The Future of Manufacturing Business:
Role of Additive Manufacturing
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Lecture-29
Quality in Additive Manufacturing

Hello everyone. I welcome you to this session in role of quality additive manufacturing. I am Adil Khan working as a quality lead in Wipro 3D.

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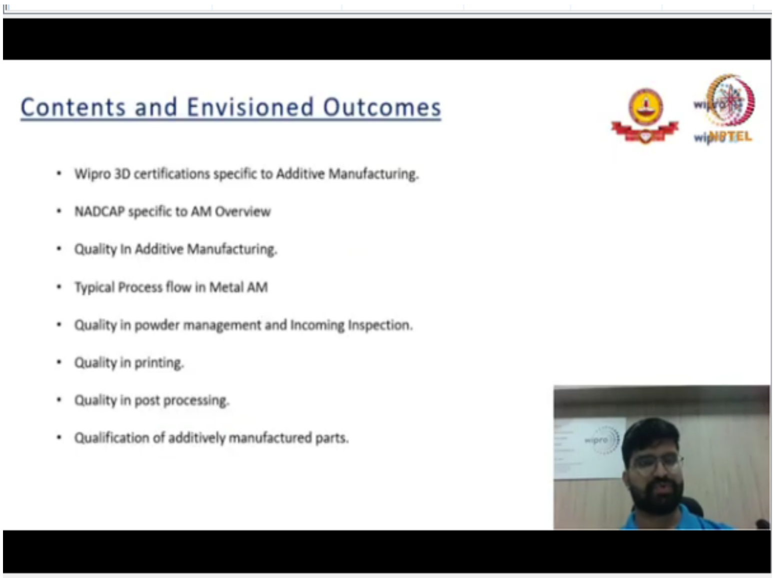

In this session we will be seeing different certifications, pretty much specific to additive manufacturing. Then a broad overview on NADCAP. Then quality in additive manufacturing, quality in power management, printing, post processing and qualification of additive manufacturing parts. So, this will be the content that will be covered in this session.

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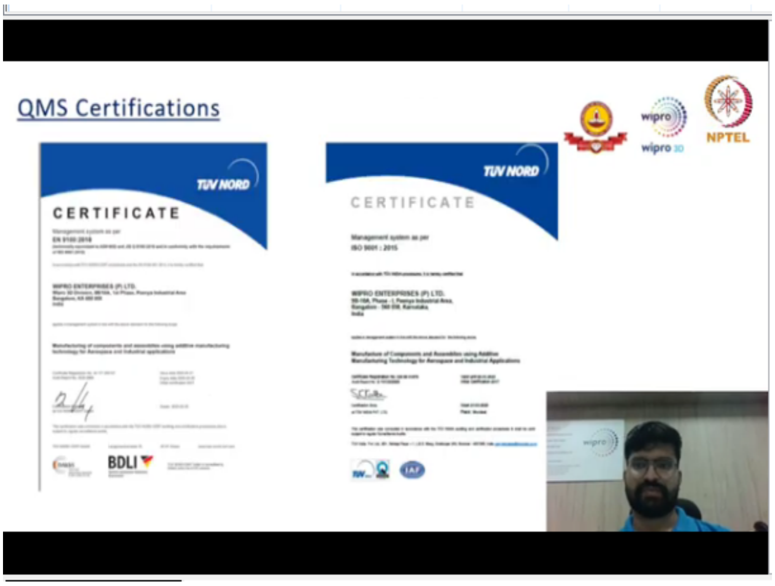

Since get primarily operating in aerospace and space we have AS9100 certification, which is equivalent to N9100, to shift the parts to aerospace or defence customers we need to have AS9100. We also shift parts to automobile in various other industries. Many of you may be familiar from your industrial experience this AS9100 or ISO certifications talks nothing much about type of industries you are in.

So, how we basically deal with this? So, several other industry verticals have come up with their own certification process. I will take you through some of them and where we stand with respect with them.

