Powder Metallurgy

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Lecture – 07
Water Atomization

Hello everyone and welcome back again, right now we are on this topic of Atomization which is a large scale production method for making metal powders.

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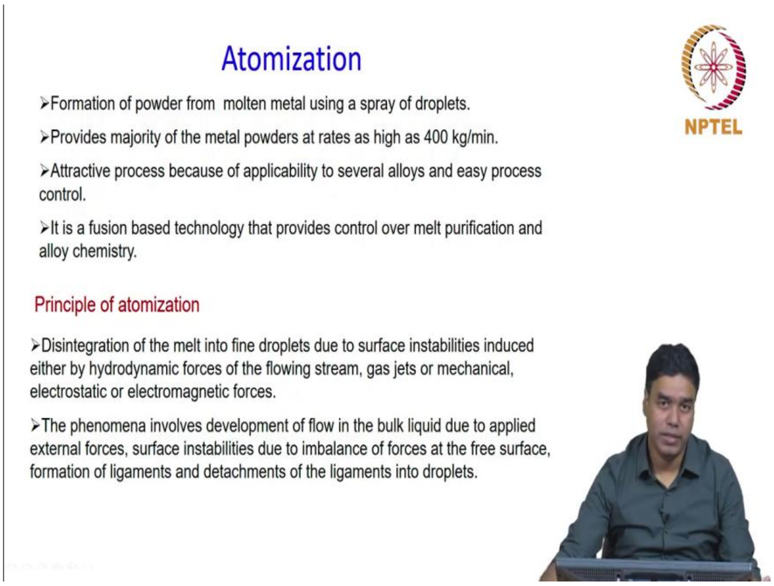

And so far we have seen the basic principle of atomization and the physics behind it.

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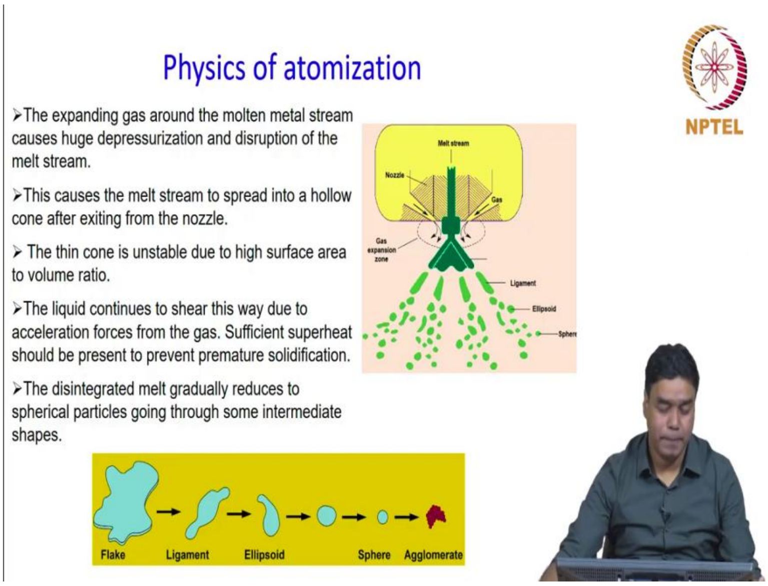

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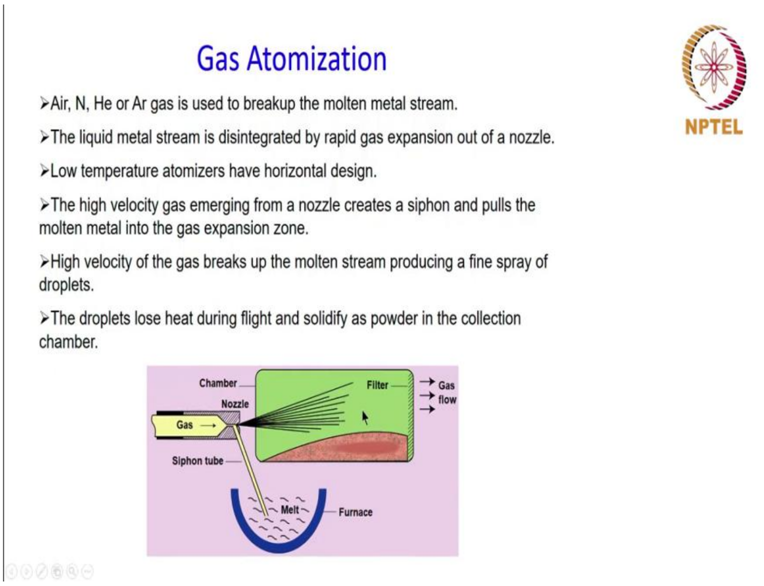

