Powder Metallurgy
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Lecture – 09
Comparison of Atomization techniques

So, lecture series on Powder Metallurgy. So, far we have been talking about powder fabrication and we have discussed about different methods of powder fabrication.

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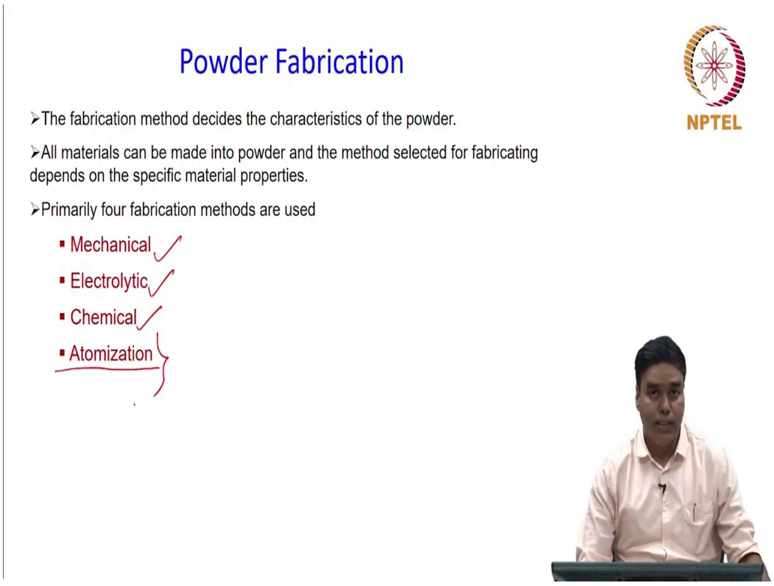

And, we have talked about them in great details about all of these techniques which are listed here as you could see. And, in the recent classes, we have been covering this particular topic atomization for making metal powders in large scale. And in that, we have already discussed about the basic principle of this process.

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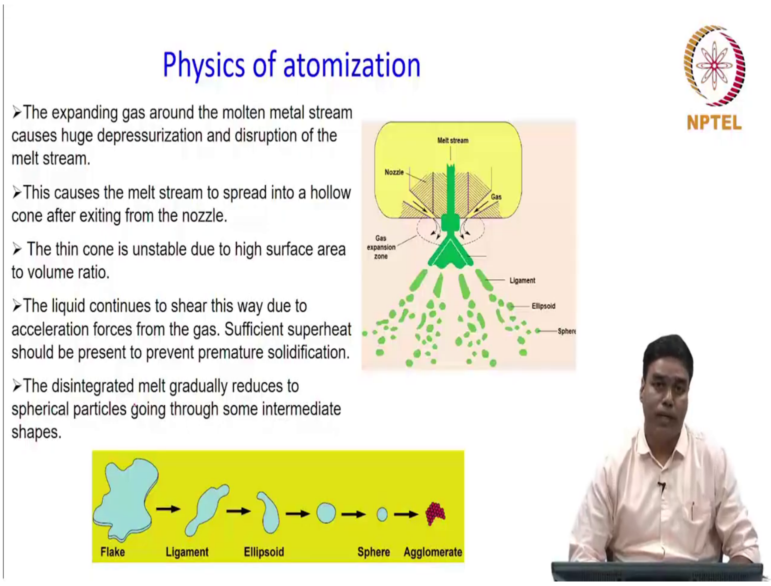

And also, the physics behind it as to how it happens you know, what are the different aspects of this technique? And, so on.

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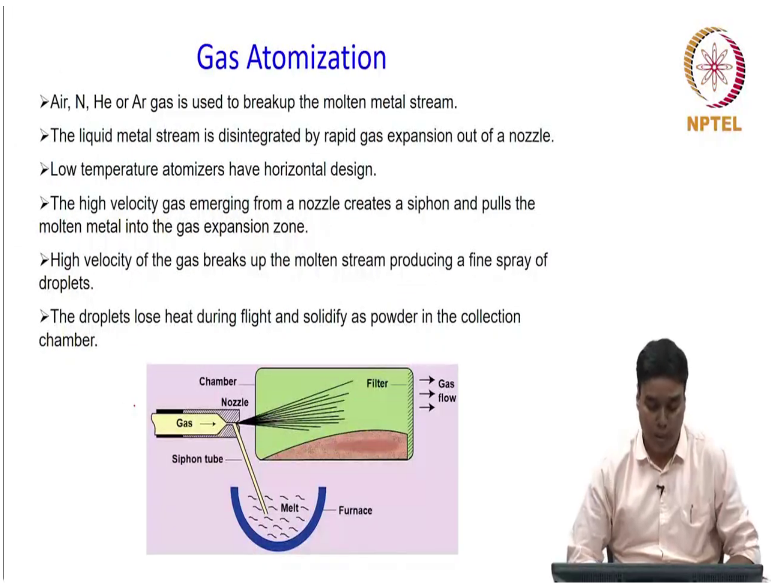

And then, we started talking about the different methods or different kind of equipment, which are used for atomization, for the process of atomization; like, the gas atomization process, we have discussed and in that, we have seen two kinds of atomization equipment in case of gas atomization and these were the horizontal one as you can see over here.

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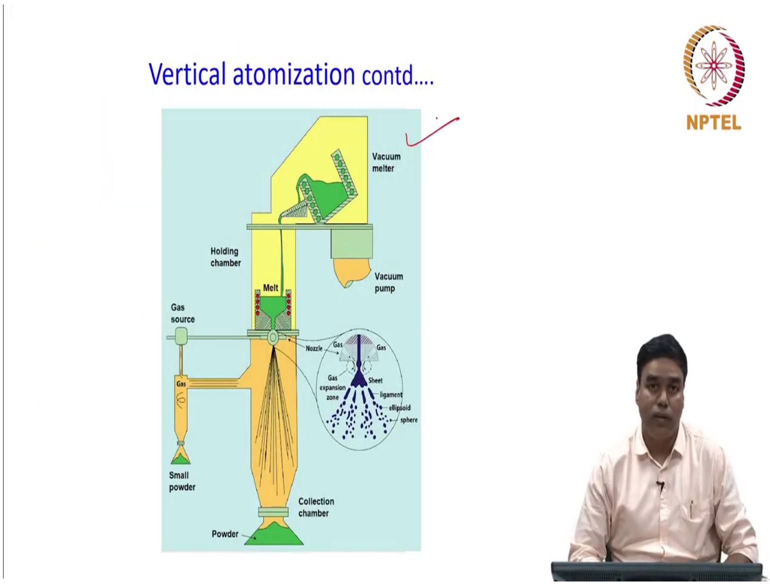

And, the vertical one that you can see in this particular image.

