Powder Metallurgy
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Lecture – 05
Powder Fabrication Methods: Atomization

Hello everyone. And welcome back again to this lecture series on Powder Metallurgy and you know so far in the previous classes we have been talking about fabrication of metal powders. And we already have seen few methods of making metal powders, which are you know categorized into different categories, depending on how they are fabricated.

For example: we have talked about the mechanical method of powder fabrication, where mechanical forces are applied to generate the powders. Then we have also talked about the chemical processes, where you use either a liquid, solid or even gases you know to precipitate the powder or get the reaction between two different elements or two different precursors to get the powders ok.

One thing that you would have noticed in all these fabrication routes is that the kind of powders that you obtain in terms of their morphology and the characteristics. So, what happens? As I would have mentioned before also that the powder morphology in terms of its size and shape and the flow characteristics of the powder, would actually influence the packing ability of the powders. That means, how well this powder can be packed during compaction.

Because, what happens in a powder metallurgy process, you start with the powder and then first you compact it in a particular shape right. So, in order to get a good compact or for the powders to be easily compacted, the powder should have better or good flow characteristics. And, this flow characteristic would depend on what kind of powder shape or powder morphology you have.

So, far the processes that we have talked about like as I said mechanical or chemical rout e or even the electrolytic process. Most of the time in these processes the powder morphology is irregular, the powder shape is irregular and as a result of this kind of irregular shape their flow characteristics are not good.

So, if the powder does not flow properly; that means, it cannot really fill the mold when it is used for compacting ; it cannot fill that mold completely; it may not be able to flow freely to actually fill all the places or all the corners and every other aspect of the mold, when you compact the powder .

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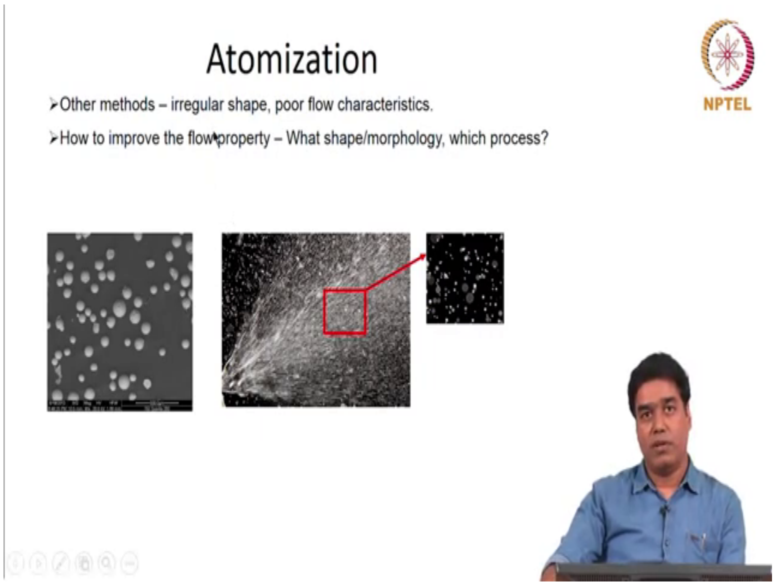

So, now the question would be as to how you can improve the flow property or what shape or morphology will give a better flow property. And, then if you want to get that shape or morphology, what kind of process or what kind of fabrication route is needed to get good flow characteristics in a powder . So, what we are talking about is if you have a shape like this, which is spherical as you could see.

This kind of shape of powder is very conducive for free flow; that means, if you have this kind of a spherical uniform particles, then this will be a free flow powder which can easily flow inside the mold cavity ok. When you fill this powder in the mold for compacting it will freely flow and it will be easier for someone to compact the powder.

So, the next question would be what process now you can have inorder to obtain this kind of spherical particles which provide good flow characteristics . So, the process that we are talking about here is known as atomization, which is nothing, but you know breaking down a stream of liquid into smaller droplets like what you can see over here in this picture .

So, this is for example, water jet or a water spray and if you look closely when you convert this water stream into this kind of a jet or when you break it down into an atomized jet or this kind of spray. Then, you can see if you take a close look that this is actually broken down into this kind of finer droplets. So, a liquid stream when if it is broken down or when it is atomized it can give rise to these fine droplets which are more or less spherical.

And, the similar process can also be adopted for liquid metals, wherein you first atomize or break down a stream of liquid metal into finer droplets which will be like this spherical in shape. And then once you solidify these droplets, this can be converted into a powder with particles of spherical morphology like what you can see in this image . So, this is the process that we are going to talk about right now, the process of atomization for making metal powders.

