Steel Making

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Module No.# 01

Lecture No. # 21

Steelmaking Additional Topics

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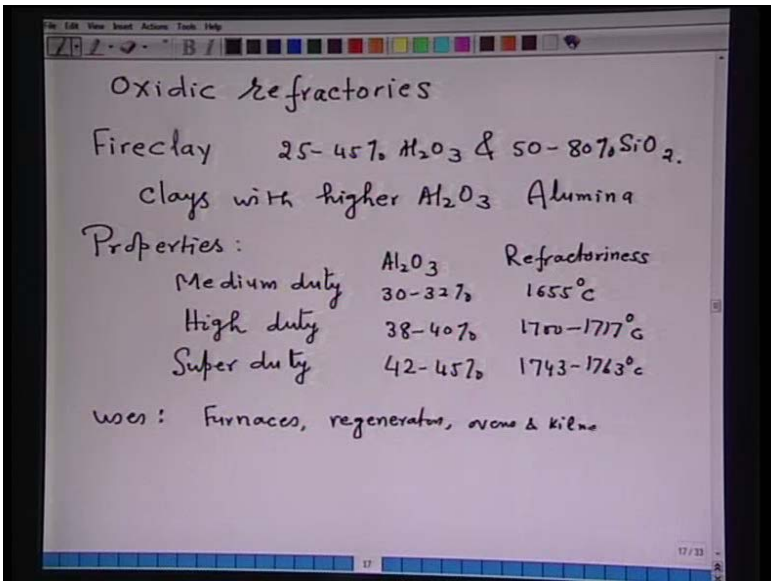

So, continuing with the last lecture, let us take some examples of Oxidic refractories.I will take few examples;for example, the most commonly used refractory is fireclay.Common fireclay contains 25 to 45 percent Al 2O3 and 50 to 80 percent Si O2.Clays with higher Al 2O3 content, with higher Al 2O3 are called Alumina refractories.

Now, the property of these refractories.The porosity varies in between 9 to 24 percent, depending on the firing temperature.At high temperatures, fireclay refractory combined with alkalis such as soda and potash.Different type refractories,for example, be a medium duty refractory, medium duty refractory, they have Al 2O3 content varies from 30 to32 percent.Their refractoriness, which is a property of the refractory, it goes upto

1655 degree Celsius.High duty refractory, the Al 2O3 content is 38to 40percent, the refractoriness is 1700 to 1717 degree Celsius.

Then, super duty refractory, they have 42 to 45 percent and their refractoriness is 1743 to 1763 degree Celsius.Mind you, in a steel industry, fireclay is very commonly used as a refractory lining ofmost of the reactors.Now, commonly uses, they are say furnaces, which are used in the manufacturing industry, cement industry,then regenerators, then ovens and kilns, they are the areas where fireclay refractories are used.

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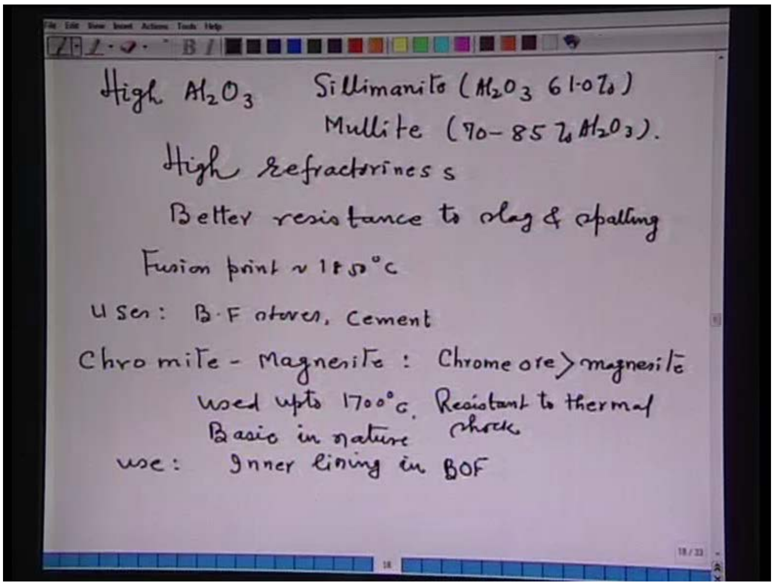

Now, next,for example, high Alumina refractories.Typical example,for example, sillimanite, which contains Al 2O3, 61.0 percent and Mullite, it contains 70 to 85 percentAl 2O3.

