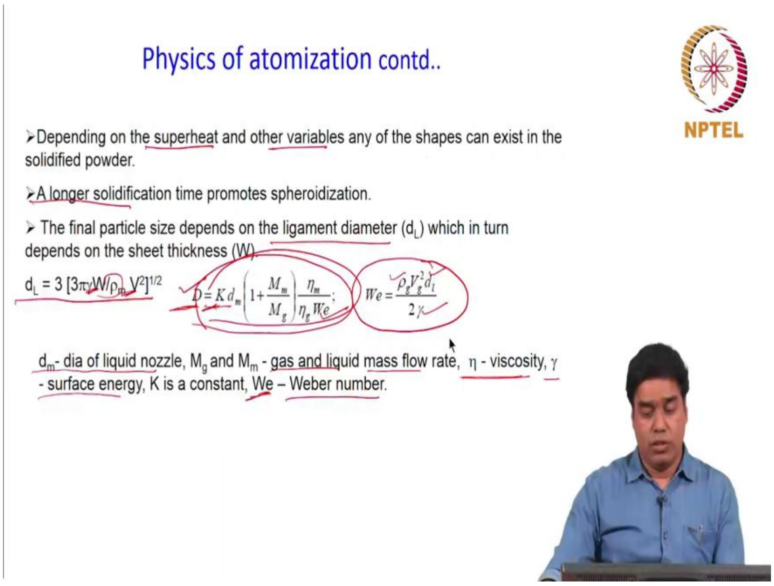
Powder Metallurgy
Prof. Ranjit Bauri
Department of Metallurgical & Materials Engineering
Indian Institute of Technology, Madras

Lecture – 06
Gas atomization

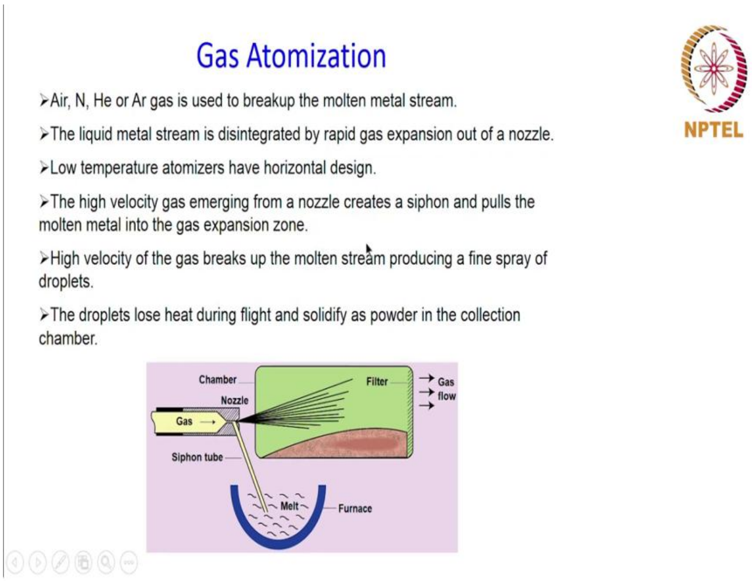
Hello and welcome back again. So, in the previous class we were talking about this process called Atomization, which is a metal powder fabrication process, a large scale metal powder fabrication process used for producing all kinds of metal powders. And, in the previous class, we actually talked about the basic principle of this process and understood the physics behind this process. We have also seen the process variables and the effect of these process variables on the final particle size.

(Refer Slide Time: 01:13)



So, now that we have understood the basic principle of this process, we can go ahead and see the methods and the equipments that are used to carry out this process of atomization.

(Refer Slide Time: 01:31)



So, the first one we are going to take up is Gas Atomization; wherein you use this gas jet as a mechanical force to disintegrate this molten metal stream into finite droplets. So, this we have seen before also, how actually this gas, this high velocity gas jet, how it actually helps in breaking down this molten stream of metal into fine droplets.

Today we are going to see how it is actually done and what kind of setup you have. So, what happens in this case is, the liquid metal stream is created with the help of a gas jet which comes out from a small nozzle.

So, the high velocity gas emerging from a nozzle creates a siphon and pulls the molten metal into the gas expansion zone. So, here (figure above) you can see this is the siphon tube, which is used to actually take this metal up all the way to this zone, which is the gas expansion zone.

