Welding of Advanced High Strength Steels for Automotive Applications
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Lecture - 04
Introduction to Advanced High Strength Steels

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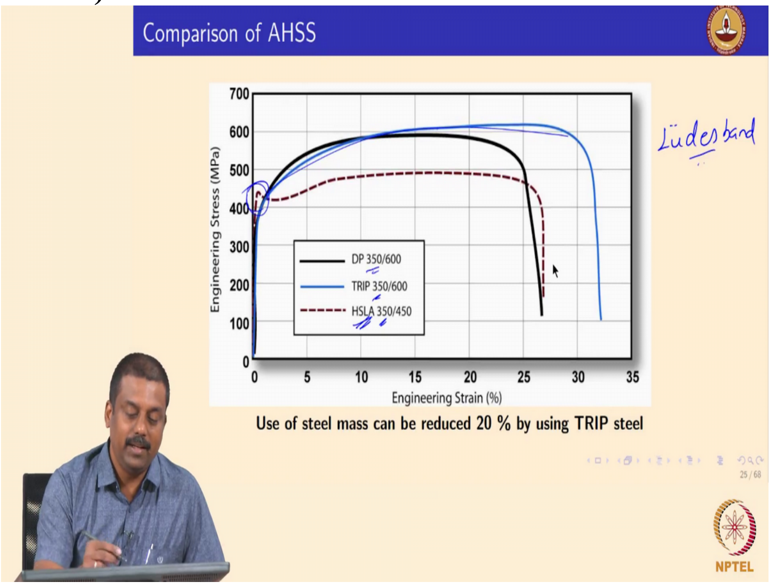

So, apart from the HSLA steels you look at it you are here so only the bake hardening Steel's would also show the Lodusband formation because the carbon is still intertial positions. So, bake hardening steel also show the yield point phenomena but IF steel do not show yield point phenomena Lodusband formation that is why the IF steel's are very attractive to; in those days to make a deep-drawn components because IF steels does not have any carbon in the intertial position.

So, IF steel will show similar behavior but the strength level will be much lower compared to DP trip steels good.

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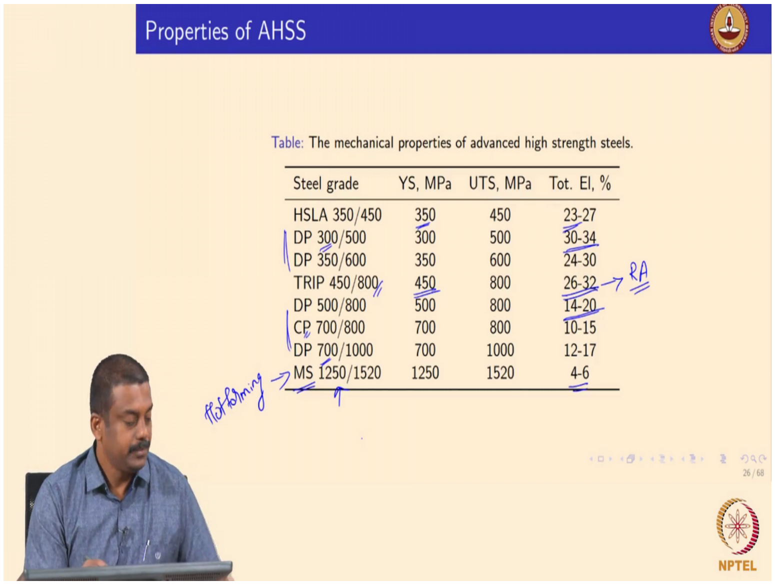

So, this table shows about the properties of advanced high strength steel's comparing with HSLA steels and if you look at it here the mechanical properties are varying from SI theorem ma Pascal until to 700 to even up to 1000 ma Pascal okay whereas in HSLA steels it is very difficult to change the mechanical properties because the microstructure is more or less fixed and the alloying elements are fixed.

But in DP and especially in DP and complex based steel's you can play around with the volume fraction of phases the amount of martensite or any other phase apart from martensite for example bainite present in complex based steels we change around play around the strength level it can change can be change from 300 to even up to 1000 ma Pascal. So, thirds generation dual phase steels and we add alloying elements and precipitates to get the strength levels even up to 1 Giga Pascal DP 1000 for example.

