METALLURGICAL AND ELECTRONIC WASTE RECYCLING

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Week- 6

Lecture-27

Greetings, we are going to continue where we had left in the previous lecture. We were discussing about the recovery of valuable materials and in this case the energy from iron making slag, glass furnace slag. We had seen that CO_2 sequestration is a bit more easier and people have tried to apply more comfortably with the steel making slag. But the iron making slag has been used for waste heat recovery and we've also seen the some of the most important challenges. The important challenges that we had discussed included the low thermal conductivity of the material that we are using. Similarly, the corrosion properties, the nature of the slag itself is such that development of equipment for heat recovery becomes a challenge and the glassy phase that is expected while the processing that may not be generated in the waste heat recovery processes that are developed. Looking at these challenges, one has to device a process that can overcome and extract the heat and make the material viable enough for other applications.

There are actually two routes for waste heat recovery which are basically thermal route and then there is the chemical route. And we will be discussing both of them and we will see what else we can describe in the process, how we will be making other valuable materials. Slag generation increases heat transfer. Slag granulation, we know that slag has been generated.

One has to think of slag granulation and we had discussed this slag granulation previously. We know that one has to make bring it in contact with water and one can think of adding too much water with some pressure or one can think of reducing the water content and applying some sort of rotary mechanism. Granulation is also happening, but it consumes relatively lesser amount of water. That part we have discussed previously. We are going to use that concept here. If you are using slag granulation heat transfer becomes relatively more easier. Why is that? Suppose that we have a pile of slag. It is at some temperature T and this pile of slag, this accumulation of slag is just radiating or releasing heat.

There are the modes of radiation and modes of heat transfer. But when it is releasing heat, only some quantity of heat that is entrapped in slag is actually getting out. If more exposure of slag to the environment is ensured, then the heat released can also be extracted. Instead of looking at a pile of iron making slag, blast furnace slag, if we somehow granulated and use this granulated slag as a raw material for waste heat recovery or even during the process itself because when we are adding water it is going to lose it or when we are bringing it for rotary operation it is again going to lose some amount of heat. How can we go about the whole process of waste heat extraction that one has to ensure. Slag granulation increases heat transfer and this heat transfer is from the slag itself to the heat exchanger and this can be done by basically just assuming a simple step that we have the reduction of particle size. Which means, which also means increase in contact area.

Specific surface area if we just divide it by volume zone. Slag granulation is going to increase the effective contact area which is good for heat transfer, instead of looking it as a pile of blast furnace slag. We know that the wet granulation, we had discussed. Granulation we will look at one more time. Granulation. We have wet granulation and we know that wet granulation means we need to add water, addition of water and there is one more important aspect that we did not look at previously which is the generation of gases. When we are adding water to slag. Depending on the composition of the slag, there is a possibility of generation of gases.

What are the gases that can be generated? We will look at them. If sulphur is present, so we can have SO_2 and/or H_2S generation when we are adding water into it. The other route is basically dry granulation. When we think of dry granulation, we are doing something of this sort.

We will have crushing, grinding, we also have blast granulation and we will have centrifugation. We will discuss some parts of this. In crushing, we are using drums or we have agitators for granulation. Blast, we are using high speed air and high pressure gas input. This gas is inert gas and it can have nearly 100 meters per second and what it does is basically 80 tons per hour processing capacity and what we also get is nearly about 3 millimeter particle size. This actually is a good route. What we are thinking of is basically having a device that can charge high pressure, high velocity gas. It will interact with the slag and what we normally would be getting is 3 millimeter size granulated blast furnace slag. GBFS, Granulated Blast Furnace Slag.

And what is the efficiency? We can have really high velocity. In this case it is 100 meters per second. What advantage does it have? Instead of having a drum and wherein we are also adding some quantity of water, so even if we have an agitator, we have to have some quantity of water added into it which is also not categorized as wet granulation altogether. But this is also giving us very fine particles which may not be available in the other routes. And of course the centrifugation. Centrifugation is having rotary centrifugator or granulator. Which is going to do what? Which is going to do centrifugation and this is either of disc type because of course this is all in dry granulation disc type or cup type. These are various designs that are available in the granulator. People have tried to have different types of granulators and they have seen that these two types of granulators work pretty well for achieving the GBFS that we are discussing and it helps in the overall heat recovery.

