METALLURGICAL AND ELECTRONIC WASTE RECYCLING

Dr. Arunabh Meshram

Department of Materials Science and Engineering

Indian Institute of Technology Kanpur

Week- 6

Lecture-29

Greetings, I welcome you all to the new lecture of this course wherein we have been discussing some of the wastes related to iron and steel making and we had discussed the slags and now in this lecture and in the upcoming lecture we will be focusing more on the other wastes that are generated in iron and steel making industries or rather we can say the integrated steel plants. One of the most important wastes that are in general recycled.

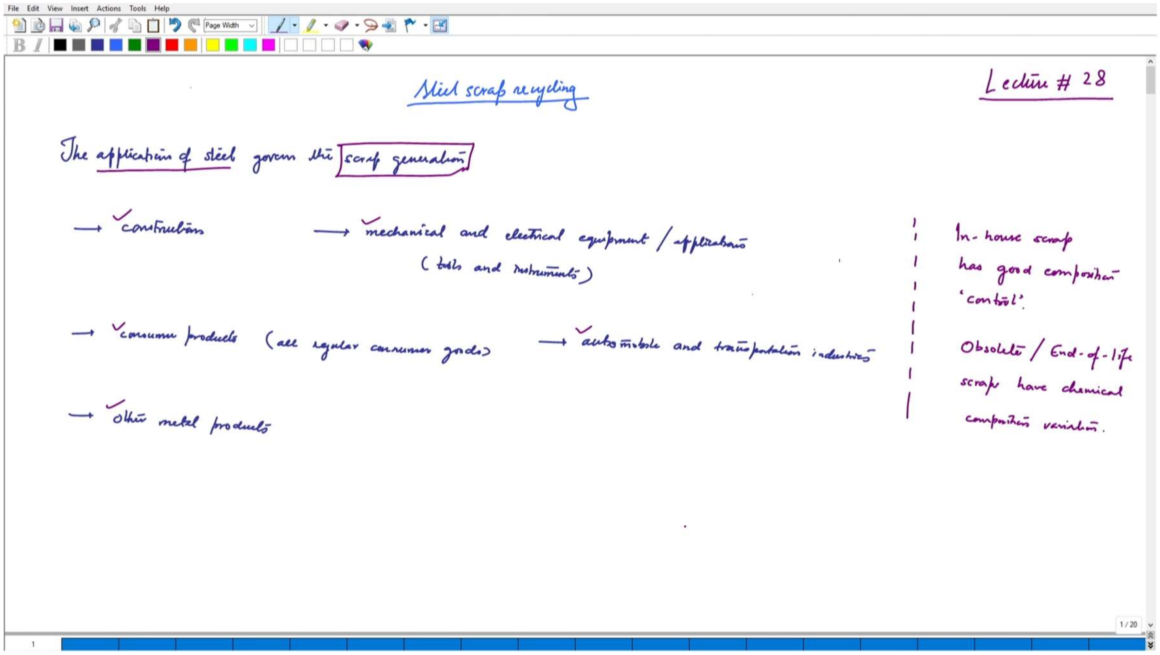
When we had discussed aluminium, we discussed copper and zinc. The scraps that are generated after uses basically obsolete scraps, the new scraps that are generated within the plants. What happens to these types of scraps? We will be discussing in context of iron and steel making industries, what happens to the scraps that are generated in the processes and how exactly these scraps are recycled. In the case of other metals like aluminum and copper and zinc, if the metal product is sorted, it can be directly reused in the production cycle itself. A similar trend is observed for iron and steel making scraps also. If we have new scrap, the scrap that is generated well within the industry and we know that the composition of the scrap really does not fluctuate much because it has not even reached the consumers, it has not even reached the secondary industry where it could be forged or other mechanical processes could be done on it so that various shapes and products of the given raw material can be made. If we know that the composition has not changed directly utilization in the process is possible. However, once a secondary product is made and it is it has reached the consumer end, then it is fair enough to assume that the scrap will return only after it has reached its end of life. For instance, some iron or steel component is used in making automobiles.