Now, these refractories are characterized by high refractoriness, better resistance to slag and better resistance to a spalling.These are some of the characteristic property of the refractory.Then, they also have higher load bearing capacity.Their fusion point is around 1850 degree Celsius and commonly these refractories are used,for example, in blast furnace stones, cement and line rotary kilns, electric arc furnace roofs, ladle andglass making furnaces.Chromite -Magnesite - in this one, amount of chrome ore is greater than magnesite.That is why they are called chromite -magnesite refractories.They can be used, say up to 1700 degree Celsius.They are resistant to thermal shock and typically, they are basic in nature.Their use, inner lining in BOF, inner lining in basic oxygen furnace converter, side walls of soaking pits.

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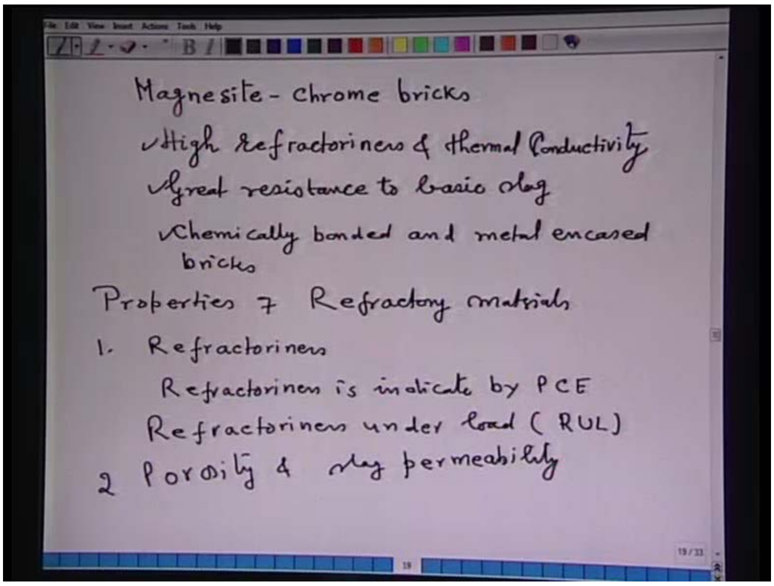

Another example,Magnesite - chrome bricks.Naturally the M g O content of these bricks is greater than the chromite.These refractories, their properties, they have high refractoriness and thermal conductivity.Then, great resistance to basic slag, but in environment, these refractories cannot be used. These refractories are, say chemically bonded andmetal encased bricks.

Now, let us see, as I have repeatedly noted, refractoriness,spalling, resistance to chemical attack, what are the properties of the refractory material. So, let us understand little bit about properties of refractory materials.First important property is, refractoriness or fusion point.This is the temperature at which a refractory will deform under it is own load.It is indicated by PCE,that is, refractoriness is indicated by PCE that is,PyrometricCone Equivalent.

Now, this PyrometricCone Equivalent number should be greaterthan the application temperature.When the refractory is under the external load, then its refractoriness will be somewhat different than refractoriness itself.So, another property which is important, is refractoriness under load.That is, you take a refractory and you load with some external load and then find out PyrometricCone Equivalent.So, in short, which is also called RUL,that is,Refractoriness UnderLoad. So, Refractoriness UnderLoad is also a fusion point, but it is lower than refractoriness.Refractoriness meansthe fusion of the refractory under it is own load whereas, RUL is the fusion point when it is loaded by the external load. So, that is thedifferent between the two.

Now, this RUL hasa important application.For example, when brick layering is been done one after the other, then, the bottom brick is under the load of the top most brick. So, in that case the refractoriness under load is moresignificant as compared to refractoriness. So, the property depends upon what is the application.

Second important property is the porosityand slag permeability.Porosity, it affectschemical attack by molten slag, molten metal and gases.That is why porosity and slag permeability, that means, if the brick is porous then slag will be able to diffuse into the pores; it will react with the oxides and all sort of… it may change the property of the refractory.What we require is the, porosity is the property which determines the resistance to penetration of molten slag, molten metal or gases.Decrease in porosity increases the strength and thermal conductivity.

