**Powder Metallurgy**
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**Lecture - 08**
**Centrifugal Atomization**

Hello everyone and welcome back to this lecture series on Powder Metallurgy. So far we have been talking about different methods of powder fabrication and in the last couple of classes, we have talked about the process of atomization for making metal powders and if you remember in the previous class, we talked about the details of the water atomization process. So, we will continue this atomization and we will see in today's class, what are the other atomization techniques which are available for making metal powders.

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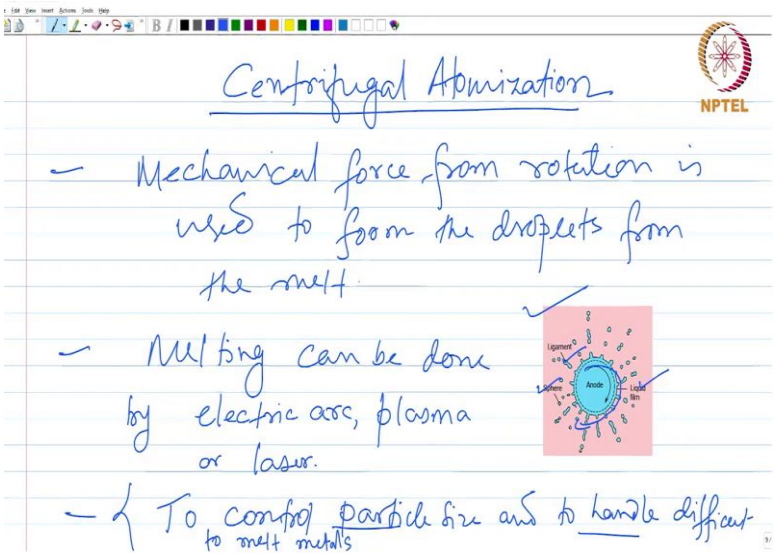


So, today we are going to talk about another atomization process which is Centrifugal Atomization. So, what we have seen so far for atomizing a molten metal stream? All you need is a mechanical force which can induce instabilities in the molten stream of metal and break it down into finer droplets.

We have seen that a gas jet or a water jet can be used for that purpose to provide that impact and break down the molten metal stream. Now, in case of centrifugal atomization, as the name itself suggest in this case the force which is used to do that to

serve that purpose of breaking down or inducing those instabilities on the molten metal stream is the centrifugal force which is nothing but, a mechanical force that comes from rotation.

As you can see from this particular diagram schematic here, that you have this metal which is being melted and also rotated at the same time at a particular velocity, at a particular rotational speed and as it rotates and melts due to these centrifugal force there is a liquid film which develops on the surface and which is quite unstable and finally, it breaks down into these finer droplets.

Let us talk about this in little more detail in a short while from now, as far as the melting is concerned that can be done by either electric arc or by using a plasma or even laser can be used to melt the metal which has to be formed into powder.

And, one more thing that, I should mention over here is the fact that this process came into use primarily because of the fact or because of the need to control the particle size and to handle difficult to melt or difficult to process metals.

Like those reactive metals or those refractory metals having very high melting point, these kind of materials are difficult to process and to exercise a better control over the particle size, this process came into being because controlling the particle size and to handle a certain type of metal that may be difficult in other atomization processes that we have discussed so far.

So, centrifugal atomization is a process which can have a better control on the particle size, and it can also handle difficult to process metals. Now, talking about this again as to how this whole process happens or the mechanism which is involved here, so as you can see the stock or the material which is being melted that can be in the form of a rod for example, which is rotated at a particular rpm at a particular rotation speed and that generates the centrifugal force.

And, as that happens as the centrifugal force is generated or as the centrifugal force acts on this melting rod, a liquid film develops on the surface as you could see over here. And, because of this mechanical force this liquid film which is formed on the surface, it becomes unstable and due to that it breaks down into smaller fragments starting from

ligament and then, finally going all the way to spherical particles like what we have seen before also while talking about the basic principle of the atomization process.

So, here also the liquid film first breaks into ligament, an intermediate shape which finally, breaks down into the spherical droplets which will solidify as the powder particles. As I mentioned in the beginning itself centrifugal force is the main force responsible for breaking this molten metal down into smaller droplets.

