Steel Making

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Steelmaking, Additional Topics

We continue our discussion on modern trends in refractory.Some, I had already discussed in the previous lecture.Today, I will be discussing on monolithic refractory.What is a monolithic refractory?Monolithic refractory is the name given to all unshaped refractory materials.

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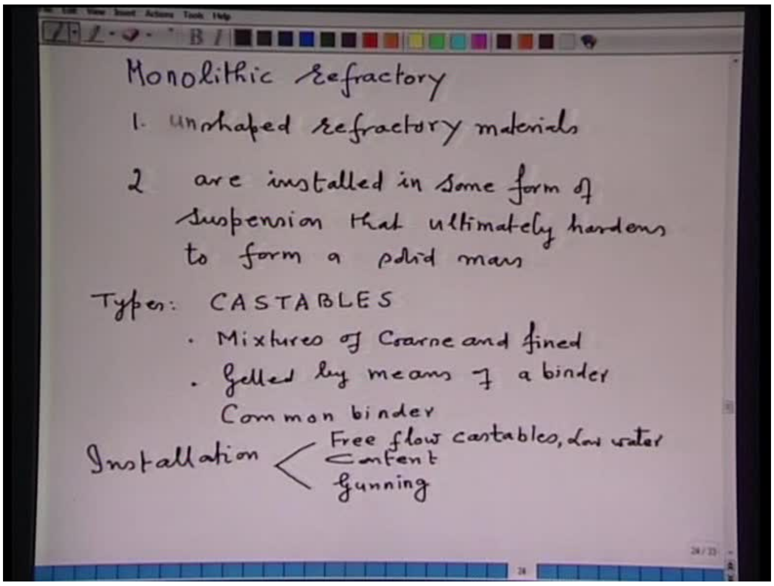

They are not like bricks, as we have seen earlier, but they are unshaped refractory materials.These materials, they are installed in some form of suspension, that ultimately harden to form a solid mass.Second, these materials are installedin some form of suspension,that ultimatelyhardensto form a solid mass; that means, this monolithic refractory material, they are,in fact, in a powder form and depending on the design of the reactor, these monolithic refractory material, they are installed right at the spot.They are unshaped one and they can be given to any shape depending on the requirement of the reactor.

So, the types which are available, they are,in fact, castables; that means, they can be cast into the shape which is desired for a particular requirement of thereactor.Remember, they are not like bricks.The shape of the brick is fixed. So, that is an important thing.So,in fact, these monolithic refractory consist of mixtures of coarse and fine grained refractory material, a proper proportioning of coarse and fine is important, because, when this is cast, then the material has to dry of sufficient strength.

So, a proper proportioning of coarse and fine size in the mix is important.Second, this is gelled by meansof a binder; that means, a binder has to be added, sothat, they can form a mass, which can flow and which can be casted.Naturally, when it is mixed with the binder, the material will be in the green form.Then, the common binder which is used is Al 2 O 3.Now, once this mixture has become ready, then comes the installation.Now, installation, we have two types of thesecastables; one is a free flow castables and these free flow castables have low water contentand another method of installation is by gunning, that is the mixture is allowed to flow through a gun at a particular pressure.

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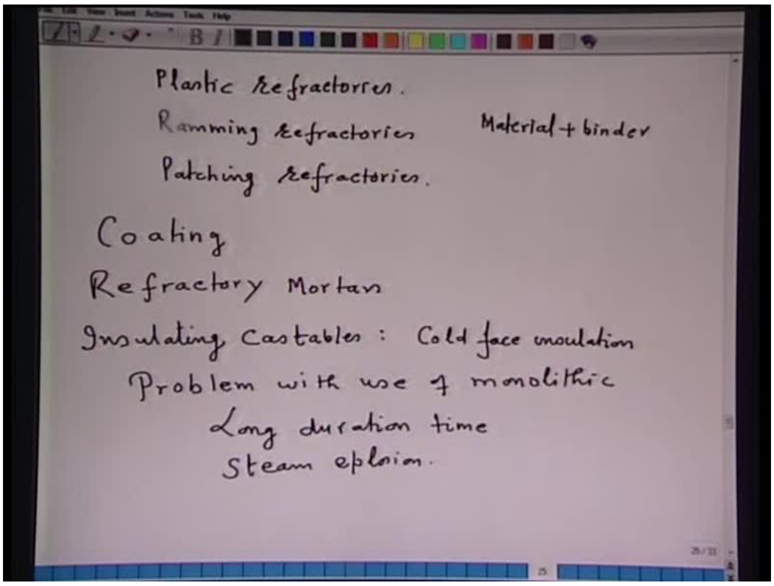

Now, we have three different types of mixture could be, one will be plastic refractories, then ramming refractories and patching refractories.Now, here,a materialplus binder,this mixture which has been formed through material and addition of a binder should have sufficient plasticity,so that, it can be rammed at a particular place.

