Inorganic Chemical Technology
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Lecture - 34
Metallurgical Industries - I

Welcome to the MOOCs course Inorganic Chemical Technology, the title of today's lecture is Metallurgical Industries part 1. This course is on inorganic chemical technology then why are we studying about metallurgical industries?

We need to have a kind of basic understanding about that one. There are a few important connections between chemical and then metallurgical industries. So, because of that reason we need to have a kind of basic information basic knowledge about metallurgical industries as well.

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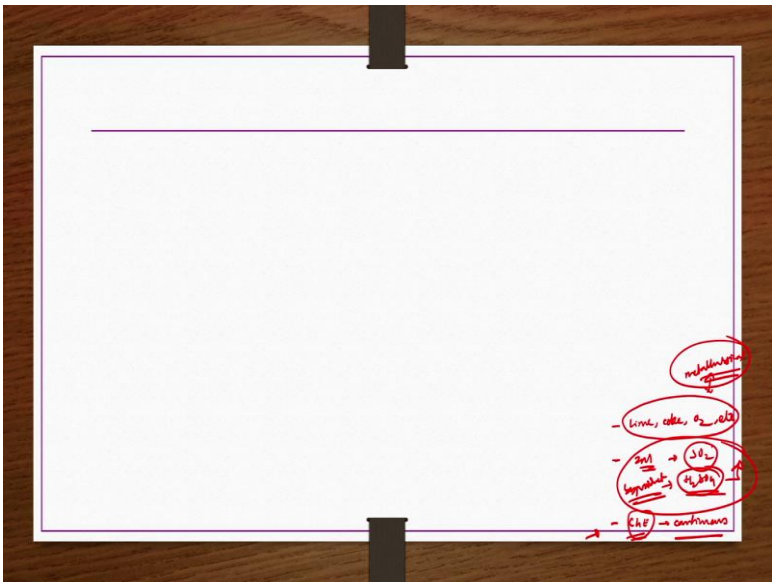

So, how can we put those connections? Let us say whatever the lime, coke, oxygen etcetera that we produce in chemical plants, these are primarily used by the metallurgical industries, utilized by metallurgical industries for different purposes for this melting process, production of iron, steel etcetera for those purpose these things are being utilized.

So, we are going to see a few of them anyway today's lecture itself, right. Another thing not only they are consumers of chemical products, metallurgical industry is not only the consumer of several of chemical products, but also some it produces some of the chemicals which are essential from chemical industries.

Let us say whatever ZnS melting process etcetera those things we have seen. So, where you know SO 2 etcetera has been produced also like you know zinc and copper smelting process, we have seen that H 2 SO 4 is a major by product. By product we though we call it by product, but it produce in such a large quantity that is this H 2 SO 4 in order to purify it that one you know plants you know chemical plants are having separate units to purify it and use it for the production.

So, these kind of things are also there, that is not only they are consumer, but also they produce some kind of chemicals which are you know important chemical plant productions as well, though they are by products for the metallurgical industries. That is one of the reason.

And then another reason is that you know so many of chemical engineering principles whatever are there which are you know on a continuous basis. So, these continuous operation principles along with the process control etcetera these are being continuously or increasingly utilized by the metallurgical industries.

So, that high output of metallurgical industries can be you know achieved by using these continuous chemical continuous approaches of chemical engineering principles, right. By using the continuous approaches of chemical engineering principles one can improve the high output of a metallurgical industries as well.

Because we are going to see like you know let us say iron or steel that making whatever we are doing, mostly you know they are fed as a batch and then you know required process has been required process used to be done in general, right.

So, in order to make them continuous you know you need to have a or you need to apply the principles of chemical engineering so that to make metallurgical processes as well continuous. Because of such kind of connections, it is essential to learn or understand about a few basics of metallurgical industries as well though being chemical engineering graduates.

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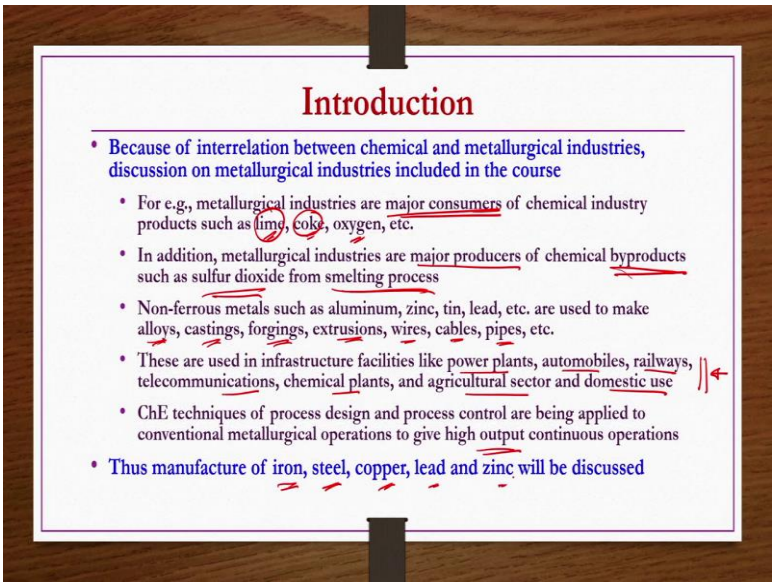

So, with this background we start about the introduction about metallurgical industries. Because of interrelation between chemical and metallurgical industries discussion on metallurgical industries included in this course because of a you know following reasons.

For example, metallurgical industries are major consumers of chemical industry products such as lime, coke, oxygen etcetera. See, this coke, lime are used in making pig iron as well as the steel for those purpose also they are used, oxygen is any way used in most of the industrial processes.

So, metallurgical industry is also one of the consumer of you know oxygen. So, that way there is a connection between metallurgical industry and then chemical industry. Further metallurgical industries are major producers of chemical byproducts such as sulfur dioxide, sulfuric acid etcetera.

These byproducts such as sulfur dioxide sulfuric acid sulfuric acid etcetera we get from these melting processes of a different types of a you know metals like zinc, smelting copper, smelting iron, pyrites smelting process etcetera. From those processes we get these gases SO 2 and then you may also get sulfuric acid H 2 SO 4 depending on the what ore has been utilized for the you know smelting of certain kind of ferrous as well as non-ferrous metals.