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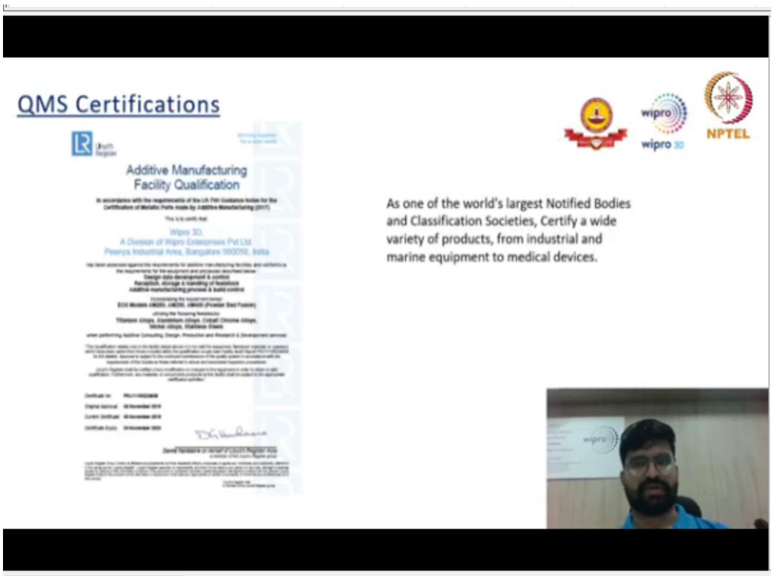

We have largest certification, also known as LR is an agent name in oil and gas industry and there are in this certification is very much specific to additive manufacturing. This is very much important, in the sense this was the first certificate when we went through our design develop pair they went through our design, development, controls. Then additive manufacturing processes, process build controls.

What type of powders we use? How we handle those powders? So, it is more on additive manufacturing specific audit was that we had a certification from them. This is the reason, some oil and gas customers from Europe, and Asia show interest in Wipro 3D otherwise people will not get orders without these types of certifications.

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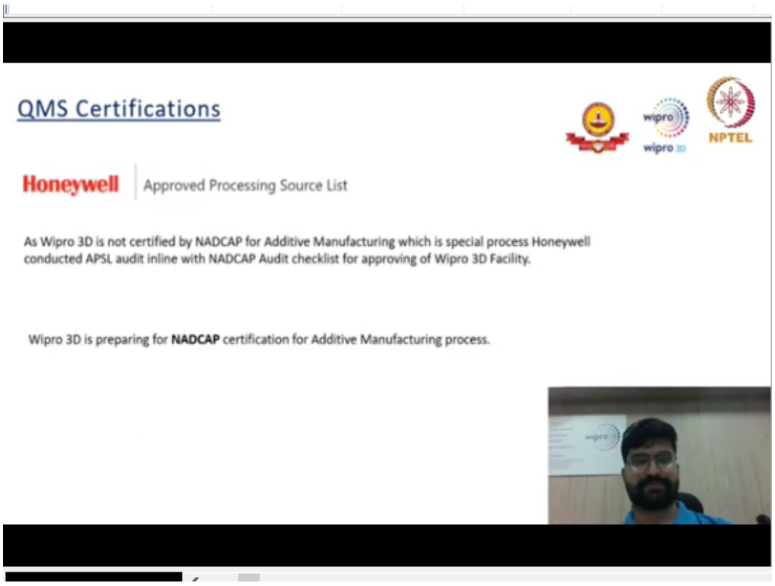

We had an audit Honeywell have their own certification process. They call it approved processing source list, or APSL. They will go in detail in the audit which is very much similar to LR, but more stringent in more detail. They look more about how we manage powder, powder quality, build quality. These are striking differences from standard processes, and they also fall under special process.

As you might be aware of the specific process you have to control inputs in order to ensure the output. All OEM customers conduct their own special process audits in line with NADCAP audit checklist. The supplier is certified by NADCAP, they get directly approval into the approved supplier list. As Wipro 3D is under process of getting NADCAP and this NADCAP certified for NADCAP, Honeywell have conducted the audit and have provided as a certificate and added as an approve processing sources list.