What I want to say is that, this monolithic refractory which are unshaped material, they are used for different purposes.One of the purpose, you want to, say refractory line a reactor, could be a torpedo vessel, could be LD converter, could be electric arc furnace, some region, you do not want tomonolithic refractory everywhere, at some particular place.You want to ram the mass.For example, you must have seen in electric arc furnace or intorpedo vessel, where I have said that, the mouth of the torpedo vessel is rammed by a monolithic mass.

Similarly, in case of BOF,similarly in case ofelectric arc furnace, thebottom of the vessel they are many times rammed, in order to achieve a high lining life.Third, could be patching.For example, once the heat is over, certain areas are warmed during theheat time and once the heat is tapped, those areas are identified and with the help ofmonolithic refractory, they are patched.So, patching type of refractory.Then, also we have coating refractory, for coating purposes. So, to coat the working lining.For several reasons, you want to coat the refractory lining,so that, the phases do not adhere to the wall of the refractory lining.

Then, we have refractory mortars. They are,in fact, finely ground refractory material, which are then mixed to form a paste, used for laying and bonding shaped bricks. So, this is the refractory mortars.Now, say insulating castables. These insulating castables, their main objective is to block the heat transferred from the vessel to the environment.So, their main objective is to provide insulation. So, they are used for cold face insulation.These insulating castables, they are made from light weight aggregates like vermiculite, bubble alumina and clay, because the insulating castable should have a low thermal conductivity and low density.

Why it should have low thermal conductivity, because thermal conductivity is a property which allows heat from the reactor to be transferred to the surrounding or not.How fast or how quickly the heat will be transferred, that will be determined by the thermal conductivity of the material.So, if the monolithic material is to have an insulating property, then it must be of low thermal conductivity and low thermal conductivity is obtained by having a porous mass. So, naturally they will also have the low density.

Now, since this monolithic refractory, they are used by mixing with a binder and water in a green state, a shape has been created either for ramming or for patching. So, in all the cases, it has to be dried.If it is not dried, then water will, then, then water will evolve and as a result, a problem would be there during the operation. So, the largest problem with the use of monolithic refractories…One of the problem is long duration time.Because, the water which you have mixed in order a solid material can flow and take the shape of the reactor or can be rammed or can be patched, it has water in it, it has binder in it. So, all have to be removed, before heat can be operated.

So, this water, it will have a sort of steam explosion; that means,a large amount of steam will be evolved. So, these two problems, they require a sort of steam explosion free drying technique.

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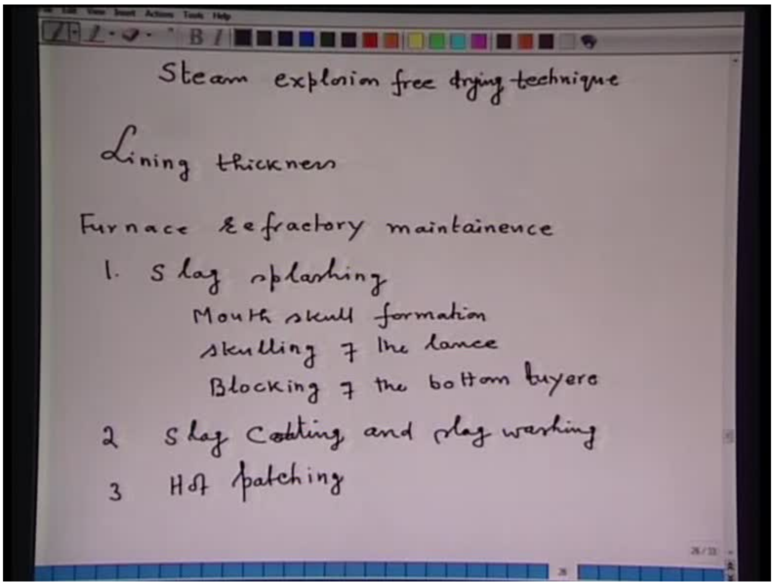

So, what we require is that, steam explosion free drying technique.Now, for your information, monolithic refractory are finding a wide application in the steel industry.Now, this is regard, the monolithic refractory.Now, one of the important things in controlling the furnaces is that, one must be able to measure the lining thickness.Inspection is also important.There are, various technologies are there, which can measure the profile of the lining.For example, eddy current technology of detecting brick cracks by elastic shock waves.They are all in commercial application.Now, let us see, some of the repairingmethods or maintenance method. So, as such, I will put the next title as furnacerefractory maintenance.