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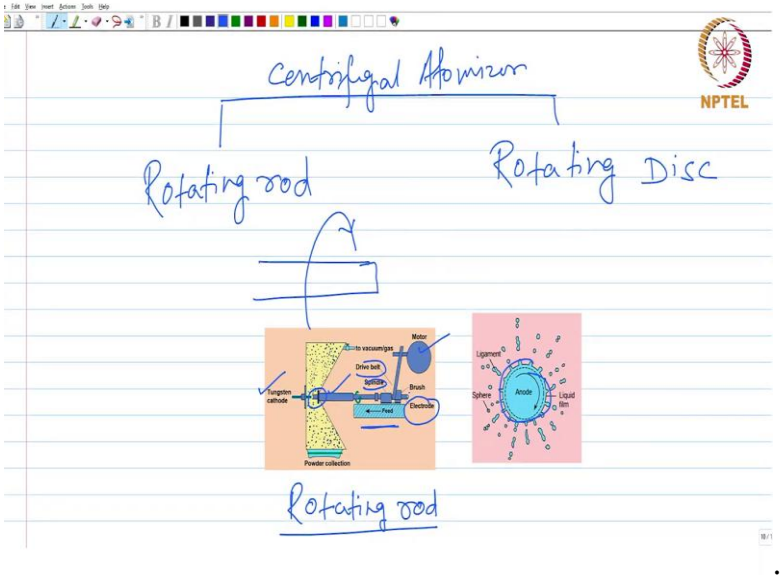


Now, if you talk about the type of centrifugal atomizers, after understanding the basic of the process we can see what kind of equipment is used. As far as the centrifugal process or the centrifugal atomizers or the equipment is concerned there are two types: one is rotating rod and the other one is rotating disc.

In rotating rod types the material to be processed is in the form of a rod which is being fed into a chamber, where it can be melted at one end and then, it is also rotated at a particular rpm and as a result of that the centrifugal force is developed and the molten metal breaks down into droplets.

So, if you see the setup it looks something like this (above figure). This is a rotating rod set up. The main parts of this type is feeding mechanism, which can feed this rod which has to be melted and this drive belt and the spindle for feeding and rotating rod which melts at this chamber.

In this case as you could see it is done with the help of a tungsten electrode; that means, here we take the help of an electrical arc to melt this rod which is being fed into this end, where the tungsten electrode is there and it is melted with the help of an electric arc.

Once it is melted by the arc, it is simultaneously rotated and because of that rotation as we have seen before the rod breaks down into droplets as you can see here that we have discussed just now.

If this is the rod when it rotates due to the centrifugal force, the molten rod or the molten metal is broken into smaller droplets. That is how finally the powder particles are generated. And, in order to fit this rod, of course you have this motor and drive belt mechanism in this case to push this rod into this device.

So, the rod itself is that one of the electrodes and the other electrode that means the cathode is the tungsten and the rod itself is the anode, which is being melted. So, once you set up the arc between this anode which is the rod and the tungsten cathode, it will melt and as you as you rotate it, that molten metal will be broken down into fine droplets due to the centrifugal force.

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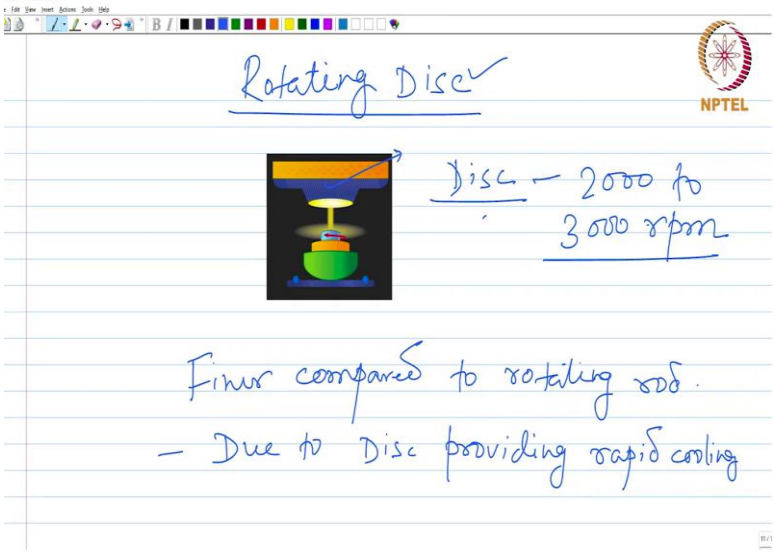


The next one is the rotating disc, which looks something like this (above figure). If you see the schematic of the atomizer or the equipment here in this case, you do not really

have a rod which is being melted like how we have seen for the previous case. Here, in this case in order to generate this centrifugal force a rotating disc is used.

So, what is done is the metal is first melted and then, it is fed into a crucible like this that you can see over here and from that, it is actually dropped into a disc which is rotated at very high speed. So, the disc as it rotates it creates the centrifugal force over the molten metal which is dropping or falling on this rotating disc.

The disc will be rotated at very high rpm between 2000 to 3000 rpm in that range and as the molten metal falls into this rotating disc, it is subjected to a centrifugal force and the metal breaks down into droplets and as far as the powder particles are concerned, the particles are finer compared to the rotating rod method.