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NADCAP certification is provided by PRI. PRI is a main certifying body for NADCAP and this is not for profit organization affiliated by society of automotive engineering. General aerospace OEMs asked for AS9100 the certification or equivalent for conventional machining suppliers in for performance special processes NADCAP certification is mandated for series production.

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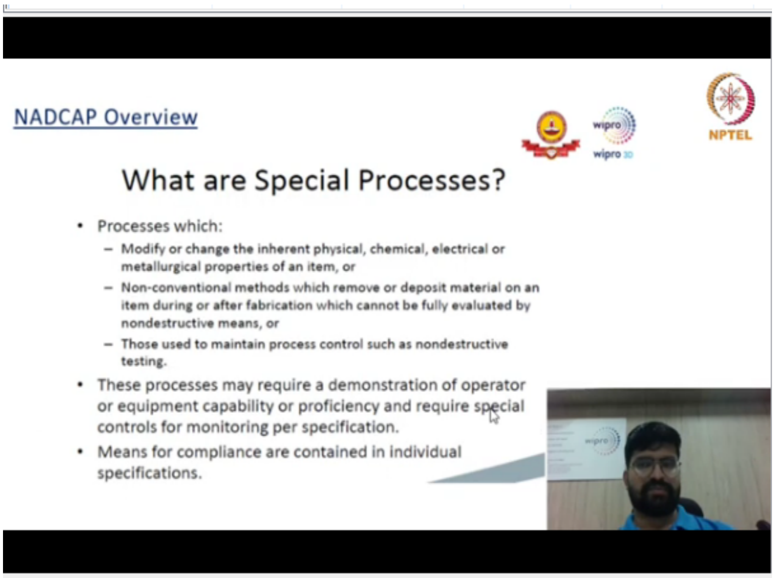

What is a special process? Any process, which changes the inherent physical, chemical, and metallurgical properties of an item is called as a special process, or any non conventional method, which removes or deposits material on item during or after fabrication, in which cannot be evaluated by non destructive means is called as a special process.

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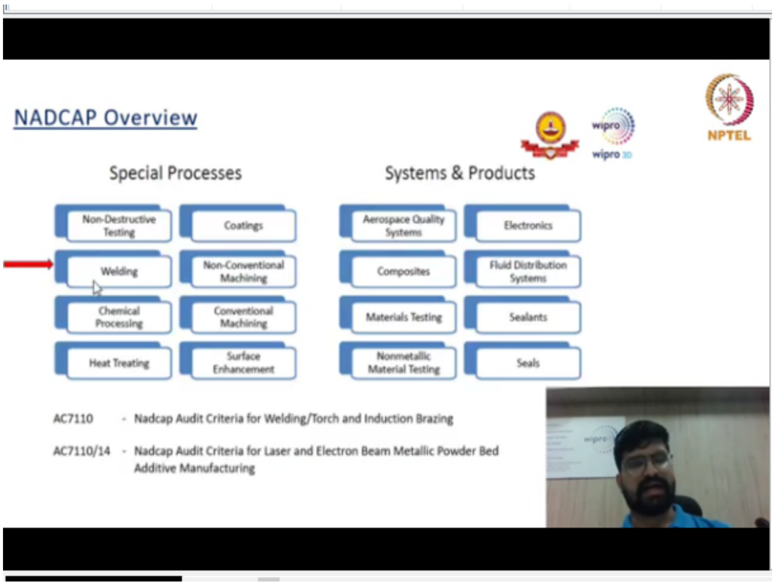

So, as per point 1 and 2 our additive manufacturing comes under special process. So, these are the different special process NDT, welding, chemical processing, heat treatment, coatings, even see home inspection comes under special process. So, AC7100 and AC7100/14. These are the 2 checklists applicable for NADCAP related to additive manufacturing. If you should look at AS9100, it is very much generic standard, whereas NADCAP is very much specific to a process, say welding.

We have NADCAP separately for EBM, we have NADCAP separately for fusion welding, we have NADCAP separately for laser welding and diffusion welding. So, NADCAP is very much specific to a particular process.

