Introduction to Materials Science and Engineering
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Lecture – 100
Residual stresses and quench cracks

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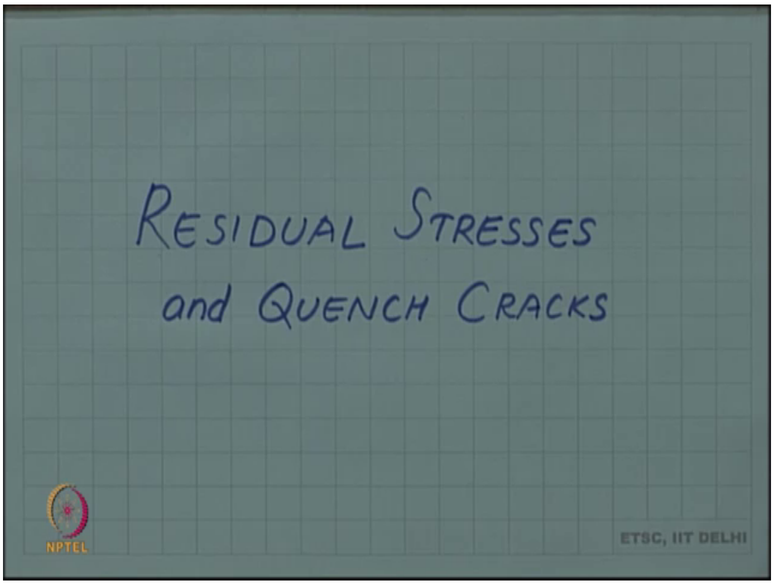

One of the problems of quenching to produce martensite is generation of residual stresses and sometimes it leads to quench cracks. So, let us see why this happens.

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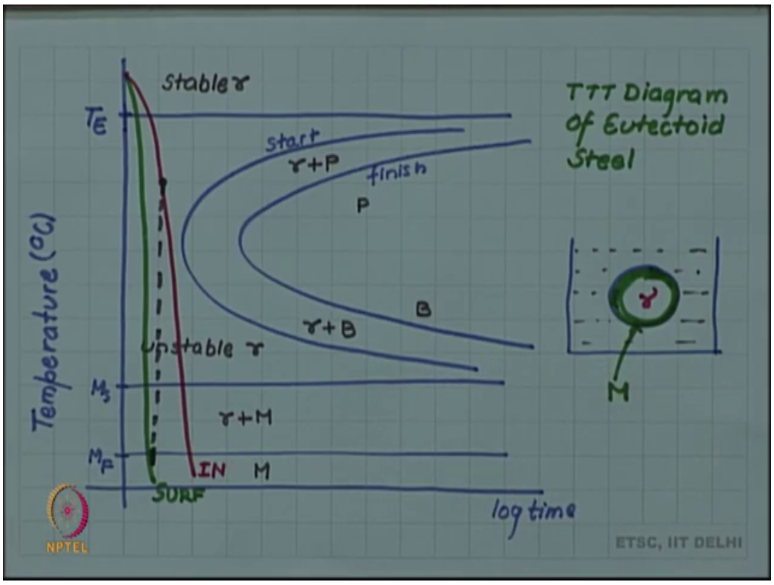

We have we have seen that in quenching we produce martensite and this can be described by a TTT diagram like this. And we drew and we drew a single cooling curve or a quenching curve like this giving us martensite, but note that if a large object is being quenched. So, the component size is large if the component size is large then all of it will not come to the quench and temperature for all of it will not cool at the same rate. So, the surface will cool much faster than the inside.

So, this is the object and the surface will cool faster than inside. So, let us say that this red curve is showing the cooling curve of inside. And let me draw another curve with a faster cooling rate which is indicating the surface, the cooling rate at surface.

Now, you can see that when the surface crosses martensite start and martensite finish at this temperature at this time. At that time the inside is still warm. So, the surface has dropped below MF temperature and has formed martensite surface can form martensite, but inside it is still warm and it is still austenite.

Now, gradually as cooling will continue the inside will also transform to martensite, but there is a problem with this kind of transformation.

