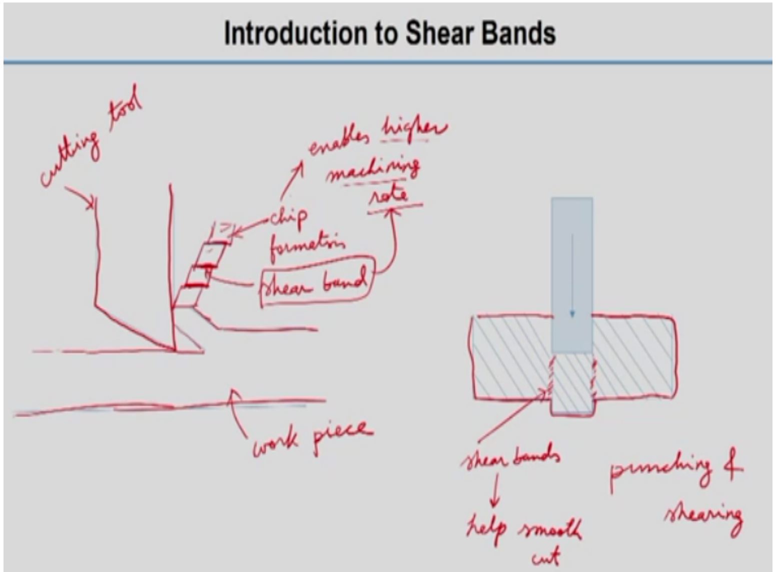

And then another application, which is also these 2 applications are also manufacturing applications. Here we have the metal work piece. I will show this is the metal work piece. This portion is the metal work piece and then this is the cutting tool. So what happened is, you know that I mean I am sure that you studied in your manufacturing classes for those students who are you know in mechanical engineering background, who have mechanical engineering background.

So you can see that these are chip formation. I mean even if you are not from mechanical engineering background you know probably about that. When you cut a material metallic material with a cutting tool, so what will happen, there will be some chip formation like this. There are different chips. This is one chip, this is one chip, and so there are like 4 chips. We are drawing here. So these that you know reason between 2 chips.

So this is basically the shear bands. So that means the shear bands will form first and that will convert the material to you know many chips and this is very important because this chip formation helps to, you know, enable a higher machining rate. So that means shear bands ultimately helps to, you know, have a higher machining rate and the last one which is also one manufacturing application punching and shearing.

So this is the material, you know, due to this punching so it will have a shape like this. So where the shear band will form here? So this is the place where the shear band will form, you know in this line. So the small shear band is here. So these shear bands, will help. These shear bands will help smooth cut. So that means the shear bands are important. They are sometimes desired for especially, for manufacturing processes, but otherwise if you see for armour applications.

So shear bands, you know, may not be desired in all cases. So we have already discussed about the basics of shear band even earlier. So what are the favouring factors and opposing factors for shear bands. So first one is the thermal softening.

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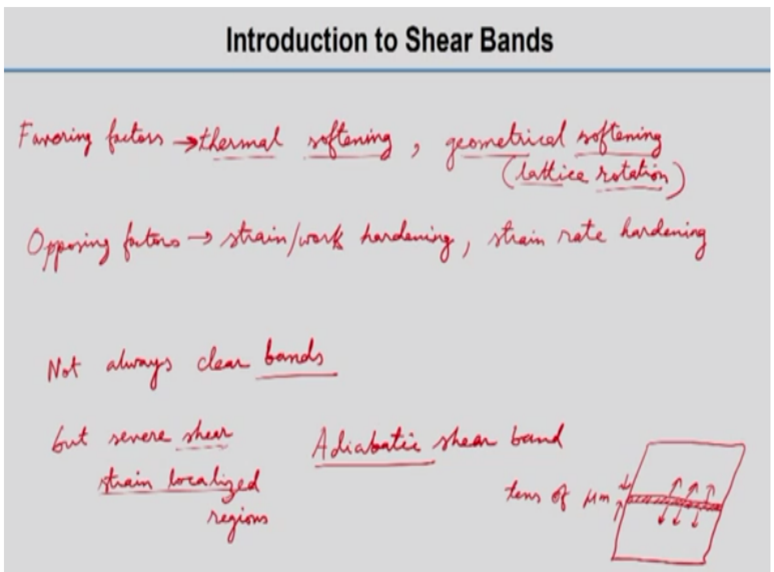

Thermal softening that is favouring factors, when you are shearing material so and as we can see that we have a shear band as a very small, you know, thin band that is in the micrometer level maybe 10s of micrometers. So what happen is, there will be a lot of heat generation and then there will be very less time to dissipate this heat or conduction to happen to the outside area. So that is why the temperature generated will be very high, very high in this region.

