Welding of Advanced High Strength Steels for Automotive Applications
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Lecture - 02
Martensitic Transformation, Introduction to Modern Automotive Steels

So, this is the typical microstructure of bainite so it is very difficult to see that whether it is upper band or lower band because we do a higher modification. But as I earlier explained apart from pearlite and bainite this another possibility of another phase transformation when the austenite is rapidly quenched to room temperature or else temperature certain below critical temperature your austenite will transform to structure known at martensite which is actually shown in left hand side.

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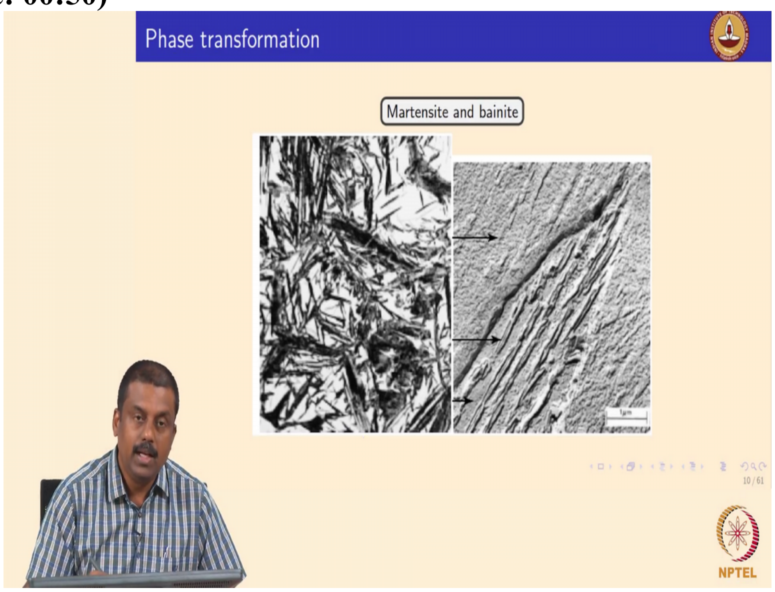

By completely diffusion-less manner so when you are rapidly quenching from austenite from high temperature to room temperature there is not you are not giving enough time to carbon to migrate triggering in the transformations. But the austenite it has to transform to another low energy state phase. So, instead of transforming and trusting and FCC structure the austenite is transforming into another structure which is body centre tetra angle structure.

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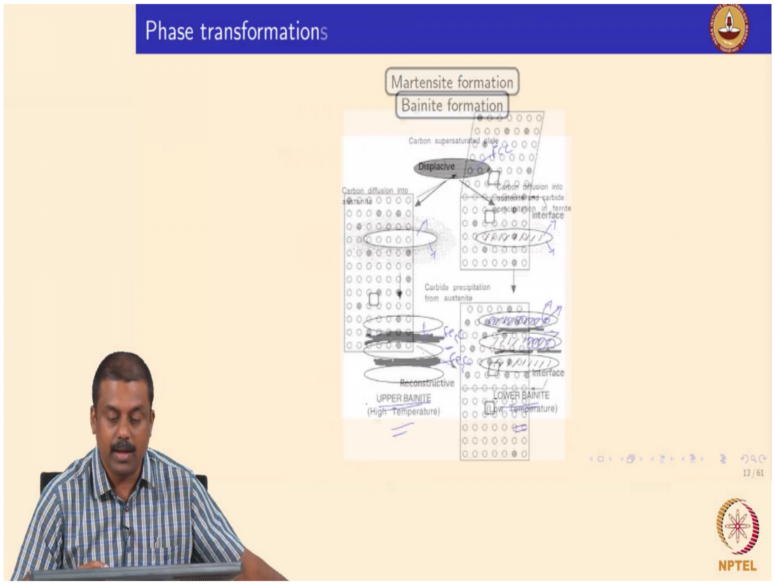

Upon cooling rapidly from the austenitic condition without diffusion of carbon by the mechanism known as displacing, so in the displacing mechanism there is no migration of carbon atom during these transformations. Now the relative positions of the; your atoms change by shear and dilatation I am not going in detail, you just understand and make yourself comfortable that the austenite transformers to phase upon rapidly cooling without any diffusion of carbon or migration of any other atoms. Simply by displasive manner that is known as the martensite transformations ok.