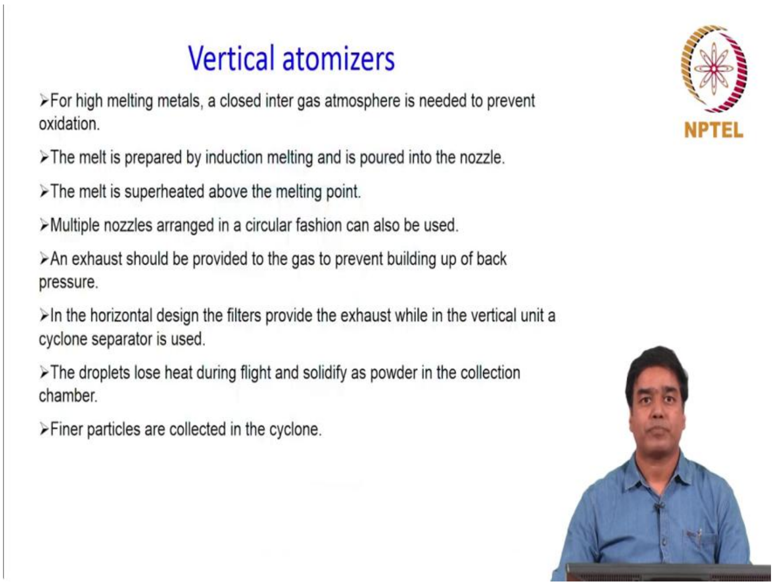
And when the high velocity gas suddenly comes out here, it provides a high amount of force on this metal stream at the exit of this nozzle. And due to that, it generates lot of instabilities and this molten metal stream is broken down into finer droplets. .

So, these droplets are now sent into this chamber, where they go through this flight path. And while going through this path they will continuously lose heat and finally, solidify and are collected in this chamber. And for these molten droplets to pass through it continuously, it is also necessary that some means and ways are there to take care that the gas is not developing any back pressure inside; otherwise this continuous flow of these droplets may be hampered.

Therefore, it is necessary that a vent is provided at the other end of this chamber, so that this gas can continuously flow out of this chamber and no back pressure is developed inside the chamber. So, this is the powder which is collected in this chamber and at the end of this process, this powder can be taken out from this chamber and can be further processed if there is a need.

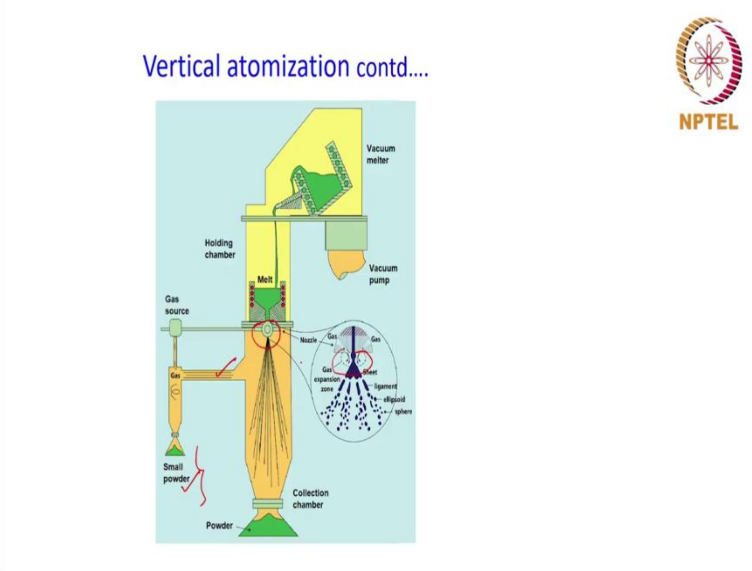
So, this is about the gas atomization process. And in this, case you see, this is a horizontal setup, where the flow of this metal is in horizontal direction. So, this is a horizontal gas atomization setup, but there could be other orientations also.

(Refer Slide Time: 05:59)



For example, you can also have Vertical atomizers.

(Refer Slide Time: 06:08)



So, in that case the chamber is vertical and the flow is vertically down.

This is particularly suitable for high melting point metals. And it can be done in a closed inert gas atmosphere in order to prevent the oxidation of the metal. In this method, the melt is first prepared by induction melting and is poured into the nozzle.

The melt has enough superheat above the melting point and the requirement for this superheat has already discussed before, as to why you need the melt to have higher superheat. You know this is needed, because during the entire process or during the entire flight of the droplet from this nozzle all the way down to the bottom of this chamber, this should be in liquid condition.

And in case of the vertical atomizer, multiple nozzles are arranged in a circular fashion. So, if there is a need, we can also use more than one nozzle and they can be arranged in a in a particular configuration, for example, they can be arranged in a circular configuration. And like what we have seen in this case, an exhaust or an exit path for the gas should be provided, so that there is no building up of any back pressure inside the chamber.

So, as we have seen before, in the case of the horizontal design, the filters will provide that channel for the gas to flow out from the chamber. And in case of the vertical unit, a separate cyclone separator is used for the outflow of the gas.

So, during their flight through the chamber, the droplets will lose heat and solidify as powder in the collection chamber, which is at the bottom of this chamber. So, these are the regular particles which are generated during the process and collected over here; but there could be very fine sized particles, they can actually float and go along with this gas to this cyclone which is connected over here for the gas to go out.