This is because, the disc provides rapid cooling. Since, it is kept at a much lower temperature. The temperature of the disc surface is much lower compared to the molten metal and as a result, when the molten metal comes in contact with the disc, it immediately cools down or subjected to a high cooling rate and due to that, the powder particles are finer. Because higher the cooling rate finer will be the particle size. Because of that higher cooling effect, the particles in this case will be finer compared to the rotating rod method.

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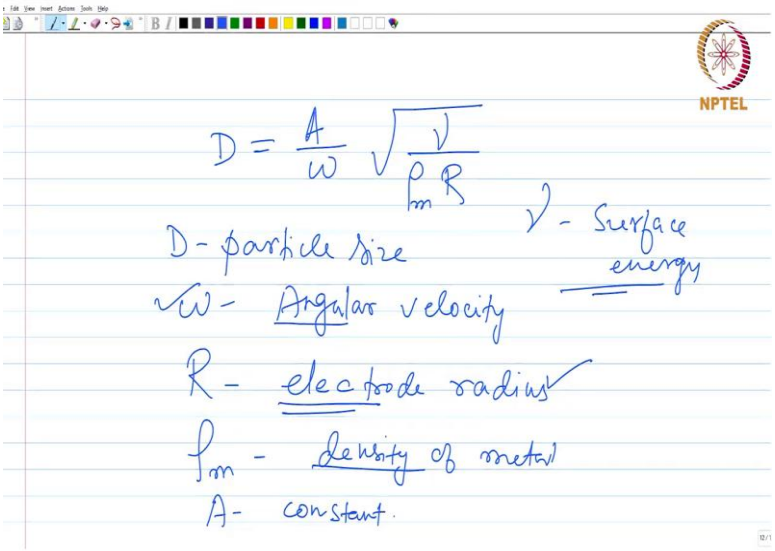

Now, if you talk about the process variables which will influence the particle size, the particle size in this case can be expressed or can be correlated with the process parameters with an equation like this,

$$D = \frac{A}{\omega}\sqrt{\frac{\nu}{\rho_m R}}$$

where D is the particle size, ω is the rpm or the angular velocity of the rotating material, R is the electrode radius, $\rho_m$ is density of liquid or liquid metal and A is a constant. So, here we are talking about the rotating rod method because in that case, the rod itself is used as the electrode, which is being melted.

Here, you can see apart from the size of the rod, the other parameters which will affect the particle size are the angular velocity, the density of the metal and also the surface energy gamma. So, these are the main parameters or main process variables, which will control the particle size and one more thing, that I should mention here particularly with regard to this rpm or the angular velocity that is whether you will use a higher or lower rpm, depending on that, the mechanism of formation of the droplets can change.

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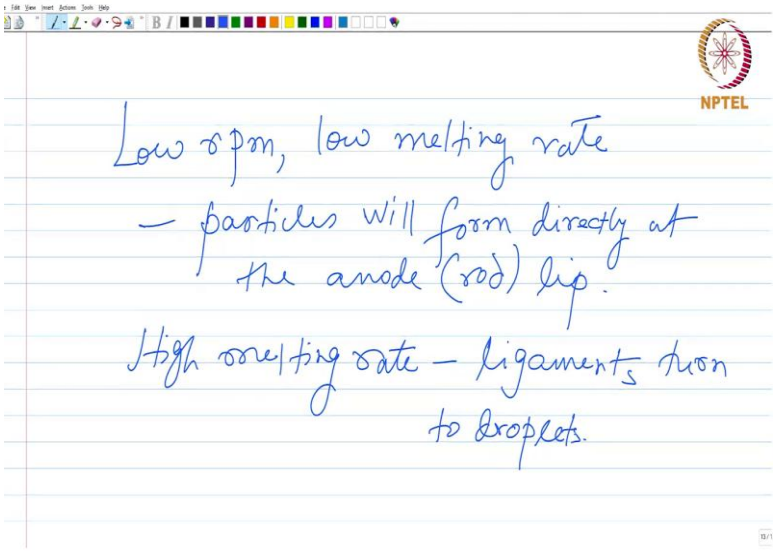


For example, if you are on the lower side, that means low rpm and also low melting rate then, in that case the particles will form directly at the anode lip anode, which is nothing,

but the rod itself. On the other hand, if the melting rate is high, then it will go through an intermediate, which is a ligament which will finally convert into droplets.

In the case of low rpm and low melting rate, the particles or the droplets will form directly at the lip of the anode at the tip or at the lip of the rod. When the melting rate is high, then first the ligaments will form first as an intermediate and then, they will be converted to the droplets.

So, that is the effect of the rpm or the melting rate, on the mechanism of formation of these droplets. Let us look at some other attributes of this process and see what advantages.