The non-ferrous metals such as aluminum, zinc, tin, lead etcetera are used to make alloys, castings, forgings, extrusions, wires, cables, pipes etcetera and all these markets are having one or other kind of connection with the chemical industries. Why because these are further used in infrastructure facilities development like power plants, automobiles, railways, telecommunications, chemical plants, agricultural sector and then domestic use uses etcetera.

So, because of this reason also we have a connection with a metallurgical industries as well. Because in most of these sectors whether it is power plant sectors, automobiles or telecommunications, chemical plants or agriculture sect sector one or other way chemical engineering contribution is required.

Further chemical engineering techniques of process design and process control are being applied to conventional metallurgical operations to give high output continuous operations. So, because of such reason we are going to discuss about manufacture of iron, steel, copper, lead and zinc in this particular week.

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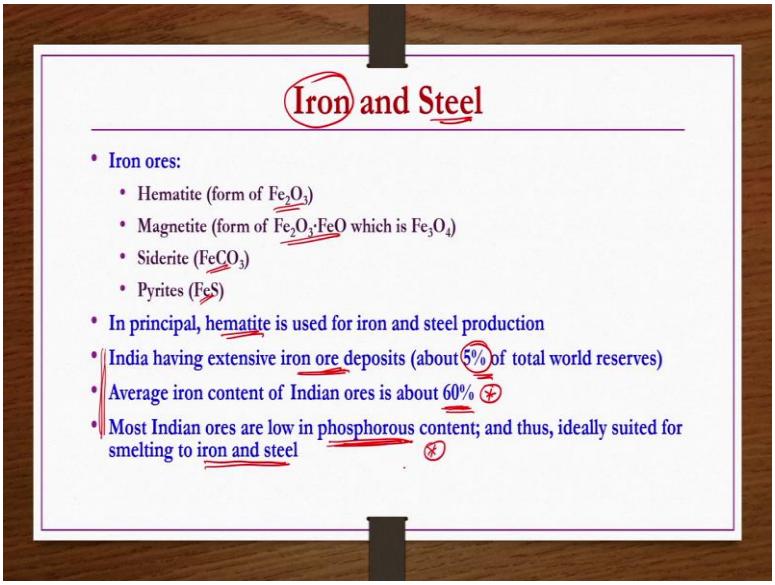

So, let us start with iron and steel, ok. What are the ores that are available to make iron and steel? So, primarily actually pig iron is made or the pure iron is made, right. So, which is mostly 95 percent or even higher purity in iron content. That iron is usually if you have 100 percent pure iron. So, that is useless because of its softness as well as the

high boiling point. So, then what you do? You do alloying of this iron with carbon to get different types of steel as per your requirement.

So, in order to get the steel first you have to get the iron and then that iron you get from the different types of iron ores. What are those iron ores? Hematite which is in the form of a Fe 2 O 3, magnetite which is in the form of Fe 2 O 3, FeO which is nothing but Fe 3 O 4. Then, siderite which is nothing but FeCO 3 and then pyrites which is nothing but FeS.

Actually, these ores you know they are rich in these contents whatever the mentioned iron contents are there. So, these ores are rich in these contents and then you do subsequent process to purify ores and then those ores further you do the processing to get the iron followed by alloying to get different types of steel, that is the process, ok.

So, let us say pyrites in the sense FeS does not mean that it is having only FeS. There may be some kind of other ingredients, impurities may also be there. So, all those things has to be removed in the purification process. In principle, hematite is used for iron and steel production in general, but however, in some case magnetite is also used.

India having extensive iron ore deposits about 5percent of world reserves of iron deposits whatever are there they are coming from India. So, such high resources or deposits of iron ores are present in India. Average iron content of Indian ores is about 60 percent which is also very high.

Further, in addition to that one Indian ores are low in phosphorus content. If the phosphorus content is less than the ideally that is suited for smelting to iron and steel actually. Actually, from pig iron and to steel we are making you know by removing the impurities like phosphorus etcetera, by oxidizing them those kind of processes we are doing to get the pure iron and then doing the alloying to get the steel, right.

If the phosphorus content itself is low in the ore so then it will be easy to make steel from the iron ores followed by iron and then steel by following that process, ok. So, that is the advantage. So, Indian in metallurgical industry is having this advantage that you know iron ores or iron ore deposits are very high and then average iron content of Indian ores is also very high that is 60 percent. And then most Indian ores are low in phosphorus content which is a very important advantage as well.

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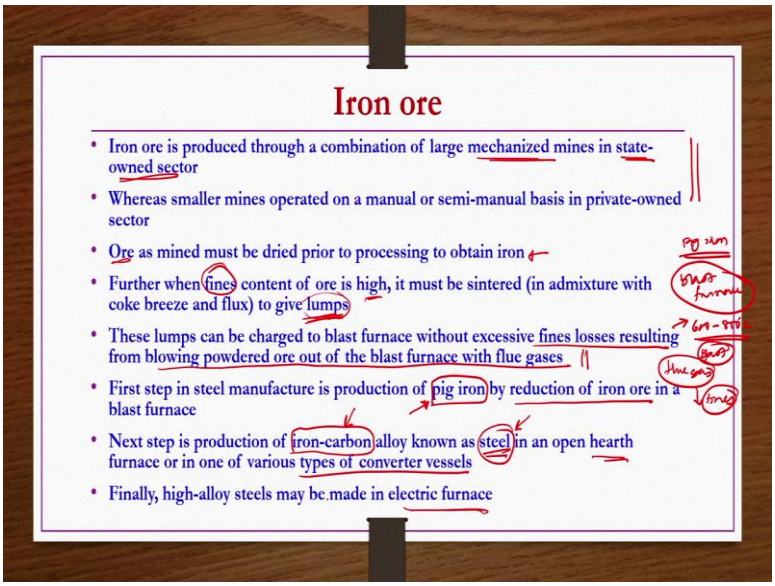

So, now we start with iron ore purification or concentration of iron ore. Iron ore is produced through a combination of large mechanized mines in state owned sector. Actually, you know continuous mechanized mines are also there as well as the small scale semi mechanized sectors are also there which are owned by the private sectors.