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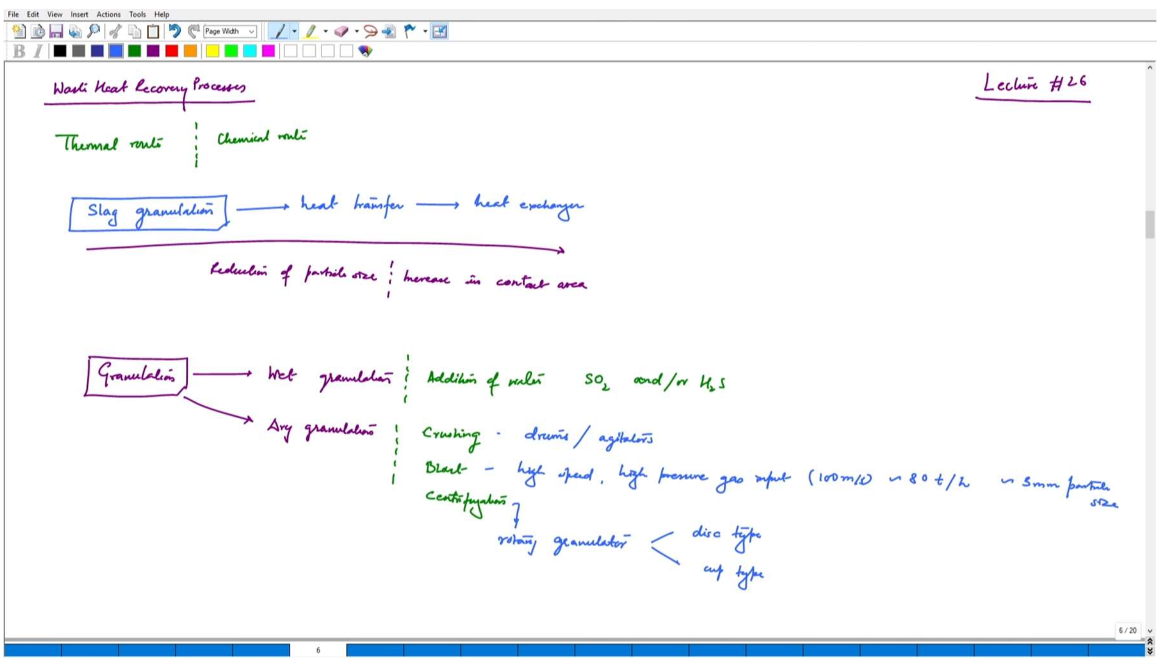
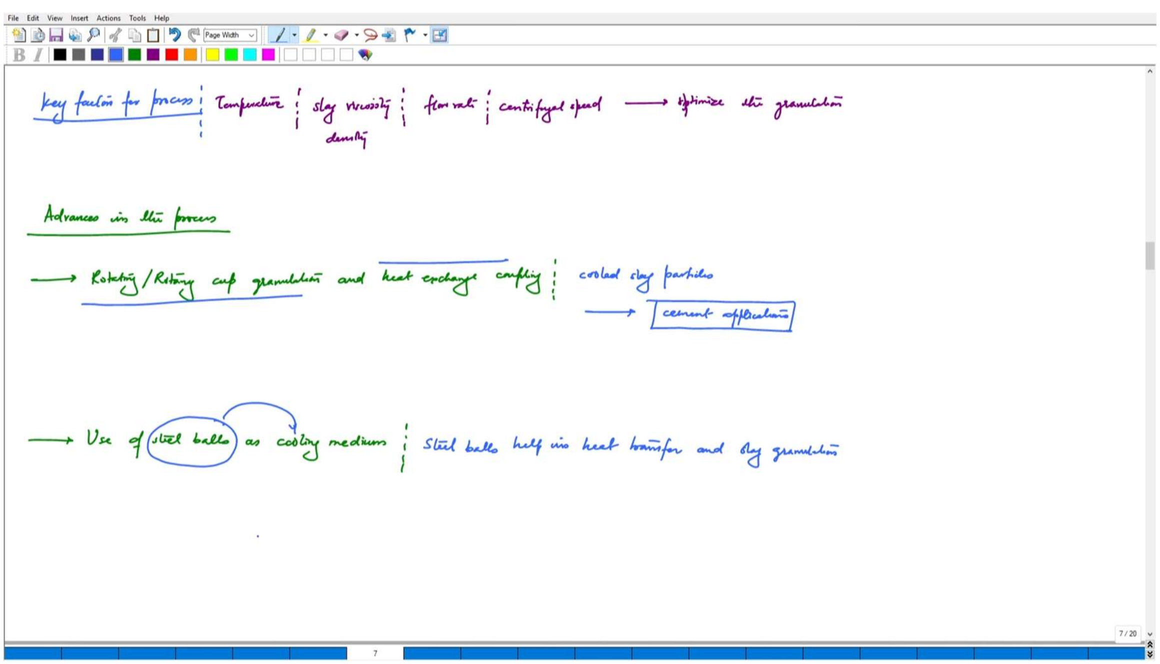