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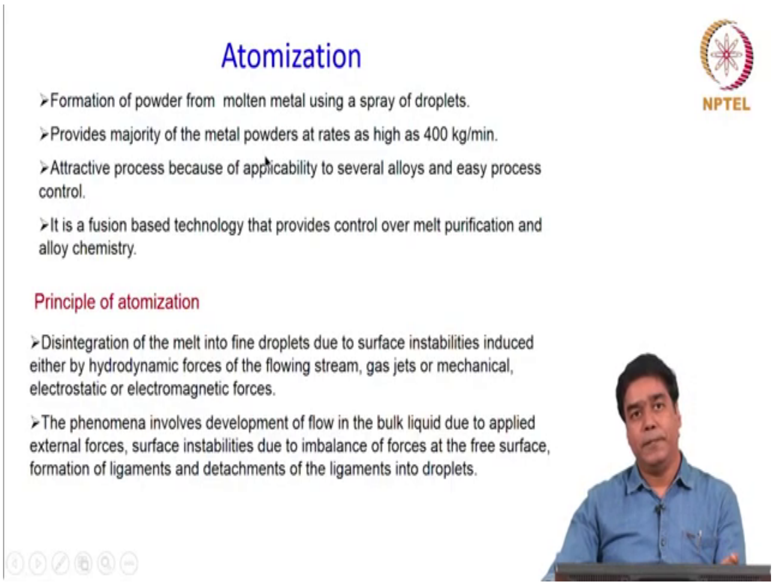

So, as I said you know the formation of powders from molten metals using a spray or droplets . And this is a process which actually provides the majority of metal powders because, this can produce metal powders at a very high production rate rates such as 400 kilogram per minute. So, the production rate can be as high as that and that is why this is one of the most commonly used method to make metal powders on a large scale.

And the process is quite attractive because of applicability to several alloys and easy process control. All kinds of metals and alloy powders can be processed by this method and the process parameters can easily be controlled. So that you can also have a control on the shape size and morphology of the powders. So, let us try and understand the basic principle of this process first. And then we are going to see how this process is actually done what is the equipment and so, on.

So, when you talk about the basic principle of atomization it is nothing, but disintegration of the melt into fine droplets. And, this happens due to the surface instabilities induced either by the hydrodynamic forces of the flowing stream. Or you can use some external forces for example, gas jets or mechanical electrostatic or even electromagnetic forces to induce these instabilities.

So the metal stream or the molten metal stream can be broken down into fine droplets . So, that is what we call as the atomization process, where you have a stream of liquid metal which is broken down into fine droplets. Then, you allow these droplets to you know fall through a chamber and then finally, they solidify as metal powders . So, the idea here is to induce enough surface instabilities. So that the stream will be broken down.

And the phenomena involves the development of flow in the bulk liquid, due to applied external forces. And then development of the instabilities due to the imbalance of forces at the free surface which first leads to formation of ligaments and detachments of the ligaments into droplets.

So, it kind of goes through certain stages where first you have a liquid stream and into that stream, you induce the instabilities by applying some external forces. And due to that you first create these ligaments which are finally, converted into droplets. So, what these ligaments are and what those stages are I will come to that and describe them, in more detail in the next slides .

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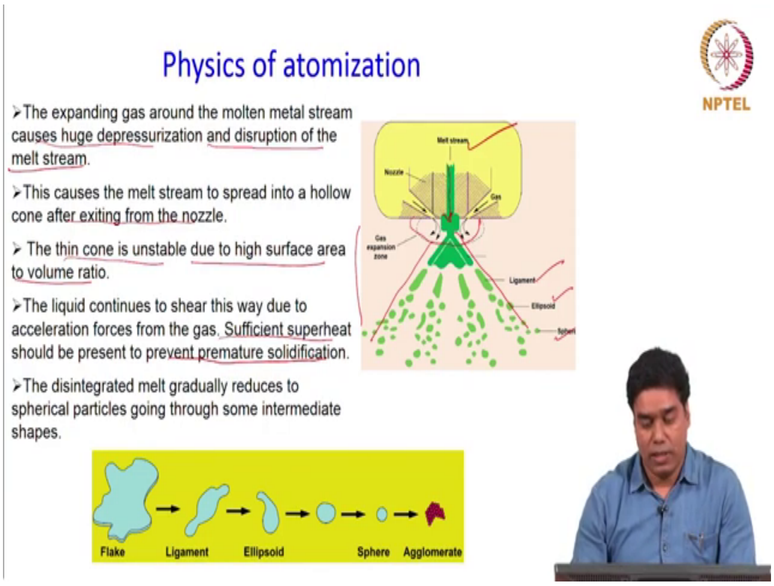

So, this is how the process is in terms of the phenomena or the principle. If you see it, we will take an example here of the gas jet, which is used to atomize the molten stream of a liquid metal ok. So, what do you have here? You have this chamber in which you have the molten stream coming through. And this molten stream of metal is sent through an opening like this through a nozzle and where, the nozzle exit is at that location you have this high velocity gas jet coming in .