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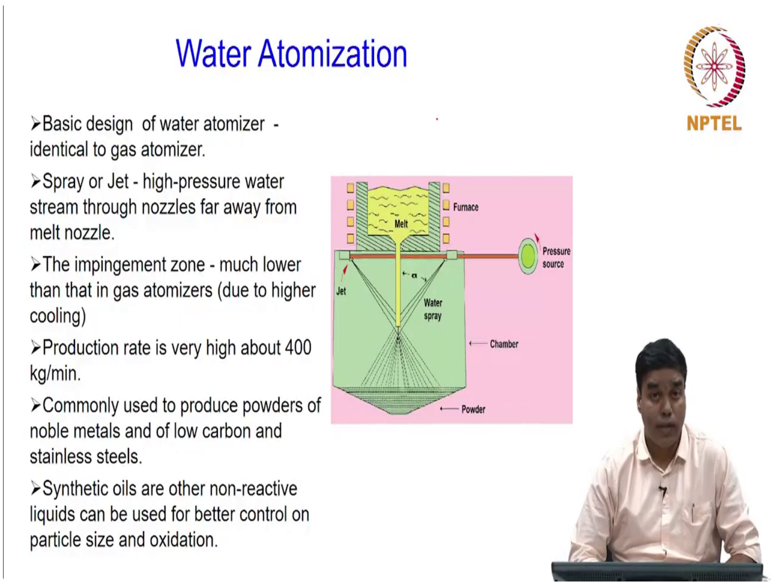

And then, we also talked about the other atomization techniques like water atomization.

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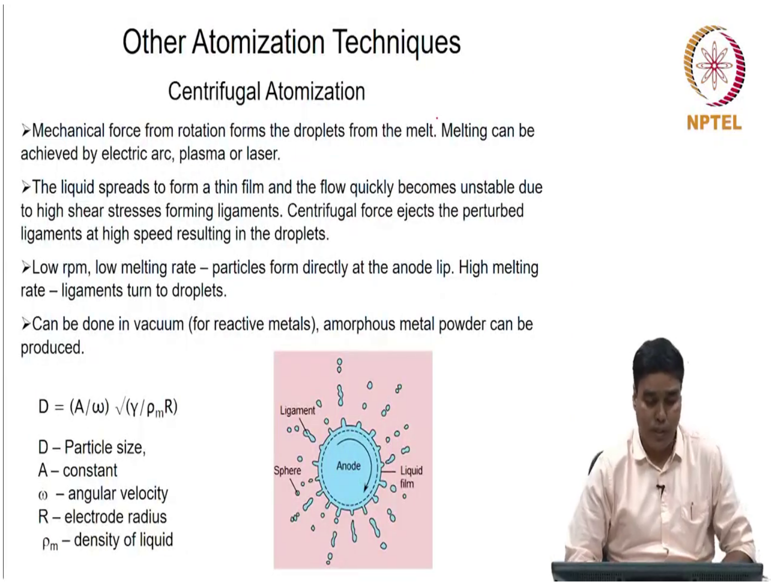

And, in the previous two classes, we spoke about the centrifugal atomization if you remember.

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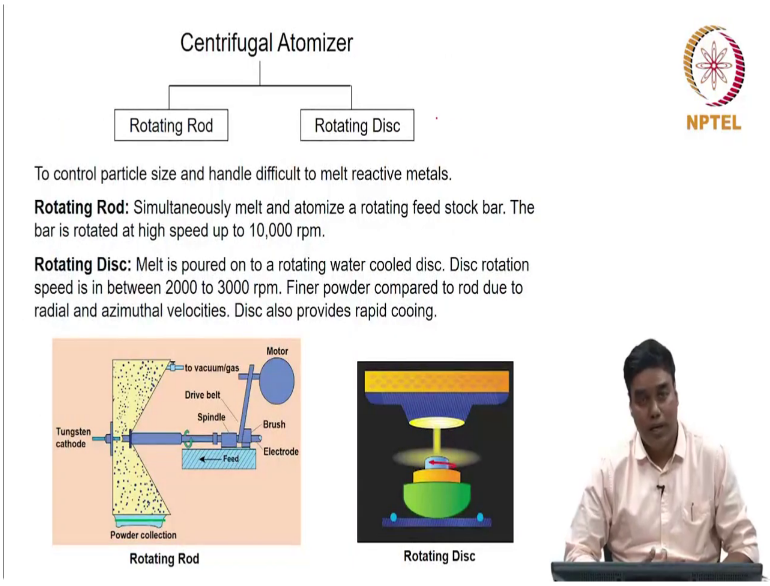

And here, we talked about two kinds of centrifugal atomizer; one is the rotating rod and the other one is the rotating disc.

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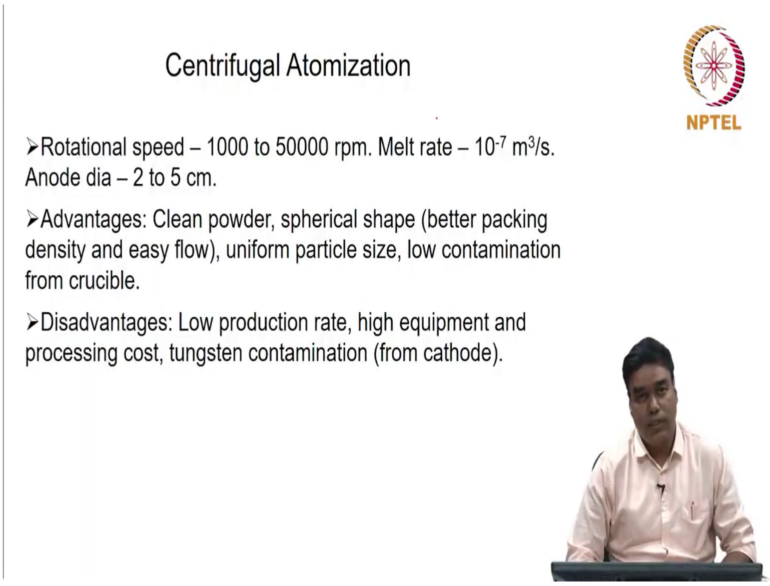

And then, we have also discussed about the different attributes of this centrifugal atomization process. So, now that we have covered different types of atomization processes, it is time for us to have a look as to what kind of process would give rise to what kind of powder particle and so on. So, let us have a look about all these atomization techniques back again and then see, what kind of powders do they produce?