And then we have discussed about two different types of equipment which are used for gas atomization, for making metal powders; one of these is a horizontal design where you can see here the chamber is horizontal.

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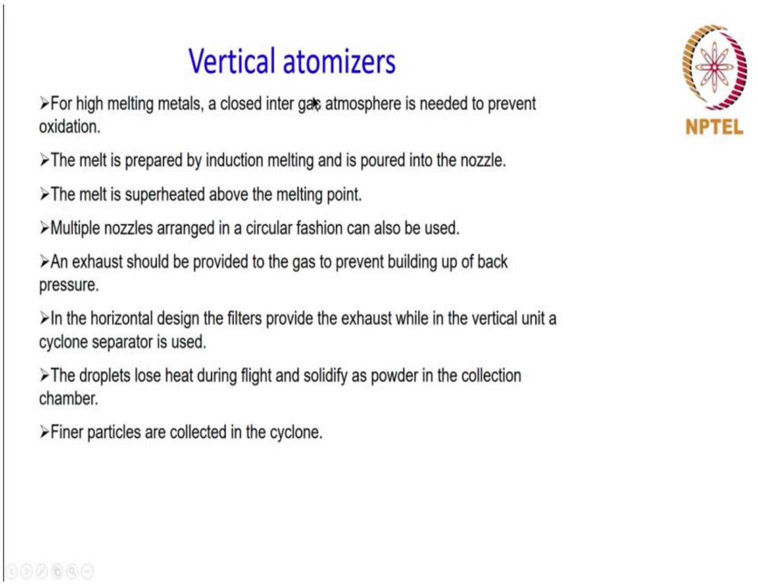

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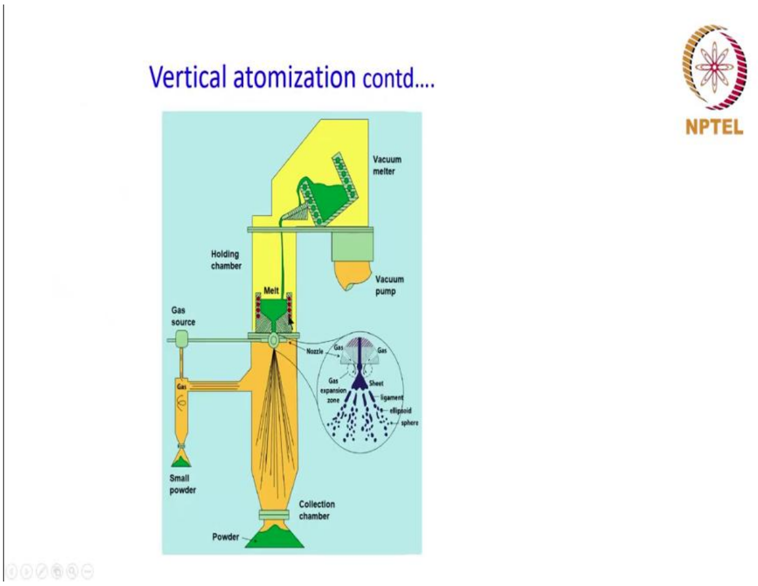

And in another design, it is a vertical atomizer wherein you can see, it is done vertically down; the chamber in this case is a vertical chamber.