So, here you have the nozzle for the molten metal to exit. So, now, it is coming down as a stream of a liquid metal and as it exits the nozzle it is exposed to a high velocity gas jet . And, when it comes to these zone this particular zone over here which is demarcated by these dotted lines. So, in this zone the gas also comes out from the nozzles and suddenly it expands ok.

So, this is the gas expansion zone. So, due to this sudden expansion what happens is this, causes the melt stream to spread into a hollow cone after it exits from the nozzle. Because, as I said what happens when this gas comes into this gas expansion zone. There is a huge depressurization that happens and this would actually disrupt the melt stream. And due to that the melt stream when it comes out from the nozzle it will actually, spread into a hollow cone like what you can see over here like this .

So, this is how the instabilities are first created into this molten stream of metal. And then you can see it goes through certain intermediate shapes like, ligaments ellipsoid and finally, those are all converted into spheres which solidify. And the powder that you obtain at the end of the process are these spherical particles ; this thin cone of this liquid stream also has high surface area to volume ratio. And due to that it becomes quite unstable and as the liquid goes through this chamber .

This continues to share due to acceleration forces from the gas , which you know leads to instabilities into this metal stream. And, it is broken down into this kind of a finer fragment for example, like ligament and ellipsoids as I said.

One thing that has to be ensured here is that the liquid stream, which is coming to this atomization chamber it should have a sufficient super heat; that means, it should be sufficiently heated above the melting point. So, that it remains a liquid during the whole process before, it is actually you know converted to these spherical particles. Because, our objective here is to get these spherical shaped particles.

So now you know we have that free flowing powder and therefore, we need to make sure that till the time this whole process is going on from. You know starting from the thin sheet of the liquid stream and going down all the way to this spherical shape, through some intermediate stages during this entire process it has to be in liquid state . Otherwise it will suffer from premature solidification. And you may not have the kind of a powder or particle morphology that you are looking for .

So, that is why the melt should have sufficient superheat. So, these are you know are the different intermediate stages, as you could see from this particular image. Now, it starts from a flake which is having a very high surface area to volume ratio. And then it gets broken down into a ligament, which is then converted into an ellipsoid and then this ellipsoid is finally, converted to a sphere.

And then you have these agglomerates of these spherical particles finally, and after this these finer particles this final spherical shape particles will solidify as powder at the end of the process. So, they will be deposited at this end of the chamber. So, this is how I know the whole process goes, going through several intermediate shapes. And finally, giving rise to these spherical particles which solidify as metal powders.

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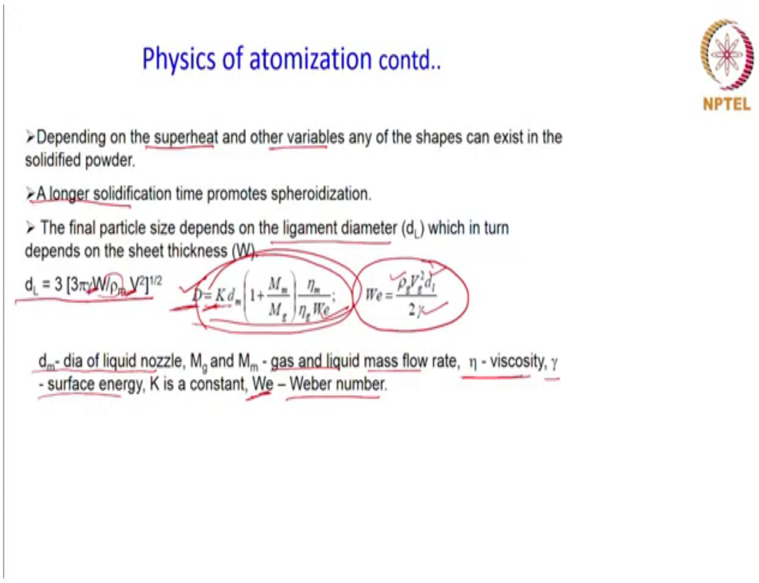

Now, continuing onto the physics of atomization, you should also see what kind of a particle size that can be obtained from this process and also the kind of shapes that you may end up with. So, both of these can depend on several parameters of the process including the superheat, as I said before and you know the other process variables. And that you can get other shapes as well depends on what process variables are actually present during the process while the atomization was done.

So, in terms of the process parameters, if you look at the time or the solidification time. A longer solidification time would actually promote spheroidization; that means, if you want spherical particles it is better that you have a longer solidification time during the process ok. And, the final particle size that is obtained at the end of this process, that actually depends on the ligament diameter because if you remember that is what you get in the beginning.