When the particular automobile or vehicle reaches the scrapyard only then we could really put a tally that okay fine such and such scrap is now available for recycling. When it is in the cycle of usage there is no chance of bringing it back to recycling as a part of the scraps. Since we had discussed scraps in so many different metal divisions that we had studied before, we will just continue with that. Steel scrap recycling involves the utilization of the steel scraps, the iron making scraps and that is generated well within the plants and the obsolete end of life products. We will write. The applications of steel govern the scrap generation. One has to revisit what are the applications of the steel so that we can understand the scrap generation and we know that these are majorly construction and infrastructure, mechanical and electrical equipment/applications wherein we can have all types of tools and instruments so we will just write tools and instruments.

We can also have very sophisticated devices in this category. Consumer products. This involves all types of all regular consumer goods. When we have these types of divisions and of course, there is the automobile and transportation. Automobile and transportation industries involves all types of industries including railways, the roadways and in some cases the naval constructions. All those constructions would require fairly large amount of steel and that would in turn finely generate large quantities of scraps. And there are other metal products that could be having miscellaneous applications. When we know that these are the applications of steel, we know that the scrap generation is going to be

observed in these areas and it is fair enough to assume that in-house scrap has good composition control so to say because we do not expect the composition to shift dramatically in the plant itself. However, when we are looking at scraps coming from these sources it is fair enough to assume that due to service conditions maybe oxidation can be happening, maybe at times corrosion is also observed, maybe during the service there is some chemical attack due to which the composition changes. When we look at obsolete scraps, the chemical composition can change. Obsolete or rather one more term is end-of-life scraps have chemical composition variation.

(Ref. 8:34)



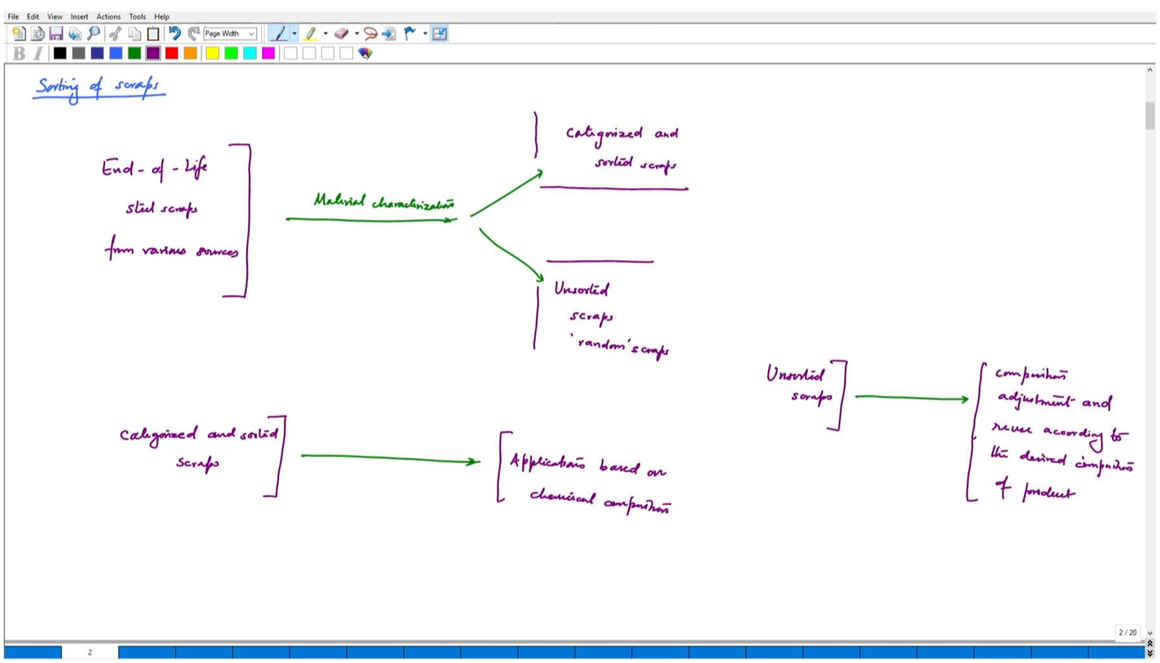
And one has to really work around this chemical composition variation. We will be discussing this in the due course. When we think of sorting of scraps, we have seen the categories of scraps that can be present. What exactly we receive is altogether different stories because all of the scrap will be provided as a pile, maybe as a stockpile and when it reaches the recycling industry, it is just a collection of lot many wastes, waste scraps in one single batch. One has to sort this scrap into various categories on which the recycling strategy can be further optimized. If this is not done, what exactly will happen is suppose, and we already know that one of the most important recycling strategies for iron and steel making scraps is basically utilizing it in the EAF, electric arc furnace, which is basically bringing it back to the steel making procedure. That is possible only if we understand completely the chemical composition. If we are somehow missing out on the chemical composition, the final product, the product steel that we are looking at will have lots of chemical imbalance which is not expected. Sorting and pretreatment as in cleaning of the scrap, degreasing all of that should be done beforehand so that when we are using it in the scrap recycling stage which is basically bringing back to EAF we do not face the composition fluctuation. We will focus on sorting of scraps. We have end-of-life steel scraps from various sources and then we have material characterization.

