Thermo-Mechanical and Thermo-Chemical Processes
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Lecture-14
Crystallographic Texture

Hello friends in continuing with our crystallographic texture discussion, today we will see few texture components especially in different type of material for example, body centred cubic and face centred cubic. Mainly as an example it will be steels and aluminium alloys. And we will try to see what are the different texture components and how it will look in the way we were looking at texture representation in terms of pole figure and ODF and how the components are located in the stereographic space or Euler space.

So, if you see the texture depends on the material. In different type of material depending upon crystal structure, purity, stacking fault energy and sometime alloying elements also changes a lot the material properties and therefore, the development of texture and of course what is the prior deformation condition.

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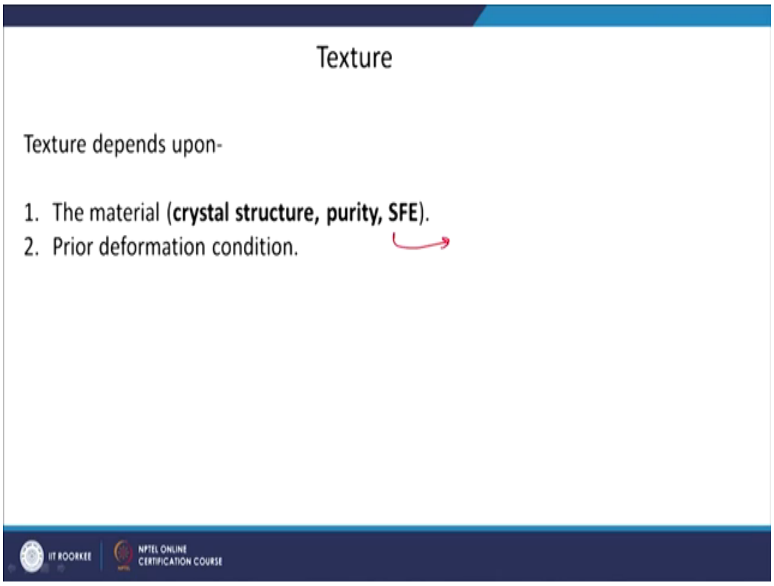

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Texture components in Steels

Material	Fiber name	Fiber axis	Important components
BCC phase	α_{bcc}–fiber	<110> parallel to RD	{001}<110>, {112}<110>, {111}<110>
	γ–fiber	<111> parallel to ND	{111}<110>, {111}<112>
	η–fiber	<001> parallel to RD	{001}<100>, {011}<100>
	ζ–fiber	<011> parallel to ND	{011}<100>, {011}<211>, {011}<111>, {011}<011>
	ε–fiber	<011> parallel to TD	{001}<110>, {112}<111> {4 4 11}<11 11 8>, {111}<112>, {11 11 8}<4 4 11>, {011}<100>
	θ–fiber	<001> parallel to ND	{001}<100>, {001}<110>
	β_{bcc}–skeleton line	≈ <111> close to ND	{111}<110>, {557}<583>, {111}<112>
FCC phase	α_{fcc}–fiber	<011> parallel to ND	{011}<100>, {011}<211>, {011}<111>, {011}<011>
	β_{fcc}–skeleton line	less symmetric fiber following local texture maxima rather than fixed coordinates	{211}<111>, {123}<634>, {011}<211>

Raabe, Steel Resaerch, 2003, vol. 74, 327

In general, if you want to see a complete picture that what different type of texture components are there in materials for example, in this case it steel. So, BCC phase and FCC phase for both it is shown here (refer to above figure). So, if you see in BCC, phase there are some fibres are written here. So, when you have a fibre, in this case my 110 direction is parallel to rolling direction but we are not specifying the plane.

So, whenever you have a fibre that means any plane whose 110 directions is parallel to rolling direction. So, it can be a 001 plane whose 110 direction can be parallel to RD or you can have another 110 type of plane or you can have a 111 plane goes 110 direction in parallel to RD. So, we are not specifying the plane here that means we are taking any plane and when you have a plane and if it contains the 110 direction that direction can be made parallel to RD.