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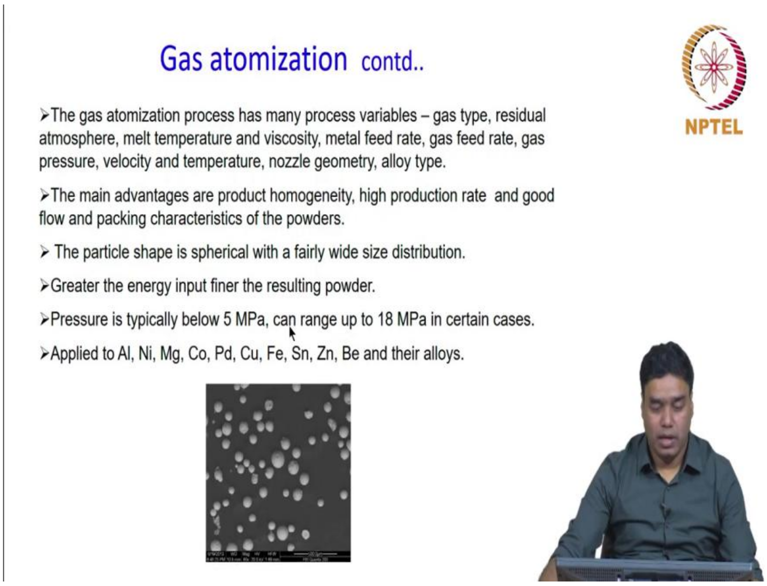

And after that, we have also discussed about the process variables of this gas atomization process.

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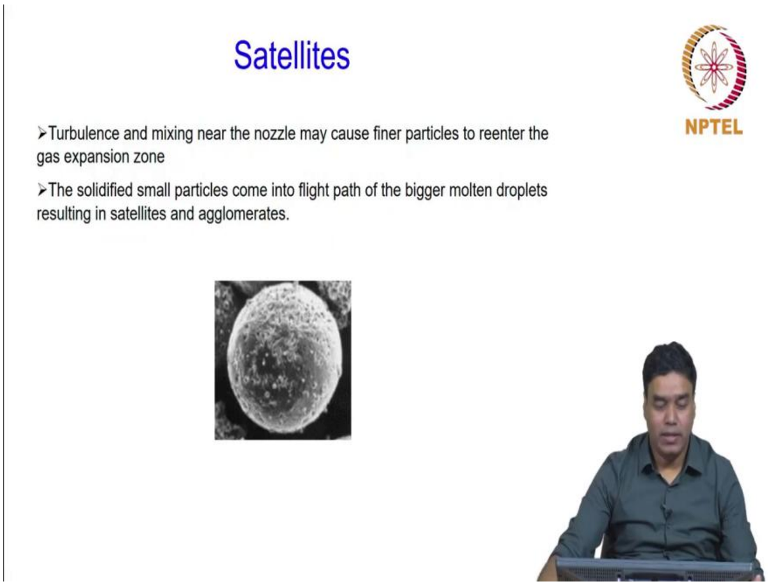

Then, we also discussed about a problem in this process which is known as satellites that occurs due to turbulence and mixing near the nozzle and satellites are smaller particles which stick onto the surface of bigger particles and make the surface rough. So, this is a small problem which might occur during the process of gas atomization.

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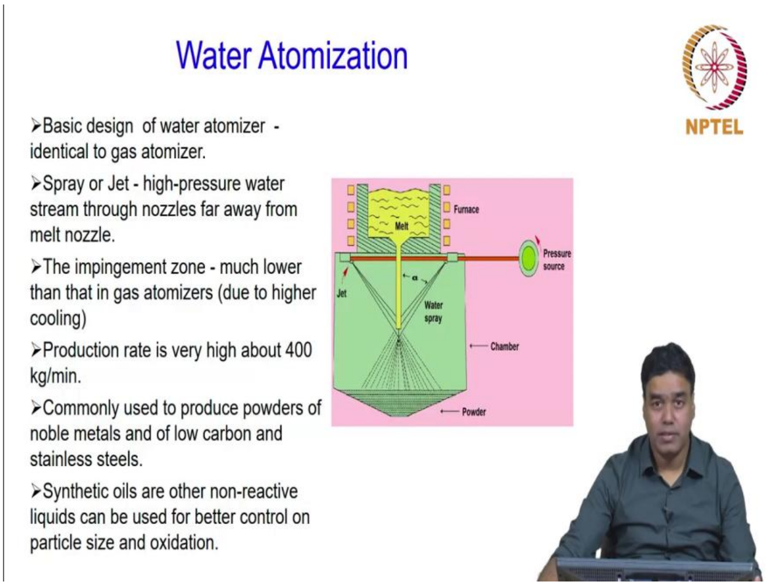