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When we say quality for additive manufacturing; we get the CAD model from customer. Then we analyze can it be manufactured in AM or not. If yes, what are the modifications we have to do. You may be knowing that we add material somewhere, we add support. So, we will be able to be build the part. Then, we also construct parameters like orientation.

Then how precisely the model should be sliced, then what kind of surface finishes expected, what precautions we need to take care and other parameters to be considered. So, that you know we get a part quality as good as possible. Necessarily all the additive manufacturing parts are always followed by some degree of post processing. In some parts, you have a lot of post processing, and in some parts we have very less post processing.

But it is very rare that we do wire cut, or chipping off the part from this part and do some kind of short blasting and send it to customer. Very few occasions, it has happened like this, but most of the cases to be very elaborate post processing and a lot of NDT involved followed with final inspection and shipping of part to customer. This entire cycle the quality of part which customer expects us to deliver has some angles.

One is the powder and its management. Second is printing or building. And third is post processing post processing on what is documentation final inspection. This comes under traditional conventional processes. I will be focusing more on build quality and build management in related issues. That is the crux of this quality control in additive manufacturing.

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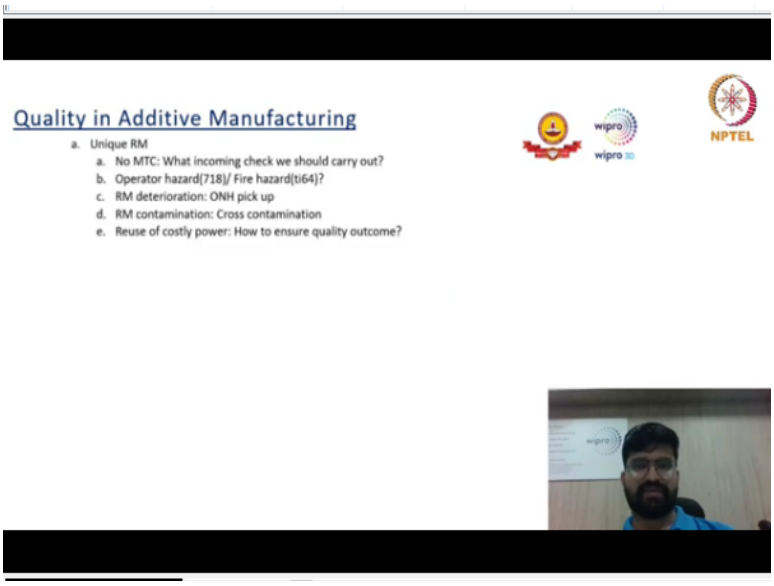

In traditional process once you get a build or forging, you always get the MTC, which will give a heat number and all other details which can be traced back for the part quality that the mill supplier issues you. Here, MTC is not there, that is the first thing to see. Only qualified holder and what are the precautions we take when we say this build quality is good above average or beyond the expectation value of the machine provider.

So, we will come to those details. Currently, we will be focusing on raw material, and about the build quality because if you think through the process the raw material, which is powder, and will be laser center and build process, which is something different from traditional conventional manufacturing process. In conventional manufacturing process you in order billet or a rod, and then you have machining process turning in variety of other CNC machining to finish the final good.

Here you are invading a powder and you have to ensure that the powder is of right quality and right quantity. Every time part is freshly build. So, to ensure the quality how you assure that part that is coming from a particular builder will have the UTS value as specified by the supplier of the machine. So, those are the questions which keep popping up from customer minds.

So, raw material unique is also defined by operator hazard or fire hazard. That is possible. There is a provision that our raw material can get deterioration. So, how do we start the raw material? What do we do to see that the deterioration or ONH pickup will not happen onto the powder? Then you how RM contamination. See for a billet, or stab it is no way possible you may mix up to incoming raw materials and have a cross contamination.

That is not at all possible. But when it comes to fine powder particles which are like 63 microns, you are using say common machine, and common accessories, which are not cleaned properly, then you have every chance, you will be mixing and contaminating one powder with another. If that happens, you are basically creating a powder, which cannot be used for subsequent builds.