If we have categorized and sorted scraps. These are basically collected in a different bin and then we have unsorted scrap. Unsorted scraps, which can be random in nature; random scraps because we do not really understand what is the source and we are not able to pinpoint where these scraps actually came from and what is the composition because many a times these scraps get enmeshed. If baling process is done and then these scraps are compacted. In such a case, there could be inclusion of lot many different types of scraps coming into steel scraps. Other metals coming into steel is going to affect the chemical composition and then isolation becomes very much difficult which is why sorting is to be done right at the beginning. If we have scraps that have inputs from other let us say sources that contain other metals let us say aluminium, copper, zinc or any other metal the composition is bound to change which is why we are categorizing them right at the beginning.

Categorized and sorted scraps will be further processed and we can have applications based on chemical composition because we understand the chemical composition so we are able to directly use it in the expected applications, directly just putting up the scrap for the intended application. However, if that is not the case then what should we do?

Composition adjustment should be done and reuse according to the desired composition of product steel. What we intend to explain here is basically if the unsorted scrap steel is remaining and we wish to use it. What we can do is we adjust the composition during the processing.

(Ref. 15:12)

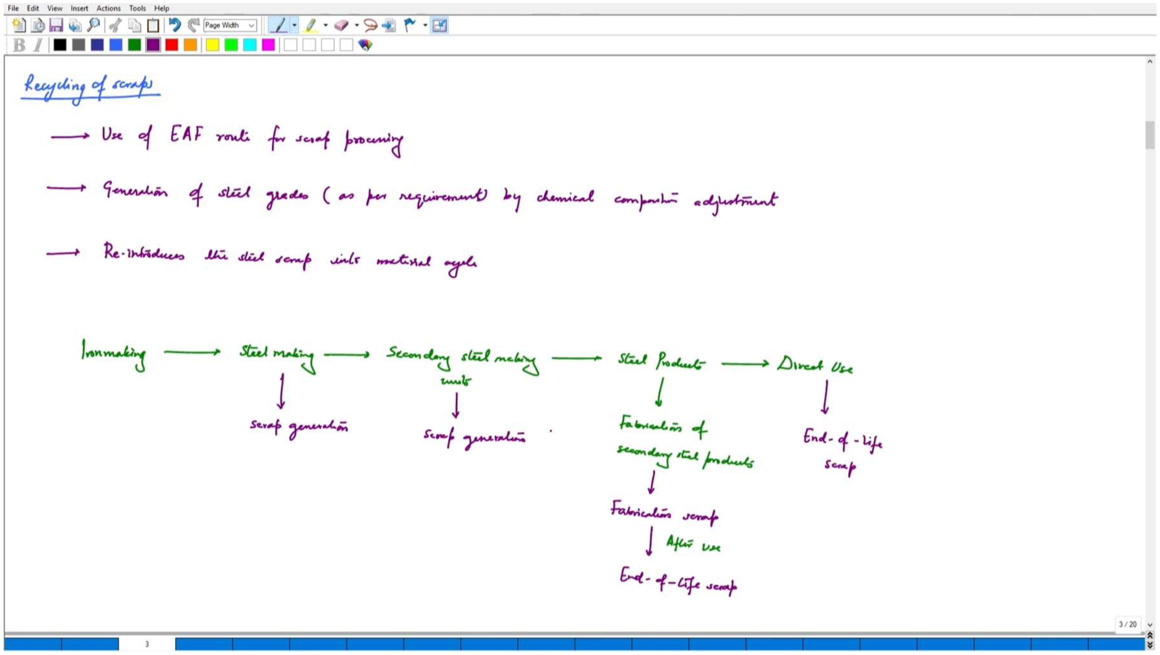


While, we are recycling it when we are using it in the electric arc furnace we should be charging other raw materials such that the overall composition matches with what is expected. So, this is just basically working around the problem in such a way that we are able to balance the composition. Now, how exactly is recycling of scraps done? How exactly