But there is no specification for plane. So, if you have that condition for example, the planes are written here. So, you can have 001 plane, 112 plane or 111 planes but for all the {hkl} <uvw> this texture component the direction will remain same. So, if you have this kind of condition then we call it as a 110 fibre which is in case of BCC material that is the α fibre. There is another fibre very important fibre which is called γ Fibre.

In this case the 111 direction is parallel to ND. So, again you can see the component it is 111 with 110 another 111 in with 112 that means that right now we are not specifying the direction in this case so, it can be plane or direction in case of cubic material.

So, like that there are other components also shown here (refer to above figure). Different fibre names and their fibre axis and the relevant component all are given here.

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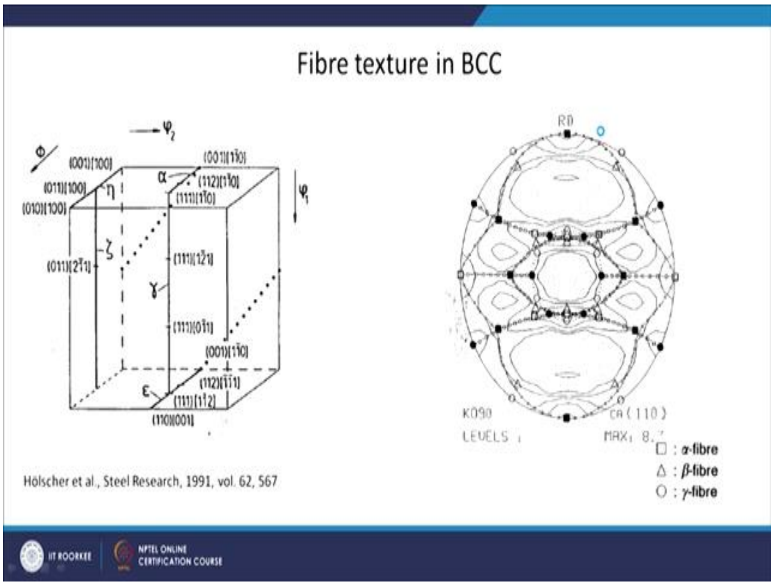

In terms of pole figure and Euler space if you want to see that how they are arranged, so the one which I was telling you about the γ fibre that is located somewhere here (refer to above figure) which is around 45°. In Φ_2, the angle is 45° another I think 45° is for Φ and in Φ_1 direction it is continuous fibre. So, it starts from (111) (110) then (111) (121) then (111) (011) and so on. So a complete fibre is there, in the Euler space.

And there are other fibres are also mentioned on the Euler space (refer to above figure). The same thing can be shown on a pole figure also. Again you have α fibre which is shown with a square notation then β fibre with a triangle and γ fibre with a with a circle. So, their positions are marked here (refer to above figure).

So, all this texture component can be shown on the either poll figure or Euler space also or in terms of {hkl} <uvw> value which we have seen in the previous slide.

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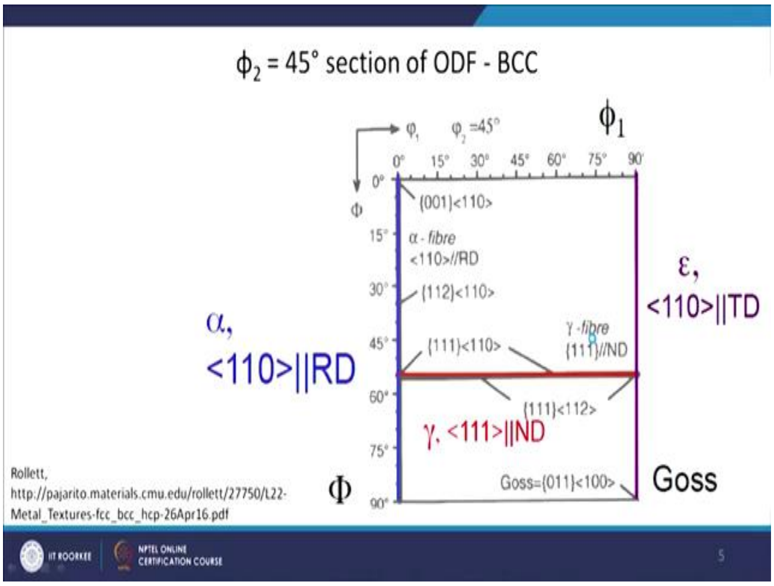