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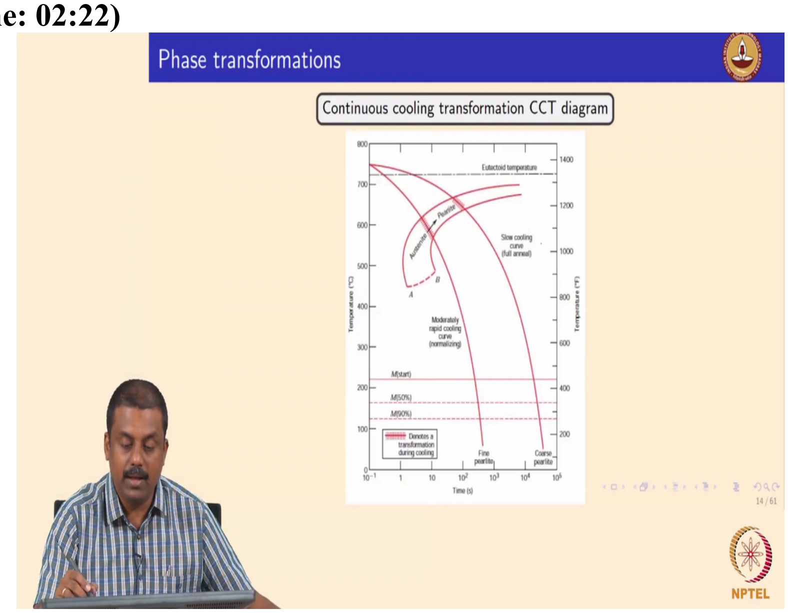

So now we will have to go back to the continuous cooling transformation diagram I already explain the first the top right corner of this CCT diagram which is explaining formation of protectoid ferrite and subsequently the austenite to pearlite transformation. Now suppose if you add the alloying elements and these lines may not stay as it is compare to iron-carbon system ok. Similarly so when you increase the cooling rate in this case if the cooling rate increasing and then you are moving to these lines along this lines. Suppose if you increase the cooling rate you may also avoid various phases that are actually forming at high temperature.

Say, suppose if you are increasing cooling rate from say this rate to the rate of this 1. So in this case you may also; instead of forming pearlite to form protectoid ferrite and subsequently the moment the temperature reaches the point. And your transformation would continue from austenite to bainite right. Subsequently if you keep on cooling down upon this temperature the remaining austenite that is untransformed which subsequent transform to martensite structure. The temperature at which the martensites start forming is known as MS temperature.

And if keep on cooling rate increase the cooling rate and you are also skip the completely the protectoid transformation for example at this point when your cooling rate is high enough your austenite would first transform into bainite the moment you have the temperature reached is bainitic start temperature and subsequently when you are cooling down to the room temperature at this point the remaining austenite which is untransformed transforms to martensite. And if you are rapidly cooling as I earlier explained cooling rate reaches the critical point ok.

If your cooling rate recharge above this point for example for this Steel 3.3 centigrade per second you completely avoid diffusional transformation of ferrite, pearlite, bainite and it will be continuously transforming into martensite. So moment you; temperature reaches at this point all the austenite present in the material transform into completely martensitic structure ok. So, now, so if you add another alloying elements based on the nature of elements whether it is tend to stabilize austenite and stabilize low temperature products.

These lines would either shift towards right or towards left. So, generally the align elements which are known to increase the hardnability or they will be ready to form martensite such as manganese or elements like carbon. You did not to shift lines towards right based on the effectiveness and the stability improved stability by adding alloying elements you can either shift the diagram towards left side or right side.