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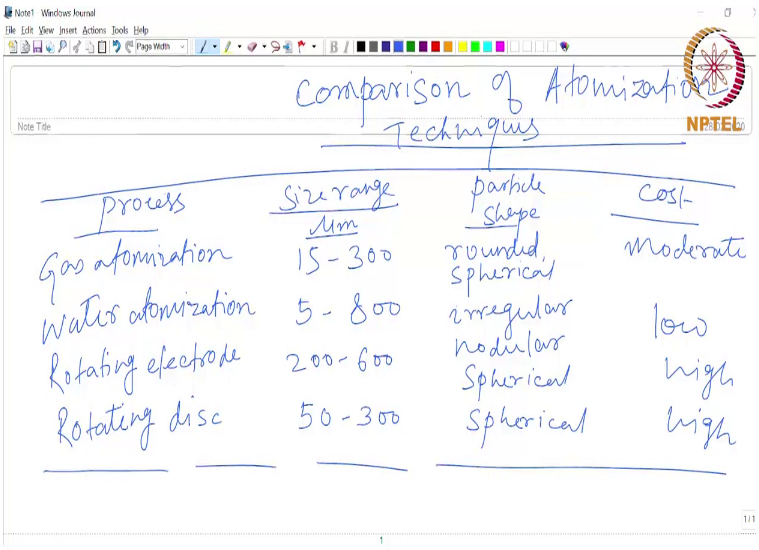

So, let us have a look at the comparison between different atomization techniques. So, let us make a table like this, where we have this different processes, then the size of powder that they will generate, the particle shape and the cost. So, starting with gas atomization process; here, the size range that you can get is from 15 to 300 microns. As far as the particle shape is concerned, it is rounded and also spherical and cost is moderate.

Then, we had talked about water atomization process. And in this case, the size range is 5 to 800 microns, particle shape is irregular and nodular and cost is low. Then, we covered the centrifugal atomization in which we had rotating electrode or rotating rod and then, we also had a rotating disc. So, let us look at the rotating electrode first.

This case, the size range is 200 to 600 microns; particles are spherical in shape and cost is high. And finally, for the rotating disc process, the size range is 50 to 300 microns; particles are spherical and here also, the cost is high. So, these are the different attributes of different kinds of atomization techniques that we talked about in terms of the characteristics of the particles and also, the cost of the process.

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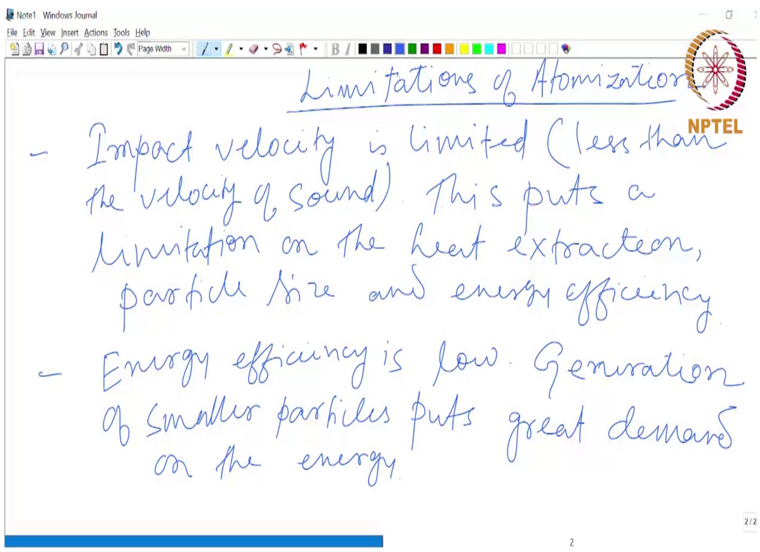

And now finally, let us have a look at the limitations of this atomization process. As we have seen in this process, there is a impact from a gas jet or from a water jet which breaks down the molten metal into fine droplets to generate the powder particles. And, as far as the impact velocity is concerned that is limited in this case. It is less than the velocity of sound and this limitation on the impact velocity also puts some kind of limitation upon the heat extraction, particle size and the energy efficiency of the process.

In fact, the energy efficiency is low for the atomization process. And, as the particle size decreases, it puts more demand on the energy. Smaller the particles that you need, higher will be the energy requirement for this process and if you remember, we talked about the parameter, which has an influence on the particle size and that was the weber number.

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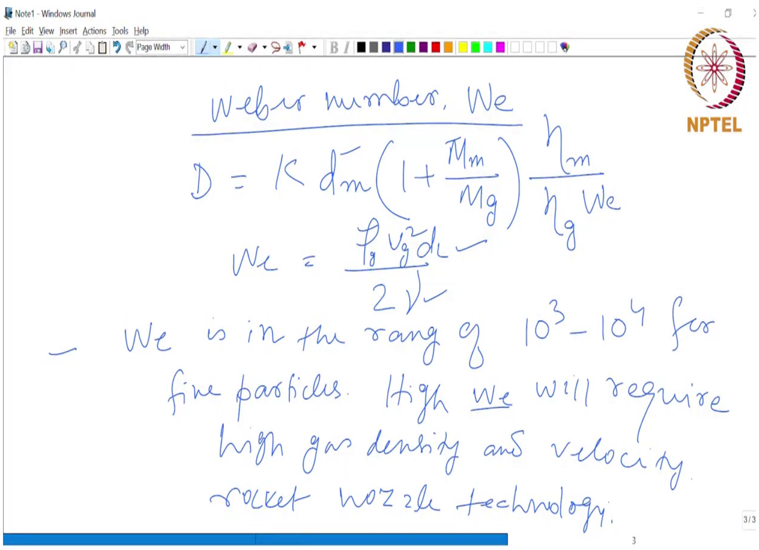

The particle size D is given by this relationship if you remember. The details of this different parameters have been already given before. Now, this weber number is given as, where ρ_g and v_g are the density and the velocity of the gas respectively; d_L, if you remember that is the ligament diameter and γ is the surface energy.

So, since the velocity is limited in this case as we discussed just now, the weber number also is low. And, it is in the range of 10^3 to 10^4 for fine particles and as you can again see from here, a high weber number, would require high gas velocity as well and high gas density also .

In fact, to generate high weber number for producing finer and finer particles, the normal nozzles which are used cannot be enough. And, this technology called rocket nozzle technology may have to be used to generate high velocity and therefore, high weber number. So, the weber number also puts a limitation on the process.