Slag splashing.This was developed around 15 years ago and today some plants, they claim that, they have achieved around 60,000 heats in 1 particular vessel by using slag splashing technology.The details of it, I had already explained to you, when I was explaining the splash technology in BOF steel making.Here, I will just put in short, after steel tapping, some amount of slag is retained in the vessel.This slag is conditioned by adding Fe O and MgO.If Fe O and MgO contents are less, then nitrogen is blown through a lance; as a result of blowing of oxygen through a lance, a jet of nitrogen impinges on the slag surface; on account of this impinging action of the jet, the slag splashes around the walls of the converter and as a result of the splashing, the slag very beautifully adheres on the lining of the wall.

Because the slag has Fe O and MgO,so, Fe O provides the adhesion behavior and MgO provides the,so called, high temperature phase. So, this is in short, the slag splashing and its application for BOF steel making or for maintenance for that purpose, I mean where ever you have a slag, this technology should beable to work; because all that you require, the slag which is retained, which is available to you,you use it for splashing and hence the lining life of the converter can be increased.Now, here, one of the importantcases is that, if the slag is more than the required, then the excess amount of slag, it builds in the bottom. So, it may destroy the bottom, instead of giving you the benefits.Therefore, excess slag has to be poured off before charging.

The problem with this slag coating is, one of the problem is, the mouth skull formation.I am referring, withreference to BOF steel making, because slag splashing has been developed for BOF steel making.So, at the mouth, when the slag splashes, slag has a lower melting point. So, immediately it deposits on the mouth of theconverter and hence, there is a formation of the skull and because it is a highly viscous, it has to be removed, that is one important issue.

And another important issue, is the skulling of the lance.In slag splashing, one more thing I would like to mention, when slag splashing is used for top and bottom blowing converter, then in that converter, we have bottom tuyeres.These bottom tuyeres should be free. So, if you use the slag for splashing, then one must take sufficient care,so that,the slag does not blockthe bottom tuyeres. So, third issue could be, the blocking of the bottom tuyereshould be avoided. So, this is in short about slag splashing.Another is that slag coating and slag washing.

Now, here, what is done is that, you retain the slag, condition it withdolomite to cool the slag and to increase its adhesive properties, then the vessel is rocked in motion. So, that the slag splashes all around. So, this is also one of therepair techniques.Then the third is hot patching.Now, in the hot patching, say self-flowing refractory mixes enables precise maintenance of the scrap preheat zone, tapping pad and bottom joint.This is for the hot patching, wherever between the heat, if there is a problem, then this hot patching can be done.

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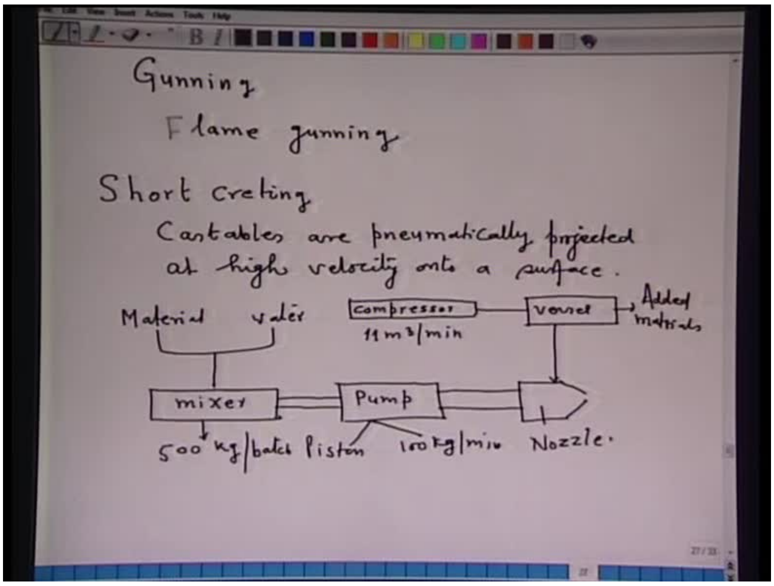

Another importantrepairing technique is that of gunning.Now, here,for example, flame gunning is used.Now, this flame gunning involves simultaneous melting of a refractory powderand gunning at the hot surface.That means, the melting of the refractory material and its injection at high speed to the area, where repairing is required, it is done simultaneously.Now, since the gun repair material is dense and fused directly on the hot surface,so, excellent result in the life of the lining is obtained,for example, in LD converter.