Majorly state owned government sector mines are large machine mines, ok. Whereas, smaller mines operated on a manual or semi manual basis is private owned sector, ok. So, either of these two approaches are followed in order to do the mining of iron ores. Ore that is mined must be dried prior to processing to obtain iron. Because whatever the ores whether it is iron ore or any ore when you will get from the natural resources, they are damp in nature.

So, they have to be dried in order to do the further processing to get the important you know mineral recovery etcetera for that purpose. So, it has to be dried prior to the further processing. And then when fines content of ore is high it must be sintered to give lumps. Why lumps? Because we are soon, we are going to see let us say pig iron making that we are going to see. So, there you are having blast furnace as an as a kind of unavoidable equipment. In fact, in this equipment only the iron is being produced.

So, here in this furnaces what you do? You give you know preheated air or oxygen which is preheated at 600 to 800 degree centigrade. And then how do you introduce into

the furnace? You introduce as a blast, you introduced into the furnace as a blast. So, when air at high temperature is introduced as a blast.

So, if the ore is having the fines so then that fines may be carried away along with the flue gases. Along with the flue gases fines may be carried away. And then that is not going to be advantageous. If the fines are being carried away the without being reacted within the furnace. So, that is going to be loss.

So, that is the reason in the this pig iron process or any other process that we are going to discuss to get you know different types of metals we avoid having fines, right. So, they are charged in in general in lumps of 2 to 5 centimetres etcetera. These lumps can be charged to blast furnace without excessive fines losses, resulting from blowing powdered ore out of the blast furnace with the flue gases.

This is the problem. So, that is the reason you try to avoid fines or keep fines as much less as possible, if you cannot avoid and then give the charge of a ore in the lumps forms, ok. First step in steel manufacture is production of pig iron which occurs by the reduction of iron ore in a blast furnace.

Then second step is production of iron carbon alloy which is known as steel in an open hearth furnace or in one of various types of converter vessels, ok. So, in order to get the steel there are two steps. First you have to get the pig iron which is almost like pure iron more than 95 percent purity something like that. So, if it is pure so, iron will be having a soft nature and then melting temperature will also be high.

So, that way it is not going to be useful in order to make different types of structures out of the iron. So, for that reason iron usually alloyed by carbon to get the steel. So, steels are not like a pure iron. So, they are iron carbon alloys kind of things. How much composition of iron carbon is there? That depends on the what is the type of a steel whether SS316 are the different types of steel that you are going to produce accordingly the alloy composition has to be maintained.

So, this alloying can be done in open hearth furnace or in various types of converter vessels as well. Then finally, high alloy steels may be made in electric furnaces as well. So, in order to get the steel first you have to produce the pig iron so that we are going to

see. And then after that we are going to see the steel making in open hearth furnace process as well.

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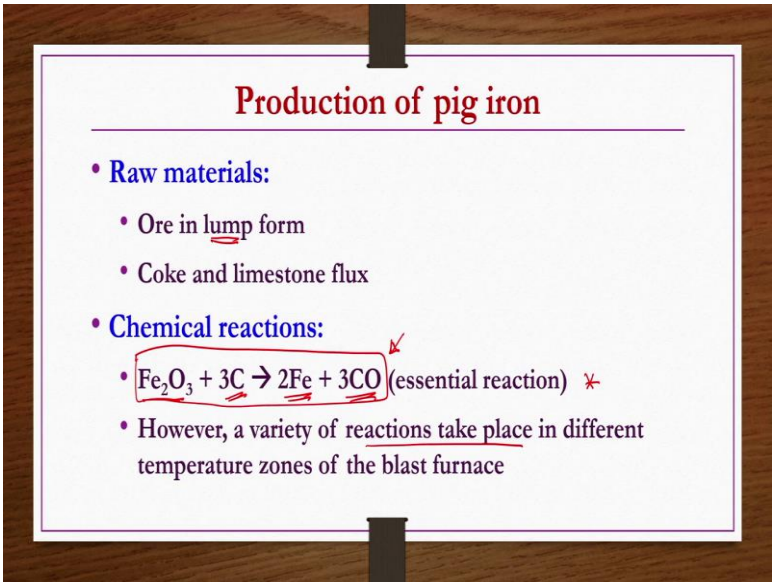

So, let us start with production of pig iron. Raw materials for the production of pig iron are nothing but ore in lump form lump form because of the reason that I mentioned. If ore is there in the fines and then when it interacts with preheated oxygen or preheated air which is coming at high temperature in the form of loss.

So, then when the blast occurs in the furnace so, then these fines would be carried away along with the flue gases. So, in order to avoid the wastage of a fines you know you introduce the ore in lump form in the furnace to get the pig iron. So, raw material that ore should be in the lump form not in the fines.

Coke and limestone fluxes are required. Chemical reactions essentially whatever hematite that is Fe 2 O 3 rich ore is there that reacts with the coke at high temperatures something around 1700 degree centigrade like that to get iron and then carbon monoxide.

This is the essential reaction, but you know furnace as we have seen in different types of glass makings and then cement makings also, you know furnace is having different temperature ranges so then different types of reactions goes on. So, here also variety of reactions take place in different temperature zones of the blast furnaces as well. So,

however, this is the primary reaction that should be you know progressed at higher rate so that to get a you know higher yield of iron.

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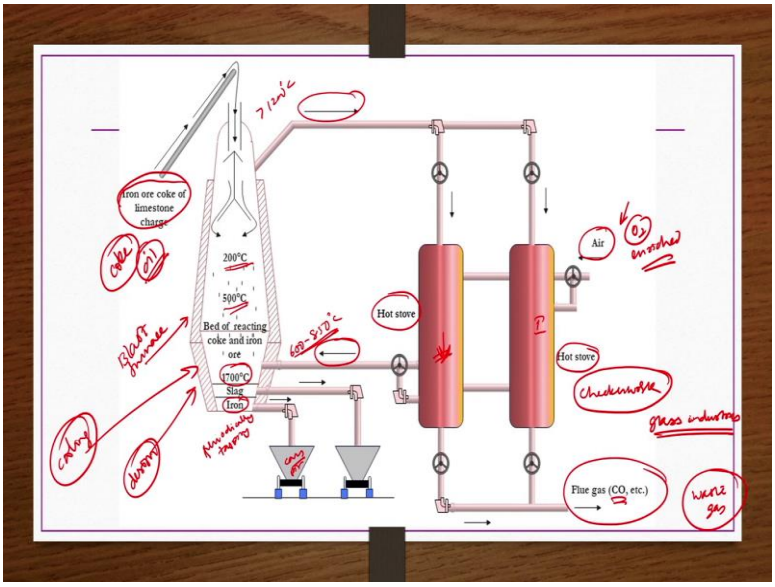

So, now this is the flow chart to get the pig iron, right. So, what we have here? We have a blast furnace; this is nothing but the you know blast furnace. To this from the top iron ore, limestone and then coke mixture whatever is there in a proper weight fractions, whatever the weights are required in order to get a required in order to have a required yield and then purity of a pig iron, you know you have to measure the weights of these ingredients iron ore, coke, limestone etcetera and then introduce them from the top, right.