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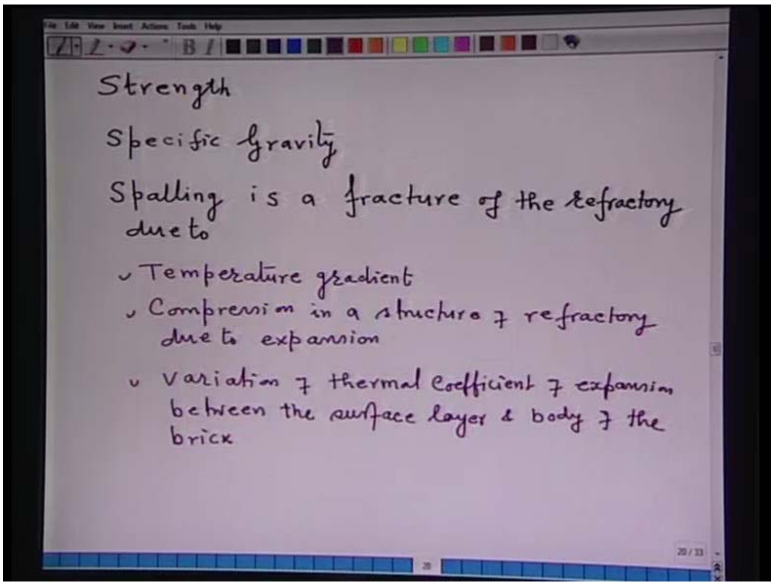

Another important point, is the strength of the refractory.Strength of the refractory - theresistance of the refractory to compressive load, tension and shear stresses.Now, when we design the taller furnaces, then the refractory has to support a heavy load.Hence, strength under the combined effect of temperature and load is important. So, that is the importance of the strength of the refractory.

Another important property, the specific gravity.It should be low to produce number of bricks per unit weight.Cost of bricks of higher specific gravity is more than that of lower specific gravity.Another very important property is the spalling.Now,spalling is a fracture of the refractorydue to temperature gradient.

Now, how temperature gradient can cause spalling or fracture?Because, temperature gradient induces thermal stresses.So, if the brick is not resistant to thermal stresses, then the temperature gradient induction will facture the refractory.Anotherfactor, that affects the spalling is compressionin a structureof refractory due toexpansion.Again, this will also induce the stresses and hence, the brick will spall.Third important factor that affect spalling is, variation in coefficient of thermal expansion.I will just write down, variation of thermal coefficient of expansion between the surface layer and body of the brick.This may occurdue to slag penetration or due to structural changes.

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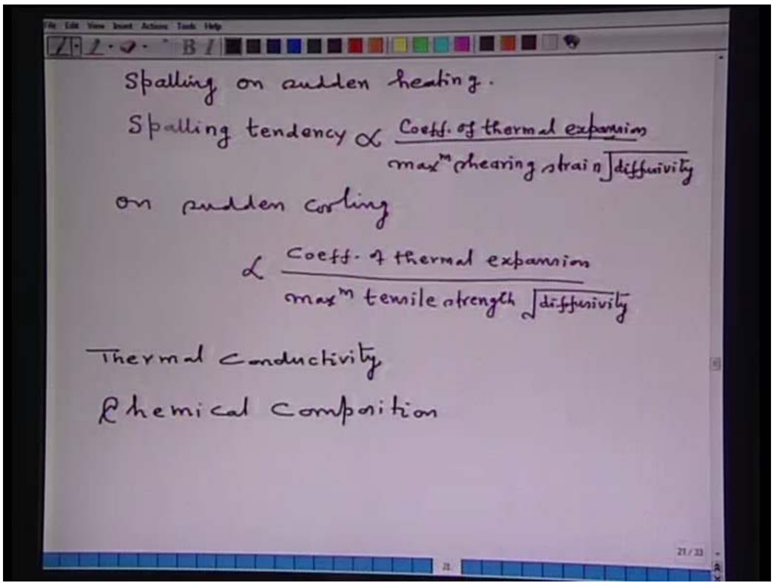

So, the spalling on sudden heating, say we can define, say spalling tendency of a brickis proportional to coefficient of thermal expansion upon maximum shearing strain into diffusivity.Naturally, if coefficient of thermal expansion is more,spalling tendency will be more.Spalling tendency on sudden cooling.So, spalling tendency here, is propositional to coefficient of thermal expansion divide by maximum tensile strengthinto square root of diffusivity.Another important property of a refractory is its thermal conductivity.

Now, thermal conductivity of the brick, it determines the heat loss from the wall to the atmosphere.Increasing porosity will decrease the thermal conductivity, but decreases the strength also.In all insulating bricks, it is required to have a high porosity, because, the porosity only can decrease the thermal conductivity and when such bricks are used, they can makethe reactor energy-efficient. So, this thermal conductivity of a brick is very important, from the point of view of the energy conservation.