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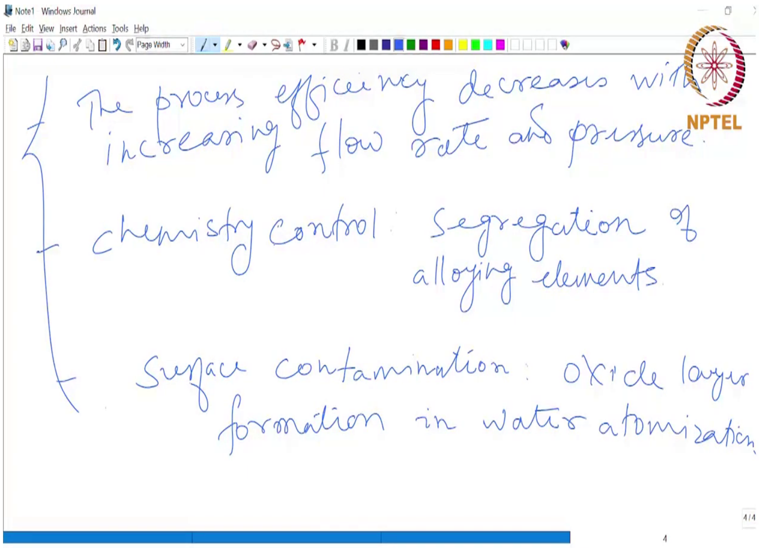

The process efficiency decreases with increasing flow rate and pressure. Chemistry control is also a challenge at times and segregation of alloying elements is an issue, when you are making alloyed powders by this process. And of course, we have seen in case of some of the atomization techniques like for example, the water atomization process, there is a problem of surface contamination that happens due to the oxidation of the powder during the process or formation of the oxide layer that happens in water atomization.

So, these are some of the limitations of the atomization process, but nevertheless this still remains one of the most commonly used methods for making metal powders in large quantities. So, this will kind of bring us to the different processes of atomization that we had lined up for this particular topic.

As far as the process is concerned, we can conclude it over here; but, there is one more thing, that we need to discuss before we actually close this topic and that has to be discussed in little more detail and we need to understand some concepts and some phenomena that happens during the process. So, we will take that up separately and probably discuss that in a separate class. But for today, before we close this, let us try and summarize as to what we have learned so far about the different fabrication routes for making metal powders.

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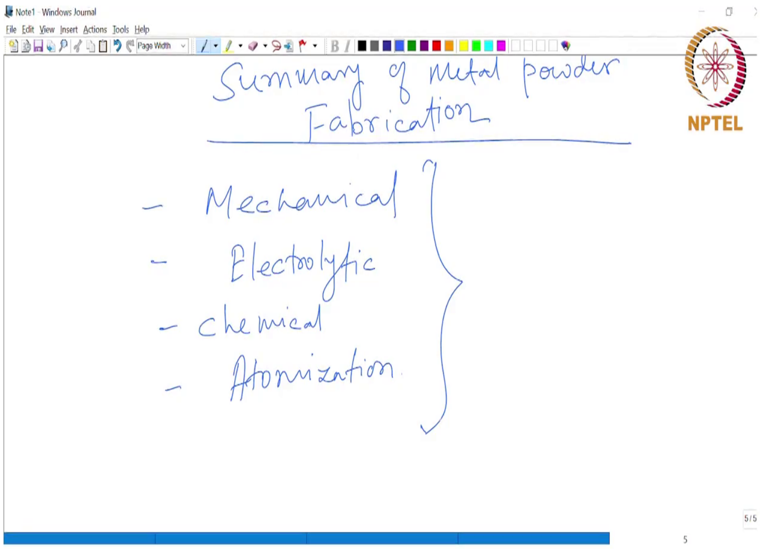

Essentially, we talked about four methods; which are mechanical, electrolytic; chemical and then finally, atomization, right. So, this is what we had and we have discussed all these processes in detail and learned about them in terms of their different attributes, process variables and so on.

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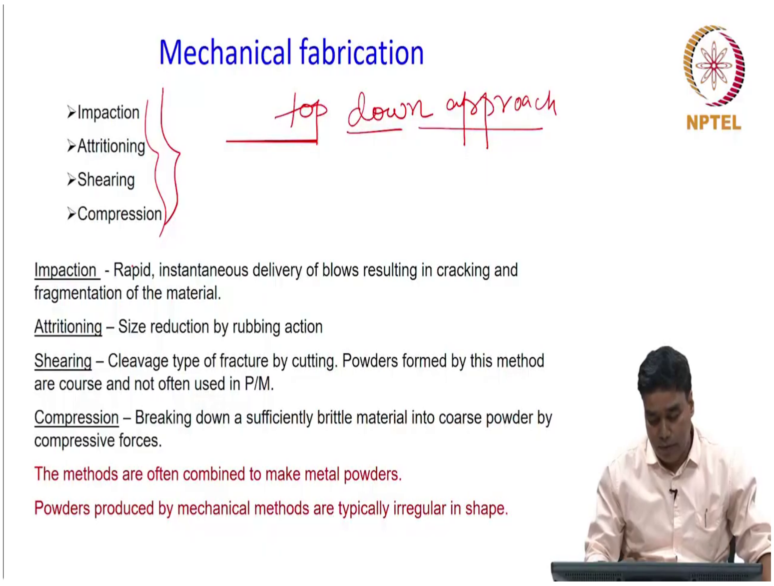

Starting from mechanical fabrication, we have seen how this technique is carried out and you know what kind of mechanical forces are used for making metal powders and we have also discussed that mechanical fabrication is a top down approach, wherein you start with the bulk material and break it down to smaller fragments to generate metal powders. And, in order to fragment it; in this case of mechanical fabrication, a mechanical force in terms of one of these processes is used to generate the powders.

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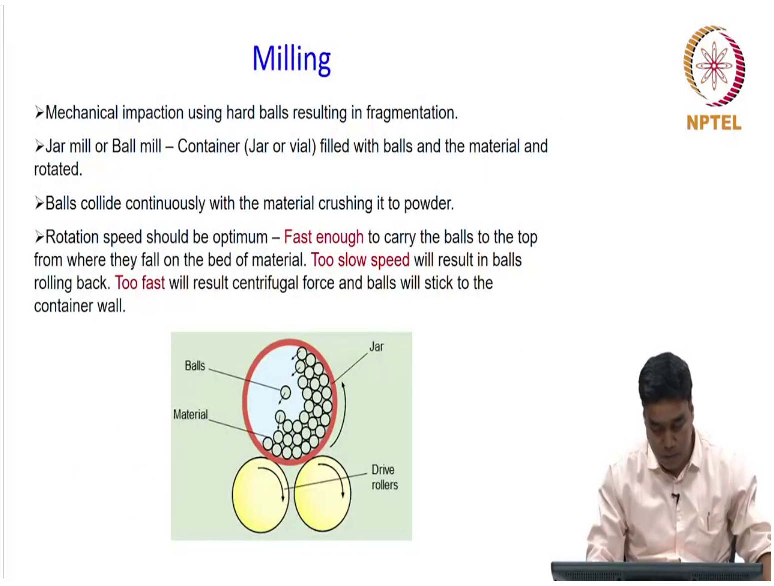

And, we have discussed what kind of you know mechanical process or mechanical forces are used like milling, attrition and other impaction techniques like compressive crushing, cold streaming and so on.