So, and therefore the DP ideal phase steals and complex phase steels in some extent trip steel's are very attractive because we can generate steels with varying properties within a reasonable ductility. If you look at it here for example the HSLA steels the yield strength again 50 ma Pascal and 450 Ets the elongation is about 25% whereas in a DP Steel's with the similar strength level provide slightly higher elongation then the HSLA steels.

And by increasing strength of course you deduce the elongation but still it is acceptable for example DP 500 and DP600 with the 20% elongation and it still is very handy to make components out of it. And trip steel and we have a reasonably in strength and the ductility is very high compared to then the similar strength containing in DP steel's because of the micro structure consisting of retained austenite okay. So, we will see what is the role of retained austenite and trip steel.

And as of now we can understand that you know this trip steel posses much higher uniform elongation total elongation than DP Steel's for a given strength level and apart from that we also have a martensitic steels and this is mainly the hot forming steels. Hot forming steels you do not need to worry about the elongation will because this elongation is actually after forming but before forming these steel's contain a simple ferriric pearlitic microstructure so you can form it easily.

And then upon forming quench it to get a martensitic microstructure so we can achieve the strength of 1200 to 1500 ma Pascal at the component level okay good.

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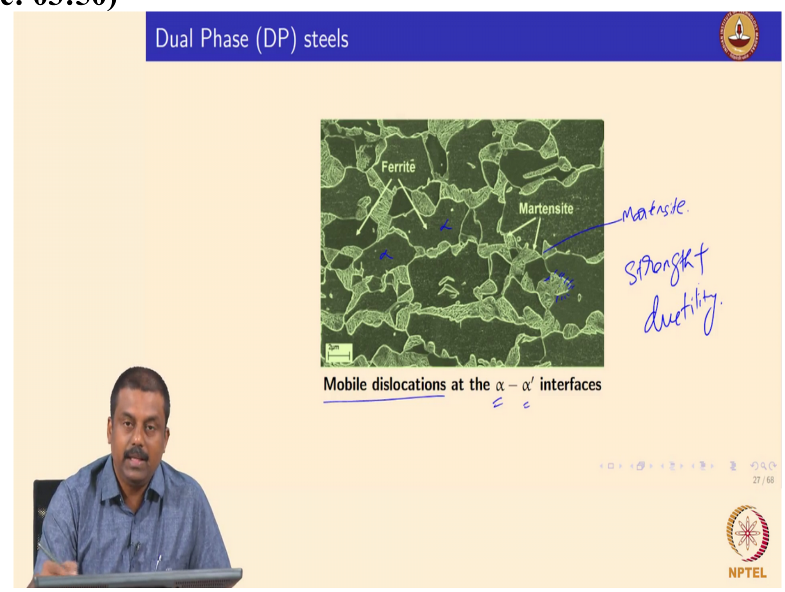

So, we now look at in detail about the physical metallurgy of these the advances high strength steels mainly dual phase trip and hot forming martensitic steels. So, as already explained the dual phase steels and these steels contained containing two phases mainly in the ferrite and martensite okay. So, here we see the matrix here so these grains are ferrite lines and in between the ferrites and you also see the grains of martensite right. And we generate this multi phase microstructure or dual phase microstructure by a special heat treatment okay.

And this special heat treatment make sure that you know we have a martensite in the reason formation reasonable cooling rate and when the martensite forms during this treatment during this heat treatment and a martensite also I mean for martensite forms in and adjoining ferrite matrix. There is significant amount of volume expansion which can lead to the formation of large amount of mobile dislocations.

At the interface between the ferrite and the martensite and to in order to accommodate the volume expansion of the martensite formation and this mobile dislocation that are present at the interface between the ferrite and martensite and increases the ductility significantly because you all know that in a plasticity information is actually caused by the moment of dislocations.

If you have large amount of mobile dislocations and these dislocations can enhance the ductility of the material significantly. So, we also know that martensite is an high-strength phase when you when you have martensite strength also increases significantly. So, by having the martensite embedded on a ferrite matrix and with the large amount of mobile dislocations at the ferrite and martensite interface and we can get the combination of strength and ductility right.

And how we get this microstructure we will see the eternal cycles what we use to get microstructure in subsequent slides before that we will see the micro structures of other steel's.