One of the most important sections when we talk about BCC material and in terms of their formability of the steel material, so, if you want formability then one of the most important section to look from all the slices of the ODF is where the Φ_2 is 45° section. And if you do that, you can see that the Φ_1 is here from 0 to 90°, Φ is there from 0 to 90° and Φ_2 is equal to 45° here in which you can see both the α fibre, the γ fibre and another ε fibre is there and you have a Goss texture. Already we have seen the Goss texture in terms of pole figure that how the pole figure will look for a Goss texture and in terms of {hkl} <uvw> this (refer to above figure) will be the texture component for Goss. So, again for formability this γ fibre is very important in case of steels.

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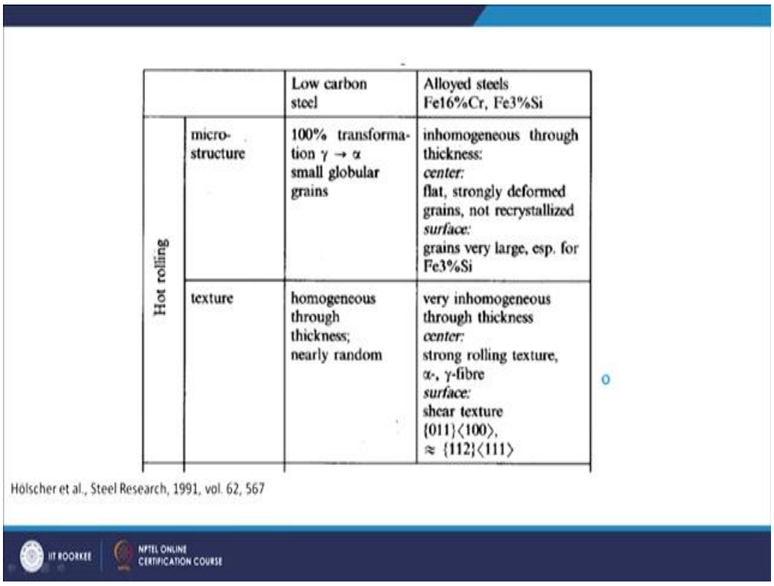

		Low carbon steel	Alloyed steels Fe16%Cr, Fe3%Si
Hot rolling	micro-structure	100% transformation γ → α small globular grains	inhomogeneous through thickness: *center:* flat, strongly deformed grains, not recrystallized *surface:* grains very large, esp. for Fe3%Si
Hot rolling	texture	homogeneous through thickness; nearly random	very inhomogeneous through thickness *center:* strong rolling texture, α-, γ-fibre *surface:* shear texture {011}⟨100⟩, ≈ {112}⟨111⟩

Now, what different type of processing gives you a texture. So, it is the effect of processing on texture. So, hot rolling, you have strong rolling texture with α and γ fibre. And also, some shear texture components will be there in the material.