From the bottom to this furnace what are you doing you are allowing air which is preheated by using hot stoves which are nothing but checker work recuperator, recuperator stoves like kind of things which operate in alternatively. So, these hot these stoves are used to preheat the air and that air is preheated to approximately 600 to 850, 800 degree centigrade something like that.

And then introduced as a blast to the bottom of the furnace so that whatever the charge that is coming charge is nothing but iron ore, coke, limestone etcetera that we react you know with this air. Then what happens? The coke that reacts with the hot air and then liberates CO and then also it liberates lot of the a lot of energy, right.

So, that energy would be utilized by the ore in order to melt and then required separation of a you know pig iron and from the impurities takes place, right. So, now here whatever the flue gases that are formed they are taken from the top and then recirculated to hot or hot stoves, recuperative hot stoves, right. So, that they are nothing but like you know checker work regenerator regenerators that we have seen in the glass industries.

So, similar kind of a things are there here. So, what is the purpose? They are operated alternatively first let us say first you know this is operated in order to preheat the air in the first cycle. So, then that reaction takes place then flue gases would be at high temperature you know order of 1200 degree centigrades or even more, right.

So, those gases would be now second time would be passed through another stove here, the whatever the sensible heat of flue gases is there that would be utilized by the air that is coming in and then that would be preheated and then sent to the furnace in the form of blast, ok. In the form of blast that is introduced.

So, like this this cycle continues. In the next cycle what happens? Rather this stove is being used the first one would be used. So, like that alternatively they are utilized, you know once it is if let us say if the first stove is providing the energy to preheat the air, second one would be receiving the energy from the flue gases and then that energy would be utilized by the air for the preheating in the second cycle.

So, further in the next time if the second one has given energy to preheat the air the first one would be you know receiving the energy from the flue gases and then that would be stored. Like that alternatively they are used so that you know energy efficiency would be high, ok.

So, in this process in the furnace different temperature zones would be developed. At the top low temperature would be there and then gradually has moved on the temperature increases because of the nature of the reaction and then in which direction reaction is taking place, ok.

Blast is coming from the bottom and then at this bottom coke is reacting with the high temperature air or oxygen to release CO plus energy. So, then at the bottom where the reaction is occurring between coke and then preheated air or oxygen. So, in that region temperature would be going to be high, right.

So, because of the reaction taking place whatever Fe that is formed. So, that is collected as from the bottom as and then taken into cars as pig. So, here the pig iron is collected, right. If at all any slag etcetera is there that is also collected from the bottom itself and then this is done periodically by tapping. Periodically, what you do? Tapping to get the molten iron from the bottom.

Same like you know periodically you are tapping in glass industries to get the a molten glass etcetera the similar process is taking place here also, ok. So, now whatever the flue gases are there CO etcetera they can also be collected from the bottom and then used for the you know different processes of the plant. Because these flue gases produce in large quantities and lot of heat also being carried by these gases. So, they can be utilized properly.

So, now this is basically about the process so, but what are the problems associated with that one? So, first one is that rather using air what you do? You can use oxygen or oxygen enriched air so that to make sure that you know combustion whatever the reaction takes place between C and then that between coke and an oxygen is higher one and then energy efficiency may be there, right.

Another option is that you know the you are using coke, coke is also expensive and it is produced from the coal industry. So, rather using coke if you can use oils you know to get the required energy for the combustion of the you know iron ore whatever your limestone etcetera that you are taken. So, then that would also be energy efficient. Because oil is less expensive than the coke, right. Because you can use some kind of furnace oil etcetera those kind of things.

So, if you can do that one. So, it is going to be energy efficient as well, right. And then this structural you know design, design of furnace this structure itself is having very big structures thousands of tons it may be having the you know weight. So, it has to be properly designed.

Next another one is that waste gases, how are you cleaning the waste gases? So, waste gas cleaning is a very essential process. So, these are a few engineering problem that you one should be careful about. But most important is that cooling, cooling of this process because at the bottom see the temperature is around 1700 degree centigrade something like that.

At high temperature if you are not doing proper cooling what happens the heat may be having the negative impact on the process, right. So, then what you have to do? Water cooling or water circulation at the bottom of the furnace should be provided. So, that required cooling should be there and then temperature should not shoot out, ok. So, this is what production of pig iron by blast furnace approach, ok. So, now whatever we discussed here the same thing we are going to discuss here in the text form as well.

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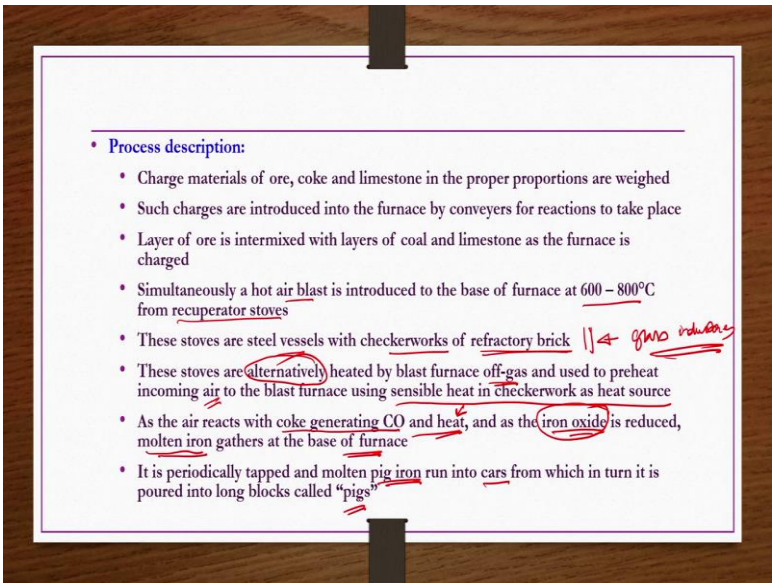

Process description: charge materials of ore coke and limestone in the proper proportions are weighed. Such charges are introduced into the furnace by conveyers for reactions to take place. Layer of ore is intermixed with layers of coal and limestone as the furnace is charged. Simultaneously a hot air blast is introduced to the base of furnace at 600 to 800 degree centigrade from recuperator stoves as shown in the flow chart.

