METALLURGICAL AND ELECTRONIC WASTE RECYCLING

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Week-2

Lecture-6

Greetings, I welcome you all to the fifth lecture of this course which is following up on the pretreatment that we have been discussing in the previous lectures. We have seen various mechanisms of sorting various types of electronic and metallurgical wastes. Now, developing on that we are going to look at some of the key examples that come across around us and how we can employ pretreatment operations in the sorting and the very initial stage of material recycling. We have already emphasized this in the previous lectures also that the first step is to identify what is the valuable content, what is the valuable material and this is done normally at the beginning stage itself. That we are able to device every other following step accordingly. Let us take the example of battery sorting. Use of X-ray images can be done for sorting of spent batteries. When we have batteries, Ni-Cd batteries or lithium-ion batteries or any other different type of batteries.

If we are using X-ray images and people have tried to explore this option, they found that this could be directly used for sorting these. Developing sorting mechanism at the initial stage of recycling. This can be done using X-ray images and of course one has to think of just by sorting we cannot be very sure whether given battery is reusable or not. One has to go ahead and do the charging and discharging, and this type of measurement can be done separately. Once we have sorted it we can again think of ascertaining, determining whether a given battery is functional or not and whether it is reusable or not or if at all it is not reusable what else can be done. The initial sorting step could be done by X-ray imaging followed by charging and discharging and this could help us in developing further process steps. Now, this could involve the use of pyrometallurgical route, hydrometallurgical route or electrometallurgical route that we will be discussing in the upcoming lectures. What are the recycling steps and what is the best route of choosing a given recycling step that is totally dependent upon what type of pretreatment was done for a given waste stream and that again depends upon what category of waste we are looking at.

Everything that we are studying in this course happens to fall one after the other and these are highly interconnected. Depending upon the efficiency of the sorting that has been carried out, one can think of developing step by step recycling route. That again depends upon what is the quality of raw materials that we get after every stage. A product of a given process could be the raw material of the next process. That is why these operations, let us say pretreatment and after that the main recycling process and then the refining, all of them are interconnected.

Now, we will look at an example in material concentration. Let us say if we look at metals. Considering metals, how would we like to make it more concentrated? Supposing that we have an initial weight of 1 kg of let us say an e-waste type of waste material, electronic waste. It could be spent batteries, we can have waste printed circuit boards from computers, we can have other electronic wastes like washing machines, any material of our choice in the e-waste category.

Suppose that we have 1 kg to begin with. We can have W_1, W_2, W_3 and so on and so forth which are basically the weights of various metals that are present in it. W_1, W_2, W_3 are all included in this given initial weight of e-waste that we are discussing. Now, suppose that we are subjecting this initial weight of e-waste to let us say pretreatment. Now, the first pretreatment that we can initially think of is bringing down the particle size by crushing, grinding and size distribution, basically sieving.

This we have covered in the previous lectures. And we know that this is the beginning step. So, when we do that, suppose let us say we are going for crushing, grinding, and sieving, we get coarser fractions and finer fractions. So, coarser fraction and finer fractions which can have W1, W_2, W_3, so on and so forth. Again, these are the weights; both of these, W_1', W_2', W_3', again these are the weights of metals in coarser fraction.

Similarly, we can have the weights for finer fractions. Now, it can happen that the coarser fraction may have higher metallic content. And obviously, the finer fraction would have lower metallic content. It is just a possibility. So, one has to really characterize the wastes and it is essential to characterize the waste streams at every step that we do.

For instance, the initial characterization gives us the value of W_1, W_2, W_3. And only after characterizing the final products of let's say coarser fraction and finer fraction, we are able to ascertain, we are able to determine W_1', W_2', W_3' always and W_1'', W_2'', W_3''. These are the weights determined after the comminution. And this equally means that metal fraction is getting distributed in both coarser and finer fractions, which means it is

not possible that let's say all of W_1 or all of W_2 or all of W_3 gets accumulated in coarser fraction only or finer fraction only.

That usually does not happen. Some parts of let's say metal 1 gets distributed in coarser fraction and in finer fraction. It can happen that a given metal may get concentrated to a larger extent in the coarser fraction. But that really does not mean it is free from distribution in various other fractions. So, any metal that is present in a given waste stream can get distributed in all of the fractions.

The concentration would be different but it is a fair possibility that they may get distributed throughout the particle size distribution. Now, we will look at another example of pretreatment and refractory management.