So, that is the kind of first shape which is generated out of this thin cone of a metal stream. And therefore, the particle diameter would also depend on the ligament size or the ligament diameter and this ligament size in turn depends on the sheet thickness right.

Because, what happens as I said first it is developed into a thin cone or a thin sheet of liquid like this, in the shape of a thin layer or a flake and from there it is converted to the ligament right.

So, the ligament diameter would also depend on the thickness of this thin sheet. So, that is what is shown in this particular relationship over here. The ligament diameter "d_L" is dependent on the sheet thickness 'W'. And it also depends on the density of the metal "ρ_m" and the velocity of the gas . Because, it is the velocity of gas or the gas state that is what was actually responsible for creating this thin sheet of liquid metal.

So therefore, the gas velocity is also an important process parameter in this case. And finally, if you see the particle size "D" it is given by this particular relationship, where in "d_m" this parameter is the diameter of the liquid nozzle from which ligament is coming out; that means, we are talking about this nozzle over here. The size of that or the diameter of that and M_g and M_m are the gas and liquid mass flow rate respectively.

η is the viscosity of the liquid and γ is the surface energy of the liquid. And the other two parameters that you see over here K, this is a constant and W_e that you see over there is Weber number , which is given by this particular equation. So, the Weber number would again depend on the velocity, the diameter of the liquid , the surface energy and also the density.

So, from here you can see in order to control the particle size d, what are the process variables or the process parameters that one has to control in order to get a final particle size, or in order to get a particular particle size finally, in the solidified powder at the end of the process. So, before we proceed to the actual method as to what kind of equipment are used and how the method of the process is actually carried out. Let us quickly recap the whole process and summarize it.

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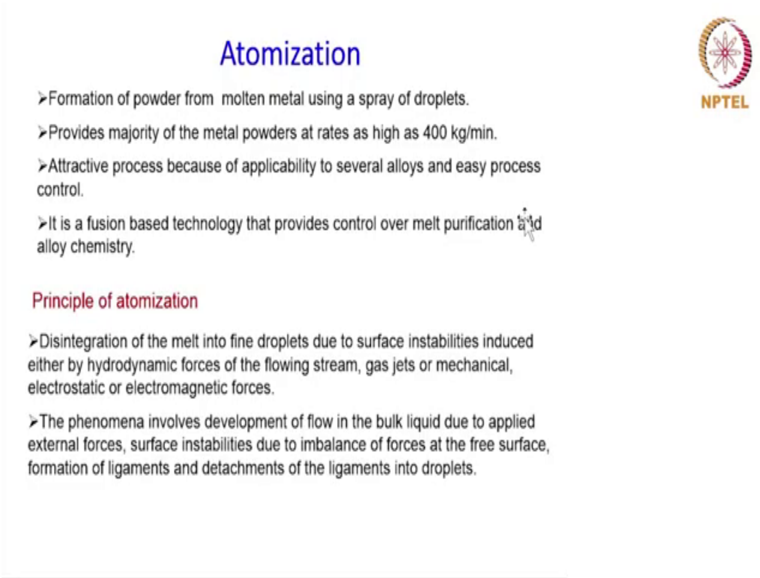

The process of atomization is nothing, but formation of small droplets of liquid. And these droplets of a liquids are actually generated from a stream of metal with the help of some external mechanical forces, which would create some instabilities on the surface of the liquid stream and break it down into finer droplets.

And what will be the shape of these droplets, that would depend on certain parameters. For example, the superheat and the solidification time which is allowed here for this liquid stream to finally solidify after these droplets are created inside the chamber.

And this process is carried out inside a chamber like this, where this liquid stream comes down from this nozzle and goes through this flight path. And finally, it gets deposited on a surface or on a solid surface or on a substrate, which is kept on the other end as powders .

So, the process is about creating enough instabilities in the liquid stream ,a kind of a condition, which can lead to a shape which is having a very high surface area to volume ratio. So that all these surface instabilities can be easily generated on that surface.

And then it will be broken down and as I said this fragmentation of this or disintegration of this liquid stream, it goes through a certain stages starting from a thin sheet or flake and then goes through these intermediate shapes or these intermediate stages. And finally, forming into a spherical particle which agglomerates as fine spherical particles which finally, solidify as powders . And, these are the process variables that we have discussed which will control the size of the powder particles.

So, now that we have understood the basics of this process or the basic fundamental mechanism of this atomization process , we can go ahead and see what kind of method or what kind of equipment is used to carry out the process and get to know different kind of metal powders. So, next we will be taking up those processes, but for today this is all I have.

Thank you for your attention.