Introduction to Materials Science and Engineering
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Lecture – 99
Tempering

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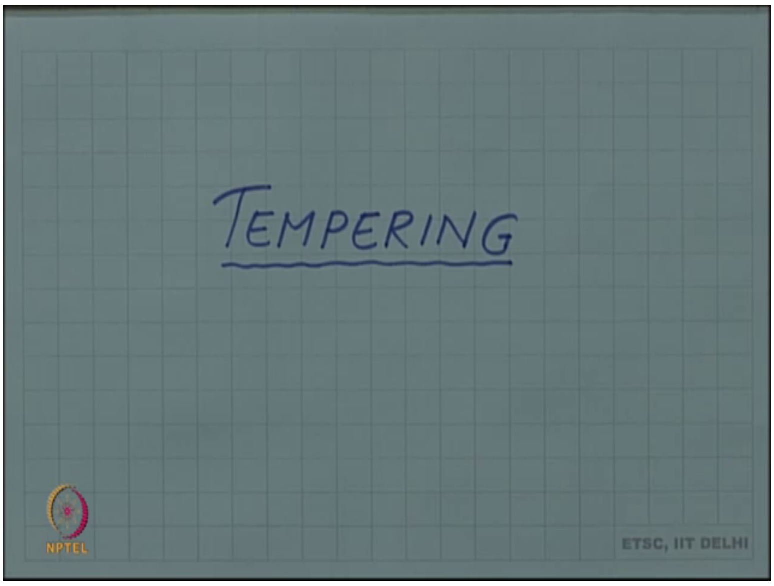

So, let us discuss the last heat treatment in our list of heat treatments and that is tempering. Now tempering we showed when I drew the time temperature diagram; temperature versus time.

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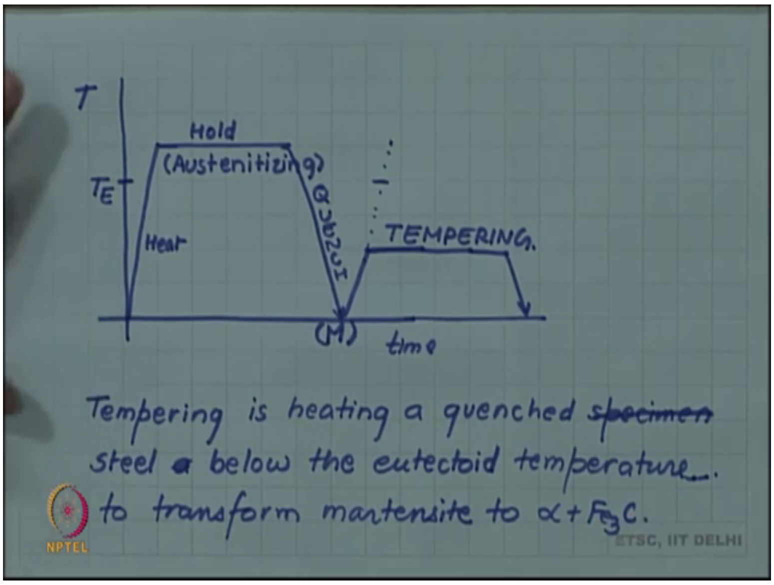

So, we heat the alloy above the eutectoid temperature for eutectoid steel. It has to be above the eutectoid temperature such that you form Austenite. So, the heating was for of forming of the Austenite and when you had full Austenite, then you quenched.

So, holding is really for forming Austenite. So, sometimes this step is called austenitizing. Austenitizing is the holding step and then here we are quenching. And quenching produces a Mmartensite gives us Martensite and then if we heat this to some temperature. Now obviously, to what temperature we will heat? So, if we heat it again about Austenite temperature. So, notice we have formed Martensite here, let me write M for Martensite. So, if I heat it again above T E then the whole purpose of holding and quenching was lost because we will again form Austenite. So, we in tempering we do not go above T E. So, we hold it below T E, the eutectoid temperature for some time and then again cool.

So, this step is tempering. So, we can say tempering is heating of quenched specimen or you can call it quenched steel below, below the eutectoid temperature. But what this heating achieves? Let us look at, Martensite was an unstable phase and if we are heating it, so Martensite form. So, let us look at the phase diagram again and carbon phase diagram.

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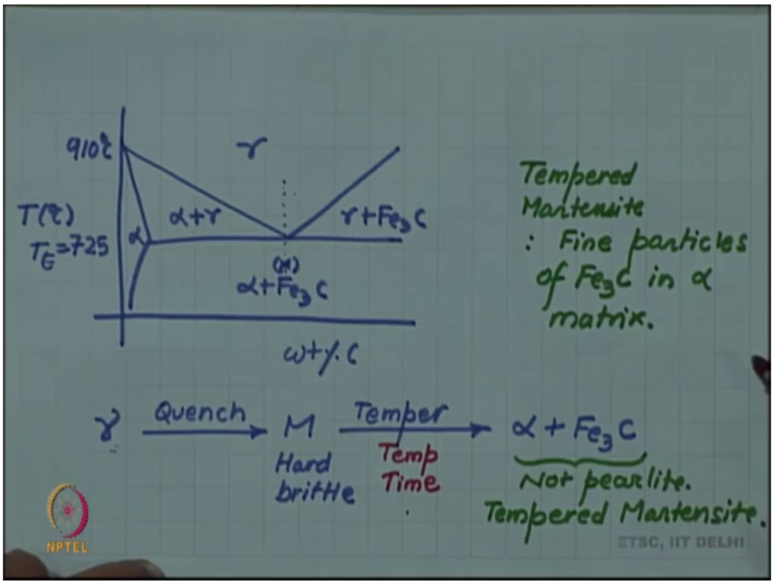