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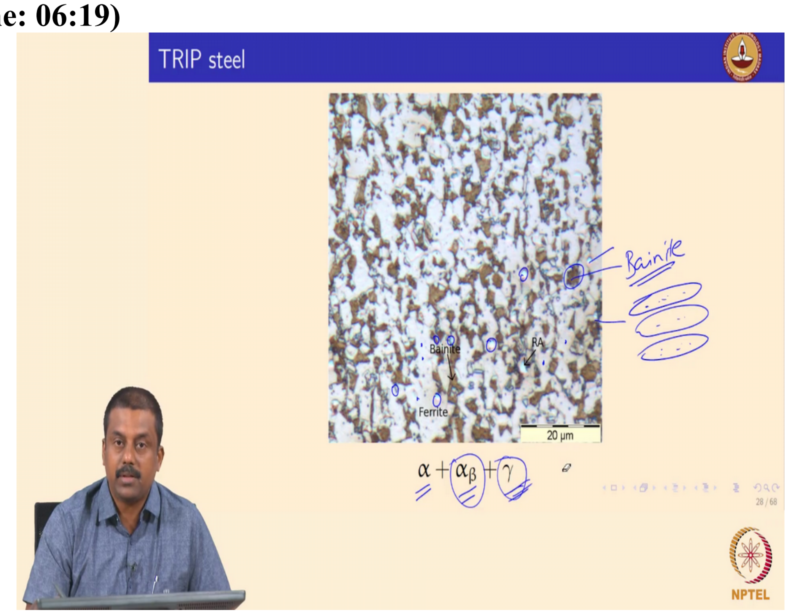

If for example trip steel again trip steel also as I explained has a very good strength as well as ductility which is slightly higher than even dual phase steel and because of this microstructure I show you now in this slide. The trip steel microstructure typically contains the ferrite and the bainite and some amount of austenite okay. So, this austenite is known as retained austenite generally we all know that austenite is high temperature phase in an iron carbon system.

But by doing some tricks, tricks meaning by adding a certain alloying elements as well as carrying out some special heat treatments we can symbolize retained austenite at room temperature among the ferrite and bainitic microstructure okay. So, you see that in this micro structure and there are three colors phases the matrix. So, these guys are ferrite and this brown guy over here so this is actually a bainite.

And that is the bright blue high lines used over here they are all retained austenite in the micro structure okay. So, again this bainite what you see over here in these microstructure okay it is not conventional bainite basically what you over here is the bainite without cementite in between the lots of ferrite. So, we recall when he talk about the bainite formation, bainite contains a ferrite lath in between you have a cementite and then ferrite and then again cementite and again ferrite and cementite in a conventional bainite microstructure.

But again in this trip steel and we add some alloying elements which can suppress this cementite formation. So, you may end up performing ferrite it is slightly supersaturated in carbon concentration so carbon atoms. And by doing so we gain some advantage of the carbon migration to the austenite that is transforming and because of that we can stabilize austenite at room temperature.

I will explain in a thermal mechanical cycle of the trip steel heat treatment wherein you know we can understand how the microstructure can be generated in a special heat treatment the advantage of this microstructure is the enhanced ductility coming from the transformation of austenite to martensite upon applying a load okay. So, this transformation of austenite to martensite upon load is actually known as a stress reduced transformation.

And so when you make a component out of the steel it can also deform it because of the retained austenite when it actually transformed to austenite, transfer martensite by stress. The mechanical energy you put it in is consumed by this transformation resulting in any increased elongation during forming. And apart from that no because the austenite is transformed into martensite during forming during deformation and we also gain advantage in terms of cross performance.

So, how suppose if you make component out of trip steel and you have a retained austenite in the microstructure and if I automotive is actually subjected to a crash load the austenite transforms to martensite during the deformation and but thereby absorbing the load. The material becomes stronger during this crash because of the formation of martensite from austenite. So, we gain advantage in terms of formability because the when they austenite transform to martensite by load.

The mechanical energy coming from the deformation load is observed to try to transform the austenite to martensite thereby we increase the elongation significantly and apart from that by leaving it in austenite in the formed component and this retained austenite can transform to martensite while applying crash load. So, the component becomes stronger in doing applications so this microstructure of ferrite and bainite without cementite and the retained austenite is very attractive for automotive applications because of the strength which is achieved from the alloying as well as the presence of bainite.

And the supersaturated bainite and the elongation superior elongation given by the stress induced transformation of austenite to martensite okay.