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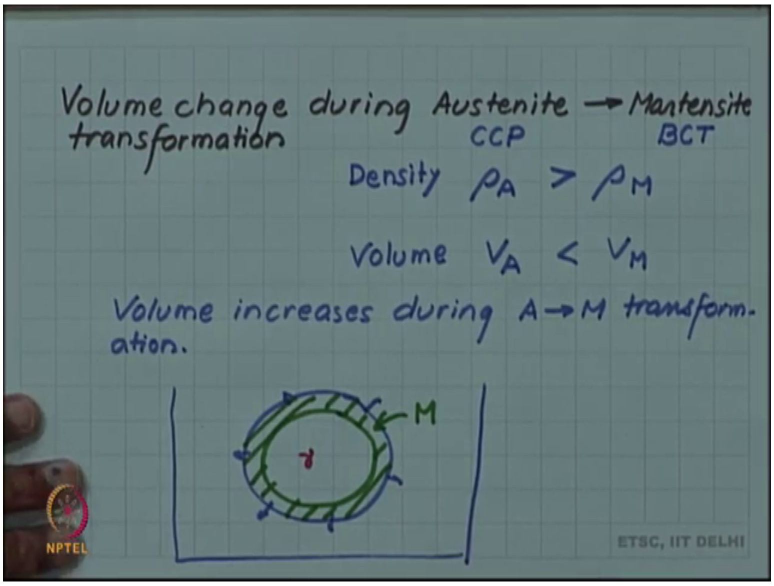

So, let us look at let us consider the volume change during transformation, volume change during austenite to martensite transformation; we have looked at the crystal structure and we said that the austenite was cubic close packed whereas, martensite was body centered tetragonal which obviously, means that a cubic close packed structure is the densest packing possible for a given set of atoms. So, this will have the highest density.

So, if I write by rho the density the density of austenite is greater than density of martensite or in terms of volume, volume of austenite will be less than the volume of martensite. So, which means an expansion takes place when austenite will change to martensite volume will increase during austenite to martensite transformation. This volume increase is now going to cause some problem in our large component quenching.

We saw that initially the outer shell which cool faster formed martensite. So, this has formed martensite and this involved volume increase, but the constraint for that increase was much less because it was in the quenching medium, machine the component was in quenching medium martensite, wanted to expand and there was a space for it to expand at least outwardly.

So, outwardly there was no constraint for volume expansion, but later on when the inside also crosses martensite is start and martensite finish and it wants to transform to martensite. So now, when this gamma will cool this will also like to expand, but then it is inside a hard and brittle martensite casing. So, there will be a resistance for this expansion leading to stresses.

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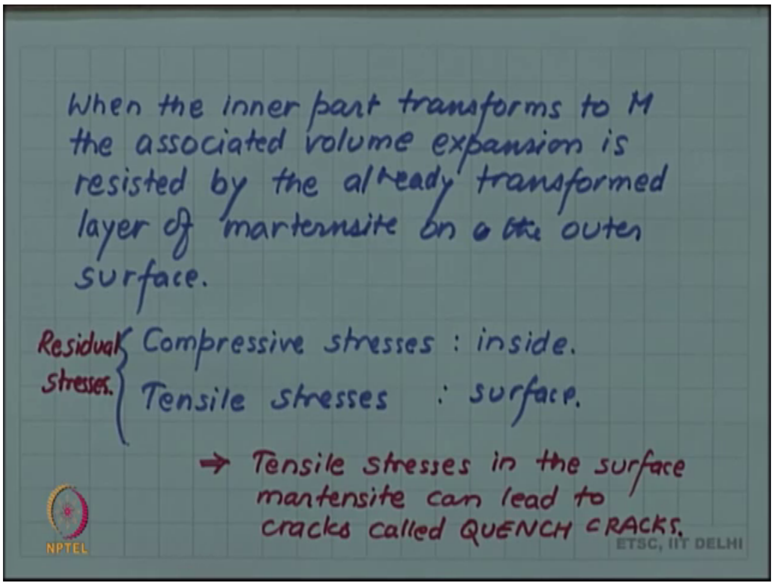

So, when the in when the inner part transforms to martensite the associated volume expansion is registered by the already transformed layer of martensite on the outer surface.

So, when this gamma wants to transform to martensite, when this will want to transform to martensite it will also like to expand that expansion is resisted. This will lead to compressive stresses. So, compressive stresses on inside and correspondingly tensile stresses on the surface, these stresses are called the residual stresses because we are not applying any external force to generate the these stresses.

And in particular tensile stresses are quite dangerous because they lead to cracking and these tensile stresses you can see are there in the hard and brittle martensite layer. So, the tensile stresses on the surface martensite can lead to cracking, which is called quench cracks. Because it is happening during quenching during the formation of martensite they are called quench cracks.

So, the whole effort of the heat treatment if quench crack happens the whole effort of heat treatment is lost. We have made effort to austenitize the sample that is we heated it to form austenite then we made effort to quench it to form martensite. And then later on we would have tempered, but before we can temper this product has already cracked. So, this is a loss from production point of view from engineering point of view and this needs to be avoided.