In these powders are pretty costly. Just to give you a reference for stainless steel, you will buy say 200 or 220 rupees a kg. For getting a similar material of excess powder, we have to pay almost like 10 to 15 times higher price for the powder per kg. So, powders should not be wasted at any point of time. If you go through the build process, if we say for example my part weight is 10 kg.

In order to build the part and meet the height of the particular, we have to use almost like 40 sometimes even 50 kgs and 100 kgs of powder. In this case, let us take an example of 50 kgs of powder has been used to produce a particular part. No, after completion of build 10 kg of part is removed. In another 10 kgs goes in 2 ways to do to variety of reasons information are outside the machine, along with the supports.

So, you are left with another 30 kgs. So, this will be split into 10 kgs in the dispenser end and some 20 kgs on the collector end on the build plate. This is already explosive powder. You have to do proper filtration. So, you remove all the particulates, which could have produced during the time of welding. So, out of 20 kgs, you do IPCM. IPCM basically acts like a vacuum cleaner, where it absorbs all the powder from the machine area and it gets collected into a bin.

So, after collecting into IPCM, the powder is filtered, this automatically filtered. Then after filtration you get like say for example, 18 kgs of powder. Now, this powder is recovered and it can be reused. There is another angle to it. When you are doing all filtration process, you are exposing it to atmosphere where some of the powder can pick up ONH, oxygen, nitrogen or hydrogen.

It may not be all apparent in the very first go, but you think of same order getting used for 10 to 15 times, then you have every opportunity of ONH pick up. In the process end it becomes powder, which has a quality issue. In the sense, if there is some pickup of oxygen, then the type of properties that to get from the build are different and your tensile or fatigue properties they started deteriorating very fast.

If you are reusing the powder without checking the ONH levels. So, you have to use the powder because it is costly. At the same time, you have to worry about it, that it gets too much exposure to atmosphere in basically lose the quality of the powder. And really, you cannot use it for any meaningful build. So, these are the challenges.

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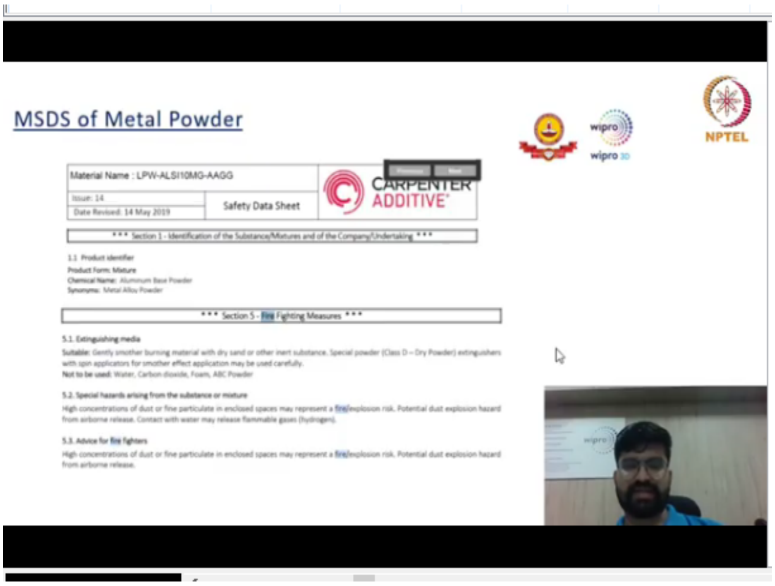

I will show you how to counter this, we will still stick to unique raw material. So, what you can see here is a material safety data sheet. We usually get material safety data sheet along with the powder. In this case it is ALSA 10 mg procured for LBW, you know once you get the material, you need to look into the safety data sheet and always the material provider we shared you our MSDS, along with other test certificates.

How safety data sheet is important is? Certain powders are fire hazards. Two of them are Titanium alloy, and Aluminium alloy. Now, these are type D type of fires, which cannot be extinguished by ordinary type of fire extinguishers, we need to have a D type extinguisher intake, which can take out material powder fire or metallic prayers. If you look at LPW ALSA 10 mg MSDS, they are very clear that there is a possibility of catching fire.

