**Indian Institute of Technology Kanpur**

**National Programme on Technology Enhanced Learning (NPTEL)**

**Course Title**
**Manufacturing Process Technology – Part- 2**

**Module- 11**

**by**
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Hello and welcome to this manufacturing process technology part 1, Module 11, we have been discussing about the equilibrium phase diagrams and particularly I had motioned about the case when 2 materials although fully soluble and liquid may have a problem while going into solid phase and they may not be fully solvable and the solid phase so in context of that we started doing the ion and carbon equilibrium diagram where this property of carbon going up to an maximum of about 6.67% in the solid phase remains or prevails and this you know would be very interesting example of a good equilibrium phase diagram so let me just sort of reiterate what I had done you know.

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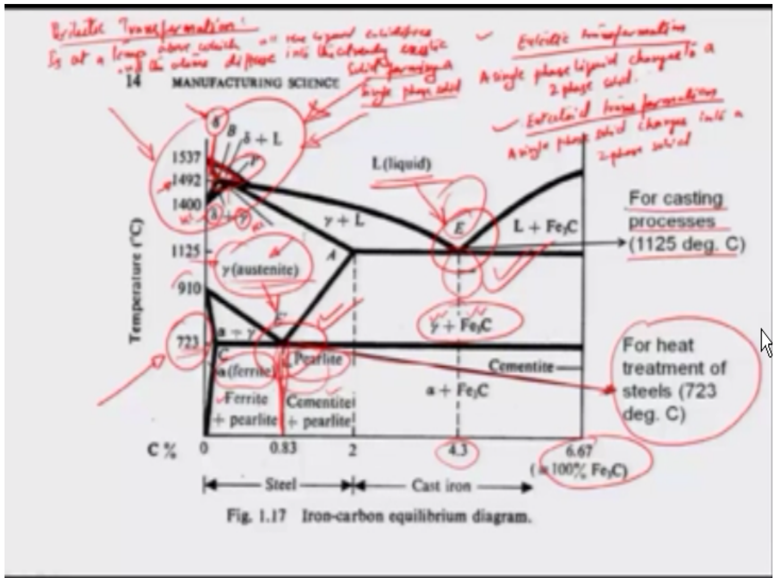


Fig. 1.17 Iron-carbon equilibrium diagram.

In this diagram this right here is the ion and carbon equilibrium diagram you can see that beyond 6.67% is 100% ferric stage which comes and we cannot load beyond this and there are many phases of this diagram for example the phase that can be used for mostly casting process or in this range of $1125^0$ C which corresponds to more than 2% carbon okay, it is about 4 and 4.3 % as this time you can see here and still it is an liquid form in this particular region so then there is a region which is important for heat treatemmat of steels which is $723^0$C which is the particular region right here.

And this is you know related to the sort of metal working process you know it can be metal forming of various kind you know so these are the some other temperatures which are used and also $723^0$ is very critical because you can change properties of the material at this particular temperature by heating cooling and doing various kind of heating, cooling and all sort of you know chemical treatments or heat treatment process like carburizing, nitrating so on forth.

So this temperature is very critical from a properties materials properties system stand point there are other there is another yet a another region which is actually important from a materials point engineering point of view which is this region right about here where there is a phase $\delta$ iron and again which is allotrope you know allotrope of ion and as you are already aware that there are 3 different states or crystal structures.

And which ion can be present one is below $910^0$ which is actually forms the α ion phase which as a body center cubic structure the movement you go above 910 all the way to about let us say

$1400^0$ C you have the $\gamma$ iron just an iron which is actually the phase interred cubic structure and then the $\delta$ again becomes the BCC, so basically it is transitions from bcc to fcc to again bcc which happens and then this $\delta$ iron bcc is always above $1400^0$C.