is that done? Most common method we have just discussed that the most common method of recycling is of iron and steel making scraps is basically in pyrometallurgy and we know that electric arc furnace melting-remelting is the place where we introduce the scraps and since we are using steel scraps, we are now just going to adjust the chemical composition at times we really don't need to do much if it is a sorted scrap just a bit of chemical additions would help. If not, and if we desire to make a special grade of steel, then further additions can be done so as to match up the chemical composition.

This is the route of recycling the scraps. Use of EAF route for scrap processing. Generation of steel grids, again as per requirement, by chemical composition adjustment. And, what it really does is basically reintroduces the steel scrap which is basically iron rich into material cycle. If you just look at a general flow, it looks like this. We have iron making and this happens in blast furnace and then we have the steel making process. This can be using the BOF or EAF. Again, EAF is already accounted here but still and then we have secondary steel making units. We have the ladle furnaces and other furnaces coming up here. Secondary steel units. Steel making units. And then we have steel products. And then if and we will have more partitions here. Fabrication of secondary steel products.

And since this is the primary product, we can have direct use. What really, we should be mentioning here is that at every stage, even in iron making, we can have some waste. We will have the iron making slag here. But if you look at scraps, so steel making scrap. Scrap generation. Same here in secondary. And since we have the product again during fabrication also, we lose. Fabrication scrap. And we are having direct use is basically end-of-life scrap. And after use we should be writing this is one part of scrap and this is after use basically. After use this will be end-of-life scrap.

(Ref. 20:22)