So, today we are going to look at the other atomization processes - Water Atomization.

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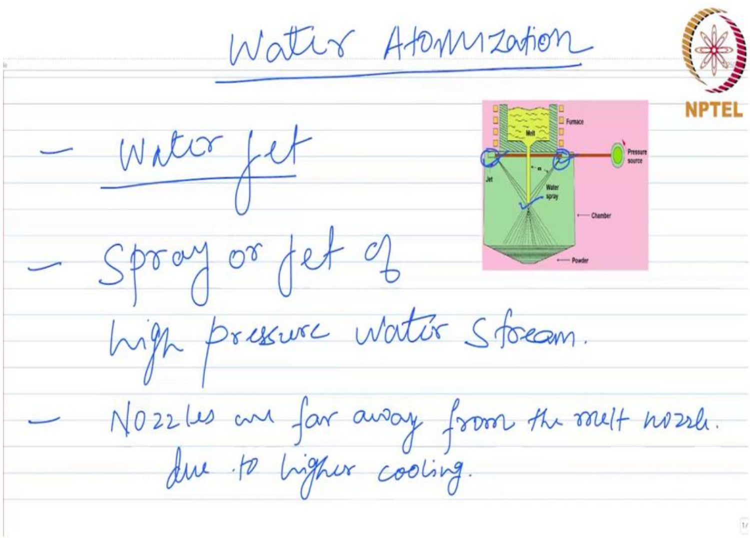

So, this is the basic design of a water atomizer; the design is very similar to a gas atomizer. Only difference being, as the name suggests, instead of a gas jet, in this case a water jet is used to atomize or breakdown the molten metal stream into finer droplets.

So, like in the gas atomization process, here you have a spray or a jet of high pressure water which comes through these nozzles, as you can see over here in this diagram (above). But these nozzles, as you could see, unlike the gas atomization process, these nozzles are kept away from the molten metal stream. This is because of the fact that the cooling rate is much higher in this case, since we are using a water jet. So, the water jet nozzles are far away from the melt nozzle due to higher cooling as I said.

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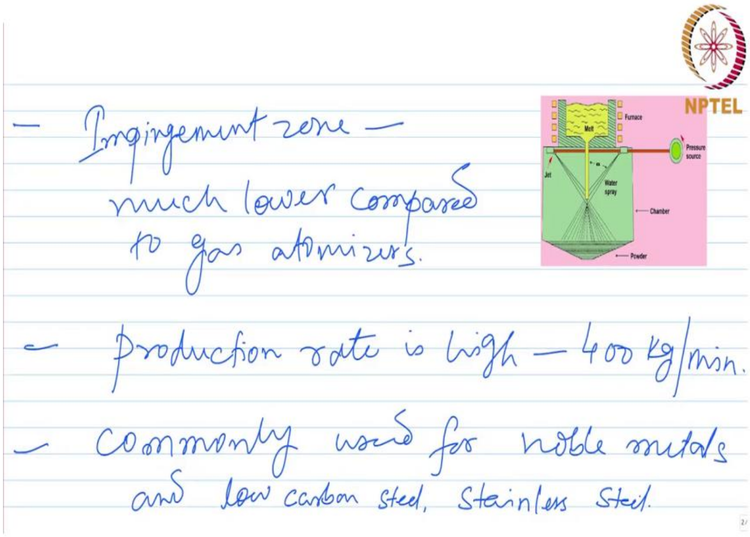

And in this case, the other difference that you can see from the gas atomization process is the impingement zone, which is much lower compared to gas atomizers.