So these heat whatever, whatever I am drawing with arrows that heat dissipation or heat conduction from that region to the outside region will be difficult and that is why a high temperature generation will lead to softening of the material. That is called thermal softening and what is the opposing factor. Opposing factors is the strain hardening or we call work hardening. What is that?

So that you already know that probably for metallic materials, what happens dislocation density increases with strain and that will in return harden the material and so that is called strain hardening. So what will happen is, the strain hardening will oppose the shear band formation and the thermal softening will favour it and apart from that, we have even strain rate hardening. One is strain hardening and one is strain rate hardening.

That means if you increase the strain rate, the hardening will also increase and another favoring factors apart from this thermal softening is geometrical softening. Geometrical softening is actually result of this lattice rotation. So we talked about it. The lattice rotation or the rotation of the grains when we are deforming the material, the grains will rotate to change the orientation, so that it can make the dislocation slip easier to facilitate the dislocation slip.

So the grain will rotate and that will result, that resulting phenomena is called geometrical softening and as we have discussed here the temperature rise will be high and then temperature will not be able to go out of this region because of the, you know, less time. So that is why it is called adiabatic shear band. So we generally consider that no heat go out of the band area and these bands are as I told, it is very thin.

It is in the micrometer level maybe probably 10s of micrometers. You can see the real micrographs, the real pictures actually micrographs from different microscopes. So that will tell you the exact thickness of the bands. So it depends on different materials, it depends on the loading, how thick the band will be and sometimes band may not be clear. So that you should just, you know, take a note of that. So not always bands, sorry not always clear bands.

That means it may not take a shape or band, but severe shear strain localization, localized reasons can be seen. So bands means it is a thin strip. So that may not happen in some cases, but still I mean basically depends on the material as well so if you see in the figures in a micro micrographs in the book, it will be, it will make you clear about that. What I am saying that shear band is also a shear strain localization.

But if it is in a shape of a band or long strip I mean thin strip, that is, then we call it as a, you know, shear band, but otherwise it is not. It is just a general shear strand localization.

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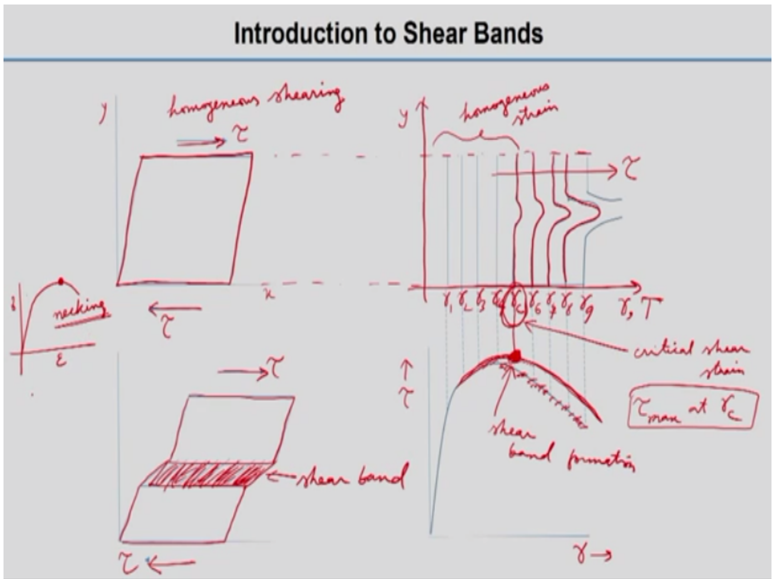

We will see in this case, so we have xy in this material is deformed in shear. Let us say the shear stress is tau and it is kind of a homogeneous shearing. It is not, you know, inhomogeneous, but what will happen is some part will be, we should have drawn this little thinner. So this shear band, this portion is the shear band, but this would be little thinner. We have made it a little, you know, thicker one. So due to the shear stresses, so this region is shear band okay.

So now what happens is, this shows on the horizontal axis, it is shear strain and temperature. They will vary in any similar fashion and this is y axis. So let us assume that we are talking about this and in these shear band region, you can see at different strains actually we are talking about. Let us assume gamma 1, gamma 2, gamma 3, gamma 4 and then gamma C that is the critical shear strain and then different, you know, gamma, let us say gamma 6, 7.

So different values of you know gamma, so what happens is at that point, sorry we had a mistake here in the diagram. So what the diagram below, it has a little mistake. So I will just, you know, I will just draw the correct one and then so we can probably ignore this. We can probably ignore this and then please check this plot like this. So what is happening in this figure? So after a critical gamma, so this will have a, you can see that the localized zone.