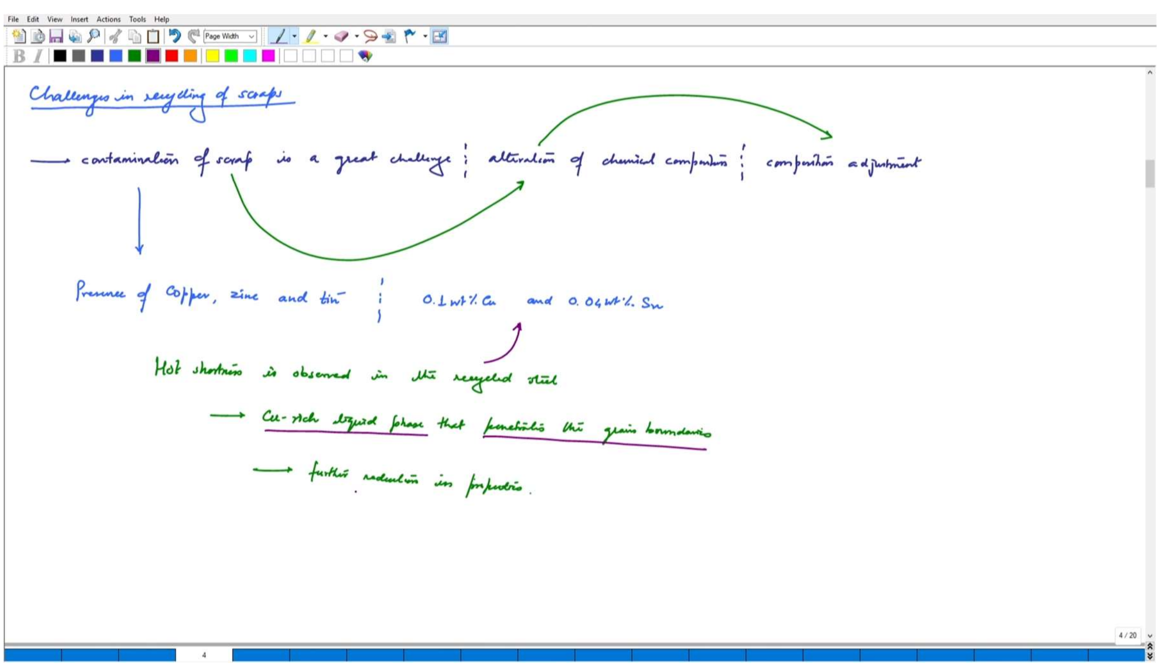


We see that in this process itself, we have iron making, we have steel making, we have secondary steel making process units, then we have the steel products, then the secondary products that come after fabrication or if we are just using the primary product that could be having the direct use. In all of these processes, we are going to have some scraps. Some of these are generated well within the plant itself, so they are directly reused. And when we mean by direct use is basically bringing back to EAF and processing the scrap. But when it has reached the consumer end, it is going to get obsolete after its end-of-life and then it is going to reach back the scraps, the scrap yard and then for the recycling. This is the overall simplified outline of how recycling of steel scraps is done.

We should be understanding what are the challenges in scrap recycling. We will just note that contamination of scrap is a great challenge. Why? Because alteration of chemical composition which means one has to put efforts in composition adjustment, basically interrelated. Contamination of scrap leads to alteration of chemical composition. And one has to think about this is remedy or basically the way out. Whereas this is the problem. The other way to look at it is somehow we just use the sorted scrap. Which means one has to think how we are going to isolate the scrap of our choice and use it for a given purpose.