So, this is about the flame gunning.Now, another important process is called short creting.In this particular process, the castables are pneumatically projected at high velocity on to a surface.I will write for you.This is a process by which castables, castables are pneumatically projected at high velocity on to a surface; that means, here the melting and gunning, both are simultaneously achieved. So, the advantages will be of course, much better.

Now, here refractory materials are designed for self-flow, that is important. So, I will just draw a flow sheet, how does it work.For example, we have a material here; put a material, some amount of water, both are mixed in the,so called, mixer and this mixer is then taken to a pump and from the pump, this mixture flows througha nozzle. So, this is a nozzle.Now, here we have a compressor.This is a compressor, this is a vessel.Now, in this vessel, some materials are added; so, added materials and this is also bound to the nozzle. So, that is the way in which the short creting method works.

Now, the material pump, that is here.There are two types, one is the piston type of pump and another it works at a speed of 100 kg per minute.Mixer capacity could be around 500 kg per batch; air compressor say of the order of 11 meter cube per minute capacity of thecompressor is required. So, this is in shortabout the modern trends or emerging trends in refractory.

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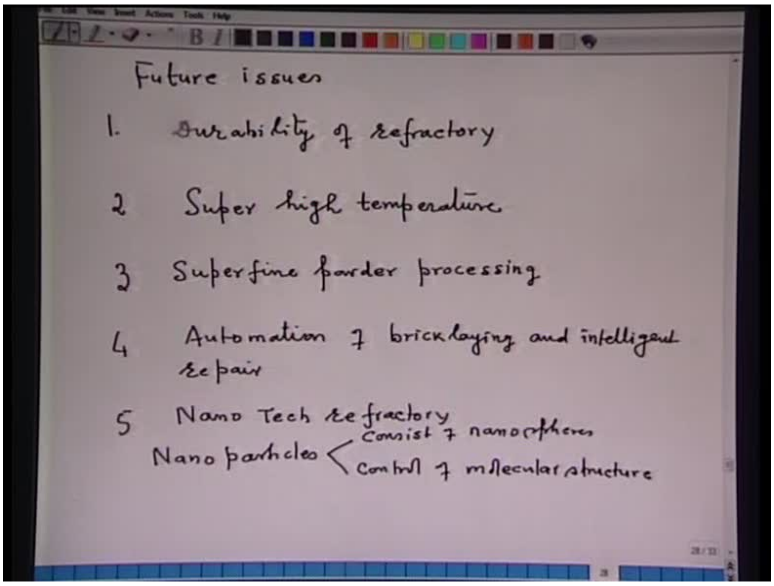

Now, as some of you who are interested in the refractory and do some work, then I willjust outline future issues in refractory technology.One would be important, what is required to increase the durability of refractory?Where?In critical areas.For example, pouring nozzle, side dams and such critical areas which are prone to wear.The durability of refractory is an important issue. So, future attempts will be directed, howto increase the durability of refractory by having better quality refractory.Another important thing, steel making technology goes together with refractory technology.As in the steel making lecture, you must have heard, post combustion is one of the important techniques to increase the energy efficiency of the BOF or electric arc furnace.

But imagine, the temperature which would be created in the free board of the BOF or EAF will be very high. So, accordingly super high temperature refractory will be required.Mind you, unless these refractory are available, one cannot implement the post combustiontechnology in electric arc furnace or BOF.That is a very important and in this connection, also, the energy optimizing furnace, where also very high temperature is created, because of post combustion in the furnace.So, the refractory development would be an important issue.

Third is that, we have to develop the processing technology and here, super fine powder processing technology is also required to be developed.Fourth that is important, the development of monolithic refractory in steel making or in refining furnaces, require to automate brick laying and intelligent repair.So, what will be required is thatautomationof brick laying and intelligent repair.Now, since monolithic refractory is not used in the entire vessel, only in the certain proportions,so, accordingly brick laying methods has to be developed.Another important thing is the development of Nano Tech refractories.Thermal shock resistance and corrosion resistance require opposite characteristics. So, Nano tech refractories satisfy both.Nano tech particle, they act in two ways.