This is again because of the fact that, here the cooling rates are higher; so your impingement does not have to be to that extent like what you had in case of a gas atomizer. And in terms of the production rate, this can be as good as the gas atomization process, which is around 400 kilogram per minute.

And this process is commonly used for certain types of metal powders like the noble metals and low carbon steel powders; and this is also used for stainless steel powders.

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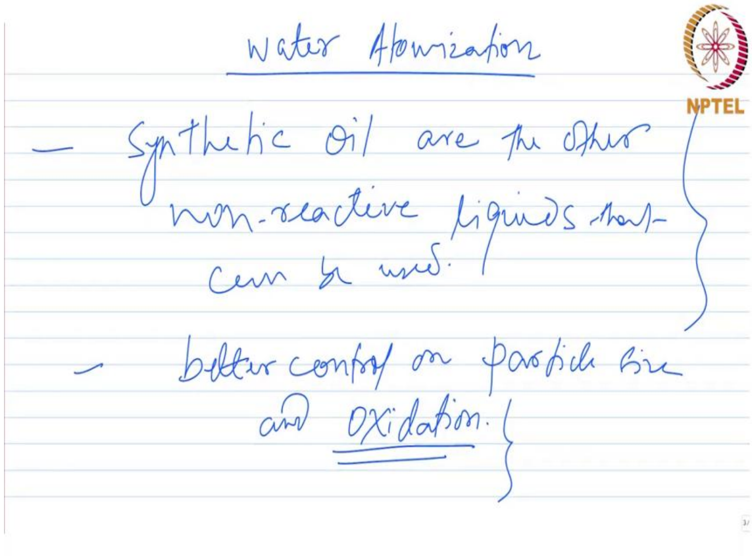

And for the liquid, apart from water; synthetic oils or other non reactive liquids can also be used. So, as long as the liquid does not react with the molten metal, it can be used as a jet to atomize the molten stream of metal and make those finer droplets which will solidify as metal powders. And at times, these synthetic oils can have better control on particle size and oxidation.

Oxidation, in case of water atomization, can be a problem for metals which can react and form an oxide layer over the surface of the particles; so that is something which has to be taken care of. And if synthetic oil is used as the liquid, then there can be better control over this oxidation.

Now, let us talk about the mechanism of atomization; how it happens like what we have seen in case of gas atomization process, which goes through several intermediate stages and intermediate morphologies to finally, give rise to those spherical particles.

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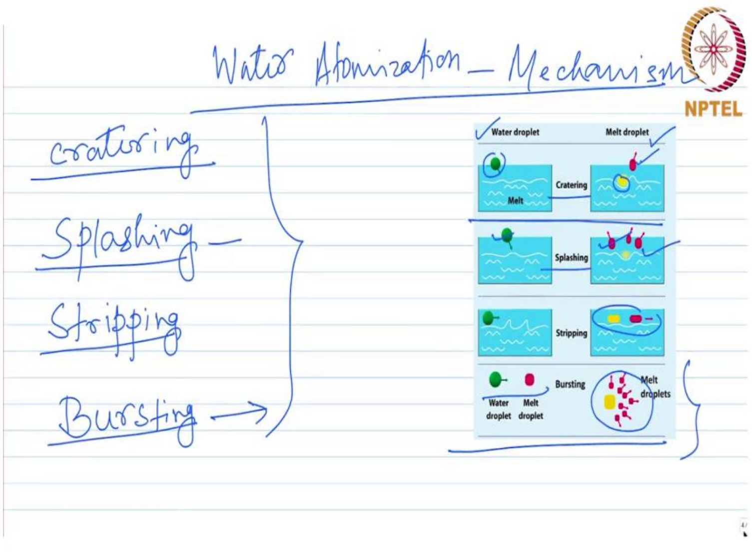

Here also there is a particular mechanism through which the fine droplets are formed from the molten stream of the metal. The mechanism has been depicted in this particular diagram; primarily there are four ways or four kinds of mechanisms through which these droplets of the metal forms with the help of a water jet.