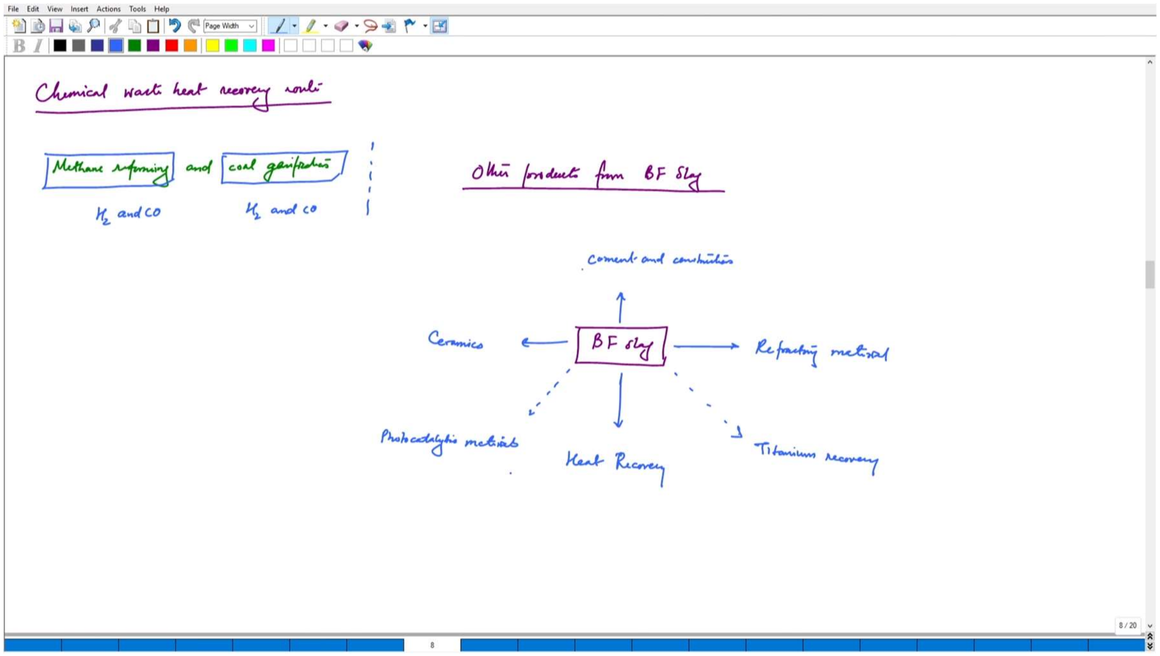
The thermal route involves the treatment of blast furnace slag in such a way that the exposure of the slag is increased and we can either go with wet granulation or dry granulation. Dry granulation is relatively better because of it does not consume too much water. What are the key factors? The key factors for this process are temperature of the process, we also need slag viscosity. One has to understand what is the slag composition and then analyze the viscosity also. Density; slag density, the flow rate, flow rate of that is present in centrifugal speed. These are some key factors that are involved in this process which helps us basically optimize... optimize the granulation. To some extent we can also think of controlling the particle size with varying these parameters. What are the advances in the process? The rotary granulation, we will just look at some of the advances. Rotating or rotary cup granulation. Rotary cup granulation and heat exchange coupling. What it does is cooled slag particles and these are fit for cement applications. If you are combining this with the heat exchanger. What we can get is heat recovery and we can use the finished raw material for cement applications. The other way of extracting heat is using steel balls within the iron making slag. This is a relatively trickier route of heat extraction wherein the hot slag is used as an input and we are adding steel balls. We are adding steel balls so that steel balls are helping in the overall process of heat extraction and you know simultaneously making the particles finer and finer as the process. Use of steel balls as cooling medium. It is, in reality is acting as a cooling medium. One might want to wonder why we are adding a steel ball, a cluster of steel balls into blast furnace slag. This is actually acting as a cooling medium. Steel balls help in heat transfer and slag granulation. This is all about the thermal route of heat extraction. **(Ref. 15:55)**



The other route could be the chemical route, wherein we are now interested in making some fuels while extracting heat. One way of extraction of heat is just directly entrapping heat as the blast furnace slag is coming in contact with heat exchanger. The other route could be making something valuable that can further increase the quantity of heat generated. The chemical route is all about that. Chemical waste heat recovery route, chemical waste heat recovery route. Methane reforming and coal gasification are the important routes by which we can think of the chemical waste heat recovery, methane reforming and coal gasification. In both of the cases we have H_2 and CO formation, H_2 and CO. In this case it is called syngas also. These are the two important routes for waste heat recovery and the heat generation is significantly very large compared to the thermal route.