So, in this phase diagram if I and if I take Austenite steel. So, if I cool slowly I would have formed Alpha plus F e 3 C. Since I quenched, I avoided the formation of Alpha plus F e 3 C and formed a metastable phase Martensite. But now if I take that Martensite to a temperature below this T E, the eutectoid temperature and heat it then again the unstable free or the metastable phase Martensite will tend to transform to Alpha plus F e 3 C.

So, in tempering the result of the tempering is temperature to transform Martensite to Alpha plus F e 3 C. So, let us say that we have Austenite and we quenched it. So, we formed Martensite and now we are tempering it to produce Alpha plus F e 3 C.

So, question may come to your minds that, why are we going through this circuitous route? That first we quenched to form a metastable phase Martensite which was hard, but was also brittle and then we again heat it. So, there is an additional cost, additional time involved to get Alpha plus F e 3 C. If Alpha plus F e 3 C was what was desired, we could have directly got by cooling of Gamma. Slow cooling of Gamma directly would have given me Alpha plus F e 3 C without going through this intermediate Martensite without going through that excessive effort and cost of quenching.

So, if as we have seen that slow cool will give me coarse Pearlite by annealing or fine Pearlite by normalizing. So, I could have got Alpha plus F e 3 C simply by direct my direct cooling of Gamma; there is no need to quench and temper. The thing is that, this Alpha plus F e 3 C which you are getting is not Pearlite just like you saw in Bainite. This is also not Pearlite, this is not Pearlite.

This microstructure Alpha plus F e 3 C is called tempered Martensite. So, distinguish it from Pearlite, it is called tempered Martensite. And the description of this tempered Martensite is that F e 3 C are in the form of fine particles.

So, tempered Martensite is fine particles of F e 3 C in Alpha matrix. So, what it achieves in terms of mechanical property is that the hardness is reduced, but at the same time brittleness is also reduced. So, Martensite was good because it was very hard, but at the same time it was bad because it was brittle. So, for many engineering applications, we cannot use a brittle phage like Martensite. However, when we temper it we are producing Alpha plus F e 3 C mixture and the distribution the size and the distribution of these F e 3 C particles in the Alpha matrix will depend upon at, what temperature and for how long you are tempering ? So, tempering has two variables; the temperature and the time.

So, we have two controls two variables to control temperature and time and depending on the way we control this, we will get particles of F e 3 C in different sizes and different distribution.

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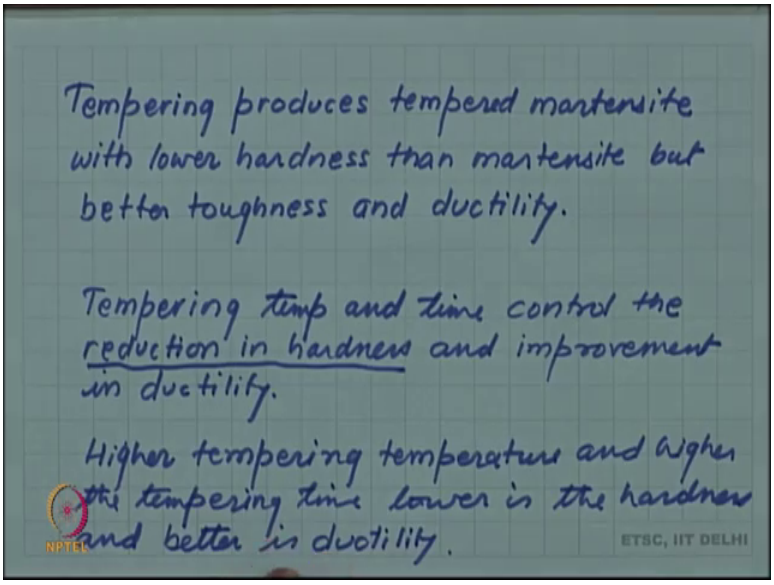

So, tempering produces tempered Martensite with lower hardness than Martensite but better toughness and ductility, better toughness and ductile ductility.

Now, how much the hardness will reduce and how much security you will gain depends on this temperature and time. The tempering temperature and time control the reduction in hardness an improvement in ductility.

So, and higher the tempering temperature temperature and higher the tempering time lower is the hardness and better is the ductility. So, this way you can control. So, you have extra control in quenching you did not have the control. So, you produce a hard and brittle Martensite. But then you can reduce its hardness and hardness will not be reduced when hardness is reduction of hardness is there. The hardness will not go down to the lower value which you will achieve in annealing or normalizing; you still have higher hardness, but you have better ductility if you temper the Martensite.