Generally the alloying elements which are added tend to shift the these lines towards right side what does it mean that means right side of the critical cooling rate to reach the complete martensite microstructure decreases ok. And this is very important to understand because some of the concept to be going to talk about advanced high strength Steel involved the ability to achieve the martensitic microstructure at reasonably slow cooling rate.

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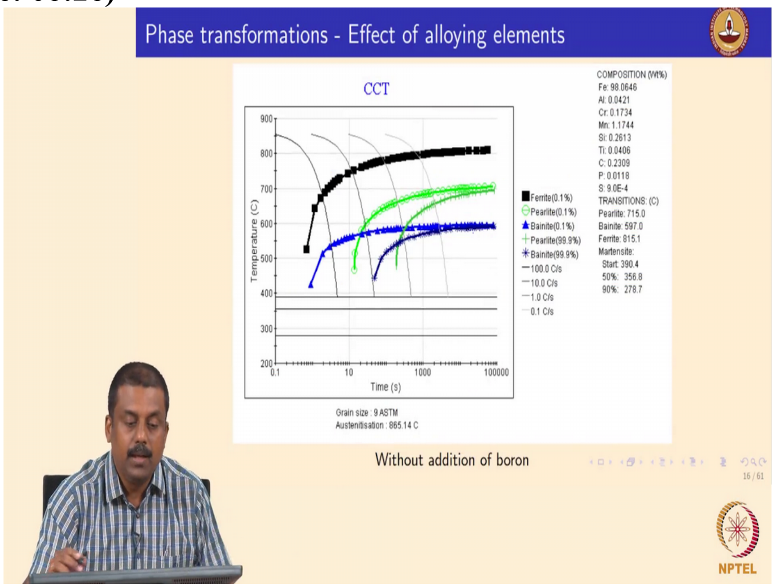

For example I am showing conditions where we have steels with various alloying elements. How the alloying elements additions can shift CCT diagrams effectively towards the right side. So, in this CCT diagram the continuous cooling transmission diagram shows the various lines these diagrams we have black, green, blue and dark blue diagrams. Black shows the start of transmission and the green shows pearlite start and pearlite end, and blue shows that bainite starts and bainite ends. And this horizontal line is the MS line and yeah so I also plotted the cooling rates on the top of it.

Again as I explained if you are cooling the austenite at this cooling rate you would first start forming ferrite and then pearlite and then some amount of bainite ok. And by increasing the calling rate obviously also change the volume fraction of the phases that are forming even for this composition what I am saying showing over here. Even if you cool it at under 100 cane per second 100 centigrade per second you would still form a significant amount of ferrite and pearlite. So now I already explained that addition of alloying elements shift these lines towards right or left.

I will show you one condition where addition of boron will significantly increase the hardanability of the material.

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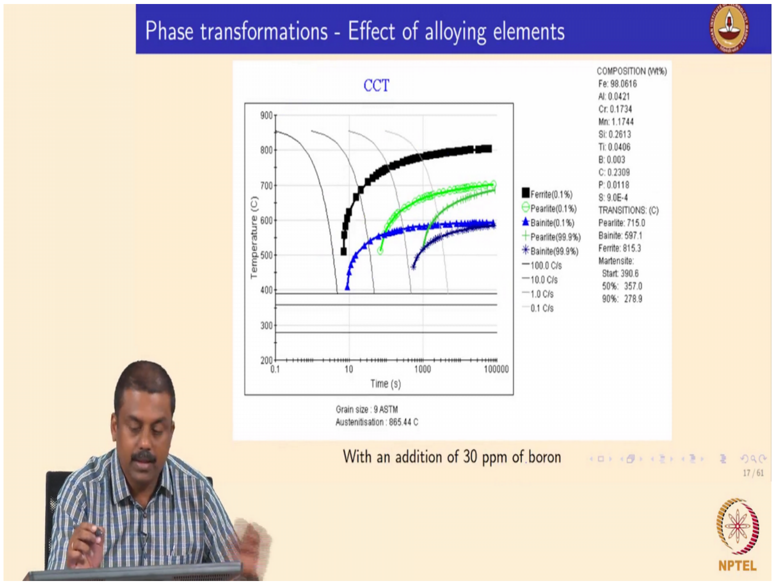