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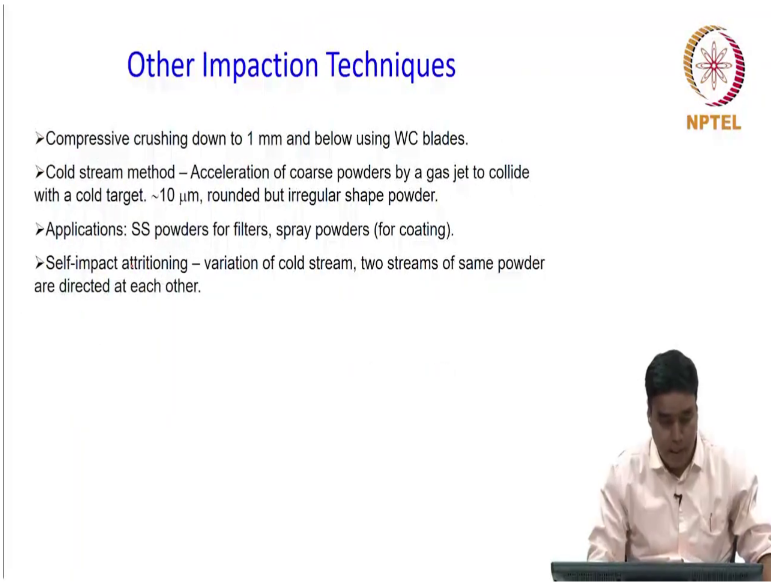

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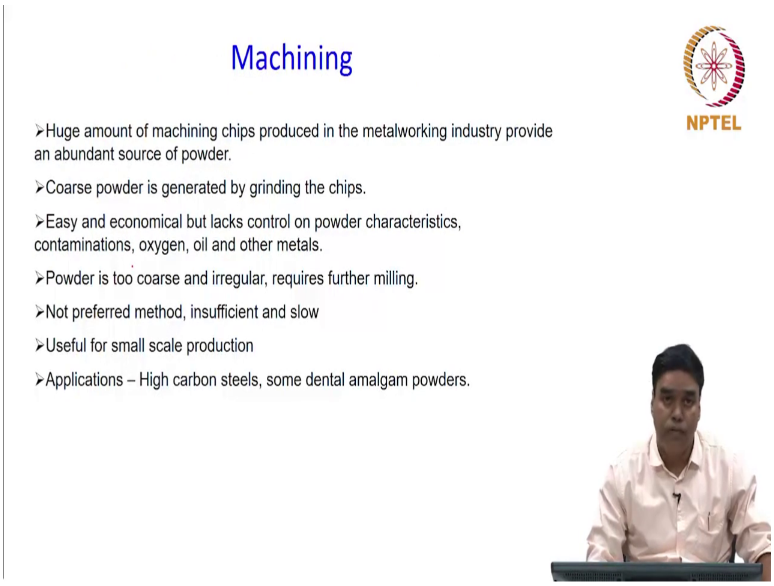

Also, we talked about making of metal powders by using machining chips.

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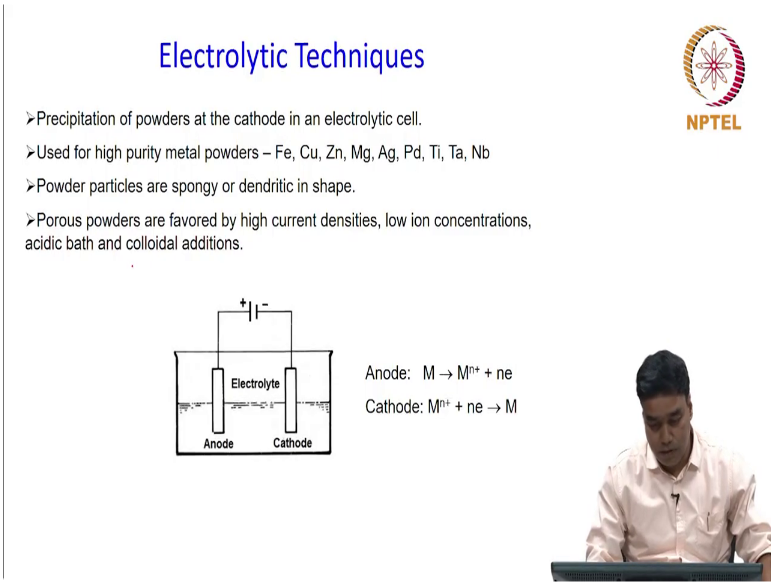

And then, we had discussed about the electrolytic technique in which, the metal powders are generated using an electrolytic cell, where the anode is the metal which is to be generated and then, through this electrolytic process, it is deposited on the cathode and from there, the powder is collected.

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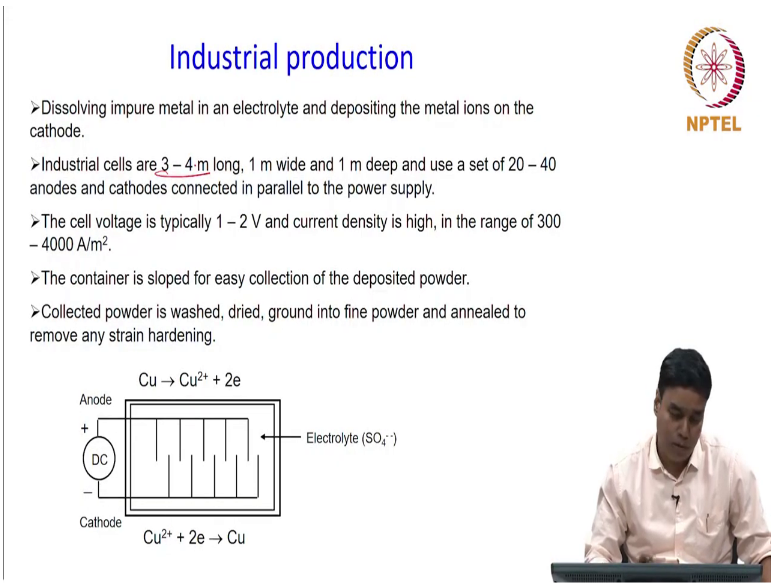

And, on an industrial scale it is actually done in a big tank which is like 3 to 4 meter long and it carries a set of a series of anode and cathodes to generate the metal powders in large quantities from a particular batch, from a single batch.