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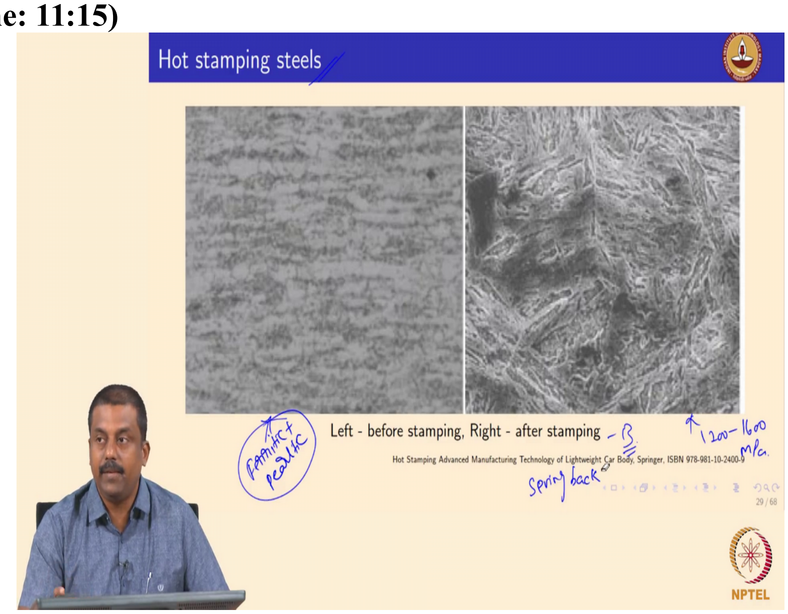

And the third generation a third significant improvement in terms of strength we achieved in automotive steels is by martensitic microstructure. So, in this process of forming martensitic microstructure we want significant change in alloying elements compared to say for example DP and trip steel. And hot stamping steel's are martensitic steels they have a similar alloying elements except some special alloying elements which increases which increase the hardenability significantly.

So, now the alloying elements is boron so we had some amount of boron the microstructure you to begin with it is still is pearlitic ferritic microstructure what you see over here and this pearlitic ferritic micro structure containing a slight amount of boron it is taken to high temperatures and to form austenite to completely transform the ferritic pearlitic into austenite micro structure and then we deform the component at high temperatures.

And then subsequently we cool it cool the components after forming to form martensitic microstructure okay and doing this cooling process we already seen from CCT diagrams if hardnability is significantly higher and even with slow cooling rates we may end up forming martensite complete martensitic microstructure upon forming.

So, the components gain significant amount of strength because of the formation of martensite this strength level can go up to 1200 to 1600 ma pascal upon forming but the forming is easy because the material flow much easily at austenitic temperatures. So, you form whatever components shapes in deep drawing and forming and then subsequently cool to get a complete martensitic microstructure.

And doing this process we increase the strength and also we overcome problems during forming just spring back. So, which is also minimized during this process so these three steals dual phase steels, the trip steels and hot stamping steels and they are all now commercially used and we look at in detail about the actual forming the micro structural formation mechanisms as well as in subsequent classes will see the welding behavior of dual phase and trip and hot stamping steels while making the auto components okay.

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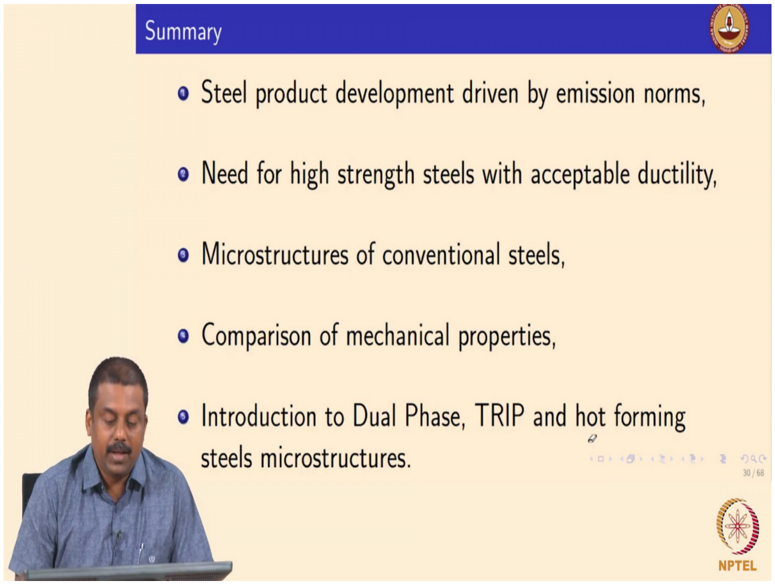