First, they consist of nano-spheres and improve properties like elasticity and strength; and second, control of molecular structure, as the particles have many small pores of several 100 nanometers. So, these are some of the future issues.Those who want to go in detail, I have given the references at the end of this lecture. So, one can follow those references.Now, with this I proceed now, to the next title that is the clean steel.

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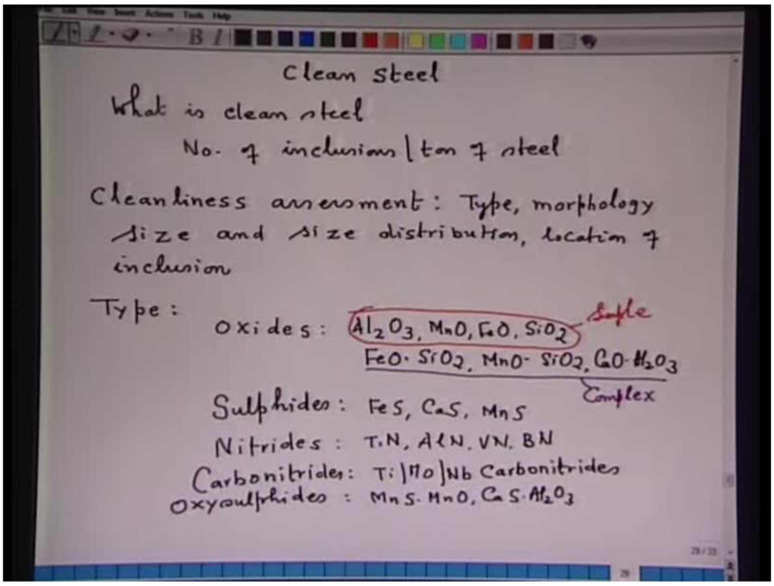

Naturally, the question is, what is clean steel?Clean steel refers to number of inclusions per ton of steel.Depending on the diameter of the inclusion and dissolved oxygen content of steel, number of inclusions may vary from10 to the power 12 to 10 to the power 15 per ton of steel. What does it mean?That means, it is not possible to produce a steel, which is free from inclusions.All that we can try, is to minimize their numbers.Therefore, we can talk about is a cleaner steel, but not in the literary meaning of clean steel, which by definition would be a steel with 0 inclusion content, which is not possible. So, what we will be talking,we will be talking how to have a cleaner and cleaner and cleaner steel, with reference to the number of inclusions.

Now, these inclusions, they affect the mechanical properties of steel.As you recall, when I was dealing with my first lecture on steel and its classification, I did mention about the role of inclusions.So, from the point of view of applications, it is important to know what is an inclusion, how it affects the mechanical properties, how their sources can be controlled.Let us see, one by one. So, first of all, we will say how we assess the cleanliness. So, first I will put, cleanliness assessment.Now, in assessment of steel cleanliness, what is important, type of inclusion, morphologyof inclusion, size and size distribution are important and it is also important, where the inclusion is located, that is location of inclusion.

Now, let us say, what is the type?An inclusion,in fact, is a chemical compound of metal plus nonmetal and hence it is termed non-metallic inclusions.What are the different types of inclusion?One of the type is oxides.For example, Al_2O_3,MnO,Fe O, SiO_2 or for example, we may have Fe O-SiO_2,thenMnO-Si O2 or Ca O-Al_2O_3.These inclusions, they are termed simple type of inclusions, where as these inclusionsthey are termed complex inclusions.They are termed complex inclusions because more than two oxides.

Another example,sulphides.The examples of sulphides are,for example, Fe S,calcium sulphide,Mn S or could be one complex type ofsulphides Fe S-Mn S or Ca S-Mn S or whatever.Then, we have nitrides,for example, titanium nitride,Al N, of course, depending on the availability of titanium or aluminum, then vanadium nitride and boron nitride, depending on the addition of these elements and the concentration of each, to form an inclusion.Then we have carbo-nitrides.