For example in the next slide the same centred system alloy system what I explained in the previous slide. In this case I added about 30 PPM of Boron, 30 parts per million of Boron into the system. You can already the see curves are going towards right compared to this compared to this diagram you already see the lines are going towards right what does it mean the Boron increases the hardanability or ability to form martensite at reasonable lower cooling rate then without Boron. So you can clearly see here so previously the 100 Kelvin per second cooling rate you are not forming the complete martensitic microstructure.

Whereas here at this cooling rate you are completely skipping the ferrite start line ok you are also skipping the all other transmission. So, at this cooling rate your microstructure would fully martensitic ok. So, is very important to understand the role of alloying elements in the transmission mechanism and the Caderilla transformation. So, you may also refer some of the basic textbooks as I already explained in my introduction slides, to understand the concept of alloying elements in phase transmission that are happening in the uncommon system ok.

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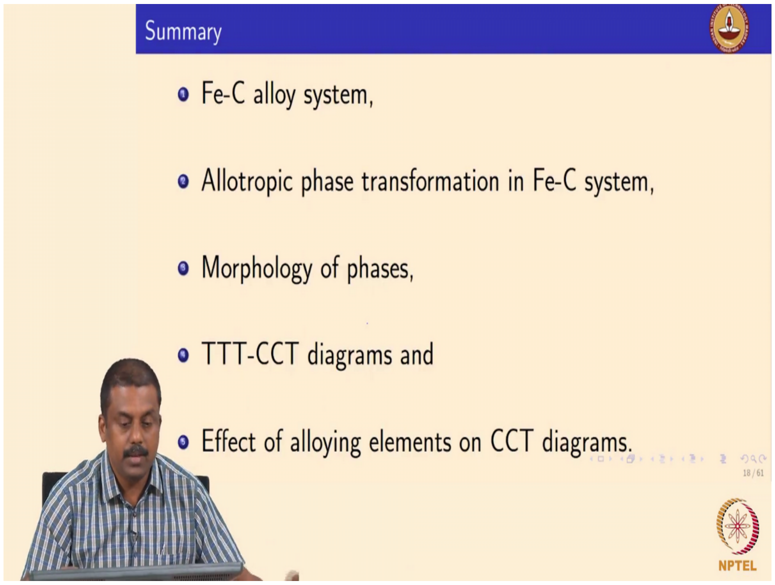

To summarise this chapter we looked at iron carbon alloy system the use of phase diagrams to describe the various transmission that are possible. In I mean high power eutectoid steels, the formation mechanism of protectoid ferrite, pearlite and bainite which are all driven by the division of carbon when the austenite transforming to these products. We looked at various allotropic phase transformation ferrite formation, pearlite formation, bainite formation and martensite formation and morphology of phases for example pearlite.

We look at the structure of inter laminar structure and we looked at the bainite structure and the structure of upper bainite and lower bainite and CCT-TTT diagrams and use of CCT-TTT diagrams and how the alloying elements are adding the that are added can change the lines in the CCT diagrams either towards right side or left side indicating the increasing hardenability of the material ok.

With that so I conclude this Steel physical metallurgy chapter. So feel free to refer basic metallurgy textbooks and make yourself familiarise with this concepts. And we will be using this concept on a very repeatedly during our course of these lectures. If you have any questions after looking at these videos you are feel free to ask me in the forum I will be glad to answer.

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So with that we will move on to the introduction to Modern Automotive Steels. First I will talk about why? What is the importance? Why do you need this automotive Steels? What is the driving force of development of modern Automotive Steels and if you look at the development in the last 20-25 years there is lot of impetus is given to making the automotives very lightweight.