These stoves are steel vessels with checker works of refractory brick. So, what are these checker work a refractory bricks etcetera those things we have already discussed in detail in glass industries chapter when we were discussing right, the same ones are being used here also.

These stoves are alternatively heated by blast furnace of gas and used to preheat incoming air to the blast furnace using sensible heat in checker work as heat source. As the air reacts with coke generating CO and then heat ok, and as the iron oxide is reduced because of this heat generated because of the reaction between coke and then air.

So, that heat will make the iron oxide to undergo reduction to produce molten iron which gathers at the base of furnace. This molten iron is periodically tapped and molten pig iron run into cars from which in turn it is poured into long blocks called pigs, ok. This is about the process.

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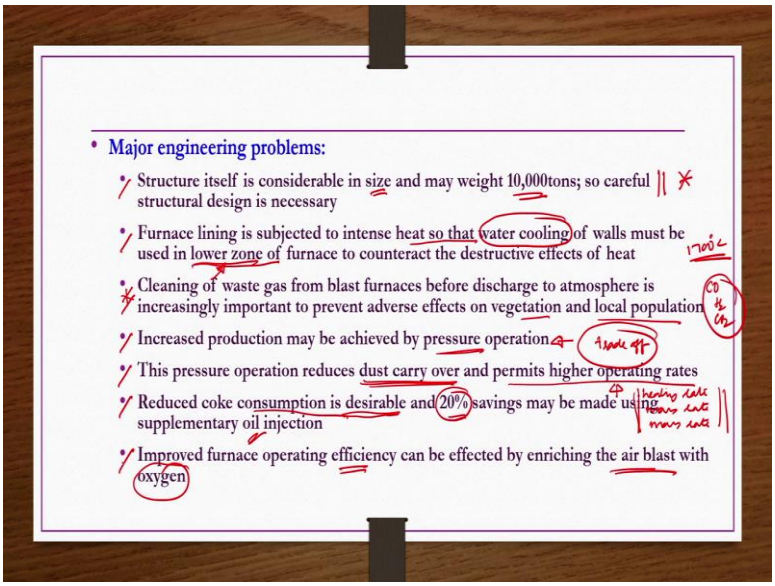

Now coming to the major engineering problems those things are also we have discussed. So, what are they? Structure itself is considerable in size and may weigh up to 10,000 tons. So, careful structural design is necessary for the blast furnace, it is very essential, right.

Then furnace lining is subjected to intense heat so that water cooling of walls must be used in the lower zone of furnace to counteract the destructive effects of heat. Why lower zones? Because in these lower zones areas only the temperature is very high in the order of 1700 degree centigrades or even more. So, you do not want temperature to go beyond that one. So, for that purpose water cooling of walls of furnace is required especially in the lower zones.

Cleaning of waste gas from blast furnaces before discharged to atmosphere is increasingly important to prevent adverse effects on vegetation and local population. So, this is very essential because you know the flue gases are primarily containing CO H 2 and then CO 2 these kind of gases are only there, ok.

Increased production may be achieved by pressure operation data. This has also been found by different researchers and being implemented in industries and then you know what pressure should you allow. That again depends on trade-off between you know temperature that you are supplying and then pressure that you are maintaining.

Because if you have high temperature, high pressure then controlling the conditions will become very crucial and then if you are not controlling the such high temperature and pressure as per requirement then you know explosions may take place and then which is not going to be good for anyone. This pressure operation reduces dust carry over as well because dust carry over. Because these dust are usually nothing but they are having some kind of fine ores so that has to be reduced.

So, the so such reduction of you know fines loss is also found to be beneficial when you improve the pressure of the operation. Further it permits high operating rates. What do you mean by high operating rates? The heating rate and then mass rate at which the feed is coming out.

And then mass rate at which periodically you are taking out the pig iron, mass rate at which periodically you are taking out the slag from the bottom. So, all these you know you can operate at higher rates also if you operate at higher pressure conditions. Reduced coke consumption is desirable is very much essential because if you have the coke then pollution is more.

So, then in place of coke if you use the oil then what happens? Not only 20 percent savings may be there, but also it reduces the pollution in the waste gas, ok. So, the cleaning of waste gas, you know the load of cleaning of a waste gas would be reduced if you use the oil not only the savings that way also it is beneficial.

Then improved furnace operating efficiency has been found by enriching the air blast with oxygen. If you use enriched oxygen or air with enriched oxygen then it has been found that you know furnace operating efficiency also improved. So, these are the some of the important points one should be careful while operating blast furnaces to get pig iron.

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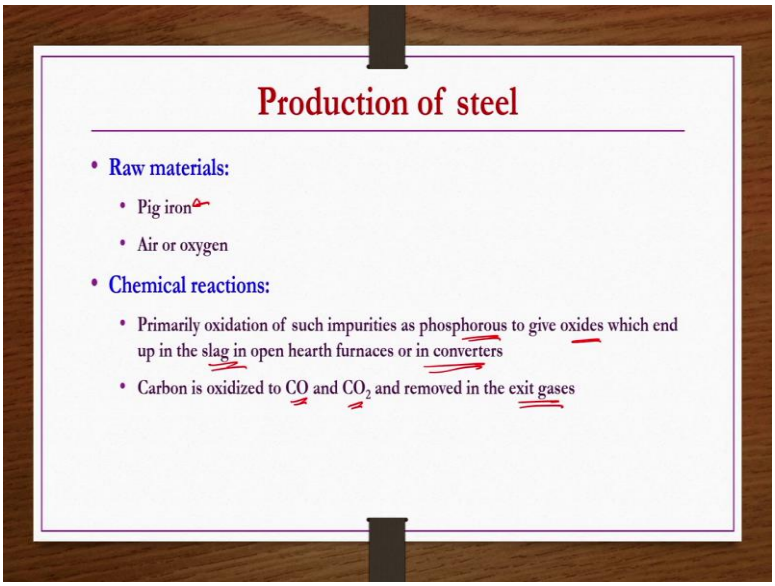

Now, we discuss about production of steel. Raw materials: obviously, the pig iron that we get from the blast furnace just we have discussed. So, that is the raw material actually production of steel is nothing but you know purifying the pig iron. Pig iron may be having some kind of impurities like phosphorous etcetera, carbon etcetera and then sulphur etcetera those things has to be removed. How do you remove?