And what should not be used is water, carbon dioxide, foam, or ABC powder extinguisher. Powder handling in following phases. Generally, if we look at the process in receiving inspection, during the time of issue of raw material, when the sieving operation take place and filtration happens, and that there is one more area near filters. So, in machinery have filters where all use it powders in particulates get accumulated.

There is a high chance that these filters can catch fire if they are not handled properly in stored and disposed with a care. So, they can be a culprit of catching fire. So, this has to be handled carefully.

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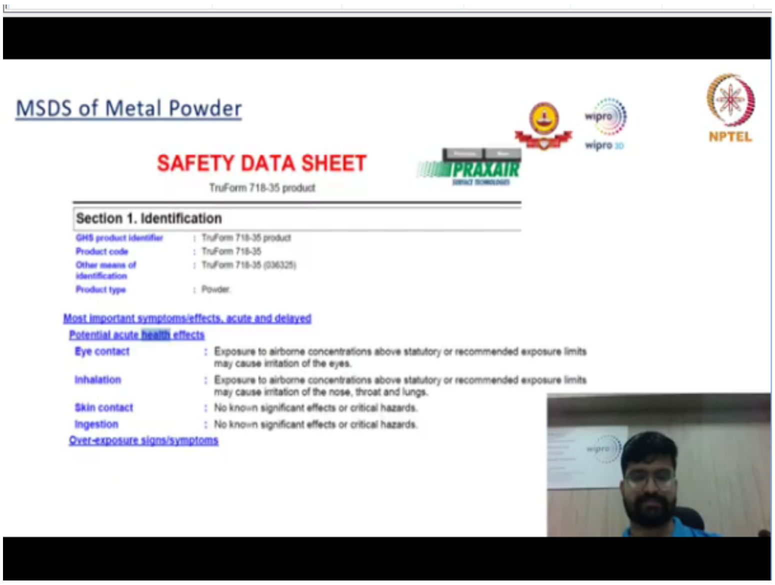

This powder is Inconel 718. If you look in its safety data sheet related to health this powder is a little carcinogenic in nature. There are some issues when this powder is directly coming into contact with eye, or when you inhale it during machine cleaning. The material provider will tell you what to look out for and how to take care of these issues.

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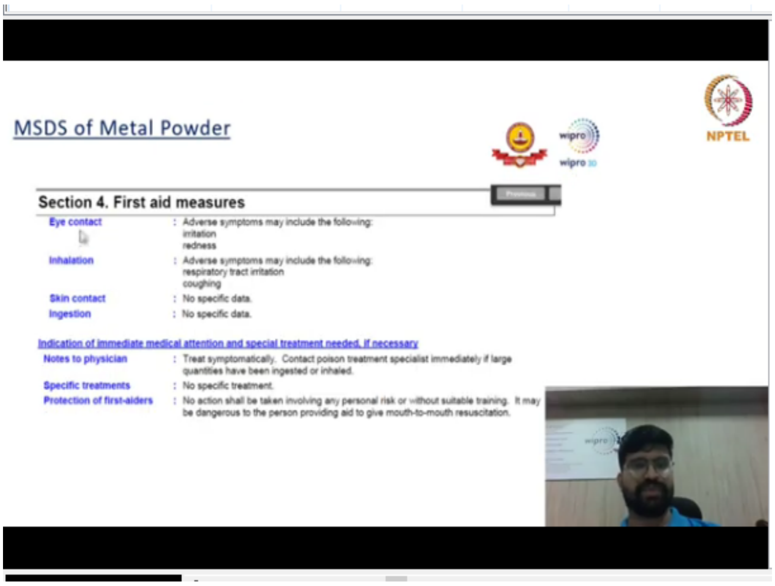

So, here if you can see here the metal provider is states should not come into eye contact, if it comes, what actions to be taken? If it has been inhaled accidentally what actions to be taken? So, this gives you a inputs of what actions to be taken do the time of handling of these material powders. Initially when we started way back in 2013-2014, we used to get powders from our suppliers.