Carbo-nitrides for example, of titanium, molybdenum, niobium carbonitrides.We can also have oxy-sulphidesand for example, Mn S-MnO,Ca S-Al_2O_3,in whatever combination, because,in fact, the impurity elements which are present in the steel – carbon,sulphur, phosphorous, nitrogen, oxygen, hydrogen and dissolved oxygen and other alloying elements, depending on the concentration, they will form a compound with metal and nonmetal.

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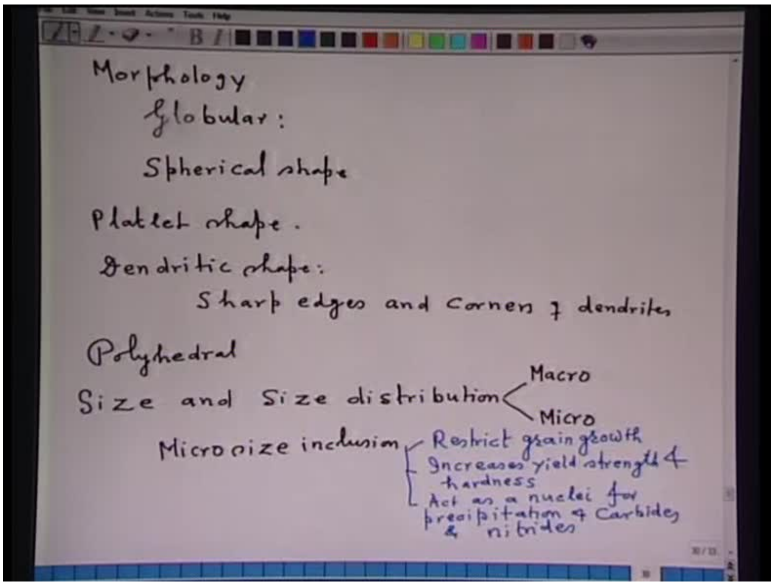

About the morphology, there could be different shapes.Say, one of the shapes,for example, is a globular shape.Now, globular shape is a preferred shape.It does not have a bad influence on the properties of steel.Another is a spherical shape inclusion that forms in a liquid state, at low contents of aluminium.Manganese sulphides and oxysulphide inclusion, they form during solidification in the inter-dendritic region are also globular in nature.So, that means, the globularnature of inclusions, they are little less harmful.It depends upon where they form, because inclusion can form either during solidification or during tapping or teeming of steel.Another shape is a platelet shape.Say for example, the deoxidized steel with aluminium,it contains manganese sulphide and oxysulphide in the form of thin film located at the grain boundaries.

Now, if the inclusion is located at the grain boundary, then they weaken the grain boundary and will affect the mechanical properties in the hot state and that is called hot shortness.So, that means, these type of inclusion that is the platelet shape, which are appearing at the grain boundary, they are more harmful than if the inclusion is present in the metrics.Another shape is a dendritic shape.

Now, by the nature of the dendrites,it is a tree like shape and the sharp edges and corners, they induce the local stress concentration and which considerably decreases the ductility, toughness and fatigue property. So, dendritic shape, I will just put few words from here, that is they have sharp edgesand corners of dendrites, they may cause local concentration of a stress and as a result they affect the,socalled, the mechanical properties like ductility, like toughness and fatigue properties.

Now, another shape is a polyhedral shape.They are less harmful than dendritic shape.Another important propertyis a size and size distribution.Say, we can have macro inclusions, larger size and we may have micro inclusions.Larger size inclusion, that is the macro inclusions, they are very harmful as compared to micro sized inclusion. In fact, sometimes, it is preferred to have micro sized inclusion in the steel.Why, because say micro size inclusion, it may be beneficial, why, it can restrict grain growth.When?For processing of the steel material, the material is heated below the melting point of the steel.Normally 1100 to 1200 degree Celsius, that is in the solid state, so, there the grain can grow and larger size grains, they affect the mechanical property as compared to fine size grains.

So, therefore, if the micro size inclusions they are present, they can influence the grain growth; they can restrict the grain growth;so that, grain does not grow duringheating,for example, for deformation processing or for heat treatment or whatever the treatment is required, to create a product of a particular property.Second important point, that is in favor of micro inclusions is that, increase in yield strength and hardness.Naturally, they are micro sized inclusions and they are distributed well in the matrix. So, you can imagine, the steel has become a composite material.Matrix with oxides,that is a composite material. So, it has a better property.

Now, only important point in case of inclusion, that, they should be of fine size and distributed well within the matrix, then one may have very different properties than if they are located on the grain boundary.Third, micro inclusion can do is that, they act as a nuclei for precipitation of carbides and nitrides.