To summarize the physical metallurgy of these first and second generation and the third generation advanced high strength steels, steels product development is actually driven by the emission norms plus the improve the crash performance required to meet the various standards. So, the need for advanced high strength steel's with the acceptable ducctility arise because of these emission norms light weighting.

The micro structure of conventional steel is used in automotive industries are very simple, simple ferritic and pearlitic but they were not sufficient to give high strength required to reduce the weight to down gauge the thicknesses of soft materials used in that. So, we looked at the micro structures of convention steel's like IF steels, bake hardening steels, HSLA, ferritic pearlitic, carbon-manganese steels.

And why these steels no it cannot be used to achieve light weighting because once increase the strength in these steels by adding alloying elements or heat treatments and the ductility comes down decrease significantly. So, we went ahead and developed some of the advanced high strength steels such as dual steels, trip steels and complex phase steels. So, we look compared and we looked at the composite mechanical properties comparison between mechanical properties of DP steel and trip steels.

Why with given yield strength DP and trip provides much more superior elongation total elongation as well as in high strength UTS and that this combination of strength and ductility is achieved by the multi-phase micro structures in trip steel and ferritic pearlitic martensitic microstructure in dual phase steels okay. So, we also looked at the micro structures of a dual phase and trip and hot forming steels.

So, what are the phases that are present in these steels so with that and we will conclude this physical metallurgy chapter and we move on to the actual heat treatment that are used to generate these complex micro structures of dual phase trip steels. And we will also look at the simple the basic thermo mechanical cycle used in hot forming operations to achieve the martensitic microstructure in subsequent lectures.

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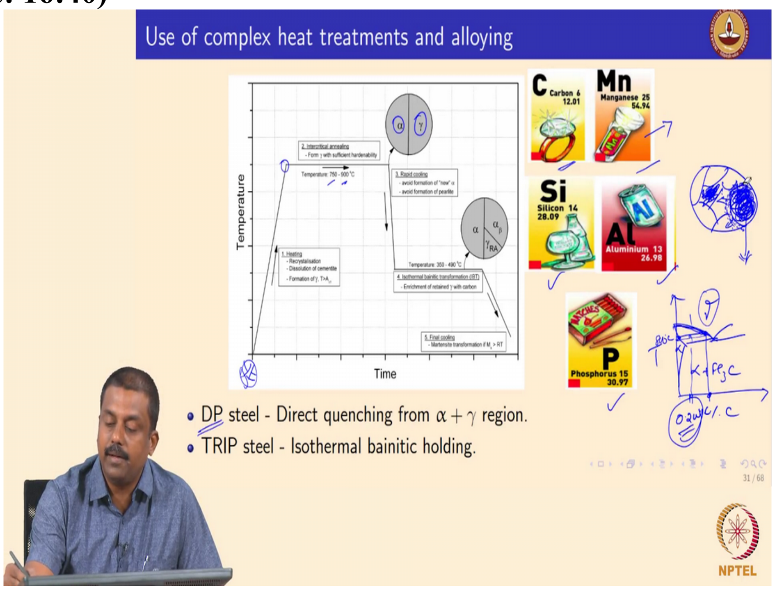

So, I will start with the introduction about the heat treatment that is commonly used to generate dual phase and trip steel micro structures okay. So, before going to that you know as I already explained apart from the carbon if they generally are added iron system to form the micro structures and to achieve the the strength and various properties and these Steel's also contain manganese, silicon, aluminum and some amount of phosphorus which is actually considered yeah detrimental for mechanical properties and weldabilities.

But we say I had slight amount of it slightly low amount of phosphorus as well for various purposes so these alloying elements are added to achieve certain goals for example manganese is added to get significant solid solution strengthening and silicon aluminum they are added especially in trip steels to enhance the formation or retention of austenite at room temperature. I will discuss it in detail when we look at the thermo mechanical cycles for trips and heat treatment.