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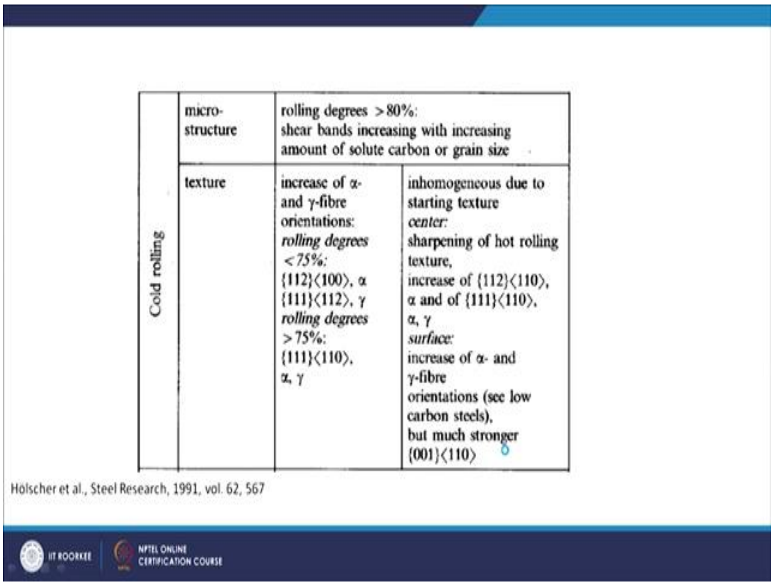

If you are doing cold rolling in steel then you will have in terms of texture, increase of α and γ fibre orientation. So, these will be the components for both of these (refer to above figure) and if rolling is less than 75% you will have α and γ like this. If rolling degree more than 75% then you will have this (refer to above figure) particular texture component and also again α and γ fibre. So, basically sharpness of α and γ increase, surface has increased α and γ fibre orientation but much stronger {001} <110> texture component also.

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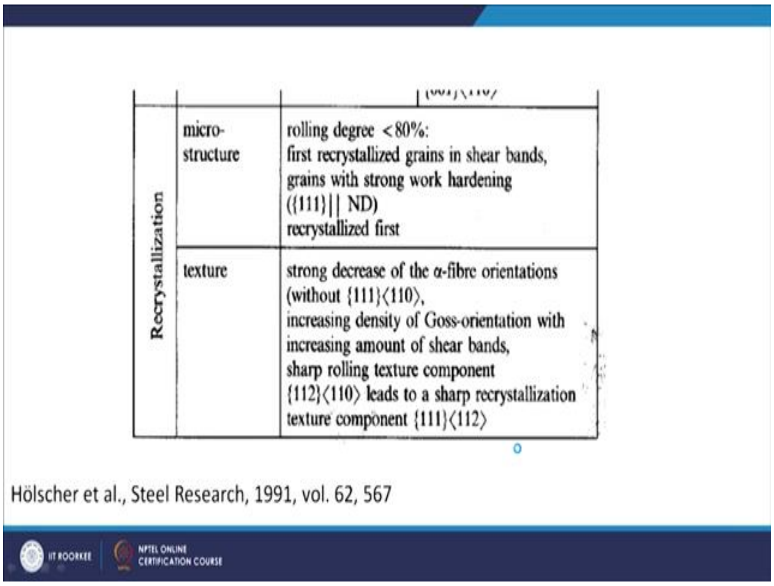

Suppose if after cold rolling you are doing a static recrystallization then there is a strong decrease of the α fibre orientation. And the increasing density of Goss orientation with increasing amount of shear band, sharp rolling texture component lead to sharp recrystallization texture components. So, if you have a sharp rolling component like this (refer to above figure) that will lead to a strong recrystallization texture component in the material.

So, these are the different type of texture which will develop due to different type of processing. So, you can do hot rolling then you will have certain texture components, you can do cold rolling that case we also call it as deformation texture. And after cold rolling you can do a recrystallization process then you will have this texture component which you are generated during rolling on to the recrystallization texture component.

Now, these are the texture components for face centred cubic materials. So, you have brass, S, copper, shear component, Goss, cube and some more are there.