When we think of direct heat recovery, the thermal route compared to the chemical route, we can easily compare that of course, hydrogen and CO when they are being produced from the blast furnace slag. These conversions itself is of larger economic value compared to the direct heat utilization. What are the other products? We look at some of the other products. From blast furnace slag recycling. We can easily predict that one of the most important areas that we have discussed is heat recovery. And we can also note that cement and construction is another important area. We also know that glass furnace lag after of course the heat recovery we can also think of refractory material as a refractory material raw material for refractory making and we can also have foam glass ceramics so ceramics.

Ceramics, could have foam glass ceramics. We can also have in under certain circumstances if we have titanium coming into the iron making system. Under such circumstances we can think of titanium recovery also. It depends whether we have titanium in the blast furnace composition or not. Under such circumstances one can think of titanium recovery also. Again, one has to really think of whether it was present in it or not and we can also have photocatalytic materials that can be developed using blast furnace slags. **(Ref. 20:38)**



These are some of the additional areas and, so many different other routes are being explored for extraction of valuable materials using blast furnace slag. We will now be focusing on the next waste of the iron making and steel making industries which is basically the steel making slag. When we think of steel making slags one of the most important aspects, we should be focusing on is that steel making and comprises of not just the conventional steel making the LD converter, BOF. It can also think/include EAF; electric arc furnace steel making route and of course, the processes that follow. If we are involved in stainless steel making, the furnaces that are being used, the processes that are being used, they also generate slags. LD slags, EAF slags and LF slags, ladle furnace slags. These are the various categories that are present in the steel making slags. When we are discussing steel making slags, we must note that of course there is the categorization of slags. We have the conventional BOF slag, basic oxygen furnace slag, We have the EAF slag, electric arc furnace slag and we have the ladle furnace slag, LF slag. The categories are based on the processes.

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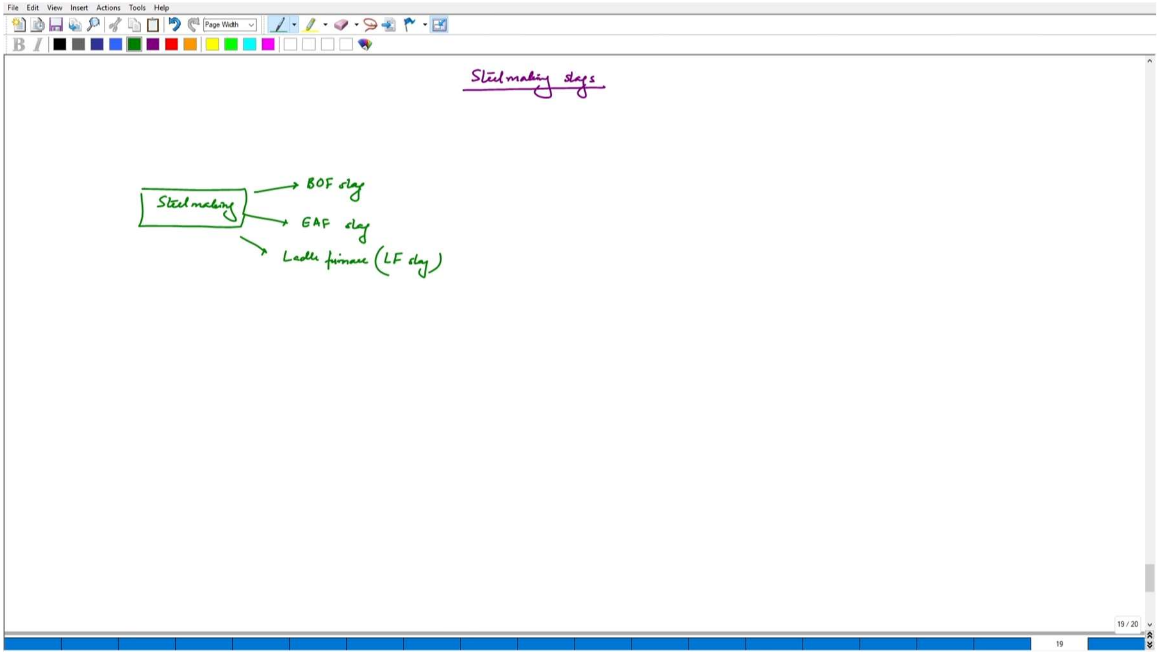