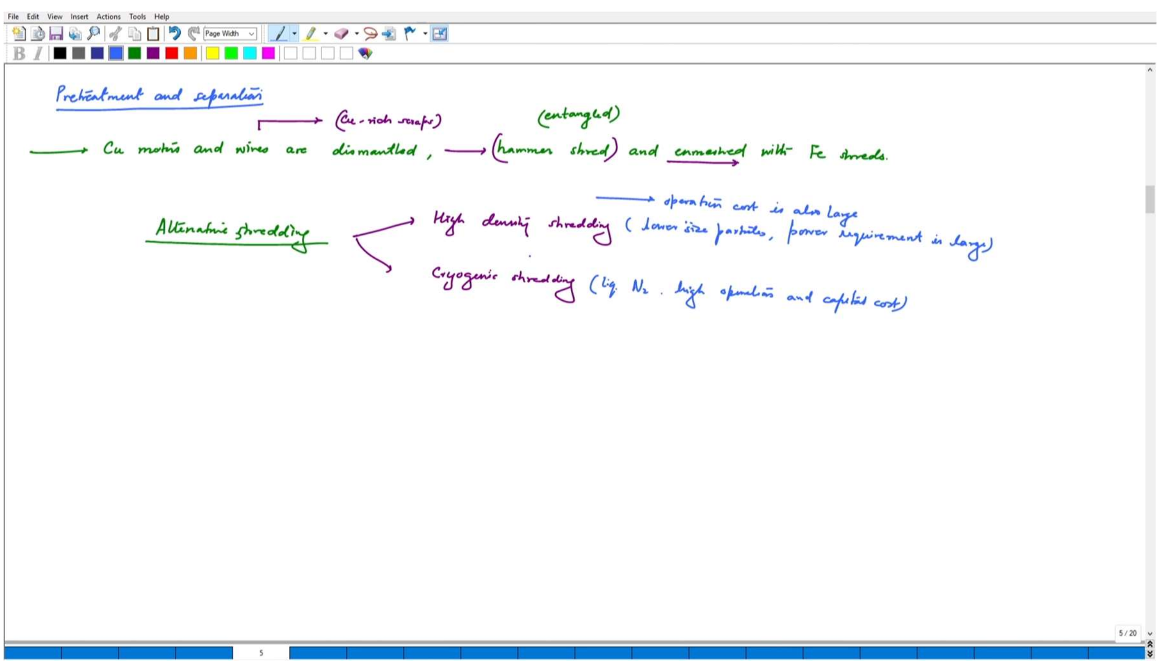
For instance, we have a fixed grade of steel that we wish to make. For that we have a scrap of the same grade that would have been ideal. Some composition adjustment is required but in general the finished product is of very good quality because we used scrap of the same grade, such is an ideal situation, however in reality we have lots and lots of scraps coming from different steel sources and they have different grades so one has to think on composition adjustment. What really are we talking of when we think of contamination, contamination would mean presence of copper, zinc and tin. What it really means is let us say 0.1 weight percent copper and 0.04 weight percent tin. This is basically leading to deterioration of the steel properties. How does it really happen? When we have copper and zinc or copper and tin in such quantities, we see that when we are melting it forms a separate liquid that basically penetrates into the grain boundaries while it is solidifying and that leads to the deterioration of properties of the finished product. One has to really think of separation of copper, tin, zinc from the scraps before it reaches EAF. It really means that one has to avoid hot shortness in the finished product after recycling.

That composition adjustment has to be done before and this itself is a very big challenge. What exactly happens at this composition and, of course, we are talking about this is the critical composition and if it reaches beyond that the problem aggravates. Hot shortness is observed in the recycled steel. This is due to copper rich liquid phase that penetrates the grain boundaries and this leads to further reduction in properties. We see that hot shortness is observed in recycled steel because of this and we see that why exactly that may happen is basically copper rich liquid phase penetrates the grain boundaries only after when we are looking at solidifying systems and this leads to further reduction in properties. One observes that the recycle product is not having as the properties as we expected. **(Ref. 27:10)**