Now, remember, these bricks have a very high porosity.Naturally, the bricks with low thermal conductivity having very high porosity cannot be used in contact with the slag, metal or gases, because then, these phases will penetrate and they will destroy thelining. So, insulating bricks of low thermal conductivity are used, normally next to the metallic shell.Now, in another say, important property is the chemical composition. Now, chemical composition of the slag is important from the point of view of that, the phases should not react with the refractory.As I have said in the beginningthat, the reactor it handles phases like molten metal, molten slag and gases, in iron and steel industry.

So, the refractory which is in contact with these phases, it should not react with the elements of the metal or oxidic component of the slag.Simply because, refractory or the oxidic refractory, component-wise, they have, are similar as that of the slag which is formed,for example, in BOF or EAF steel making.Typically, slag in BOF or EAF steel making contains S i O2, calcium oxide,M g O, Al 2O3,FeO andsoon.The bricks, as you have seen, they also contain Si O2, Al 2O3, Ca O,M g O andso on. So, as such, the chemical composition of the refractory is important from the point of view that, the refractory material which is in contact with the phases, it should be not reacting.That is, the important part of thevarious property of the refractory.Now, let me tell little bit about, how the refractories are manufactured. So, manufacture of refractory.

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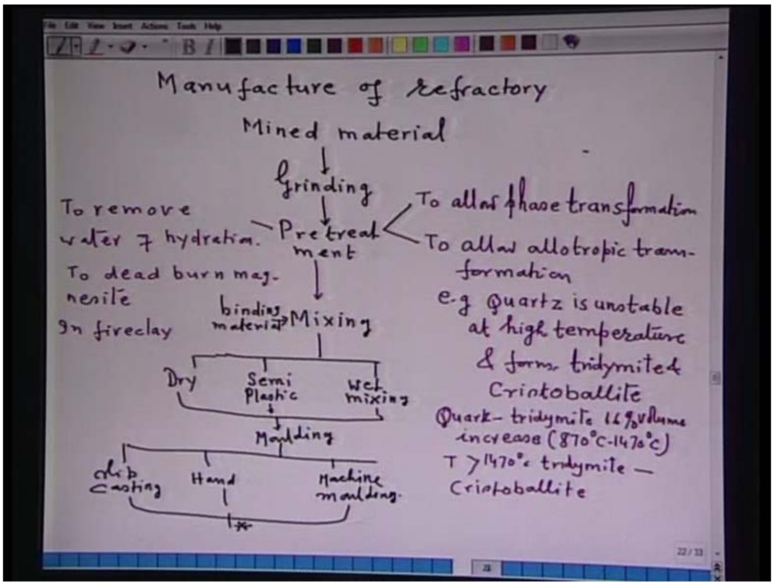

So, let us see the manufacture of refractory. How these refractories are manufactured?Remember, refractory are produced from the natural resources.It is not, that is refractory material occur in the nature.You can take from there and directly you can use it into the furnace, no.They are being manufactured and refractory manufacture is,in fact, a very big and high temperature industry.It is manufactured from several type of different raw materials.They are mixed in certain proportions, certain pretreatment is being done, in order to generate required property in a refractory.

So, let us see the manufacture of refractory.Now, what is done, say a mined material ((knowing)) from run of mine, that is subjected to grinding operation, for thesmaller practical size and then the ground material is subjected to pretreatment, and this is a very important stage, they subjected to pretreatment.Pretreatment means what?The ground material is heated to a very high temperature.Why?Because, materials have different phases at different temperature.There may be allotropic transformation, which may be accompanied by volume change. So, if these changes are not incorporated during the production of the refractory, and if you put that material directly into thereactors, then the phase transformation or allotropic transformation will occur at that point of time, and the whole refractory will collapse.

So, this pretreatment, that is firing of the refractory at a particular temperature, depending upon the phase transformation of the material and allotropic transformation of the material, they both are temperature dependent, it has to be done. So, the pretreatment stage has 2 objectives.The first objective is, to allow phase transformation and second objective, it has to allow allotropic transformation.

Now, say for example, Quartz.Quartz is unstable at high temperature and forms,Quartz is unstable at high temperatureand forms 2 phases,tridymite and cristoballite.Now, what does it mean; that means,Quartz to tridymite, this transformation is accompanied by 16 percent volume increase.Note down, this is a very important.16 percent volume increase and this transformation temperature is 870 degree Celsius to 1470degree Celsius.When temperature T is,for example, greater than 1470 degree Celsius, then tridymite again transforms to cristoballite and that results in the contraction of volume.Another important issue in case of pretreatment, to remove water of hydration.