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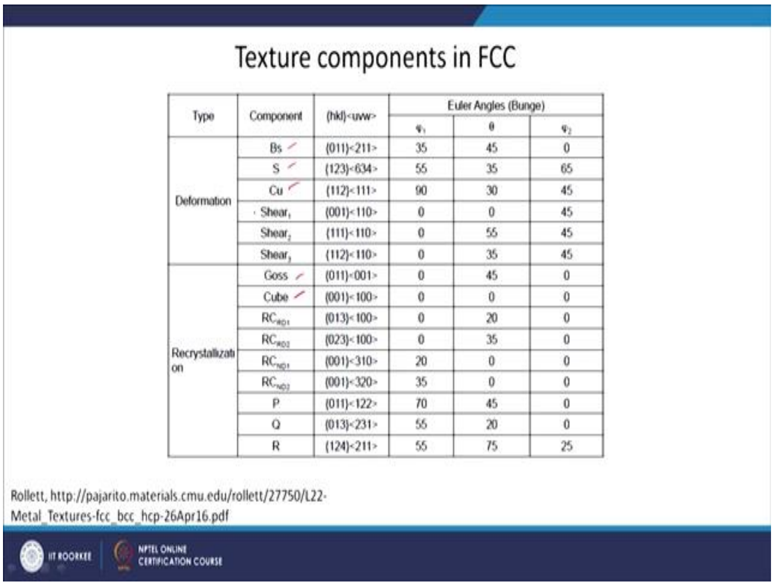

Type	Component	(hkl)<uvw>	Euler Angles (Bunge)		
			φ_1	θ	φ_2
Deformation	Bs	(011)<211>	35	45	0
	S	(123)<634>	55	35	65
	Cu	(112)<111>	90	30	45
	$Shear_1$	(001)<110>	0	0	45
	$Shear_2$	(111)<110>	0	55	45
	$Shear_3$	(112)<110>	0	35	45
Recrystallization	Goss	(011)<001>	0	45	0
	Cube	(001)<100>	0	0	0
	RC_{RD1}	(013)<100>	0	20	0
	RC_{RD2}	(023)<100>	0	35	0
	RC_{ND1}	(001)<310>	20	0	0
	RC_{ND2}	(001)<320>	35	0	0
	P	(011)<122>	70	45	0
	Q	(013)<231>	55	20	0
	R	(124)<211>	55	75	25

So, the first these ones (refer to above figure) are deformation texture component which arise due to the deformation process and these texture components are there when you do some static recrystallization of the deformed material. So, deformed material leads to recrystallization. So, there will be some change in the texture components. So now you will have Goss, cube, rotated cube, rotated cube means if you few put cube you can rotate it in any of the axis, so, either RD1, RD2, ND1, ND2 and so on.

And these (refer to above figure) are the Euler angles for all the texture components and you maybe able to understand that cube should always have 000, as I already told you because in case of cube the unit cell is already aligned with our sample geometry. In case of Goss it is just a rotation of 45° on one angle. So, that is what you can see here and instead of θ, I will put the capital Φ here that is what we discussed in the previous lecture.

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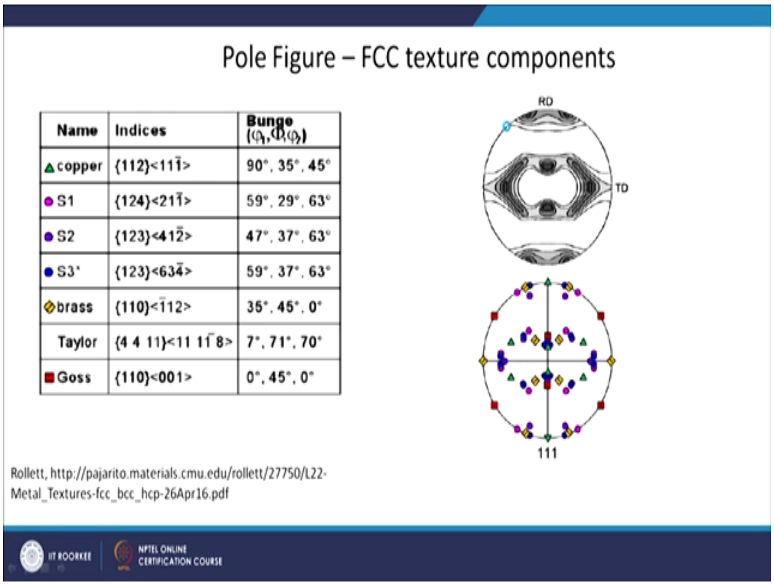

Again, this same FCC texture component we can look in the poll figure and the poll figure will look something like this (refer to above figure). So, this is a 111 Pole figure in which you see a typical shape like this with some intensities near RD. So, this is the 111 Pole figure and all the components which are visible here are shown here (refer to above figure). So, the triangle is copper. Then you have S which has three different variants. Then you have a brass which is shown by yellow square.

