Thermo-Mechanical and Thermo-Chemical Processes
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Lecture-15
Crystallographic Texture: Application

Hello friends, in crystallographic texture this last lecture in this particular module will be on application. So, what is the application of understanding of texture on one of the properties that is what we are taking.

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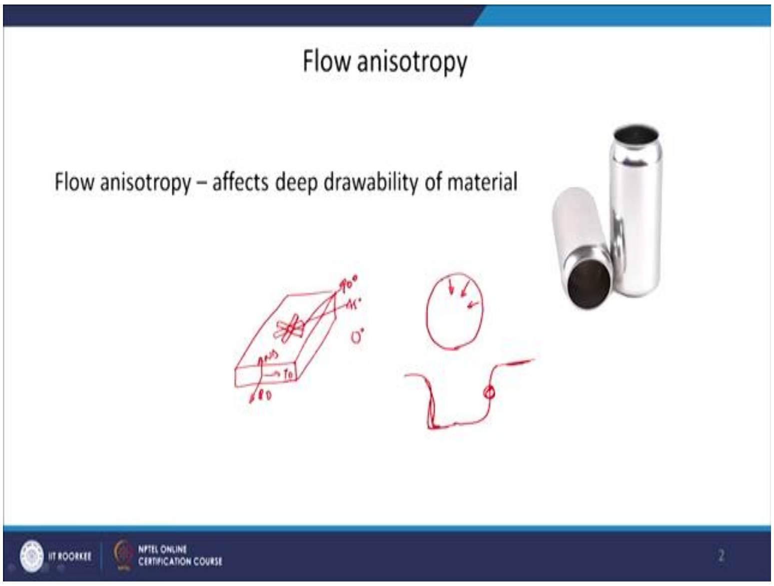

And that is what we have discussed earlier also that when you are deforming or you are doing a deep drawing of any sheet material, there is a flow anisotropy. That means, let us take a material or a roll sheet for example. So, this is my rolling direction, transverse direction and normal direction (refer to above figure). Suppose I am measuring the flow properties in this direction.

So, I am taking a sample from here and this is I would call as 0° and then I will take another sample like this at 45° or another sample like this parallel to TD that I will call as 90° (refer to above figure). And if I measure the flow properties in each of these condition if the flow properties are same the ductility, the yield stress and so on, then the material is isotropic and there would not be any problem in the formability of the material but usually the issue is that suppose if I take a round blank like this (refer to above figure) and I am deforming it.

So, in the cross section suppose it is deforming like this then there will be thinning in this region because you are stretching the material this part will not deform at all (refer to above figure) if the material has different properties in different direction. Suppose it is a circular blank which we are deforming, what will happen that in this direction deformation is easy, but suppose in this direction deformation is may not be easy for example or in this direction that deformation is not easy.

So, what will happen the deformation will take place in this direction, but in this direction the material will just get instead of stretching it will be pulled by the punch (refer to above figure), that deformation is not uniform throughout the sheet.

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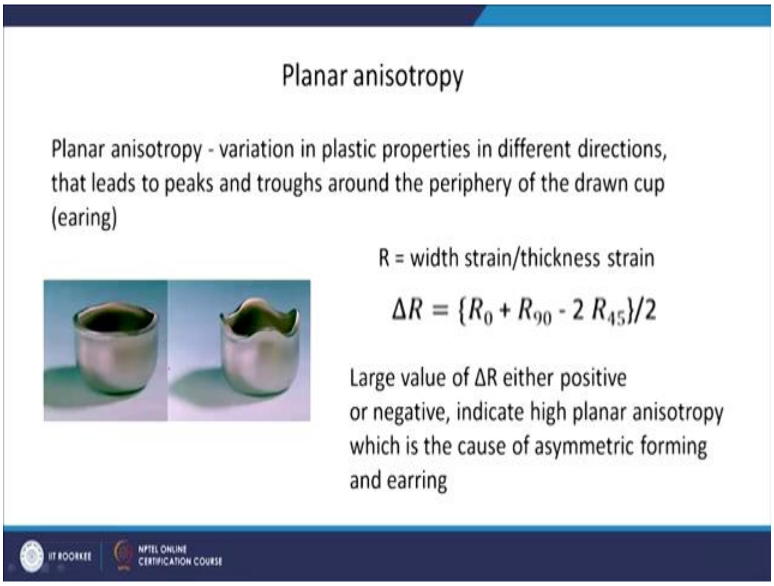

So, this kind of anisotropy develops what we call as earing phenomenon as already have told you. So, in this direction the material is not able to deform but in this direction material is able to deform that is why you are seeing that the material got pulled by the punch whereas in this case it the deformation took place material did not pulled by the punch but other problem will always be there that will be thinning here, it will get thin in this location (refer to above figure).