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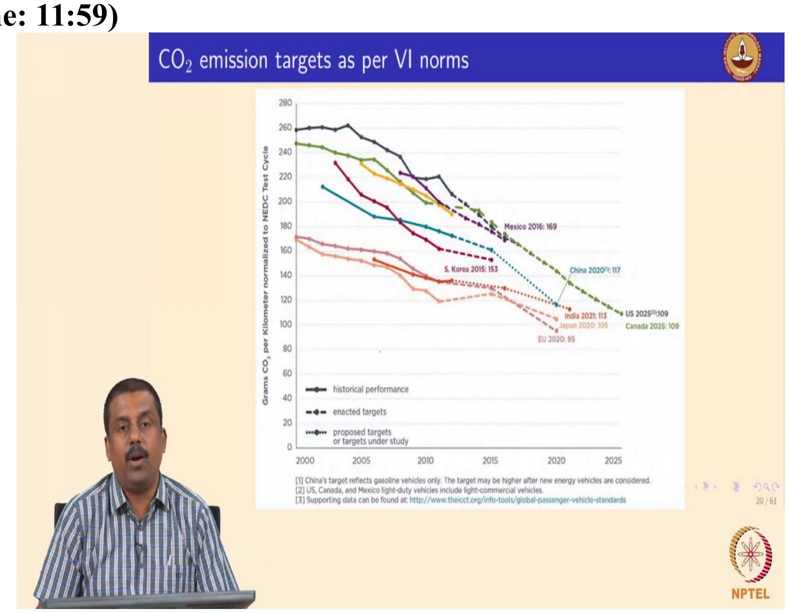

It is actually driven by the various statutory norms defined by the various forums to limit carbon dioxide emission ok there is actually defined areas norms for example this slide shows the evolution of CO2 emission over the years in per kilometre of vehicle travel. So this graph is actually obtained from the nomenclature defined in the Euro form Euro 6 norms. If you look at this graph what it shows is x axis is the CO2 emission per kilometre over the years from 2000 to 2025 ok. So, the actual target over the yes change the significantly we are leaving somewhere over here and if you look at the actual target right now what we are meet, India is some where about 100 grams of CO_2 per kilometre.

So, some were over here so that is a target, so if you want to achieve the target right now we are not even near to the target 100-105 grams kilometre of travel. So if you look at various countries the norms are changing for example Euro 2020 the norms says that only 95 grams of CO_2 to be released to atmosphere per kilometre of travel. So there is lot of effort are put by the automakers to meet this norms. These norms can only be met by making the vehicles very efficient in terms of fuel consumption. So the automakers are all looking towards increasing fuel efficiency by reducing the weight of the car.

Apart from fuel efficiency improvement and by light weighting and various driving force for light weighting that includes use of battery powered vehicle which actually requires vehicle should be as light as possible but without compromising the safety aspects. So, apart from the carbon emission norms and there are the safety norms which are governs performance of the vehicle which also demands light weighting ok. Both the carbon CO_2 emission targets as well as the crash performance targets demand that automatic should be made as light as possible.

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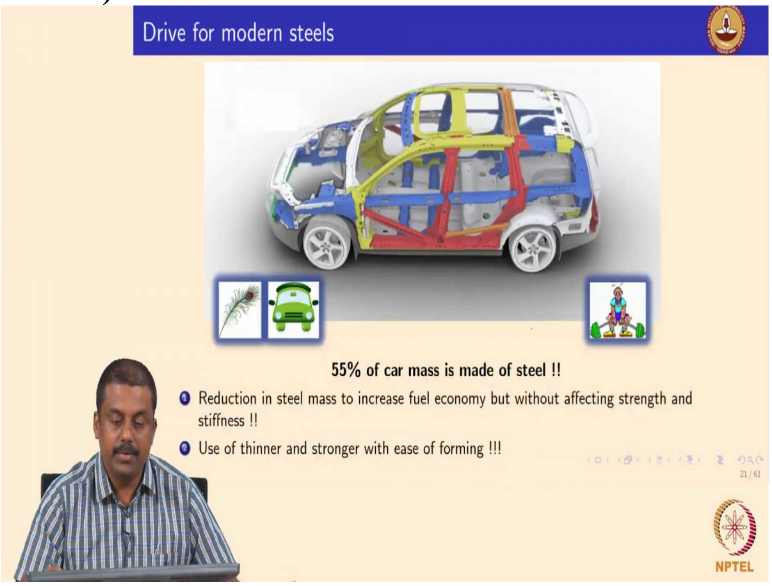