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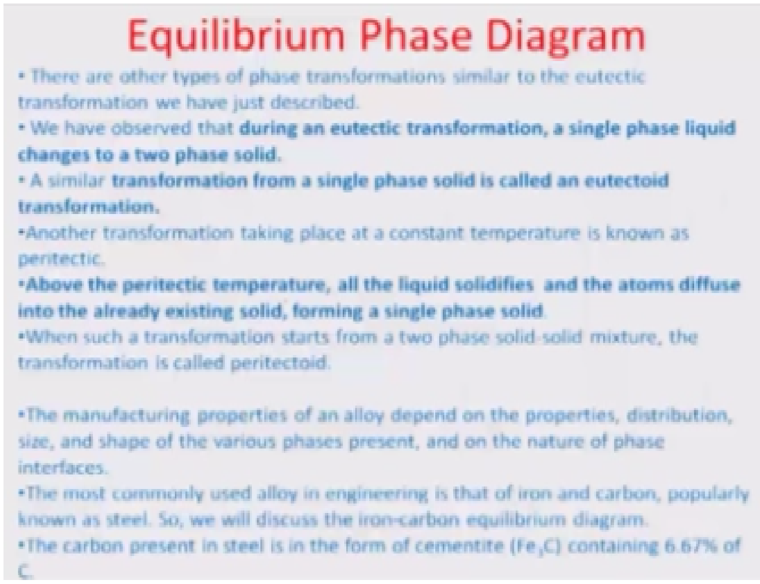


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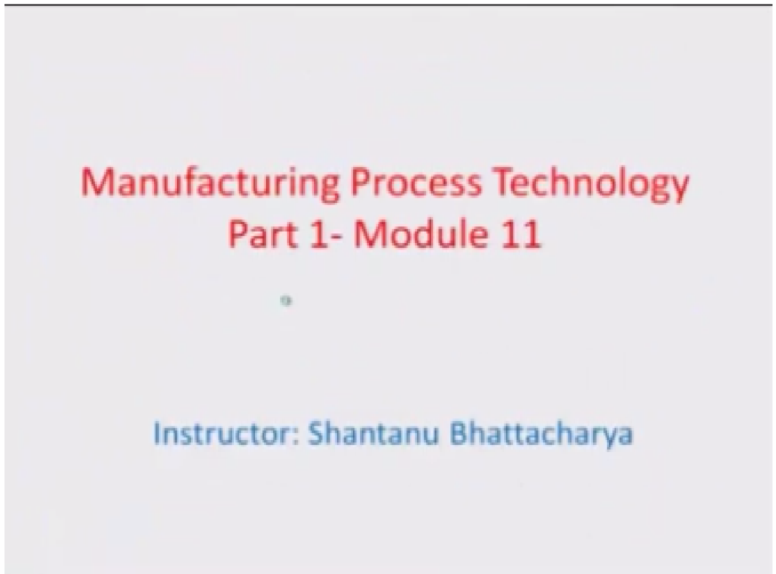


If we may remember from the last lecture.

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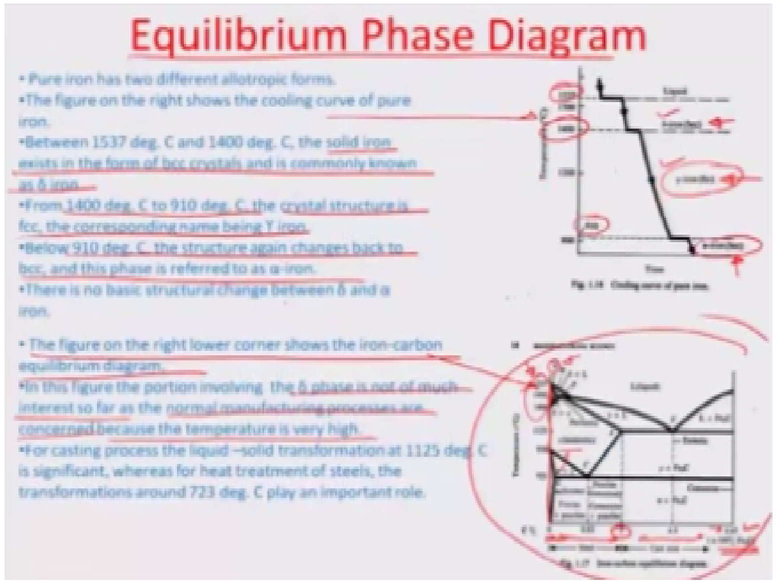


We had discussed this you know where we are made sphere how this iron changes states how distill structures at different temperature ranges so this is also a very important zone particularly this zone, particular this zone here from the materials engineering stand point although in the applicative stand point it may not be many much used because at such a high temperature metal is seldom use for any of the practical applications, so the two zones of this curve which are really important from application stand point are this zone write about here $1125^0$C and this zone which is about $723^0$C.