So, this anisotropy now I can divide into two different type of anisotropy, the first is called planner anisotropy and this planner anisotropy is the cause for this kind of earing phenomena. And basically, it is simply that the property in the in different direction is different.

So, that can be found by a relationship like this

$\Delta R = \{ R_o + R_{90} - 2{*}R_{45} \}/ 2$

where R is, if you are doing a tensile Test if I divide width strain by a thickness strain then that ratio will give you R and this width and strain ratio if I determined for a sample taken from parallel to rolling direction then it will be R_0 if it is parallel to TD that means at 90 ° to rolling direction then it will be R_{90} and if it is at 45° it will be R_{45} and in this three direction we are trying to see what is this ratio width strain to thickness strain.

So, if you have a large value of ΔR whether it is a positive or negative that means absolute value of ΔR because it can be negative also if R_{45} is more than some of R_0 or R_{90} or it can be positive so, if we take the absolute value of ΔR without worrying whether it is positive or negative then it indicates high planar anisotropy which is the cause of earing phenomena.

So, that means if ΔR is more that means anisotropy in different direction is there, you will have a earing phenomena. So, our purpose is to minimise or to bring down the Δ R value.

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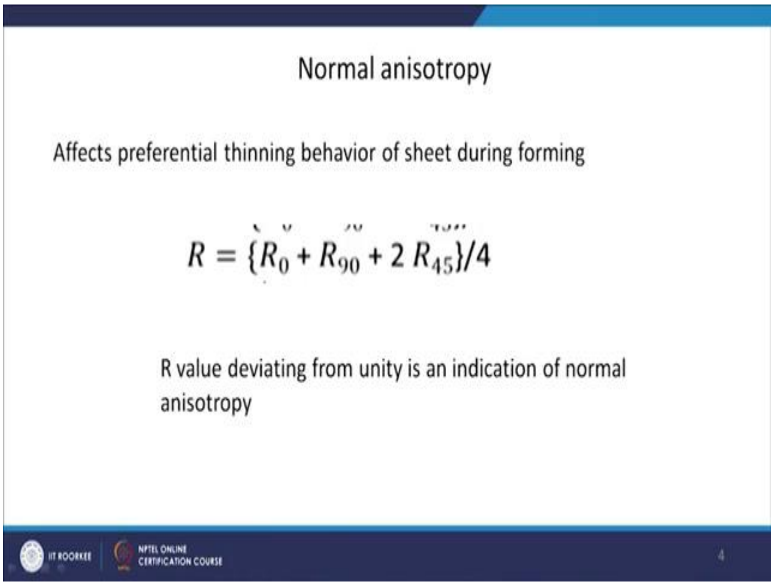

Another value of importance is called normal anisotropy. And that is basically the thinning characteristic of the material.

$$R = \{ R_o + R_{90} + 2{*}R_{45} \}/ 4$$

So, if you have large value of R that it is good. That means there is a little tendency for thinning when you have a higher R value, because if you see this particular relationship is slightly different and the previous one we had a minus sign here, but here we have a plus sign.

So, it is just as kind of an average R value. So, average R value if it is high than it is good because then you will have less thinning tendency because our R is width strain divided by thickness strain. So, high R value will be there when your thickness strain is small, that means thinning behaviour is less. So, if it is deviating from unity then it is an indication of normal anisotropy. This means there will be anisotropy behaviour along the thickness.

So, one is in different direction in the plane of the sheet. And one is that you have different strain value in the width direction and the thickness direction. So, these two values determine the formability of the material. So, for a good formability, I need a high normal anisotropy value and low absolute value of planar anisotropy.