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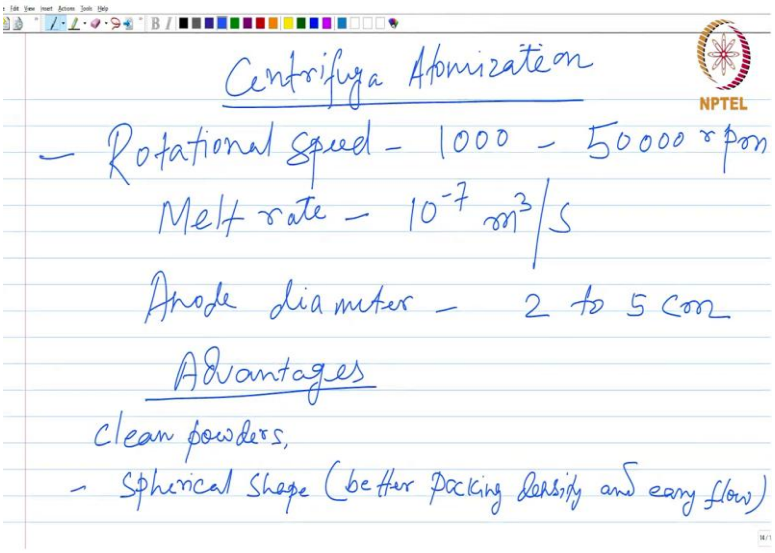


This process of centrifugal atomization can offer, one of the main attributes of this process is the rotational speed and it can be in the range of 1000 to 50,000 rpm.

Just now, we saw that the melting rate also has an effect. And, in this case the melting rate typically is around $10^{-7}$ $m^3/s$, and when you talk about this rotating rod method, the anode diameter is typically 2 to 5 centimetres. Now, let us also look at the advantages and the disadvantages of this process. Advantages are the powders are clean; they also have spherical shape which will provide better packing density and better flow to the powders.

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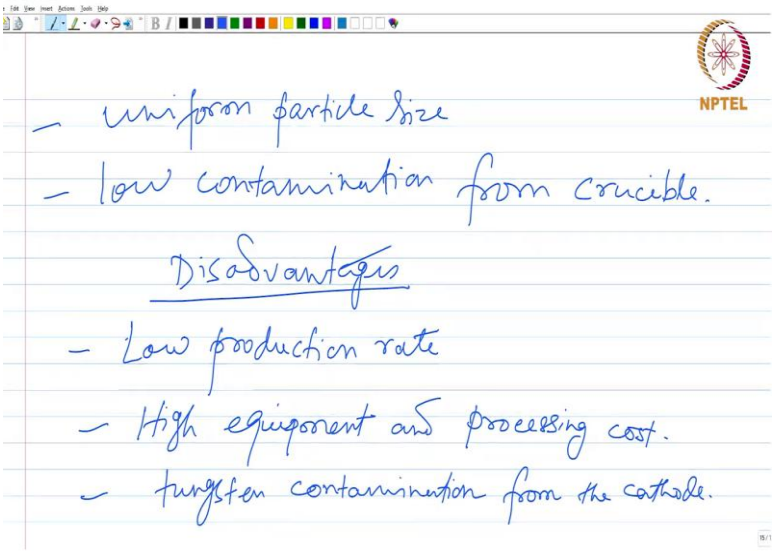


And other advantages are uniform particle size, contamination is lower compared to other processes like for example, the water atomization process. And every process will have it is own disadvantages also.

So, if you look at the disadvantages of this process, some of the limitations are like low production rate, a high equipment and process cost. Since a tungsten cathode is used, there is a chance of tungsten contamination from the cathode. So, these are some of the attributes of this centrifugal atomization process and as we have seen this is a process which can exercise better control on the particle size and as well as it can also handle difficult to melt or difficult to process metals.

So, before we close today's class, let us quickly summarize what we have discussed today, as far as this centrifugal process is concerned. Centrifugal atomization process as we have seen it as basically breaking down a molten metal by the centrifugal force which is generated through the rotation and this rotation can be created in the metal itself which is being processed or it can be additionally created with the help of a disc on which this metal is being dropped.

So, depending on that, there are two types of centrifugal atomizer: one is the rotating rod, where the rod itself is being melted and then converted into droplets and in other case, it is a rotating disc where the metal is dropped on a rotating disc to break it down into droplets. And, as far as the mechanism is concerned due to this rotational force or due to

this centrifugal force of rotation, first a thin film is developed on the surface and when the film becomes unstable, it breaks down into ligament and then finally forms as spherical particles. Whether the ligaments will form as an intermediate or not that depends on certain parameters.

For example, the rotational speed and the melting rate. For example when the melting rate is low and rpm is low, then the ligament does not form the particles are generated directly from the lip of the anode and on the other hand, when the melting rate is high, then the ligaments form which finally convert to droplets. And, with that we will finish today's class.

Thank you for your attention.