For example, fireclay it occurs in the nature and the water is in combined form.Also, free water is there. So, this water of hydration has to be eliminated,so that, at the time of its application, when water evolves, then it will create lot of problems.Another, say, important thing is to dead burn magnesite.What does it mean?Magnesite is $MgCO_3$.If as such it is used, at high temperature $MgCO_3$ decomposes to MgO and CO_2 and CO_2 will create problem.So, to dead burn, dead burn means complete elimination of carbon dioxide from magnesite.Another thing important say, in fireclay,mullite formation is important, because the mullite, it imparts resistance to slag as well as, it imparts high temperature strength to the refractory material.

This is, the socalled pretreatment stage, is a very important stage in the manufacture of refractory and lot of care is to be taken,so that, any contraction in the material, as a result of heating, any expansion in the material as a result of heating, any volatile substances,for example, H_2O or CO_2 in the material, they should be removed, they should be properly treated, so that, the refractory which is produced from these material is good and does not create problem at the time of application.After pretreatment stage, then mixing and in the mixing, binding material is added.

Why binding material,so that, you can get a shape.Because this is solid mass,((ordering)) mass.Unless you bind it, a proper shape, you will not get it. So, binding material is rather added andthen, this can be in dry, semi plastic or wet mixing and all these 3, either in the dry stage or semi plastic stage, they are subjected to molding.You can have slip castingor hand molding or machine molding.Machine molding can be done either by exclusion or by pressurized de-airing.

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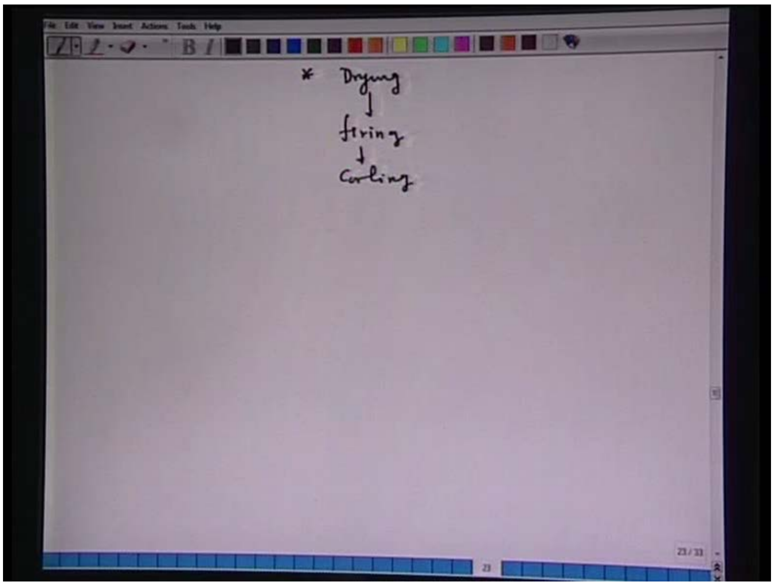

So, the product from all these, whether slip casting, hand or machine molding, they is subjected to drying and that I am taking after molding, the material from here is subjected to drying.Drying, atmosphere drying or mechanical drying, anything which is available can be done; subjected to firing; firing could be batch or continuous.Now, it is the firing schedule is very important.Time and temperaturecycle is important. So, after drying youfire material, then cooling, sorting, whatever important is taken and whatever reject material is again circulated for mixing. So, this is how the refractory materials are manufactured.

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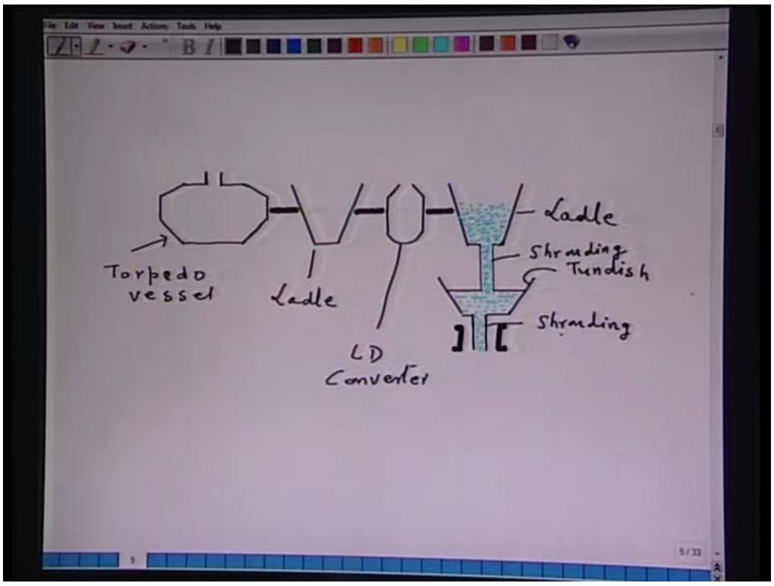