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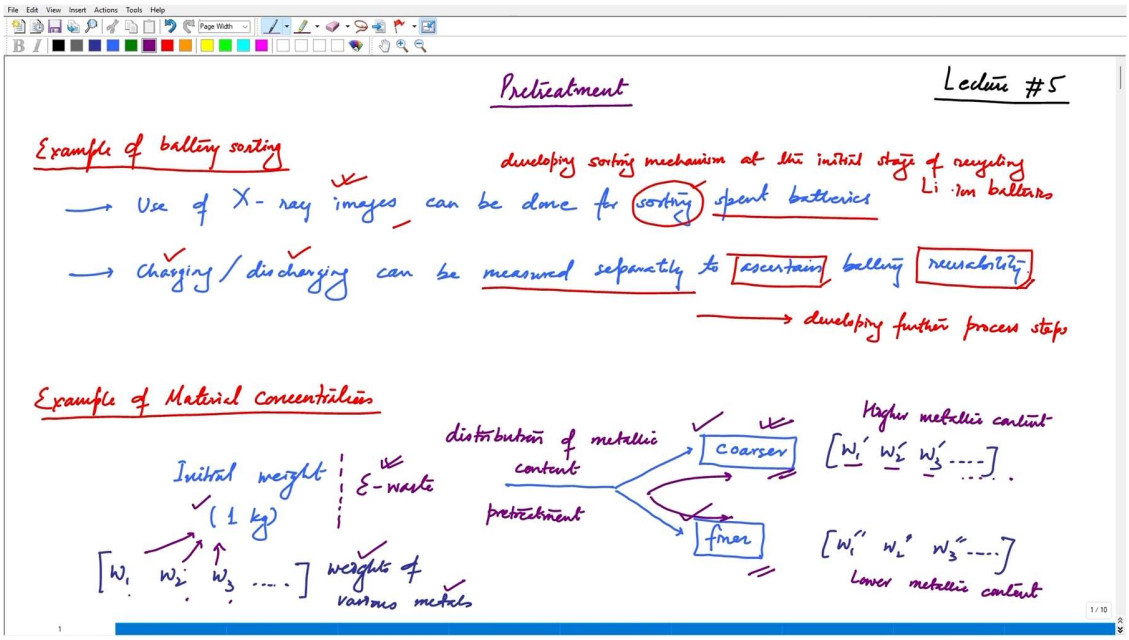

So, refractories are key components in furnaces. The furnaces that we normally use in metallurgical systems, metallurgical industries, in our laboratories, we have refractories as the protective lining.

Now, when these refractories are discarded, these also generate wastes. So, discarded refractories can be reused depending upon composition. Again, the service conditions and we already know end of life state. So, if we know all of these three things, let us say composition, what is the composition, what was the service condition and what is the

present end of life state, we can device basically good recycling process based on all of these information.

Now, suppose if we have a raw feed of refractory mixtures, now what happens about, what do we mean by refractory mixtures? Normally, in an industry, multiple furnaces generate different types of refractories. And these refractories are normally not sorted. Of course, some industries may would like to sort these refractories at the beginning itself, but it is a fair possibility that these are not sorted at the beginning.

So, that is why we have refractory mixtures. What is the first thing that we are supposed to do when we go for pre-treatment? We take these refractory mixtures and of course it is very difficult to sort them at the beginning itself. So, we would like to go for crushing, grinding, sieving and drying. And if at all it is possible to characterize these, then an initial step of sorting is also possible.

But that depends upon whether the sorting mechanism is available or not. So, we can go for crushing and grinding, post crushing we will go for sieving, drying and then depending on the finished product we will have further processing. So, it is essential to note that all of these processes involve the emission of various dust products and of course, these consume energy. So, apart from emissions, we have energy consumption as well and all of these steps are done to recover valuable materials from the refractories. Supposing that we have identified a given type of refractory material. Now we can think of reusing it. What do you mean by initial application basically the using reusing it as a refractory material itself or one can think of determining a different recycling route based on composition. It could be raw material for a different product altogether.

if we want to sort refractories. One of the mechanisms that is available in literature is basically LIBS, Laser Induced Breakdown System, LIBS. LIBS is another example of sorting mechanisms. In the previous case of spent We had seen that people are using X-ray images.