So there are other type of you know transformation similar to the eutectic transformations we had discussed eutectic if you remember in the last lecture where you know in the eutectic case in the eutectic transformation, a single phase liquid, changes to two phase solid if you remember in the ice salt diagram we had talked about salt water which was completely uniform and it gets freeze below – $22^0$C at a certain percentage of salt and that structure although it is not distinguishable.

But it is a two phase so basically salt is entrapped homogenously within the ice crystals, so that is what eutectic transformation is here also the similar kind of a behavior can be observed and here really a the eutectic transformation point could be this point E write here, where we have a convergence of the liquid into homogenously available two phase solid structure which has γ iron which is the fcc iron and Fe3C you know cementite is dispersed uniformly a across the γ iron phase, so there is nothing called excess cementite or something like that it is all one structure that is there.

And so this is how you can actually change the process and make a one phase a single phase liquid completely convert into two phase solid, two phase solid meaning that you have the presence of both the phases throughout the particular crystal. The other point which is interesting for us to consider is the eutectoid and the eutectoid transformation in this diagram corresponds to a situation where instead of a single phase liquid a single phase solid changes in to a two phase solid okay.

So in this diagram we look at carefully this particular point E' write here we have one hand $\gamma$ austenite which is a complete FCC, so in this case as you know the austenite is already a FCC structure and then you can going to convert that in to perlite which is again you know sort of again two phase solid structure of so it is you know combination of cementite and ferried, ferried being the $\alpha$ iron which we commonly known as the BCC crystal and cementite is Fe3C so basically again it is another case where the solid that is formulated as a continuous distribution of both the $\alpha$ as well as the cementite the ferrite as well as the sementite although the crystal.

So similar to the composition what is here two phase solid similar kind of a composition exist in this particular region and this is known as perlite. So that is the eutectoid point, so these two transformation are very important from the stand point of the application you know application in the industry but the material engineering properties as I told you comes in this phase where there is another transformation which is actually known as peritectic transformation.

And I will just defined what peritectic transformation means. So this peritectic transformation refers to a point of you know is then at a temperature about which all the liquid solidifies and the atoms diffuse in to already existing solid forming a single phase solid if we look at this point right about here you have a single phase solid $\delta$ in this region over it right so this is $\Delta$r and you have an $\delta$ iron liquid in this particular region which is showed by this so you have semi solid semi liquid kind of a transition here now if I look at the structure which is just about here it is the combination of the $\Delta$ and the $\gamma$ iron you remember $\delta$ is the BCC phase and $\gamma$ is the FCC phase.

So both of them are combined here and the moment it is changing the temperature it is going into a single phase solid that is Δ+ liquid so whatever is happening to the γ structure you know it is sort of reorienting itself towards the BCC from the FCC structure okay so you are formulating a single phase solid above this temperature and below this temperature it is always a two phase solid.

So basically from a two phase solid to a single phase solid in terms of the structure is converted when we talk about the paretic point so this is of not much significance although but they materials is stand point of an engineering stand points material engineering stand points we try to explore this a particular point of temperature.

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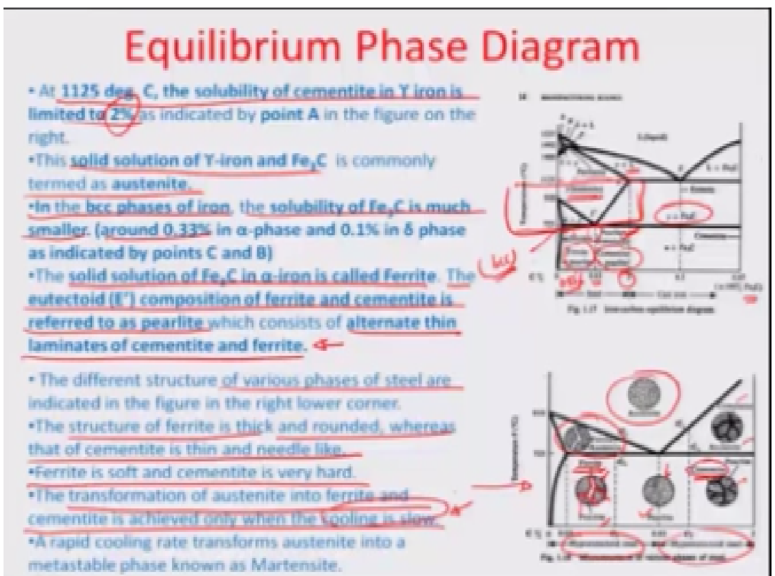


So having said that we have this three eutectic, eutectoid and paratactic points in the atom carbon equilibriums diagrams so let see structurally again so at 1125° Celsius the solubility of Cementite in γ iron is limited to 2% so you can see this write about here in this 1125° Celsius is this temperature right now and you can see that beyond 2% carbon which obviously formulates $Fe_3C$ or cementite the phase change is from γ+ liquid okay so any further rise would lead to change the phase.