So, that drive our objective for producing Modern Automotive Steels and if you look at any automotive vehicle if you look at it in a passenger car segment as I show in this slide about 55% of the car mass are made up of Steel so obviously if someone wants to reduce the weight of the car first thing they look at is reduce the mass of steel that is used in an automotive. Show the reduction in steel mass to increase the fuel economy can be achieved if you replace the conventional Steel with high strength Steel ok.

But you cannot straightaway do that because these parts are also made by various forming operations. So you also need some amount of formability you cannot just like that replace conventional Steel with very high strength Steels because you also make component out of these steels right. So, these steels also should also have reasonable ductility ok. Their lies challenge to make the automotive Steels by increasing his strength without compromising the ductility.

Show the automakers and steel makers over 2 and 2 and half decades so they are trying to develop Steels that can I have reasonable ductility with much larger strength. So, that they can reduce the thickness of the Steel plates that are used in various automotive components but that is not straight forward we will see why in the subsequent slides. So the driving force actually comes from light weighting to develop the modern automotives which can give much improved fuel economy without compromising the class performance.

So, that is again we cannot even if you are using high strength Steels which can replace the conventional Steels but the performance should also be taken care of, for example crash as well as the forming of formability that should be taken care of. So, there are lot of challenges in terms of Steel that are going to be used in modern automotives. So we will see in subsequent slides so what are the conventionally used Steels in over the years in the automotive applications.

And due to the stringent emission and deep crash performance norms so how the Steels development took place, taking place over the last two decades in subsequent slides. To summarise this slide the modern Automotive Steels are getting stronger and stronger but they also have reasonable ductility so that we can also form we can also make component out of this Steel ultimately by using these very high strength Steels we can make the auto bodies lighter ok.
We can also make the autos greener because of reduction in the weight but without compromising in the crash performance. So ultimately the outline of; so this development of Advanced high strength steel is we have to use thinner gauge materials which are stronger. But you should also able to form these modern Steels with reasonable difficulty good.

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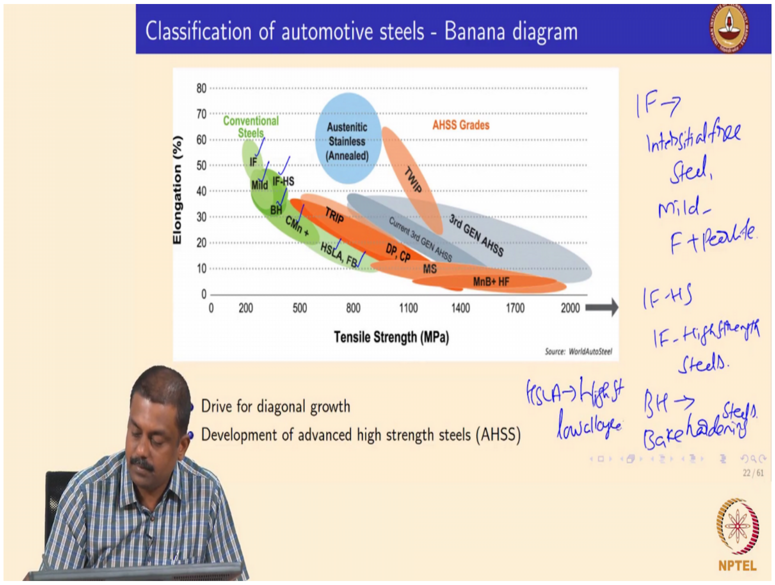

So, we will move on to the next slide which actually shows the classification of Automotive Steels that are actually used in the past the targeting commercially, commercialized at this point of time and the peak future of Automotive Steels that can be that can be commercialized over very near future or they are under development ok. And these are very important graph what I am going to show you because it describes the entire development over the years that are happened in the automotive sector. So, this side actually shows the relationship between the total elongations as the function of tensile strength.