You do the oxidation of this pig iron. So, that those phosphorous, carbon and then sulphur etcetera they will be removed from the pig iron in the form of their oxides right, and then pure iron you will get that you can do the alloying with the carbon to get the steel that is the basic process, ok.

So, raw materials is pig iron. So, air or oxygen is required because you are doing oxidation of a pig iron to remove the impurities from the pig iron. So, that purified iron can be alloyed to get the steel, ok. So, that means, oxygen is essential raw material here.

Chemical reactions if you see primarily oxidation of impurities such as phosphorous to give oxides which end up in slag in open hearth furnaces or in converter. So, then oxidation reactions only primarily taking place. However, carbon is oxidized to CO and CO 2 and removed in the exit gases also. This is the other reaction that is occurring in the open hearth furnace process.

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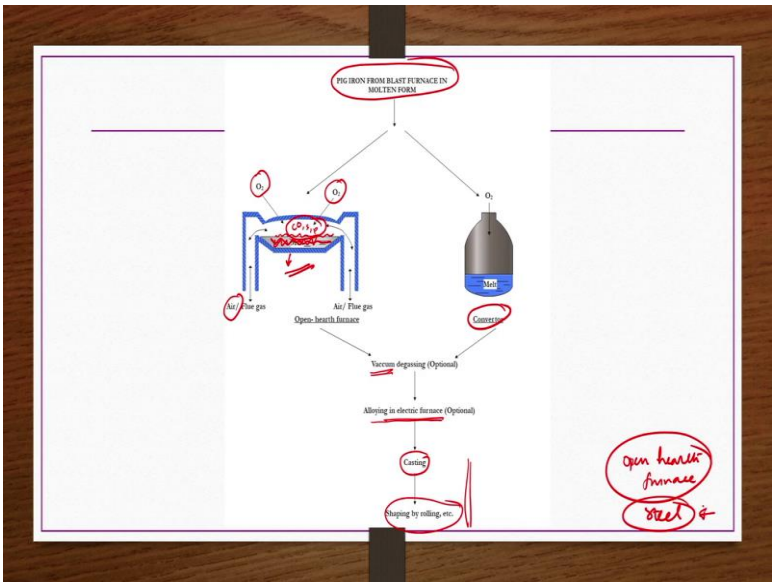

So, this is the open hearth furnace process to get the steel, right. So, here we have a open hearth furnace as shown here, to this one pig iron from the blast furnace in molten form is taken. So, that molten form pig iron whatever is there that is taken here, right. And then to this one air and flu gases are being supplied and then required temperature of 1200 or something like that is maintained here, right.

So, then what happens? Whatever the impurities phosphorous, sulphur, carbon etcetera that are present in the more this molten pig iron. So, they will be oxidized and then they will be released as their oxides and then almost like pure iron whatever is there that you can get from the bottom by periodically tapping it, ok.

So, this air flu gas locations directions are given both sides. So, that it is they are supplied alternatively, they it can be done by a cycle kind of thing. So, for few hours or few minutes it can be you know supplied from one direction and then collected from the other direction.

After some time, the direction may be you know reversed that can be done. And then oxygen lances are provided at the top in order to improve this oxidation process here, in newer kind of furnaces are having these provisions. So, this air or oxygen whatever is there that can be blown over the surface or across the melt can also they can be supplied, right.

So, now what happens? When these reactions take place this molten boils off and then when it boils off it releases the CO and then oxides of sulfur oxides of you know phosphorous etcetera if it all present they will be taken out. So, from bottom whatever the almost pure iron that you get obviously, since it is under boiling condition there will be some gases.

So, then vacuum up would be applied to do the degassing. Once removing the gases by applying the vacuum proper alloying of this iron with the carbon is done in electric furnace to get required steel and then followed by the casting, shaping, by rolling etcetera as per the requirement.

Same thing can also be done in different types of converters in which molten pig iron is taken and then across that one oxygen is supplied across to that one or along the surface they are supplied. So, that the required oxidation reaction takes place and then you know oxides of sulfur phosphorous etcetera will be removed.

And then once the oxides of sulfur phosphorous and then carbon etcetera are being removed so the pure iron would be passed through a vacuum degassing section to remove the gases if at all present, followed by the alloying with the carbon in electric furnace casting and then shaping by rolling as per the requirement of the consumer. This is the you know process about you know open hearth furnace to get the steel, ok.

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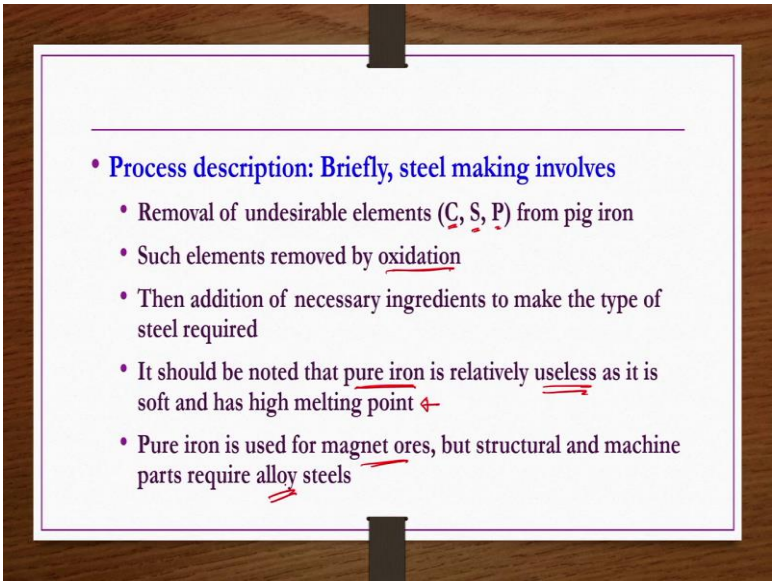

The same thing description, if you see process description briefly steel making involves removal of undesirable elements like carbon, sulphur, phosphorous from pig iron, such elements removed by oxidation reactions only. Then addition of necessary ingredients to make the type of steel required what type of steel you required accordingly you have to do the alloying.