So, on this diagram (above), you can see; on the left hand side you have the water droplets depicted as a bigger green color droplet. And on the right hand side, you see how this water droplet which is coming from the water jet, how it is producing the metal droplets from the stream of molten metal which is sent to the chamber.

So, there are four kinds or four types of mechanisms as I said; the first one is known as cratering, which is like impingement of this water droplet into this molten metal. And then it creates a crater due to the impact and it ejects a metal droplet; depicted as red color drop (image above); that is the ejected metal droplet when this water droplet impinges on the surface of the melt; this is called cratering.

And then the second mechanism is known as splashing, which is nothing but, creating splash on a pool of liquid. As we all would have seen whenever the liquid pool is impacted with something, it splashes. And due to that splashing, it creates droplets from the pool of the molten liquid; in this case the molten liquid is the molten metal. So, when these water droplets come and impact on the surface of the molten metal, there is splashing and due to this, these metal droplets are generated from the surface of the molten metal.

And then next (third mechanism) is stripping, which is like stripping a layer of liquid from the surface, as the water droplets bombard on the surface of the molten metal, it strips of a layer from the surface of the molten pool of metal. And then once it is stripped off, these molten metal droplets are created. So, that is the process of stripping, like a whole layer is stripped off from the surface of the molten metal, as the water jet comes in contact with the surface of this molten pool or this molten stream of metal which is coming in contact with the water jet.

And next (fourth mechanism) is bursting, which is like a water droplet hitting a melt droplet, which is already created, at high velocity and breaking it down into finer droplets with that impact. So, it is like the molten metal droplet which comes in contact with the water droplet, bursts into smaller droplets and creates those finer globular or final spherical particles which you need in the final powder; so, this is the process of bursting.

So, these are the four different mechanisms of water atomization through which these molten metal droplets are created and finally, you get these fine spherical or fine globular powder particles at the end of the process.

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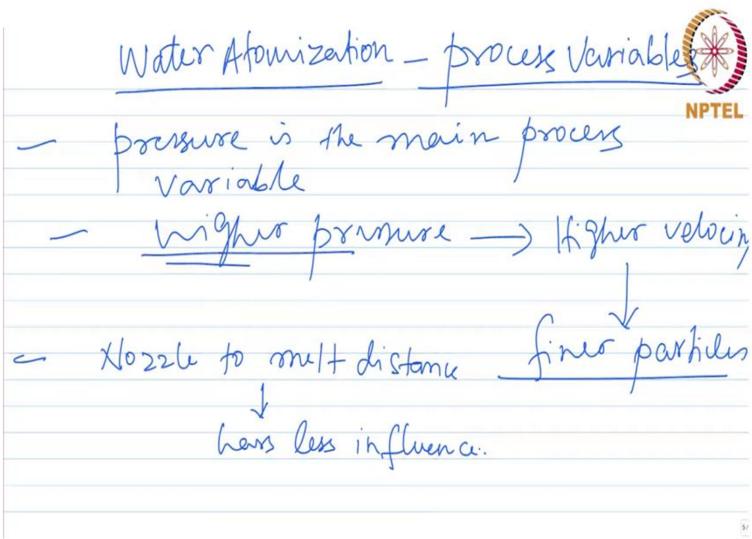

Now, if you talk about the process variables of this water atomization process; here pressure is the main process variable because higher the pressure, higher will be the velocity and higher the velocity, finer will be the particles.

So, if you want to control the particle size; you need to control the pressure, the water pressure which is used in this water atomization process. And other factor is the nozzle to melt distance, but this variable is not that significant compared to the pressure. This has less influence.