We used to receive them with folded hands, never asked what is the quality that you are delivering. Whatever is delivered we try to manufacture with it. Over so many years we have learned what is it we should be looking for and what is the thing we should be asking our suppliers, mind you, all our suppliers are OEM suppliers. They are all out of India. So, talking to them needs a lot of understanding.

What we want and what we do not want? and make sure that this is communicated. When we are issuing the inquiry itself. We specifically say, what is the chemistry required? other details required, as every right to reject these requirements if they are not moving.

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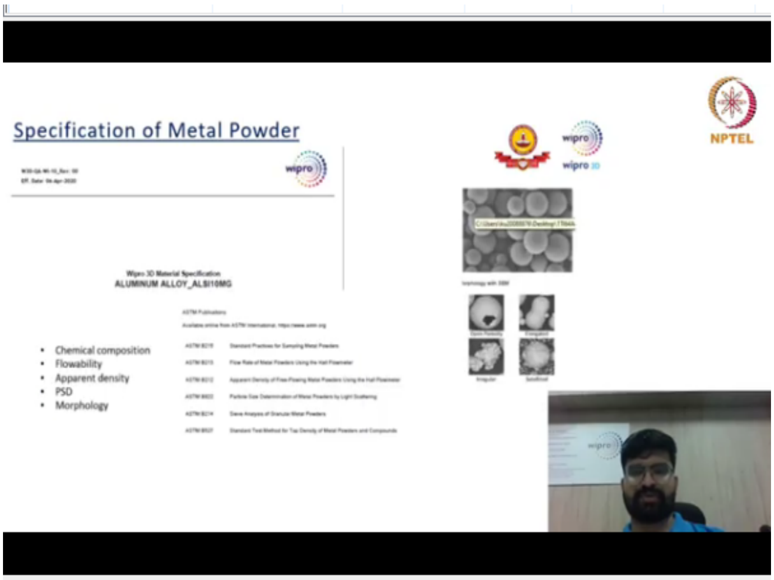

I will show you what we do for a typical powder. Nowadays we are very much specific about what we want, what standards the supplier should follow and how each test should be performed on the powder. So, here we define what the different tests to be followed and which standard they have to follow. This will ensure that when we perform the same test here, we will have a correlation between both the results.

If he is following different standards and we are following different standards, then definitely there would be some correlation issues, which could be triggering during the time of receiving inspections. So, we clearly notify them, which standard they have to follow. Then we also mentioned, what is the chemical composition expected for this particular material? then what is the flowability expected for this particular material?

What is the apparent density? What is the particle size distribution expected? What is the morphology expected? So, this is the image of how morphology should be and these are the images of how morphology should not be for any particle. Generally, we expect the particles to be spherical in shape. If there are any open properties this could result any unfilled or void during the time of buildings.

If there are any elongated particles, if one end of the particle gets welded, then the other end of the particle will be left out, which will create undue projections or uneven surface finishes, irregular shapes, or satellite shapes. These sorts of issues will affect the physical and metallurgical properties of the actual part that is being produced. So, these are undesirable effects and these are required effects of the particle.

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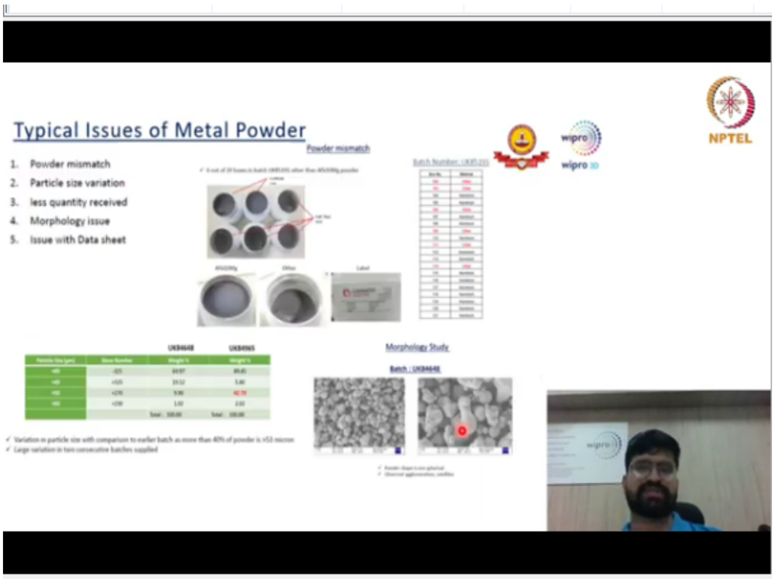