So, that alloying is done in electric furnaces in general. Because pure iron is relatively useless as it is soft and has high melting point. So, then you do not want to have pure iron rather pure iron you make alloying with carbon as per the requirements and then produce steel, ok. Pure iron is used for magnetos, but structural and machine parts require alloy steels only, ok.

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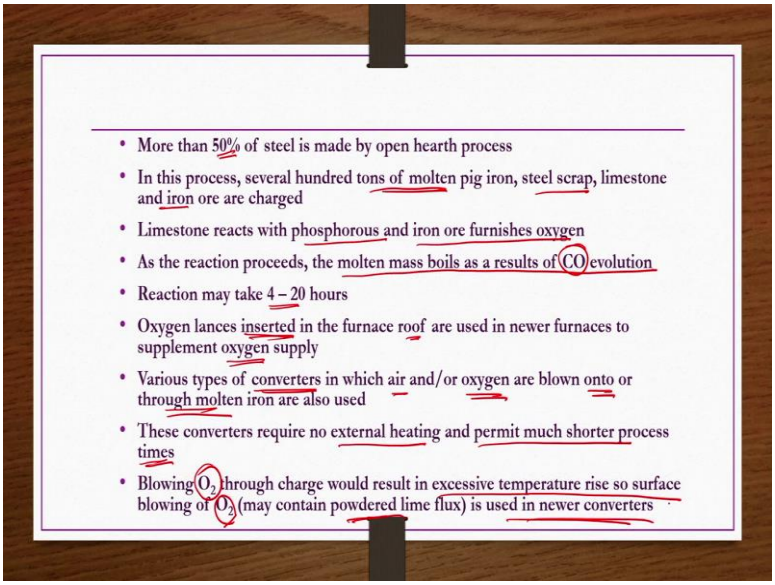

Coming to the description of the open hearth process more than 50 percent of steel is made by open hearth process. In this process several 100 tons of molten pig iron, steel scrap, limestone and iron ore are charged. Limestone reacts with phosphorus and iron ore furnishes the oxygen. As the reaction proceeds the molten mass boils off as result of a CO evolution.

This reaction may take 4 to 20 hours. Oxygen lances inserted in the furnace roof are used in your furnaces to supplement oxygen supply which is not fulfilled by the air that has been provided from the bottom to the furnace. So, for that purpose this oxygen lances are being inserted at the top of the furnace roof. Further various types of converters are also

used in which air and or oxygen are blown on to or through the molten iron are also used. So, either of them are possible.

These converters require no external heating and permit much shorter process times, ok. Blowing oxygen through charge would result in excessive temperature rise. So, surface blowing of oxygen which may containing powdered lime flux is used in newer converters as well. So, that is about the steel making by open hearth furnace process.

If you see its engineering problem, if there is a nitrogen in the air what happens that will make the a steel brittle. So, embrittlement of the steel may take place if the nitrogen is present in the air that is supplied for the oxidation of pig iron to get the you know pure iron right. So, so you have to make sure that there should not be any nitrogen in the air or you know you should be you should able to remove it you know before getting into the iron contents and then making it brittle.

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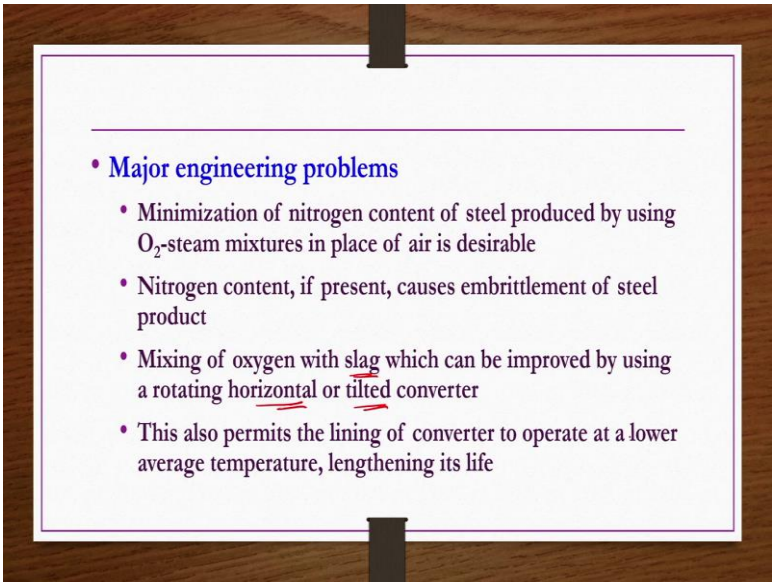

Minimizing of nitrogen content of steel produced by using oxygen steam mixers in place of air is desirable because nitrogen content if present it causes embrittlement of steel product. Further mixing of oxygen with slag which can be improved by using a rotating horizontal or tilted converter is another important advantage if you can manage. This also permits the lining of converter to operate at a lower average temperature lengthening its life.