Similarly, the composition also changes within these processes. We look at the chemical compositions now. Composition of, and this slag is basically the steel making slag. So, we have the categories mentioned here. We have the BOFS, we have the EAFS, and ladle furnace slags, LFS actually, it's not LDS, it's ladle furnace slag. We know that the chemical composition changes with the process. Well, we will just discuss this, we see that in this case also just like the iron making slag that we had discussed, we have CaO, Fe_2O_3, SiO_2, Al_2O_3 as the major layers and MgO, MnO, Na_2O, TiO_2 are present in relatively very less quantities. We see that the biggest contribution comes from CaO and Fe_2O_3. SiO_2, silica in this case is relatively lesser than Alumina is also less, MgO is also less, MnO is also less. The major contribution is actually coming from three important phases, CaO, Fe_2O_3 and SiO_2. And many a times in many of the articles and books, there is the ternary diagram of CaO, Fe_2O_3 and SiO_2. And of course, the ends can have Al_2O_3 at times but CaO and SiO_2 and Fe_2O_3 are usually the three phases for the ternary phase diagrams which explains why these phases are so much important and so widely studied. We see that in all of these categories BOFS, EAFS and ladle furnaces, the CaO ranges in range of let us say 30 to 40 percent, Fe_2O_3 ranges from 20 to 40 percent. SiO_2 can range from 5 to 20 percent and then the phases of alumina, MgO, MnO, these are present in relatively lesser quantities.

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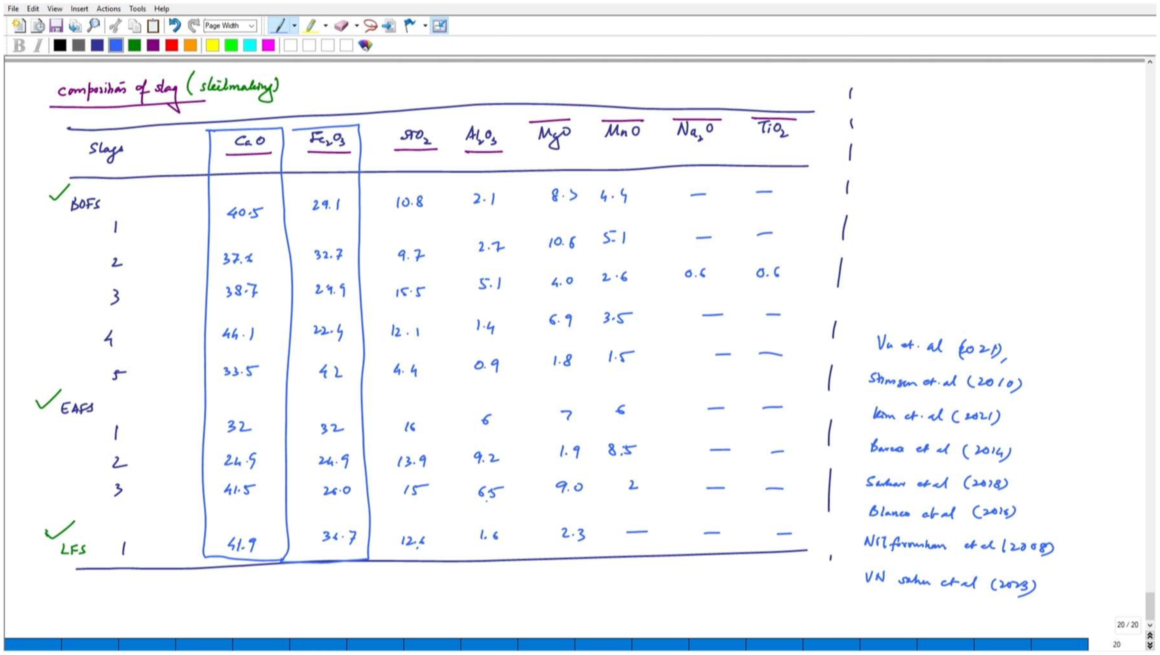

This explains that the most important phase that one should be thinking of while recovering, while devising a recycling process is basically CaO and Fe_2O_3. And in the previous classes we have also seen that there is the possibility of using slags, steel making slags for carbon sequestration. In the upcoming classes we will be discussing about the possibilities of using these chemical compositions at the advantage so that the recovery of calcium or recovery of iron can be done and at the same time carbon sequestration is also achieved. We will continue in the next class. Thank you.