Now, after this, let us see, the iron and steel industry, where the refractories are used.Here I have just shown a schematic sketch of various vessels, where refractory material are used.The first one is a torpedo vessel.Now,this torpedo vessel typically, handles hot metal from blast furnace and transfer it to the LD steel making.That means, this torpedo vessel is the vessel which handles hot metal at around 1300 to 1450 degree Celsius and hence refractory has to be used.

Then, this torpedo vessel either can be directly put to LD converter or through a ladle,it can be put to LD converter. So, this is the ladle.This is the LD converter, where refractory is used; and this is again ladle, which is used for continuous casting,that is also requires a refractory; and this is a Tundish of a continuous caster, where refractory materials are also required.This is the shrouding,shrouding of a fallingliquid steel stream.There also refractory materials required.This is again a shrouding of liquid steel stream, that is poured inside the mold.

So, these are the various areas or various vessels that require the refractory.Now, in the lectures on BOF steel making and electric arc furnace steel making, I have told there, what refractory materials are being used. So, what I have thought in this lecture, let me tell you some of the emerging trends.

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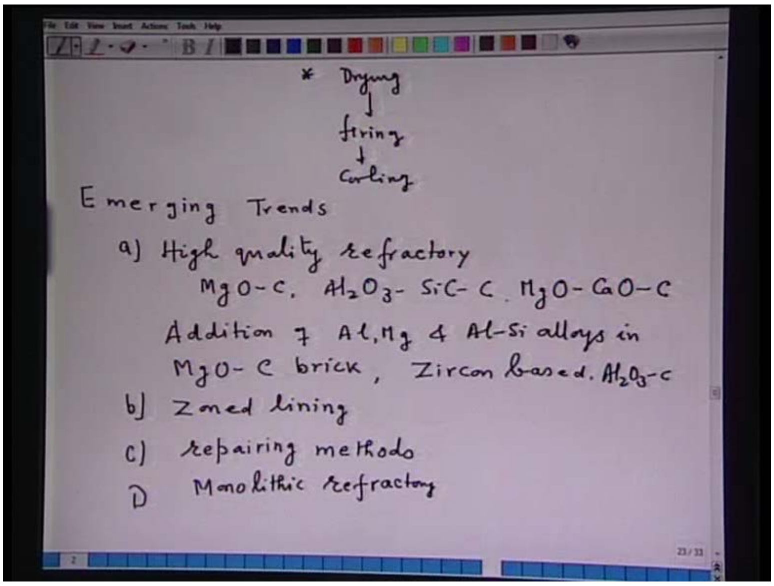

Now, in the previous ((user)) you must have noted, that right from hot metalto cast product, refractory materials are used. So, refractory is a heart of steel making.You cannot produce a steel, if there are no refractories available.So, refractories play a very important and dominant role in the steel industries. So, let us see, what are the emerging trends in the refractory industry.The objective of the emerging trends, is to see, how life of the lining can be increased.It is in this direction the various development took place.

The first is development of high quality refractory for critical applicationsand the critical applications mean, those areas in the reactor where erosion and corrosionof lining is maximum.For example, slag line, impact area of molten stream, bottom Tuyeres in hybrid blowing, immersion nozzles in continuous casting, they are some critical areas where the refractory erosion is maximum and the cost of the product will be decided, to some extent, on the wear and tear of the refractory. So, these are the certain critical areas where high quality refractories are required.

Now, here the several high quality refractories are developed.For example, M g O - C refractory,Al2O3SiC carbon refractory, M gO- CaO -C refractory, then addition of Aluminum,Magnesium and Aluminum-Silicon alloys in M gO - CO brick to generate some special properties, then zircon based refractories,Al 2O3 - C refractory. So, these are some of the refractories; however, many more are there, that you can collect from the literature.Another important thing in the emerging trend is,the concept of zoned lining.Zoned lining means, those critical areas, which are subjected to high corrosion and wear, you line it with a very high quality material.That is a zoned lining.

Third emerging trend is the repairing methods.Slag splashing, some part we have seen in the BOF lecture, slag coating, hot patching, gunning and here, flame gunning has been developed and flame gunning involves melting and spraying on hot surfaceand last portion, which I could, that it is the monolithic refractory.