Then you have Goss component, which is shown here. So, in a 111 Pole figure, this is how all the different texture component will be distributed. So, if you see intensity for any particular component only at a certain location for example, and not for others then you will be able to say that there is a Goss texture in the material. For example, in this case brass, so it will be a brass texture in the material.

You can see it in terms of ODF also, as we saw in case of BCC material. So, this are my Φ, Φ_1 and Φ_2 all from 0 to 90, 0 to 90 and 0 to 90. So, you have different components and some fibres also you have α fibre like this and γ fibre like this so same name as in BCC, but their location in the Euler space is different. And you can also see the different component here for example, this is a Goss component here, this is your brass component here, this is S and cube also. So, C is your cube component.

So, all the components are at different location they are situated and additionally you have fibre in the Euler space and all the angles are also given here for different component as well as their {hkl} <uvw> values.

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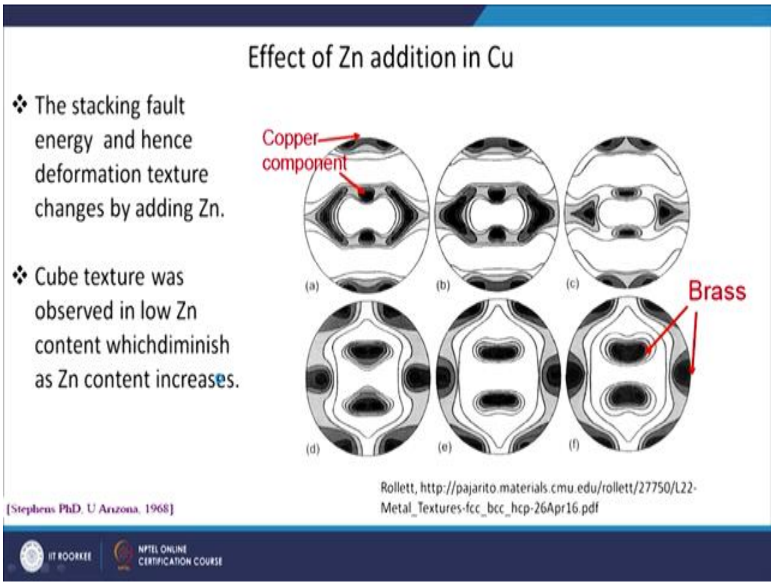

Now, what will be the effect of alloying element on any texture component is shown here (refer to above figure) for example, this is a deformed copper and initially you have copper components which we have already seen in the previous slide. So, your copper will have these component {112} <111>. So, you will have intense copper component, but as we keep adding zinc and we are trying to make a brass material which is an alloying element of copper and zinc.

You can see that what is the effect on the Pole figure and also texture. So, it is getting concentrated and giving rise to a brass component which is we discussed in the previous slide. The reason for this change is that when you add zinc the stacking fault energy changes. And because of that the texture component changes because you will have a different deformation mechanism.

So, there will be also effect of alloying element on the texture component. So, we have seen that there can be different types of texture component in different material with different crystal structure for example, BCC and FCC and we have seen the exact location of different texture component in these two different types of material and we have also seen that there will be effect of alloying element also on the development of texture as a function of processing.

So, this was a short lecture to give you an overview of different type of texture components, which can be there in the BCC or FCC materials, so with that thank you for your attention.

Key words- Texture, Brass texture, Goss texture, S texture, Cube texture.