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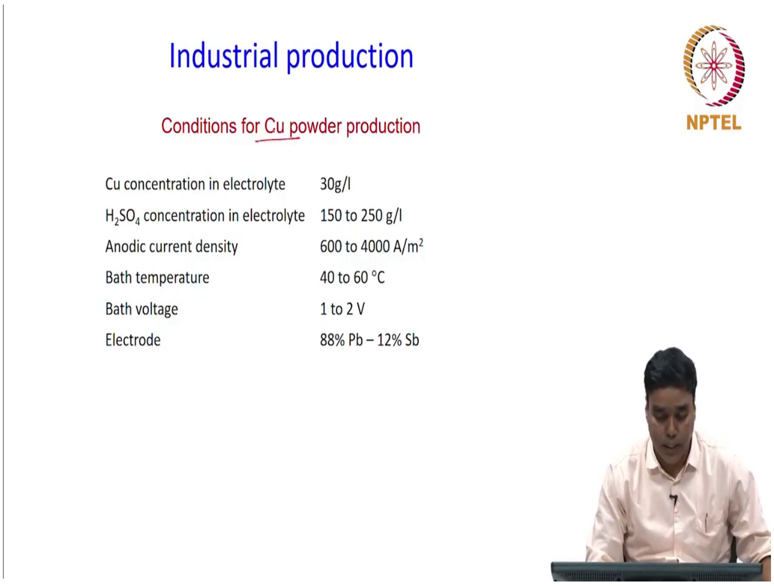

And then, we also talked about a particular metal production by this process taking an example of copper.

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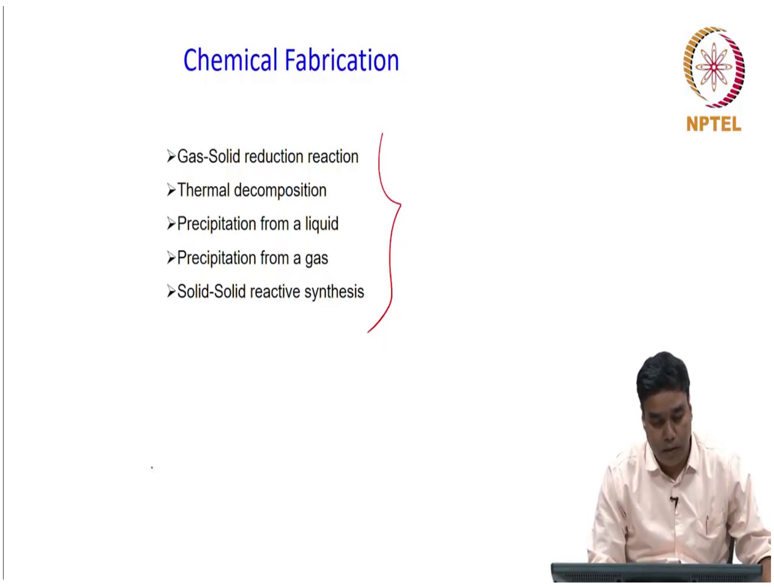

And then, we also discussed about chemical fabrication, where there are different routes again in this category; starting from gas solid reduction reaction.

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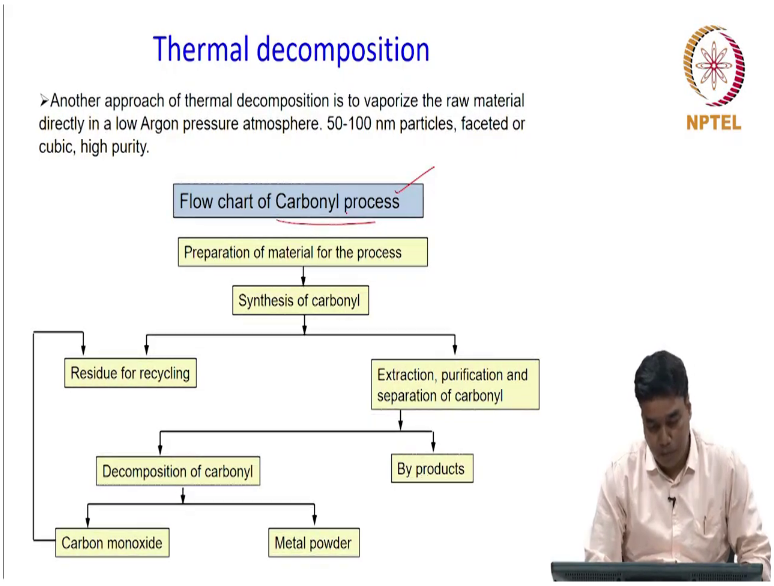

Then, we had thermal decomposition, where we used a process called carbonyl to generate metal powders by thermal decomposition of this volatile compound of a metal.

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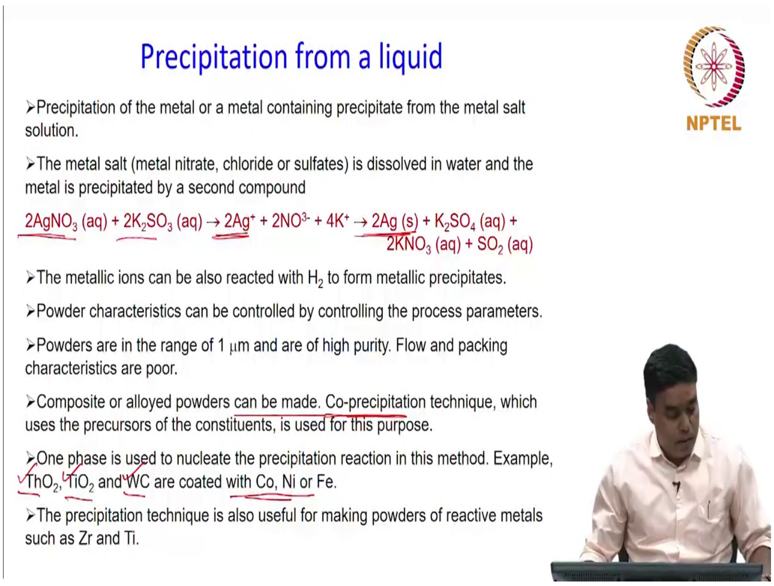

And then, we talked about precipitation from a liquid wherein, you have a metal salt which is dissolved in a solution and with the help of a precipitating agent, that metal is released and precipitated in the form of powders and you know with the help of this a variety of metal powders can be generated.