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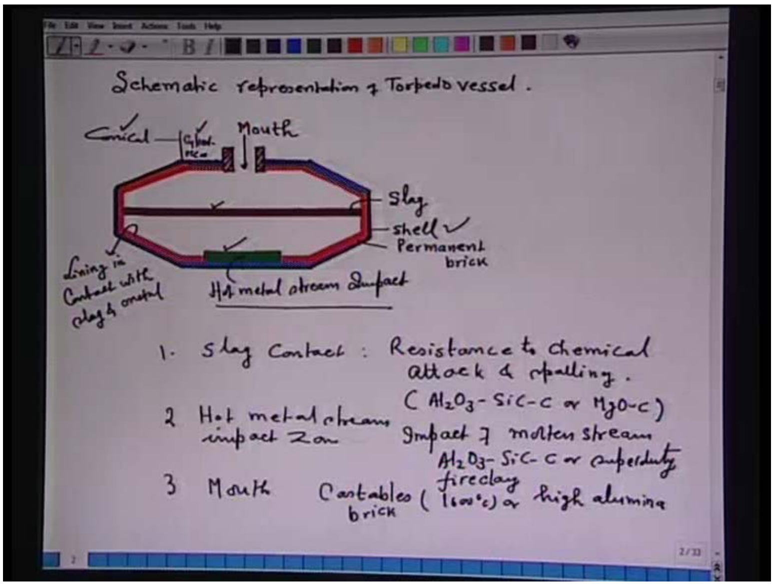

So, what I have thought, let me show the zone lining in certain reactors of steel making, and first I have selected is a torpedo vessel.A schematic representation of torpedo vessel is shown in this particular figure.Now, you see this torpedo vessel, it has a cylindrical portion, it has a conical portion.Then, hot metal it enters from the mouth and it directly, rather had an impact on the bottom of the torpedo vessel.So, this isthe hot metal stream impact area.This is the shell.This is the slag. This is the permanent brick and red one is a lining, in contact with slag and metal.

Now, in the earlier, the torpedo vessel was used to transfer the vessel from blast furnace to converter steelmaking, but with the increasing quality requirement, torpedo vessel are increasingly employed to carry out refining, in terms of removal of silicon,sulphur and phosphorus. So, the lining of torpedo vessel has changed drastically, because, now the lining has to be nonreactive, with the fluxing agent that are used for removal of sulphur and phosphorus.

Many a time, soda ash based fluxesor calcium oxide based fluxes are used.Hence, the lining which was used to transfer the vessel, now they are no more useful, if the torpedo vessel is to carry out the refining.Therefore, here particularly,a concept of zoned lining is beingemployed.Now, if you see now, zoned lining means, first of all we have to identify which areas are critical, from wear point of view of the refractory. So, the first is slag contact area.You are seeing, that this is a slag and this area is in contact with the slag. So, the important property that is required, resistance to chemical attack and spalling.

Now, here typically Al_2O_3- Si C - C brick lining or MgO- C lining is used in this particular area.Because, that area is subjected to highly corrosion from the composition of the slag.So, the refractory material which is used is Al_2O_3 -Si C- C or Mg-CO brick.Another critical is the impact zone or the hot metal stream impact zone.That is, I mean this particular area where the stream falls. So, this is also subjected to thesocalled, impact of molten stream. So, this particular area should have resistance to impact of hot metal stream, that is very important, compared, in comparison to corrosive action or whatever action is concerned.So, in the impact zone again,Al_2O_3 -Si C and carbon brick or super duty fireclay brick are used.

Third important is mouth.That is from here, the molten stream enters.Now, this mouth is made of castablesandof around 1600 degree Celsius or it may consist of high alumina brick.So, this is what the concept of zoned lining.Now, well, in the zoned lining, what is important, is to have a good binding between the different refractories at different points, but such things are now being done and it has increased the life of the torpedo vessel.Another example, zoned lining in duplex blowing.Though I have said, when I was taking the lecture on BOF steelmaking, I have also given you the idea of the refractory.Now, in the duplex blowing, that is combined top and bottom blowing, the concept of zone refractory is also being applied.

Now, in combined blowing one of the critical area is, the Tuyere set are employed at the bottom to inject the bottom steering gas.There the corrosion and erosion of the refractory material of the bottom Tuyeres, that determines the life of the bottom.Because, when the Tuyeres are eroded, you have to replace the Tuyere and accordingly the life of the converter is affected by that.