So, if you look at this line so we see various colours legends what you see here over here and the green legends shows the conventional Automotive Steels and that are used 2 decades before. So you see over here IF, IFHS mild steel, back hardening Steel and plain carbon manual Steels and HSLA Steels and ferrite and bainite steels, so, I will first explain the actual classification of the conventional Steels and why they were used in Automotive and steel used in some of the automotives and because of their performance requirement in various parts.

So, if you look at this steels we go with high elongation to lower elongation the first if you look at it over here I given as IF steels which is nothing but the interstitial free Steel ok and mild steel is nothing but ferritic pearlitic steels. So, the formation of ferrite and pearlite you recall from my previous lectures and we have IFHS nothing but high strength variant of interstitial free Steel IFHS means interstitial free high strength Steel IF high strength. Then we have bake hardening steels ok. Then we have HSLA steel which is high strength low alloyed Steel.

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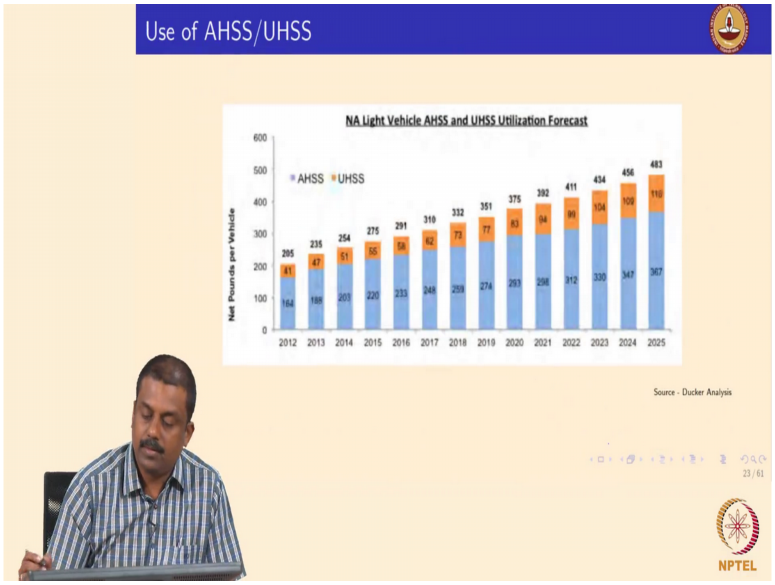

And we also have the FB another classification similar to ferritic pearlitic, which ferritic bainite steels and carbon Manganese and carbon Manganese Steels is similar to you can classify as HSLA or in a mild steel category where we have simple ferritic pearlitic microstructure. And we will go first in detail about each classification of the conventional steels and what are the problems that are associated with the Steels and why deals Steels cannot directly used for light weighting application. So why we need advanced high strength Steels and what are the pros and cons of using these tools compared to advanced high strength Steels.

And we will discuss in detail about why these steels are getting replaced with the advanced high strength Steel in the subsequent classes ok. To summarise this chapter so we look that modern introduction to advanced high strength Steels and what are the main driving force for development of high strength Steels. So, we look that the common emission norms and carbon dioxide emission norms and the drive from the emission and safety norms towards development of new steels. And we look that the various conventionally used Steels in Automotive bodies.

For example IF steels, mild Steels, IFHS steels, bake hardening steels, HSLA and ferrite pearlitic Steels and we will also see in subsequent classes we will begin with what are the microstructure that phases that represents the conventional Steels. And then we move towards the advanced high strength Steels micro structures and why the conventional Steels are replaced with advanced high strength Steels.