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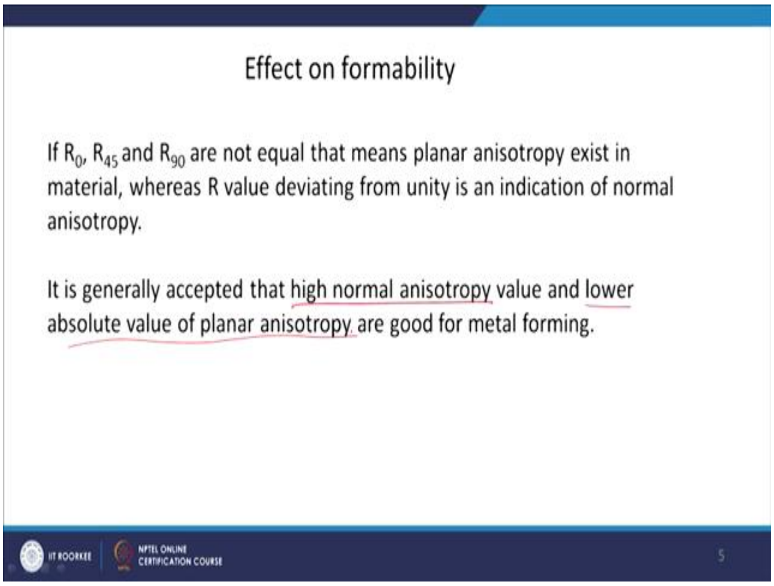

And when you will have a high planar anisotropy that which is not good actually, when if R_0, R_{45}, R_{90} are not equal that means planar anisotropy exists in material whereas, R value deviating from unity is an indication of normal anisotropy as I told you. So, I need a high normal anisotropy value and lower value of planar anisotropy.

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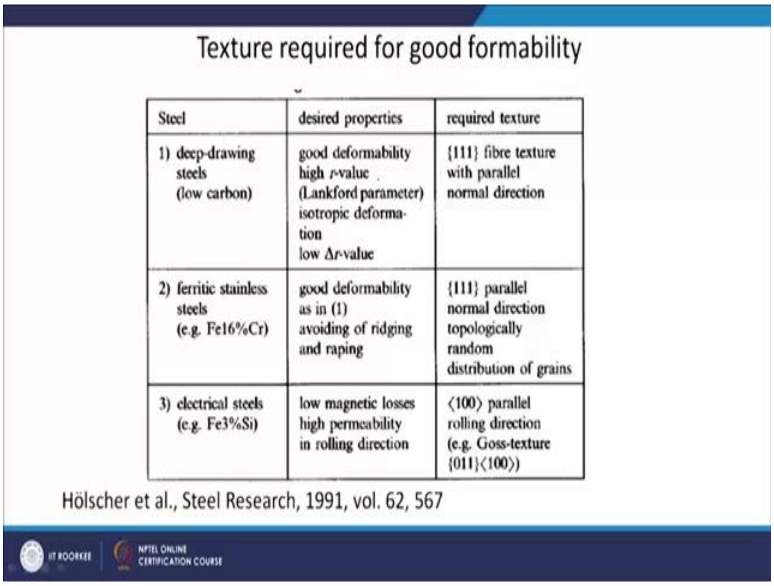

Texture required for good formability

Steel	desired properties	required texture
1) deep-drawing steels (low carbon)	good deformability high r-value (Lankford parameter) isotropic deformation low Δr-value	{111} fibre texture with parallel normal direction
2) ferritic stainless steels (e.g. Fe16%Cr)	good deformability as in (1) avoiding of ridging and raping	{111} parallel normal direction topologically random distribution of grains
3) electrical steels (e.g. Fe3%Si)	low magnetic losses high permeability in rolling direction	⟨100⟩ parallel rolling direction (e.g. Goss-texture {011}⟨100⟩)

Hölscher et al., Steel Research, 1991, vol. 62, 567

Now, what is the texture with which is required for this kind of behaviour. So, deep drawing is still low carbon desired property is good deformability with high R value. And isotropic deformation with low ΔR value as I just told you. For this you need a 111-fibre texture which is parallel to normal direction.

We have already seen the fibre texture so; you need a 111-fibre texture. In ferritic stainless-steel 16% chromium good deformability and again 111 parallel normal direction topologically random distribution of grains (refer to above figure). So, again you need 111 fibre direction which was the γ fibre if you remember we discussed in the previous lecture. If you have a electrical steel, now electrical steel the purpose is different, there the purpose is not the formability but the purpose is to reduce the hysteresis losses.

As you can understand that this electrical steel are used in transformers where you have these primary and secondary windings, so, primary windings have 50 hertz electrical supply that means 50 times it is getting magnetised and demagnetised as the current is flowing. So, if you have a very high hysteresis losses, it means every second, 50 times you are having that hysteresis Loop. If you remember, you have a hysteresis loop like this (refer to above figure) and in each loop whatever is this area that decides the energy loss.