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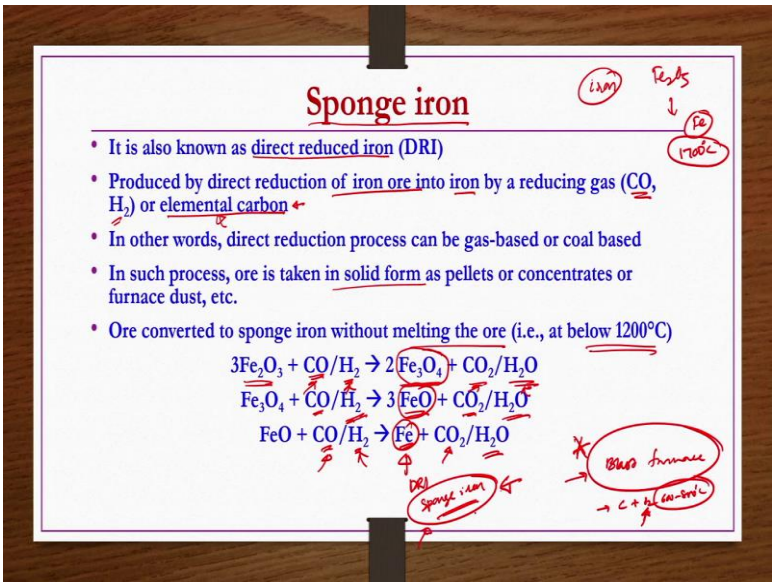

Now, let us talk about sponge iron, what it is? Sponge iron is nothing but direct reduced iron, it is also known as direct reduced iron. Actually, whatever the iron that we are getting how are we getting? We are getting you know Fe 2 O 3 is there and then you are trying to do the reduction and then get the iron that is what you are going to do, that is what you are trying to do whether it is pig iron and followed by steel making whatever it is, right.

But here the temperature is very high like 1700 degree centigrades etcetera to melt the iron ore, ok. So, that melting temperature such high melting temperature requirements can be reduced if you do the direct reduction of iron ore. So, when you do such direct reduction of iron ore to get the iron then the product whatever you get is known as the sponge iron which is also having iron content about 92, 93, 94 percent similar like pig iron, ok.

So, it is produced by direct reduction of iron ore into iron by reducing gas CO or H 2 or elemental carbon obtained or achieved from the natural gas or coal. So, whether are you using gas CO or H 2 or both in order to do the reduction of a iron ore or whether are you using elemental carbon to do the required reduction of iron ore. So, this DRA process can be gas based or coal based, ok.

Such processes ore is taken in solid form as pellets or concentrates or furnace dust etcetera, they are not you know melted completely to do the required you know reduction

of the iron ore, ok. Ore converted to sponge iron without melting the ore that is you operate at temperature below 1200 degree centigrades.

What are the reactions that occur in this process? Let us say hematite if you take and then react with CO or H 2 then you get the magnetite Fe 3 O 4 plus CO 2 or H 2 O. If you are using CO then you get CO 2, if you are using H 2 then you get H 2 O.

Similarly, in the subsequent step this Fe 3 O 4 that is magnetite that reacts with CO or H 2 to give ferrous oxide. If you are using CO as a reduction agent then you get CO 2, if you are using hydrogen as a reduction agent then you get water. This ferrous oxide would further be reduced to iron by using CO or H 2. If you are again using CO then CO 2 you get if you are using H 2 then you get H 2 O, right. So, this iron whatever is there. So, that we call it DRI are sponge iron. So, what is the point of using this one?

The use of blast furnace, actually blast furnace though it looks very simple process in the flow chart, but operation wise you see you are reacting coke with oxygen which is preheated to 600 to 800 degree centigrade and then this oxygen or air you are introducing into the furnace as a blast.

So, when it enters in the furnace at high temperature as a blast then you know a kind of explosion takes place in the furnace. So, then you have to properly control the conditions. So, that is very that is a very danger. And also, whatever the molten iron or slag that is forming at the base of the furnace that also be periodically continuously has to be removed otherwise process cannot be continuous, right.

So, such kind of problems would be there in the blast furnace that is used to get a pig iron. So, that requirement of such blast furnace would be avoided if you do this direct reduction of iron ore to get the sponge iron. But what are the problems then if you have this sponge iron by this process?

The problem is that it may be having some siliceous gangue etcetera so which is which has to be removed while making the steel. That is the only disadvantage otherwise sponge iron is a very good and then efficient and newer technology.

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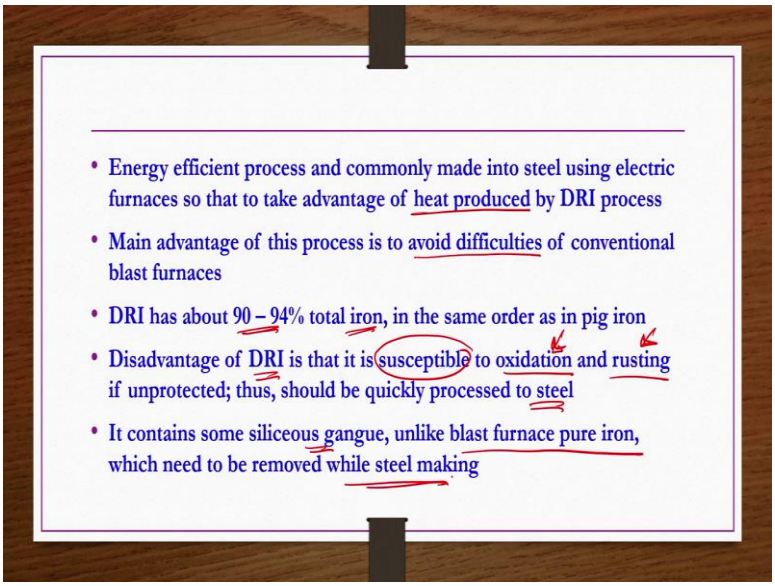

It is energy efficient process, commonly made into steel using electric furnaces so that to take advantage of heat produced by DRI process. Main advantage of this process is to avoid difficulties of conventional blast furnaces, right. This direct reduced iron whatever is say that is having 92, 94 percent total iron which is on par with the pig iron not much less. However, it has a disadvantage that it is susceptible to oxidation and rusting if you do not protect properly.

So, because of a its susceptibility to oxidation and rusting you it is immediately processed to make a steel, quickly processed to make steel in general, ok. Other disadvantage that it contains some siliceous gangue unlike blast furnace pure iron. So, this gangue need to be removed while steel making. So, that is all about the production of a iron and steel by different processes. In the next lecture we are going to discuss about the production different types of a non-ferrous metals.

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The references for today's lecture are provided here. The first one is Outlines of Chemical Technology by Dryden which is edited and revised by Gopal Rao and Marshall, 3rd edition, then Chemical Process Industries by Austin and Shreve, 5th edition.

Then, Encyclopaedia of Chemical Technology, Kirk and Othmer and then Unit Processes in Organic Synthesis by Groggin's. However, the entire lecture notes that has been presented in today's lecture is prepared from this reference book Dryden that is Outlines of Chemical Technology.

Thank you.