And phosphorus is also added because it is very effective solid solution strengthener okay. So, this graph shows the normal thermal cycle and it is used to produce the dual phase as well as trip steel microstructure okay. So, in a first we look at the dual phase thermal cycle. So, in a dual phase steel thermal cycles so we take the micros the microstructure can this could be even ferritic pearlitic microstructure to a temperature where we have a two phase equilibrium exists.

For example we do not take it, in conventional heat treatment if you look at the phase diagram we call the phase diagram I taught you in the first classes, so we have a phase diagram showing the protectoid region okay. So, we have a austenite and we have a ferrite plus austenite, ferrite and here ferrite plus cementite. So, in a conventional a heat treatment annealing, normalizing you must have heard the the material is taken to a fully austenitic region right.

And then subsequently you can cool it to various cooling rates to get the micro structures of ferrite pearlite or whatever the martensite even if you quench it faster based CCT diagrams. Whereas in the in dual phase or trip steels heat treatment we would not take it to a fully austenitic region so we take the material to a temperature where we have a two phase microstructure exist.

In this case we take it to a temperature regions where we ever both pearlite and austenite exist coexist this microstructure. The advantage is I will explain now so we take the material to a temperature for example here say in this case I mentioned about sound 759 degree centigrade that is where conventional DP steel and if you have a say 0.2 weight percent carbon and will take it to a temperature say 800 degree centigrade and we hold it there to form a microstructure with the mixture of ferrite and austenite okay.

So, what happens here is ready explained when you hold it here this line gives the the carbon in austenite line and this line gives the carbon in ferrite line. So, by keeping it in these two regions if you have a bulk concentration of .0 .028 percent the austenite which is actually forming well during this holding at this temperature say for example 800 degree centigrade we get enriched because of the carbon partition, carbon migration from the ferrite that is coexisting with austenite.

So, your austenite that is forming at this temperature would have much higher carbon concentration then the bulk carbon concentration. So, by doing so by enriching the austenite that is actually percent in the; this holding at 800 centigrade will have a much higher carbon concentration of the; than the bulk carbon concentration. The advantages over here is we all know that the hardnability increases significantly by increasing carbon concentration okay.

So, now by holding a two phase microstructure region and we enrich the austenite in carbon given by the your A3 line this line and because of this enticement now if you cool it to room temperature the microstructure containing both ferrite and austenite and this austenite would easily transform to martensite. So, you have a microstructure okay there are two phase microstructure okay.

So, we have austenite over here and for example austenite here and these two austenite’s are now enriched in carbon compared to the ferrite and ferric carbon concentration is much lower compared to austenite. So, now this austenite because of the increase in carbon concentration when you cool it even at reasonable cooling rate austenite can transform to martensite right. So, that is how we form the martensite slightly easier than in the conventional heat treatment.

Where in heat treatment if you go to the complete austenitic region your entire austenite would have bulk carbon concentration is now 0.2 whereas in here because of with this the partition of carbon between the ferrite and austenite we enrich the austenite in carbon and that by being increased the hardnability of the austenite significantly. So, when it subsequently cool to room temperature we transform the austenite into martensite okay.

And the cooling rate is again dictated by your process and if you have a high carbon concentration even it is slightly significantly lower cooling rate then the austenite contain only 0.28% you can achieve the martensitic transformation of this austenite. Now these austenite forms austenite transform to martensite. This transformation also accompanied by the volume expansion in the lattice.

So, if you have a volume expansion so what will happen then this austenite when it transforms to martensite okay. so, you will of also have expansion driven a dislocation formation at the interface between the austenite and the ferrite right because the volume expansion we will be accommodated right. So, this accommodation is actually done by deforming large amount of mobile dislocations at the interface between the ferrite and austenite.

So, we have two advantages the austenite forms to martensite we increase the strength and because of the volume expansion we also increase the number of the density of more by dislocations that represents at the interfaces to accommodate the volume expansion. So, now because of this the special heat treatment where we take it to inter critical region and then we quench it or cool it to room temperature.

So, the austenite which is present in the; inter critical region transform to martensite and thereby strength increases as well as because of the volume accommodation volume expansion accommodation we also generate a large amount of mobile dislocations which can give us the increased ductility okay. So, with this we will conclude and then we will come back again we look at the trip steels heat treatment and what are the roles of these alloying elements and forming the multi phase micro structures thank you.