In this case, we are using laser-induced breakdown system, which means some part of laser is going to penetrate into the refractories and it helps in identifying the material present in it. Say, for a typical LIBS system, we can have a rough penetration of around 100 micrometer. That helps in identifying the material that is present in the feed and this again is going to help here. By basically adding one more step initially, before crushing and sieving and drying, we can think of one more step here which would be focusing on sorting. When we are sorting it and then crushing and sieving and drying, we can think of

making a better recycling step, recycling route and of course this is again contained in the pretreatment section only.

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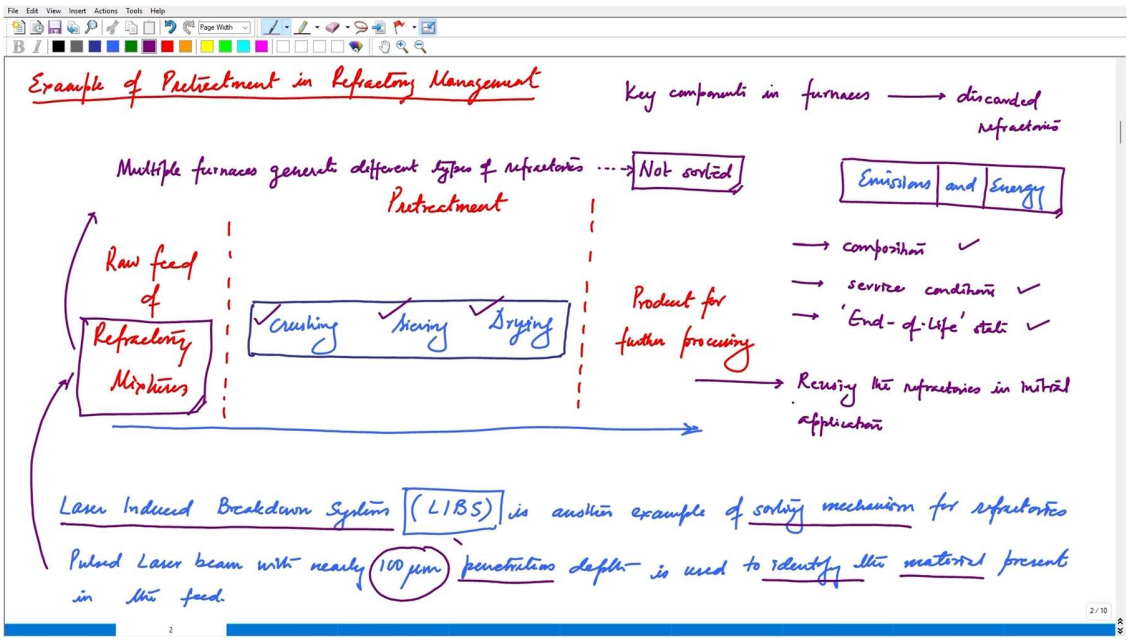

This is a schematic diagram that describes the flow of materials from raw materials to products. It is a one can think of top-down flow. We are basically moving from raw materials to products and how exactly should we read this? So, the raw materials are subjected to first pretreatment stage 1.

When we look at material pretreatment stage 1, it could be basically crushing, grinding, sieving and material comminution. That could be included here in pretreatment stage 1. Now, pretreatment stage 2 could be used depending upon what type of phase we are expecting. And what type of phase we are expecting in the recycling stage 1. The flow of the sheet is material pretreatment 1 followed by material pretreatment stage 2 followed by recycling stage, recycling process stage 1 and recycling process stage 2.

And of course, we can club as many pretreatment stages and recycling stages as required and we can also have refining stages after the main recycling process to improve the quality of the finished product. Now, let us just begin. Raw feed 1, Raw feed 1 could be the starting waste stream that we are initially having. So, assuming that the waste stream is sorted, classified, categorized and we get a single stream of waste, we begin with this

waste stream raw feed 1, subjected it to the first pretreatment stage, stage 1, we get a finished product 1. Now, we have already emphasized that the raw material of a given product of a given process could be basically the product of a previous process and it simultaneously continues in the subsequent stages as well. So, the product of pretreatment stage 1 is basically product 1 which is the raw material of stage 2. These are actually the same material.

Product 1 is feed 2. And this is again going to be the initial raw material for pretreatment stage 2. What we get after this is basically product 2. And of course, this is after the pretreatment stage 2. This product could be the raw feed of stage 1 recycling process which would further give us product 3 and so on and so forth.