And, we have also seen that using the same process, it is also possible to coat a particular surface. For example, a ceramic material surface like thoria, titanium or tungsten carbide can be coated with the metal like cobalt and nickel or iron when we use the process of co precipitation, where both of these materials will be precipitated together.

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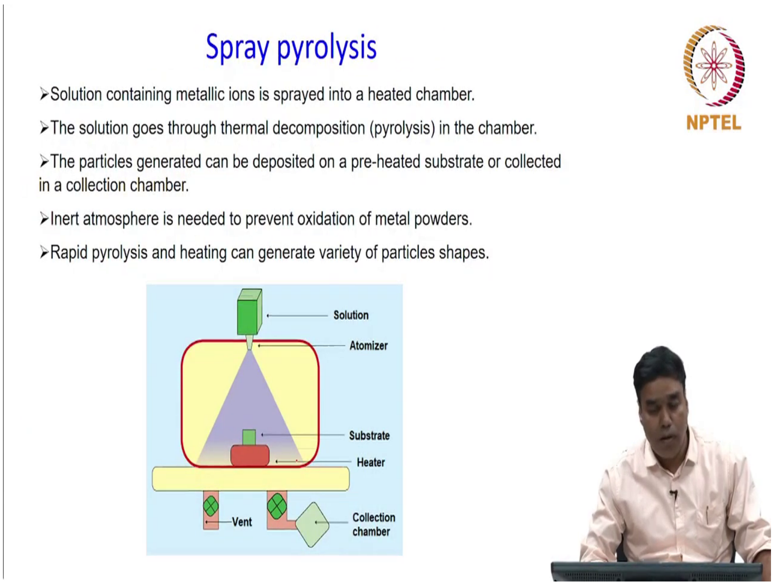

And then, we talked about this process called spray pyrolysis, wherein a spray of the metal salt solution is sent into a chamber, where it is thermally decomposed to generate the metal powders, which are collected at the end in this collection chamber. And, we have also seen that the powder which is generated inside this chamber by the thermal decomposition process can also be coated on a preheated substrate. So, this is also a process of making a coating apart from making metal powders.

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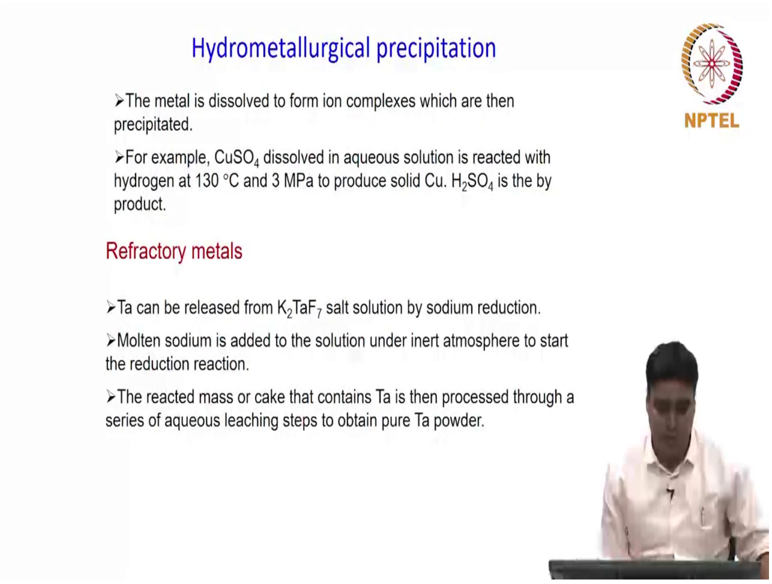

Then, we talked about the process of hydrometallurgical precipitation, wherein the particular metal is in a compound which is dissolved in a salt solution and in this case, we took the example of tantalum which is dissolved in sodium and it is made into a cake and once, it is into the cake, the metal in this case ,tantalum is released by washing and once it is obtained as powder, it is crushed followed by milling, ok.

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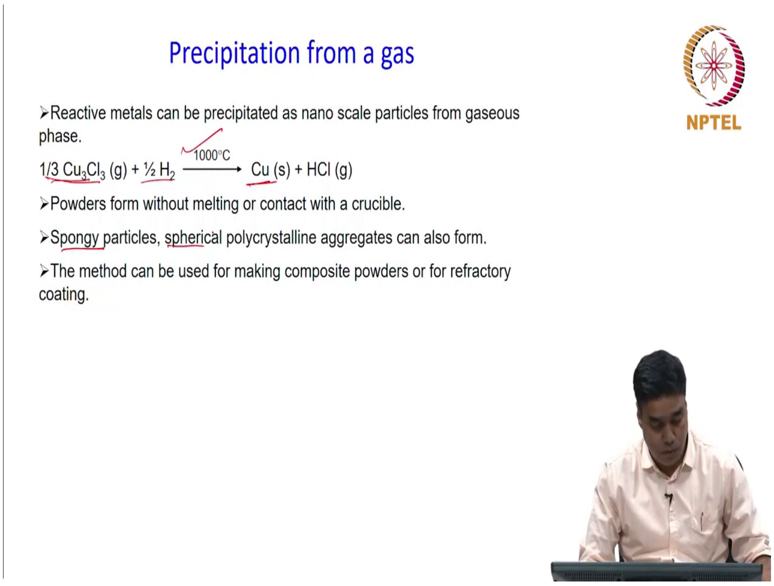

We also talked about precipitation from a gas, wherein the metal compound is in the form of a volatile gas, which is reduced by reducing gas at high temperatures to generate the metal powder. We also talked about the different attributes of the powders generated by a particular process like in this case, the powders are spongy and spherical in shape.

Similarly, we talked about the other processes also as to what kind of powder morphology and powder characteristics, they generate. If you remember for example, in the mechanical case, the powder particles are generally irregular in shape and their packing and flow characteristics are also not that great, due to that particular shape or that irregular shape.