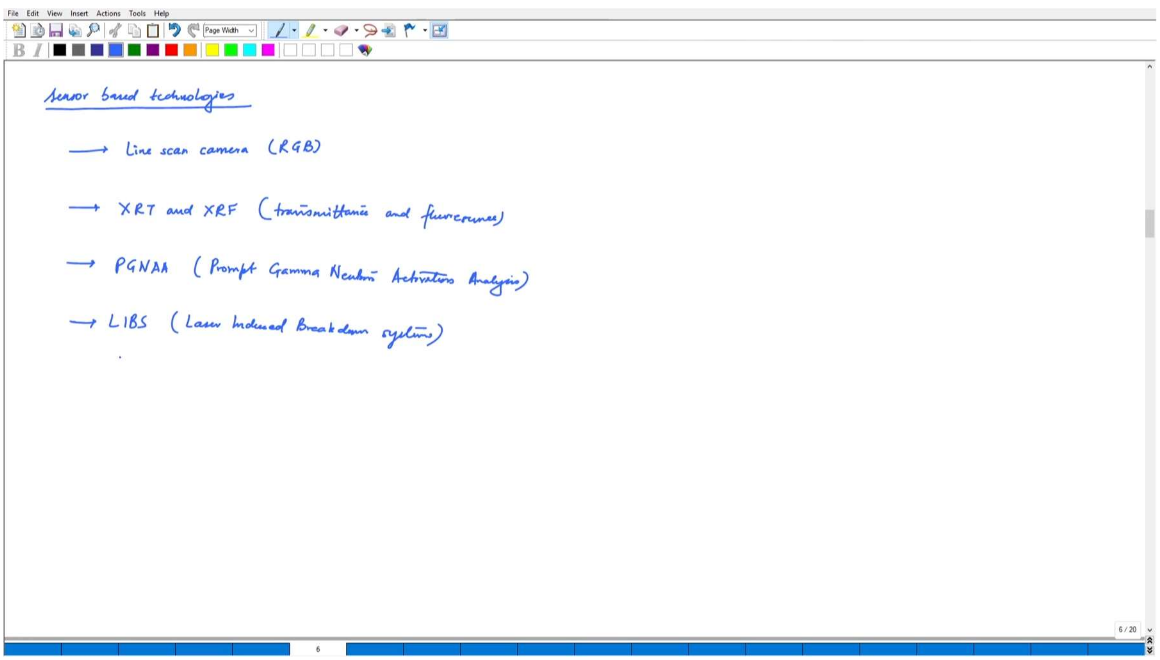
It is our duty to identify the potential applications of pretreatment and sorting or some other route by which we can isolate these impurities, these hazardous impurities that may affect the overall properties of steel. What exactly can we do when we think about pretreatment and separation? The problem comes when copper motors and wires are dismantled, hammer shred and enmeshed. Dismantled, hammer shred and enmeshed and while in meshing we also have entangled with iron shreds. This will generate what? This will generate copper rich scraps. And these scraps are basically shredded. Since we are doing hammer shredding and it is getting enmeshed.

We have a scrap that is iron with copper. We can say the copper quantity is relatively very less. But iron is having copper enmeshed with it. One has so much of variation due to this. One really can think about having different types of shredding operations. Alternative shredding. What alternative shredding can be applied? One can think of high-density shredding. This reduces particle size even further and one can apply magnetic separation. So, this could be followed by other magnetic separation and then we can have a good removal of copper. Or one can think of cryogenic shredding. But there are some really big disadvantages here. In high density shredding we do get lower particles, lower size particles. The power required is very large. and we also mean that since part requirement is large operation cost is also large because we are going into very fine particles. Cryogenic would require liquid nitrogen which again leads to high operation and capital cost. **(Ref. 31:30)**



Although, these shredding operations are really helpful it really does not help in when we are considering all of the costs that are involved in the shredding and one has to also employ magnetic separation beyond these shredding operations to remove copper. What else can we really apply? The sensor-based technologies. We will just note down the sensor-based technologies that are available and we must note that these technologies are being used to identify the scraps and isolate them before it even reaches the recycling unit of EAF. We know that the line scanner camera, line scan cameras, RGB and we have XRT and XRF, transmittance and fluorescence. We have PGNAA which is basically prompt gamma neutron activation analysis and LIBS. LIBS we had discussed in the in the very beginning of the course where in we have the laser beam coming in and it leads to the characterization where laser beam is penetrating this surface of the sample and gives us these readings spectrometry readings of the surface. That is also possible. Laser induced breakdown system (LIBS). This we had seen for the recycling of refractories.

(Ref. 34:00)



This same concept can be used in so many different applications XRT, XRF, PGNAA, LIBS these technologies are very much expensive and one has to have very good control in plant to basically separate out the scraps based on these sensor-based technologies. And if we have good quality cameras, we can somehow identify the scraps and isolate the scraps given before it reaches the recycling unit. In this way we can think about improving the efficiency of recycling and reducing the burden on the overall processing. In the upcoming classes, we will be discussing on wastewater recycling, the wastewater that is generated in the iron and steel making industries. And then, we will be completing this module on iron and steel making, the steel scraps and wastewater recycling.

Thank you.