So gamma will be more in this region, so that means when we increase the tau in this direction, so after a critical gamma, that means I would write critical shear strength and before this, this area whatever strain we are talking is, this is homogeneous strain and after that it was inhomogeneous, because the shear band started you know forming and then this, the last figure is this is stress-strain diagram, shear stress versus shear strain.

And you can see that why I told this little incorrect, because the maximum stress tau max should be at gamma C. That should correspond to the gamma C that we had made a mistake. So while drawing it. So now gamma maximum is that, sorry, tau maximum should be at the gamma C. So if you see this that means at gamma C the shear band starts forming and you can this is actually analogous to our necking formation at uniaxial stress strain curve with tension in uniaxial tension.

So as you can see from an uniaxial tension test, so this maximum load point will represent that after this point the necking will happen, neck formation, but in this case this is different. This is shear band formation. So what is the exact difference, because in neck formation that is not a high strain rate. So we talked about localized deformation. Yes, both are localized deformation, both necking and shear band formation are localized deformation.

But necking does not involve any high temperature or thermal softening. So in this case shear band formation, we have a very high strain rate and that will lead to high heat generation or temperature and that is why thermal softening is there. That is why it is more severe than a necking formation and shear band is very thin, severe localized region. We want to inform one more aspect of these shear bands.

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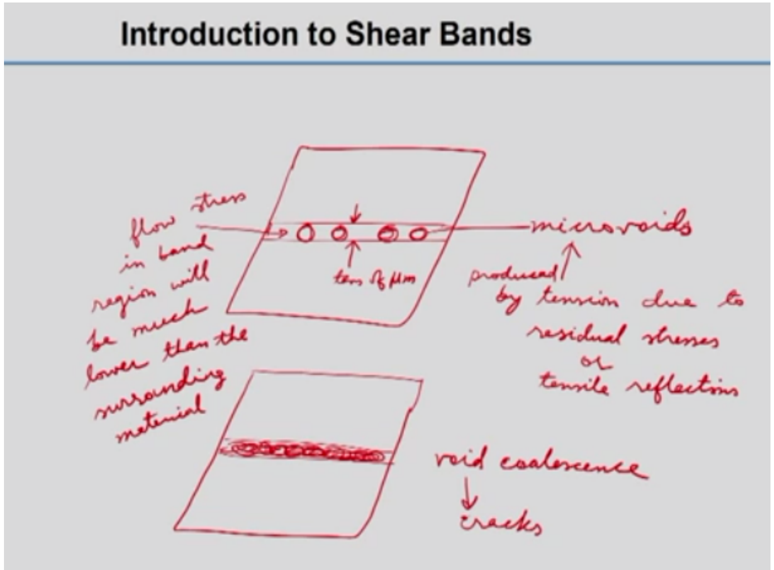

So what happens, suppose if you have a material and shearing and then this shear band is forming here, so there can be some void formation. So these are some voids that is we call micro voids. Microvoids that you know what is microvoids. That is not crystallographic voids and the small region, I mean they desire without any material, but crystallographic voids are, they are in a, you know, angstrom level and that is the gap between the atoms.

So what will happen, the first of all the void will form. These are the shear band regions. So these voids will grow and they will, you know, join each other. That is called as you know void collisions. So then this will lead to the crack. That means you see that this is now continuous and these form the cracks. So this will lead to cracks and these voids are generated, produced by tension due to, also tried produced by tension due to residual stresses or tensile reflections.

That you know what is tensile reflections, the wave reflections we are talking about and we should understand that the flow stress of the material, that means the flow stress means the stress at which the material will deform plastically, so the flow stress in the band that means shear vent region will be lower or rather we should say, would be much lower than the surrounding material.

So void diameter of the voids are very close to the you know thickness of these the bands that means in the order of, as I told you maybe 10s of micrometers, you can see in the book, the real micrographs from electron microscope. So I think that is all for today. So what we have discussed is basically the, you know, introduction to shear bands. So very basics of the shear bands we discussed in the initial chapters, initial lecture actually.

And then in today's lecture we have discussed that the how the shear bands influence our applications like manufacturing applications, the shear bands are beneficial and for military applications, how the shear bands affect and then we have seen that how these voids generation and growth and collisions happens in these, you know, shear band region. So you should understand that these voids are mostly, you know, concentrated on these shear band regions, so not the other region of the material.

So these voids can you know lead to cracks and fail the material. So that is why as we have started this discussion at today's discussion that shear band is a precursor to a fracture. So shear band itself can be a failure, but surely it is a precursor to fracture or failure. Thank you.