So, in short, what I wanted to say is that, not all sized inclusions are harmful. So, statement that inclusions are alwaysharmful has to be modified, in terms of what is the size of the inclusion, we are referring.If the inclusion size is very small, say micro size inclusion, then you may not like to remove them, because they will be beneficial during theprocess of heating or reheating the steel, to create the special properties. So, that is an important thing over here. So, what is important from here is that, it is the distribution of inclusion is also important.The inclusions are present at the grain boundary and if the inclusions are present well distributed in the matrix, then they will have an altogether different influence on the properties of steel.Now, let us see, the inclusions and mechanical properties.

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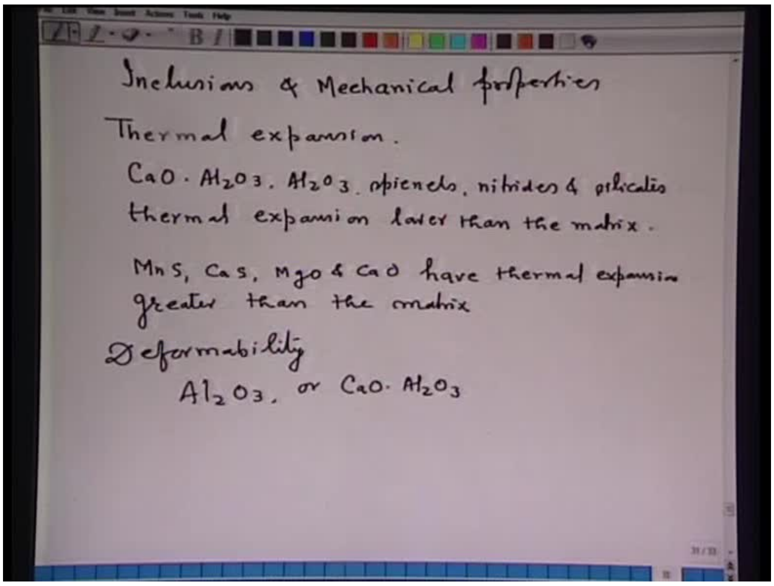

Now, inclusions have very different physical properties than the steel matrix.For example, thermal expansion, say inclusions like calcium oxide,Ca O,Al 2 O 3,Al 2O3,spienels, nitrides and silicates, they have thermal expansion lower than the matrix.What they will do, on heating, these inclusions have lower thermal expansion as compared to the matrix.So, internal stresses of thermal origin will develop and these type of inclusions are detrimental to fatigue properties.Remember, the detrimental to fatigue properties arises from those types of inclusions, which have thermal coefficient lower than the matrix.You can imagine also, how this will happen, now, when you heat it, one will expand larger, another will expand less larger. So, that is important.

Another extreme is that, say for example, inclusions like manganese sulphide, calcium sulphide, MgO and Ca O have thermal expansion greater than the matrix. So, void or parting of matrix can occur and thesevoids can act as cracks. So, this is one of the important physical property differences between the inclusion and the matrix.Another difference is deformability.Some inclusions are highly deformable and some inclusionsare less deformable.For example, inclusions like Al 2 O 3 or calcium aluminate,Ca O Al 2 O 3,they are un-deformable at all temperatures, used for deformation. So, they will crack.

On the contrary, manganese sulphide is highly deformable up to about 1000 degree Celsius and similarly Fe O,MnO are plastic at room temperature, but gradually loose plasticity above 400 degree Celsius.Inclusions like silicates are deformable at high temperature, but un-deformable at room temperature. So, what I wanted to say from here is, during hot deformation processing, which type of inclusion is present, that is an important.Inclusions like F,Mn S will not be giving any problem, but inclusions like Al_2O_3 or calcium aluminate, because they are not deformable at high temperature,so, immediately that will crack.Third important property is that of the melting point.Melting point of all the inclusions, except alumina, pure alumina is, most of the inclusion is lower than the steel matrix.

So, what I want to conclude from here is that, inclusion matrix do not match with each other.I repeat again, because of the very difference in their physical properties, like thermal expansion, like deformability, the inclusion which is present in the matrix, it does not match at all with the matrix.So, this particularphenomenon is very important depending upon what is the thermal expansion or what is thedeformability andso on.The crack or local stress concentration will be developed and on deformation or on providing a load, they may crack at each other.The further aspects we will take in the next lecture.