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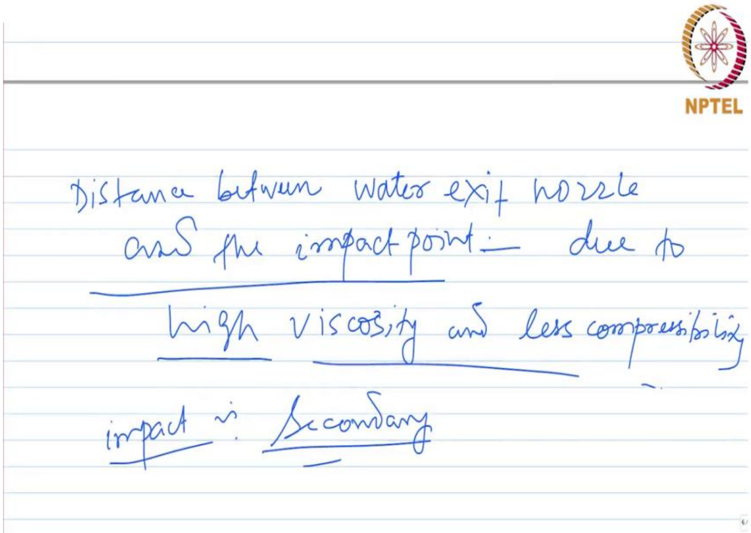

And the other parameter or the other factor that you can think of is the distance between water exit nozzle and the impact point. But, this again, does not have much influence on the process as such and this is because of the fact that water has high viscosity and less compressibility. So, the impact of this distance is secondary due to high viscosity and less compressibility of water.

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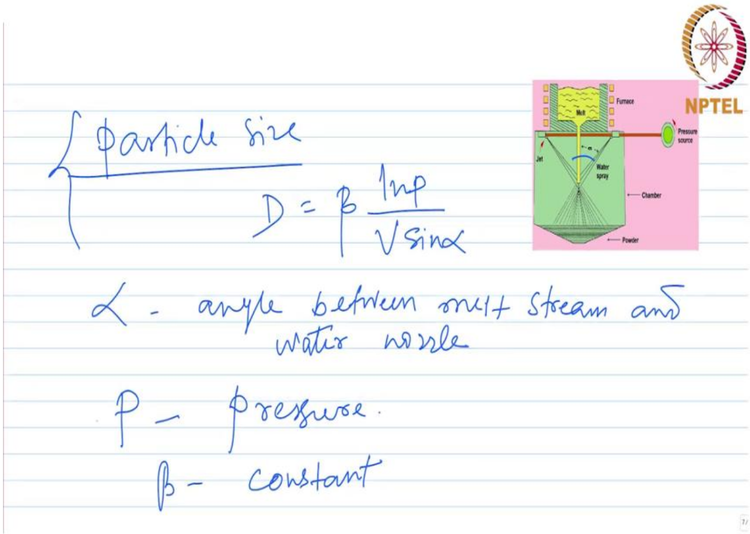

Now, if you talk about the particle size and see how it depends on the process variables that can be expressed with the relationship like this:

$$D = \beta \frac{\ln P}{V \sin \alpha}$$

where, D is the particle size which is given by this particular relationship, where α is the angle between the melt stream and the water nozzle right.

So, we are talking about this particular angle here; this angle α that will have an effect on the particle size. But here again you can see, the main variable is the pressure and beta is a constant. This was about the particle size. Now, we can talk about the particle shape which is the other important particle property or particle characteristic.

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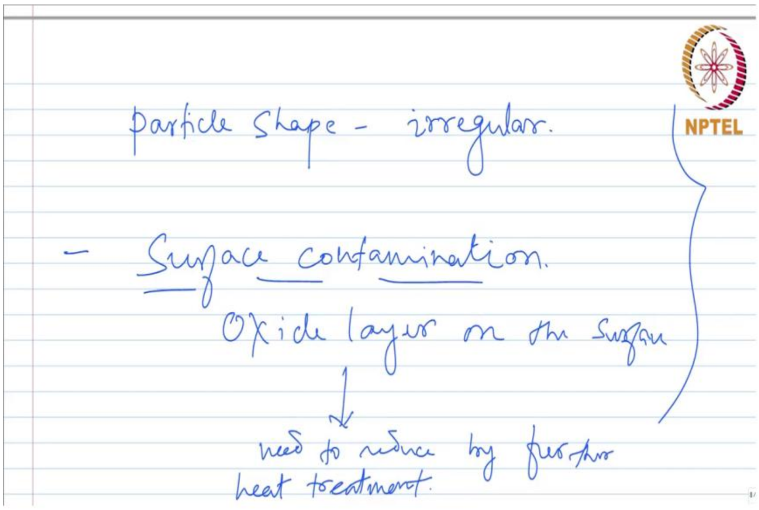