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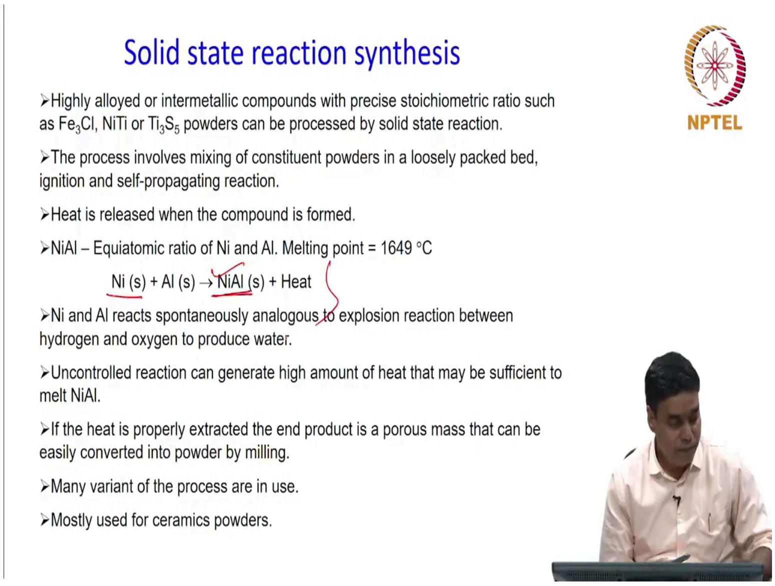

Then, we also talked about this process of reacting to solids you know to make another solid in the form of powder, but this is kind of more suitable for making intermetallic or ceramic powders rather than metal powders.

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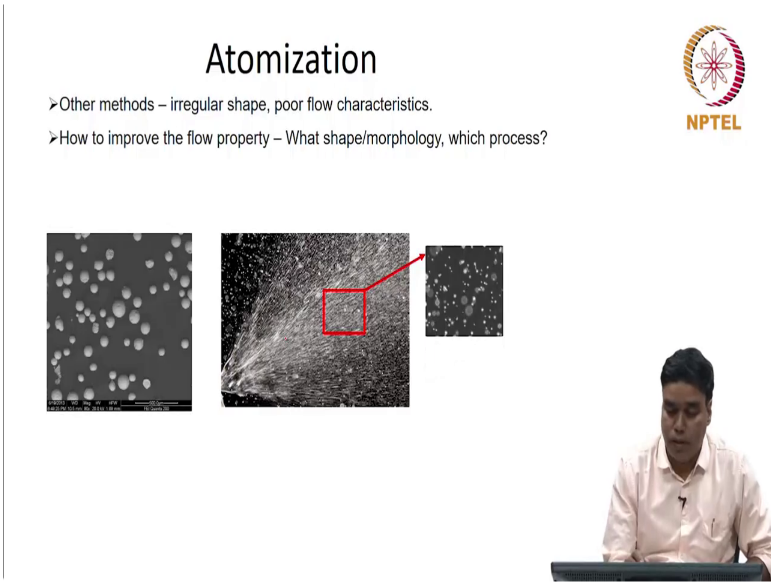

And finally, in last few classes, you know we have talked about this process called atomization, which is a large scale fabrication route for metal powders with production rate of as high as 400 kilogram per minute.

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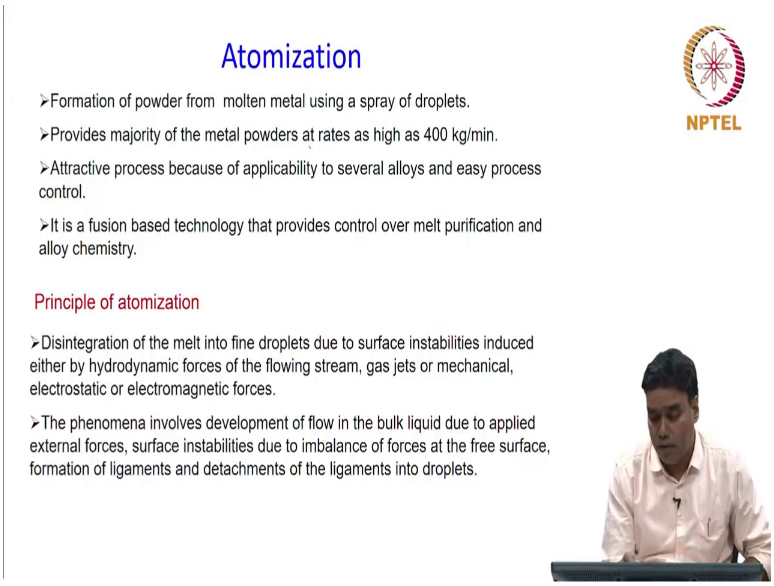

And in this case, you know what we have seen is that, the powder particles are spherical. And as a result, their flow and packing characteristics are very good. And, in this process of atomization, we have also seen different types of atomization processes like gas atomization, then water atomization and finally, the centrifugal atomization process.

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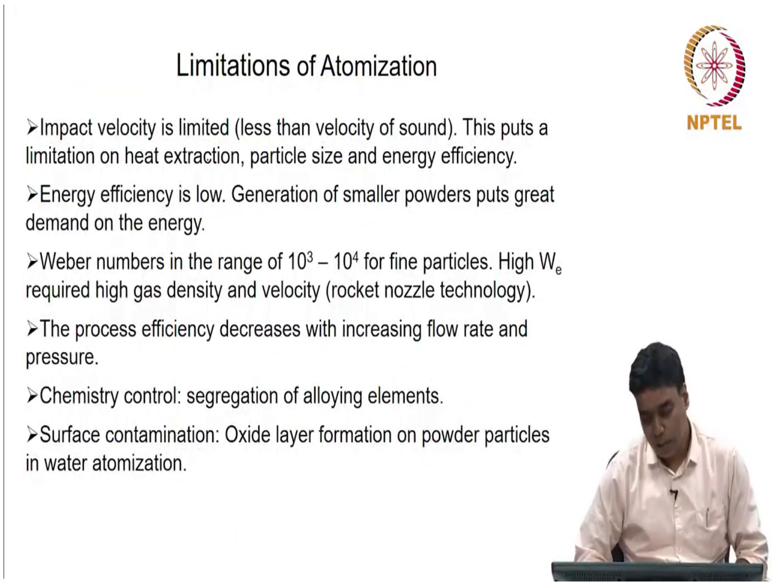

And then, we also had a comparison between them to show you what kind of powder particles are generated by each of these atomization processes and also, what is the cost for this atomization processes. So, with this, I think we can conclude this topic of powder fabrication. And, as I said in the next class, we have one more very important aspect of powder fabrication process; particularly, with regard to these atomization process wherein, you start with a liquid stream and then, solidify that liquid into powders, right.

So, there is a solidification aspect which is involved here and we need to understand that. So, that is a very important aspect of this atomization process and that is something that we are going to take up separately, as I said before in a different class. But for today, this is all I have.

Thank you for your attention.