So, what we are trying to emphasize here is there are multiple stages of processes that are essential to recycle a given waste stream. Now pre-treatment stage 1 and pre-treatment stage 2 help us in identifying and developing the essential raw materials for recycling. And one has to note it is very important to note that multiple stages of pretreatment are required for developing a complete recycling process. Depending on just one pretreatment only of given types.

For instance, comminution only, we can think of magnetic separation, separation types only. That type of pretreatment is not going to give us our finished products. Depending on only given types of pretreatments may not result in desired phases and of course we are talking of the raw materials that we are planning to use for the recycling processes. Now what could be the recycling processes?

These are essentially metallurgical processes categorized as pyrometallurgical process, hydrometallurgical process and electrometallurgical process, which we will be discussing in the upcoming classes. Now, these processes both pretreatment as well as recycling processes are devised in such way that they complement each other. Pretreatment process if it is done in a proper way with high efficiency, it would give us the raw material of higher metallic content for recycling and if we get higher raw feed basically high in metallic content the possibility of extracting, recovering metals from such raw feed is obviously higher because at every stage we know that there is a possibility of losing some material as byproducts. Now, here it is also important to note that right now in every step that we have studied, we see that there is only one raw material and only one product. Say for instance, if we begin with raw material feed 1, it is a single product.

It gives a single product. It is a single raw material that is giving a single product. Normally, this does not happen. it is a fair possibility that we can have product 2 as well right here at the beginning. For multiple products, we can have multiple flow sheets.

And this is the challenge that many recycling processes have that at every stage we develop different types of products and recovering metal or material of our choice depends on how we are handling these wastes, these byproducts. So, maybe we are interested in product 1 because it has higher metallic content, but we cannot say that product 2 does not exist. It's a possibility that product 2 can also be used in some different applications. One has to devise a different recycling route for product 2 as well which can be produced right here at pre-treatment stage 1 and this is possible with every step pre-treatment stage 2 or recycling stage 1 or recycling stage 2 or any other subsequent process.

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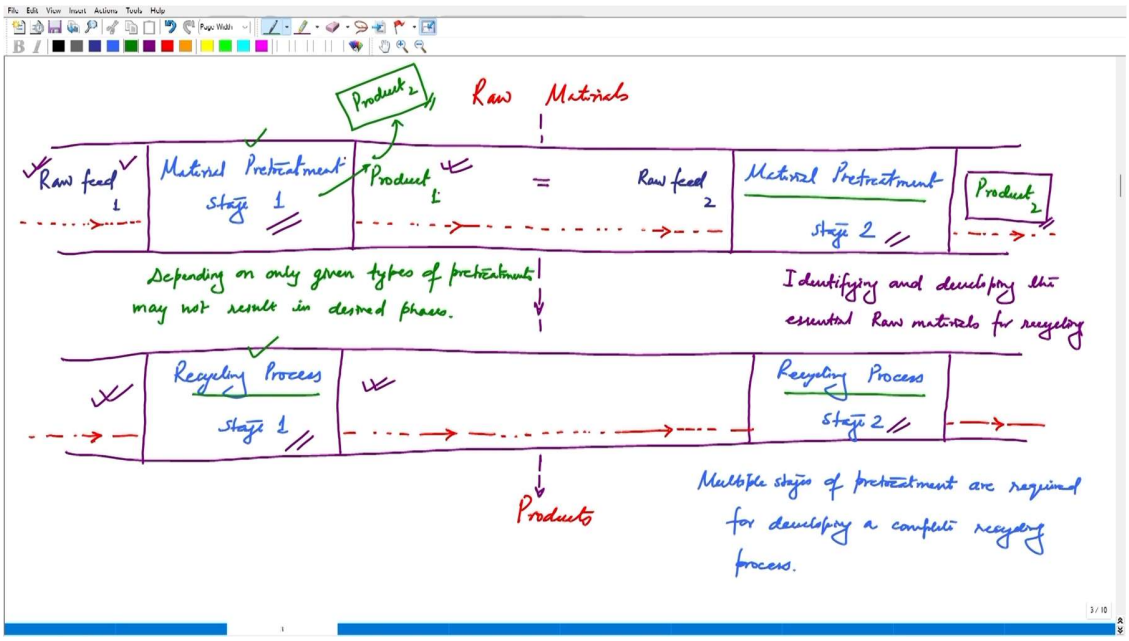

We will continue in the next lecture. Thank you.