So, if energy loss is very high then of course transformer gets heated up and also you your efficiency will be low. So, for reducing these hysteresis losses particular texture component is required which is called Goss texture already we have seen this. So, if you have a Goss texture in the plane of these small strips of the transformer then this (refer to above figure) particular direction is the easy magnetisation direction and the demagnetisation also off course, so, your hysteresis losses will be low. So, for that the texture requirement is 100 parallel to rolling direction, for example Goss texture which has 100 parallel to rolling direction. However, whatever texture is required for electrical steel is usually not good for the formability and whatever is required for formability is not good for electrical steels.

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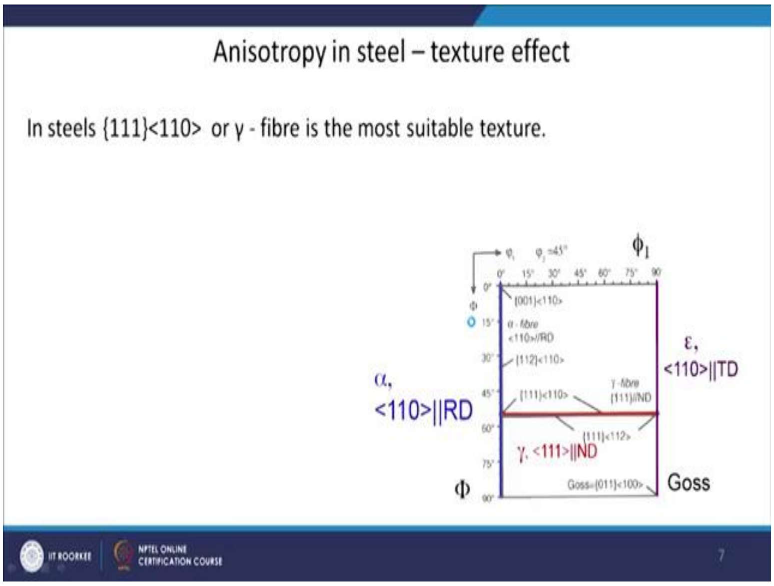

So, as we have told that you need a γ fibre is most suitable texture for formability and that lies here (refer to above figure) which comes in 5 to 45° section. And location is somewhere here which is basically 111 plane parallel to ND. So, you can have different directions. So, for example, it is starting from {111} <110> and the last one is {111} <112>. So, basically the 111 is parallel to ND that is the component we need for good formability in steels and if you have this you will have lower planar anisotropy and that will be good for your earing behaviour.

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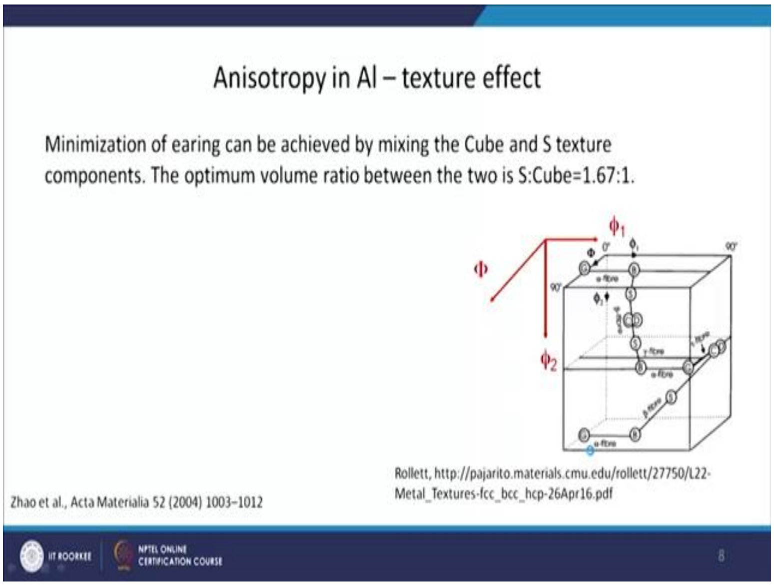

If you see anisotropy in aluminium alloys effect of texture (refer to above figure), minimisation of earing can be achieved by mixing the cube and S texture. These two components if you mix then the earing phenomena is kind of a distributed throughout the you can say circumference and the optimum volume ratio of these two is S and cube is 1.67:1. If you have this kind of mixing of the two texture components then you will be having a good formability.