And cementite would start coming out .so maximum 2% can be held and that is where the steel zone really is beyond this starts becoming model casting if so the solid solutions of γ iron and $Fe_3C$ is commonly known as austenite which is actually right here okay you know this γ iron and

$Fe_3C$ these are the austenite in BCC phase of iron the solubility of $Fe_3C$ in much smaller around . 33% as you can see here this is the BCC phase of the iron ferrite.

So you call it ferrite okay and you know the moment the percentage increases to anywhere more than 0.33% carbon again the pearlite starts coming out okay as you consider this particular zone is ferrite pearlite and if it goes beyond certain a point .83 again starts formulating cementite pearlite rather than pearlite, pearlite remember is the eutectoid single phase I mean two phase system of ferrite and cementite distributed through the structure homogeneous okay.

So if I look at these structures is here this is how pearlite would look like so it is only uniform homogeneity in the mixture of ferrite and cementite on the other hand if we look at how the mixture of ferrite and pearlite can be so there are some additional you know you can see this white marks here all though these the actual structures but it is just a cartoon indicated of what is going on.

So you have the peer zone of ferrite you know apart from the pearlite regions which are the two phase solid you know which we are talking about and in this particular you have the peer zone the black zones the peer zones of cementite which are over and above the pearlite which is again combination of fenoid so two phase solid of ferrite and cementite so this is how you understand the iron and carbon equilibrium diagram.

So the solid solution of Fe3C in α iron is called as ferrite so you have the ferrite in this particular region the eutectoid composition of ferrite and cementite is pearlite again you have this pearlite here which consists of alternate thin laminates of cementite and ferrite so that is what I am saying that the two phase solid you must always the market as a one wear structure there is no difference represented of both the phases are equal throughout the crystal matrix okay, there is no separate zone for the presence of the one over the other. So that is how eutectic coed or eutectic composition would typically happen okay.

But there any where between the before or beyond the eutectic or eutectoid composition, which are also known as the hypo eutectic or eutectoid, hyper eutectic or eutectoid composition. You always have this tendency of one phase coming out and becoming independent.

In this case you can see for example, the ferrite phase came out; in this case too saw the cementite came out. So there are pure zone formulated, over and above the uniform two phase solid structure pearlite which is their okay. So that is how you basically try to understand the iron carbon equilibrium diagram and the different structures of the various phases of the steels are kind of indicated here, you have this ferrite Austenite, which is again a two phase solid combining.

But then three homogenous is distributed around the matrix and then you have cementite and austenite combination which happens over this temperature, in this particular region, so the structure of ferrite is thick and rounded, where as the cementite is thin and need a like. Here is the some of the properties, ferrite is soft, cementite is very hard,. The transformation of austenite into ferrite and cementite is achieved only when the cooling is slow.

That is the very important factor as well and we are going to do the time temperature diagram very soon, after this where we talk about the impact of the cooling in the various structures. So if a rapid cooling rate is for example provided to, you know let us say, austenite it may transform in to altogether into marten site okay. So the rate at which the cooling happens is also, is going to enable what is the final structure that gets formulated.

Because you are not giving it enough equilibrium time and obviously the diffusion process are very slow. So there are going to be some changes in the crystal based on that. So having said that, that is how you study this equilibrium phase diagram of very important iron ad carbon, and used very commonly in the industries, so one snapshot go off what phase? What temperature? What percentage? Let us say structure gets formulate. So you can visualize this entire thing in the single sheet of paper through this diagram.

So having said that we want to sort of close this module but then in the next module I am going to do something related to control of material property where the cooling rates become very important and we will talk about the diagram, which is famously known as TTT or time temperature transformation diagram. With this I close this module thank you so much.

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