The particle shape in this process is generally irregular. And the other thing which I was mentioning is the surface contamination due to the oxide layer that forms on the surface of the particles. Because here you are impacting the metal stream with a water jet and due to that, there is a possibility that this molten metal droplet react with oxygen and then form an oxide layer over the surface.

So, there may be a need to reduce this oxide under reducing condition by further heat treatment. So, this was about water atomization process which is another method of making metal powders, particularly the spherical or globular type of metal powders apart from the gas atomization process.

So, let us summarize the process of water atomization before we close today. So, water atomization is another process of making metal powders like gas atomization process. And as we have seen the design of the atomizer is very similar to a gas atomizer, main difference being the water jet and the impingement zone.

Since the water jet has a higher cooling effect compared to a gas jet, there are two differences that you can see right away in the design; although, the basic design as such remains the same. One is the nozzles which are kept far away from the melt nozzle which is not the case, in case of gas atomizers that you might have seen before like this vertical atomizer for example.

And the other aspect is being the impingement zone which is much lower compared to a gas atomizer; this is again due to the higher cooling rate. And apart from water, you can also use synthetic oils which are non reactive and in that case; in fact, you can have better control on the particle size as well as oxidation.

And as far as the mechanism is concerned in this case, there are four mechanisms that can operate to generate these metal droplets from the stream of molten metal which comes in contact with the water jet. And these are cratering, splashing, stripping and bursting.

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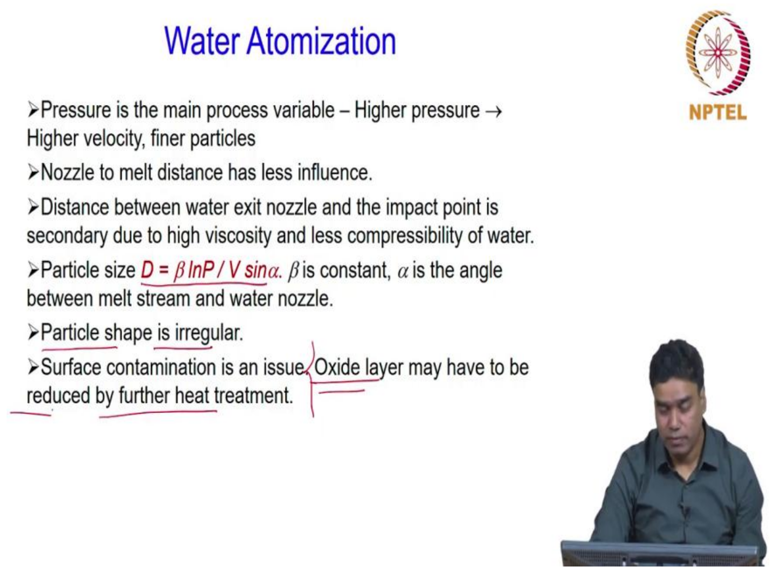

And then finally, we talked about the process variables of this process. And pressure of the water jet is the main process variable which controls the most of the powder characteristics, like the particle size and particle morphology and so on.

And other parameters or other factors like the nozzle to melt distance or the distance between the water exit nozzle and the impact point have for less influence compared to the pressure. And the particle size is mainly dependent on the pressure which is the main process variable. And the angle between the water jet and the melt stream, you know that also has an effect, as you can see from the above equation.

And in this process, the particle shape is generally irregular and one problem that one might encounter in water atomization process is the oxidation of the powder particles which leads to formation of an oxide layer on the surface. And therefore, there may be a need to do further heat treatment under reducing conditions to reduce this oxide layer from the surface.

So, this was all about water atomization process and this is all we have for today's class, I will see you again for the future classes.

Thank you for your attention.