So, again you can see that this particular cube is of course, will be at these locations at the corner locations and S is you have at these locations (refer to above figure). So, if you have a good combination of this S and cube you will be able to achieve a lower planar anisotropy and that will help you in the earing phenomena.

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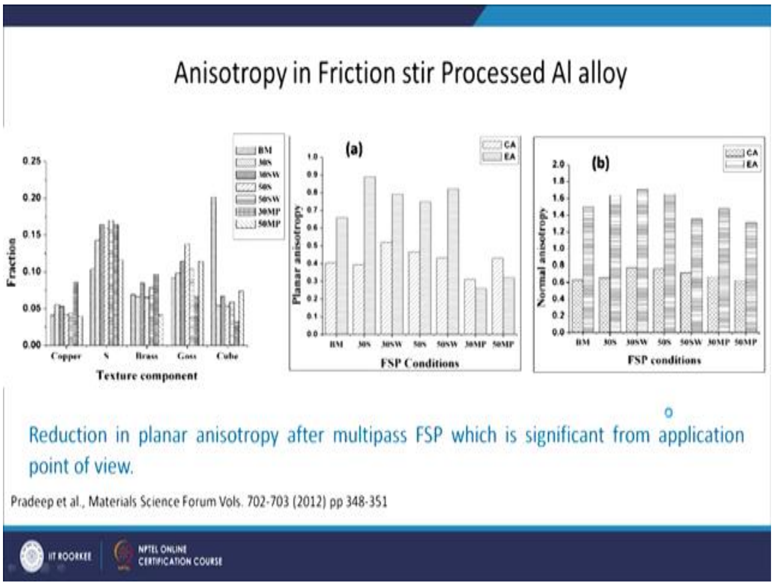

There is another work of our survey where we studied the anisotropy in fiction stir processed aluminium alloy. So, in the first figure, we have different texture components copper, S, Brass, Goss and Cube. And on the Y axis their fraction is noted down. So, basically these (refer to above figure) are the different friction stir processing condition there is one module on severe plastic deformation, there we have discussed the friction stir processing in more details.

Basically this 30, 50 all these are traverse is speed and MP here is used for multiple pass. So, we have done multiple passes here. So, that you are able to get enough amount of sheet for doing forming experiment or doing anisotropy experiments. So, texture components are there Copper, S, Brass, Goss and Cube all are there and their fractions are noted on the y axis and you can see that this is the planar anisotropy plotted for different condition.

So, in multi pass you can see that the planar anisotropy values are much lower than all the other conditions which is a good thing for sheet metal forming. And also the normal anisotropy value also is lower but reasonably high. So, that you will be able to get the benefit of both lower planner anisotropy and high normal anisotropy. So, basically there are two type of calculations done here.

So, one is what we have done or what we have calculated from the actual experiment. So, you have experimental value and calculated anisotropy. These particular ones are the experimental ones (refer to above figure) and these are the estimated from the texture analysis. So, you have different texture component, they will affect the anisotropy property. So, you can see that there is a nice matching between the calculated anisotropy and the experimental anisotropy, both are increasing and decreasing almost in a similar fashion.

And in multi pass both are showing very low value. That means the combination of texture component which is we have achieved in 30 and 50 MPa. So, you have low cube, cube is coming down. And similarly, if you see brass, copper is going up in case of this 30 mega Pascal where you have the minimum planar anisotropy. For S also more or less same, but for 50 multi pass it is coming down ok.

So, the effect of that you can see on the planar and this normal anisotropy. So, since it is achieved in the multiple pass friction stir processing, so, that is a very good condition for forming. So, with that this is again a short lecture on the kind of a case study or application of texture in mechanical properties. So, now we have seen that what do we mean by texture and we also have seen that different processing condition give rise to different type of textures, texture components and this texture component ultimately affects mechanical properties.

So, this gives you a complete picture that how the processing conditions affect the microstructure and texture and then how that in turns affect the mechanical properties, that is the ultimate use of the material for example, either it can be in case of forming process or it can be in terms of electrical steels. So, this should be a good example of control of different microstructural properties by processing and then seeing the effect of that on the properties. So, thank you for your attention.

Key words- Earing, Electrical steel, Anisotropy, Copper texture, S texture, Brass v, Goss texture and Cube texture.