So, this gas can also carry the finer particles from this chamber and therefore, the finer particles are actually collected in the cyclone instead of this chamber. First as I said, you have to melt the metal and in order to do that, induction melting furnaces can be used or a vacuum induction melting unit can be used.

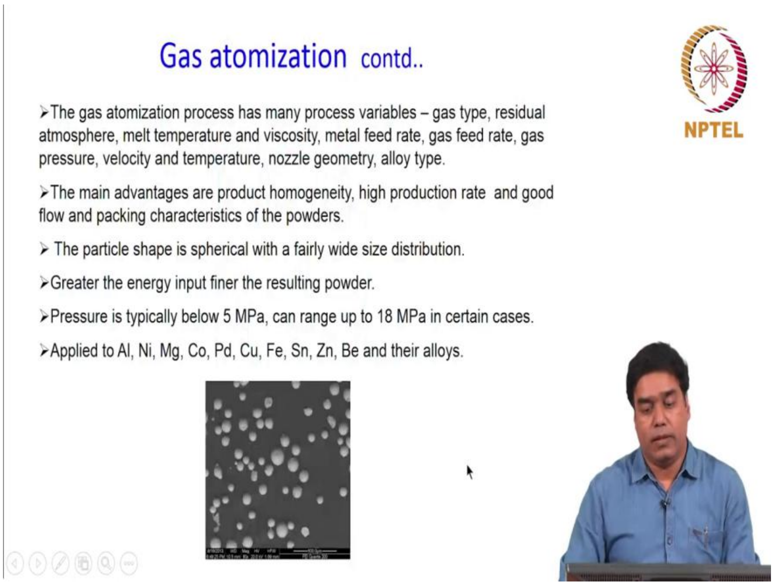
The primary melting unit has a vacuum pump. So, this is vacuum induction melting where the metal is first melted and through the nozzle, melt is sent to this chamber where the molten metal actually enters the atomization chamber.

So, here also this part is kept under high temperature. So, there are heaters here as you could see these red circles (figure above) which are there; this actually represents a furnace or a heater, so that the melt at this point, at this location should have higher superheat. And then it is sent through this nozzle to the atomization chamber.

And near the nozzle, you have the gas jet coming in. So, here you have a gas source which sends the gas at a high velocity to this place, where it suddenly expands and then there is huge depressurization of the gas which creates enough instability in the molten stream of metal which is coming out through this nozzle. And it is broken down into fine droplets, which are then passed through this chamber and gets deposited at this collection chamber as powder.

Near the nozzles, a thin sheet of metal forms first due to the depressurization of the gas which creates the instabilities. So this thin sheet of liquid metal, it will have a very high surface area to volume ratio and as a result of that, it is not very stable and therefore, it breaks down to smaller fragments and goes through different stages. Once the sheet is broken, it is first broken down into a ligament, which is converted to the ellipsoids and which are finally, converted to the spherical particle which solidify and the powder is obtained at the end of this chamber and collected at this collection chamber.

(Refer Slide Time: 14:08)



So, now for this gas atomization process if you see the process variables; there are many variables in this process like the gas type, for example, different types of gas like air, nitrogen, helium or argon can be used and they will have their own effect on the process. So, the type of gas which is used is a process variable.

Then the kind of residual atmosphere you have inside the chamber might also affect the kind of powder or the powder particles generated. The melt temperature is a very important parameter here, because ultimately this has to solidify and also during the process it has to be in the liquid state before it goes to the final shape of those spherical particles. And the other parameters like the viscosity, the metal feed rate and the gas feed rate will also have their own effect on the process.

Since the gas pressure creates the finer droplets from the liquid stream of metal; the gas pressure also is an important process variable and apart from that the velocity and the temperature of the gas are also important. And since both the gas and the liquid metal comes from a nozzle, the nozzle geometry or even the configuration of the nozzle, as to how the nozzles are arranged if we have multiple nozzles in the system, will also affect the process. And of course, what kind of material or what kind of alloy you have, depending on that you can also get different powder characteristics. So, that is also a process variable in this case.

Now, if you look at the major advantages of this process of gas atomization, these are as follows; the homogeneity of the product, that is one of the biggest advantages that you have in this process. The powder or the powder particles that you obtain at the end of the process are very uniform in size.

So, if you control the process parameters properly, you will get uniform spherical particles. And the homogeneity is also in terms of the chemistry when you are making alloy powders. So, it can also take care of the chemistry or the homogeneity of the powder. And as I have said in the beginning this is high production rate process, the production rates are very high. So, this is large scale production of metal powder.