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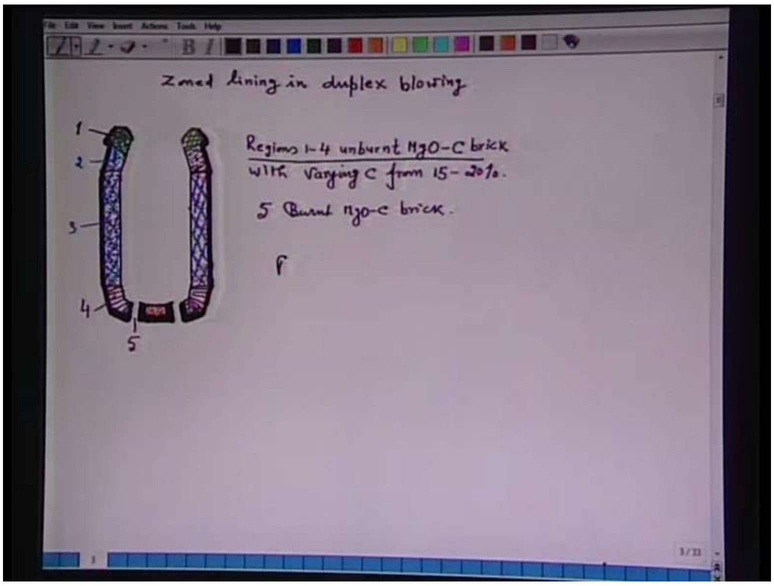

So, here also, the different zones are rather, are rather lined with the differentrefractory material.For example, region 1 to 4, it has un-burnt Mg O-C brick, with varying carbon from 15 to 20 percent.Then fifth, which is the Tuyere, they are burnt Mg O-C bricks are used.Now, the whole idea of putting the zoned lining is, to increase the life of the converter.Wherever the wear is there, it is effect is minimized by utilizing a high quality refractory.That means the whole idea is to develop a refractory lining, considering wear balance of the refractor; that is which area, I mean that area, which is subjected to maximum wear is lined witha high quality material,sothat, lining is minimum; that is what the idea of zoned lining.

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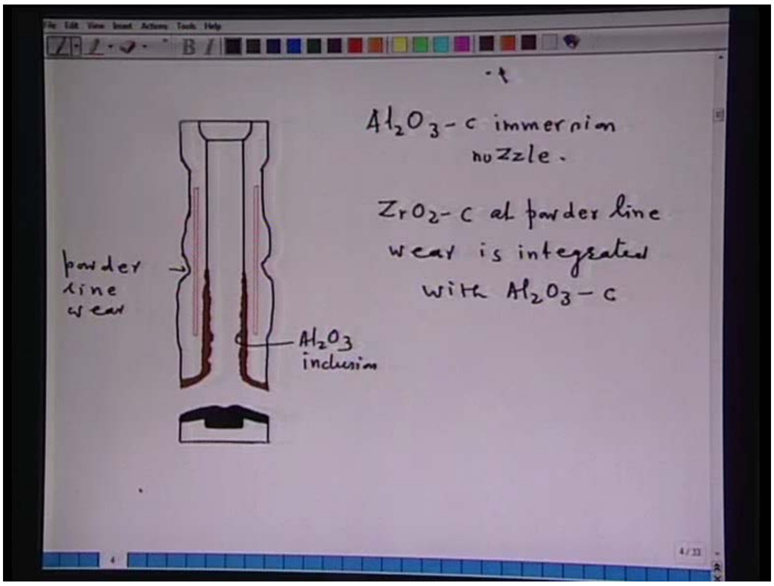

Now, another important that I can show you, this is the immersion nozzle, which is used for continuous casting of molten steel.From the Tundish the liquid steel enters into the mold and this is being done by nozzles and these nozzles are made of Al 2O3- C immersion nozzle.Now, you see, in the mold this particular nozzle is dipped into the mold and the mold is covered by fluxing. So, this area you are seeing here, this is the powder line wear.

Powder line wear and here, they are the buildup of alumina inclusions, if you are casting aluminum killed steel. So, when the alumina builds up on the walls of the immersion nozzle, then what will happen, it will affect the flow rate of molten steel, because the continuous casting is being done by the constant flow rate of liquid steel from Tundish to mold.So, if the aluminainclusions are buildup, then the casting rate will be affected. So, for this purpose, the ZrO2- carbon at powder line wear, this refractory is used and that is integrated the zirconia carbon refractory with A l 2O3- C refractories.Now, by mixing the ratio of zirconia particles, it is possible to decrease the powder line wear of the refractory.Next portion, we will be dealing in the next lecture.