And the powders which are generated do have good flow and packing characteristics, because of the kind of morphology and shape they have. These kind of spherical powders have very good packing and flow characteristics. And apart from this spherical shape which is obtained, the size distribution is also fairly wide; because in a metal powder for it to be processed, particularly with respect to compaction, it should also have a size distribution rather than having a single size, which is not good, as far as the compaction process is concerned. So, if you have a mix of smaller and bigger powder, it is good for compaction. And that is something that we are going to talk about later on when we actually discuss the compaction process as to why it is necessary for the powder to have the size distribution instead of a single particle size.

So, this process would allow you to actually get a fairly wide size distribution in the powder. And you can see in this image for example (below), you have bigger particles; you also have the smaller ones.

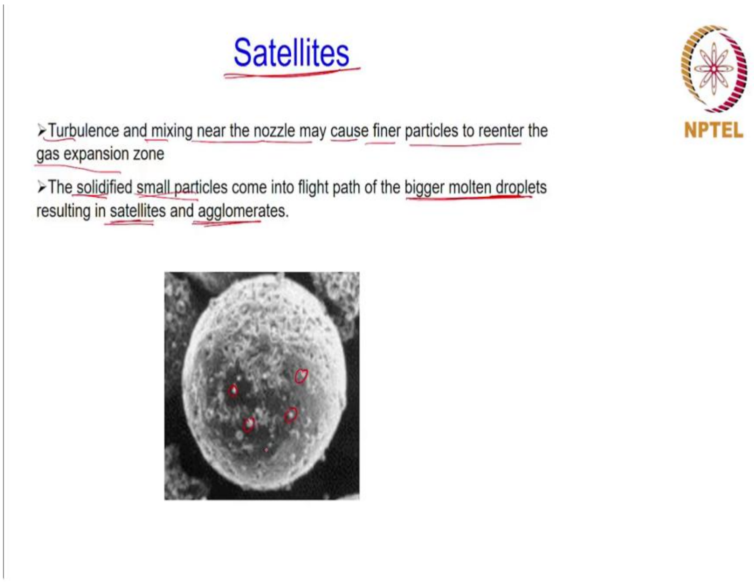
So, the size range or the size distribution is fairly wide in the powder which is obtained by the gas atomization process. And when you talk about controlling the size of the powder or getting finer particles, that would depend on the energy of the process which can be controlled by many of the process parameters, for example, the gas pressure or the gas velocity.

And greater the energy input, finer will be the resulting powder. And if you talk about the gas pressure which is used in this case, the pressure is typically below 5 MPa and can range up to 18 MPa. So, 5 to 20 MPa is the pressure range which is used in this process.

And this pressure can vary depending upon various other factors like the kind of material being processed, the quantity of material being processed and so on. And this can be applied to all kinds of metals, like aluminum, nickel, magnesium, cobalt, palladium, copper, iron and so on.

So, a whole range of materials or most of the commonly used metals can be processed by this process.

(Refer Slide Time: 21:41)



Now, every process has its own pros and cons. So, in case of this particular process of atomization, there is a small issue which basically arises due to those finer particles. If you remember, we talked about this finer fraction which is present in the stream along with the normal average sized particles.

So, these finer particles which are generated inside the chamber, inside the atomization chamber, those would travel along with this exhaust gas and should go to this cyclone and get collected over there. Now, for any reason, if these particles, the finer ones, instead of going to this gas exhaust and to the cyclone; if they come into the chamber in the flight path of these droplets which are coming down, then there is a problem. And that problem leads to what is known as satellites.

So, these satellites are nothing, but those finer fragments of the particles which might get deposited on the bigger particles. So, what happens inside this atomization chamber is, there may be turbulence and mixing, particularly near the nozzle where the gas is suddenly expanding. And as a result of that, it can lead to these finer particles reentering the gas expansion zone.

So, here if those finer particles reenter, then they will actually come into the flight path of the droplets which are coming down to make those spherical particles which you finally, get as powders. So, when these finer particles enter the flight path, they will come in contact with the bigger molten droplets.

And when they lose temperature during this flight path coming from top to the bottom, these smaller particles will solidify on the surface of the bigger droplets which you can see probably from this image over here (above); you can see finer droplets like this or this (red circles).

So, when the finer particles stick to the surface of the bigger droplets they are known as satellites; the agglomerates of this finer particle sticking to the surface of the bigger particles. So, this may lead to some change in the condition of the surface of the bigger particles. Due to this agglomerates sticking to the surface of the bigger particle it might turn rough and as a result of that, the flow property of these powder particles may be hampered.

So, that is a problem which arises due to the smaller particles reentering the gas expansion zone due to turbulence and mixing. But nevertheless, if the process is controlled properly, then these finer particles can be prevented from entering the chamber and they will be taken away by the exhaust gas and carried to the cyclone where they will get collected. So, with this, we come to the end of this class today. I will see you again for the future classes, for today that is all I have.

Thank you for your attention.