So, when we started flowing down all these requirements we have come across some issues from suppliers, which we will be seeing in the next slide. One mismatch is that we had a powder mismatch. We have received saying that this is a 20 kg powder of we have ordered ALSA 10 mg. So, we have received 20 kg powder. When we check the weight, weight was matching, there was no issue with the weight.

But when we open the box and see what we identified was one box was fully filled, when you compared to another box it is almost like 3/4 th filled or half filled. But when we look at the weight both weights are same. So, then we identified that some other material has been mixed up and supplier has shared some other material. We do not know what it is, but some other material instead of ALSA 10 mg.

Then, because there is distribution. We have analyzed the particle size distribution for the current lot in the previous lot that was shared by the same supplier. We noticed that there is so much change in the particle distribution. See, a basically when I say, I need a particle of 50 or 53 microns, make every particle need not, may not be 53 micros practically. So, it may lay anywhere between 40 to 60 microns.

So, the way the particle is distributed we also control it, should look at here there is huge difference between the particles size which is greater than 53 microns. So, by looking at this result we identified that there is in some inconsistency in the powder quality, which is a powder particle size. Then, less quantity received, say for example, in a box if there is 20 grams less, you may feel it is not a big issue.

When you are receiving like 20 boxes 20 grams into 20 which will cost of 400 grams of material. Powders are very costly. So, it is possible to compromise in such type of small variations. Then, less quantity receives, like we said earlier, then morphology issues, here if we look at this morphology, our ideal preferably should be spherical in shape, you should look at this somewhat elongated, then some are satellite.

Some have uneven surface finish. So, these all particle sizes will result in, they will affect me surface finish, as well as the desired mechanical end metallurgical properties of the finishing part, that has been produced by using this powder. So, these are typical issues that we come across.

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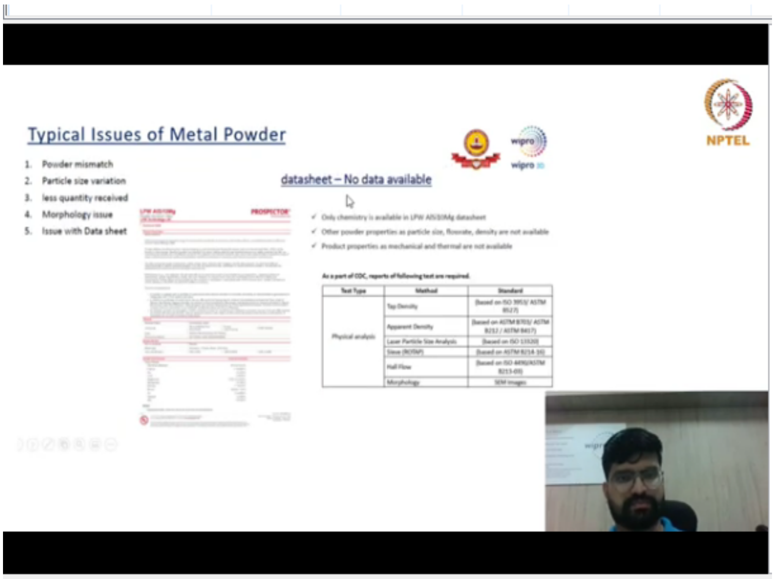

Then we also come across issues like data sheet not received. Like I said earlier, we need to go through the material safety data sheet in order to understand what are the hazards that are impacted when we are handling these powders. So, sometimes suppliers do not share us the material data sheets, sometimes they do not share us the reports. So, we say all this test has to be done and all these reports along with the shipment.

Sometimes we notice we do not receive all the reports. We receive only some reports will not be shared by the supplier. So, these are the typical issues that could be arising during the time of receiving inspection of coders.

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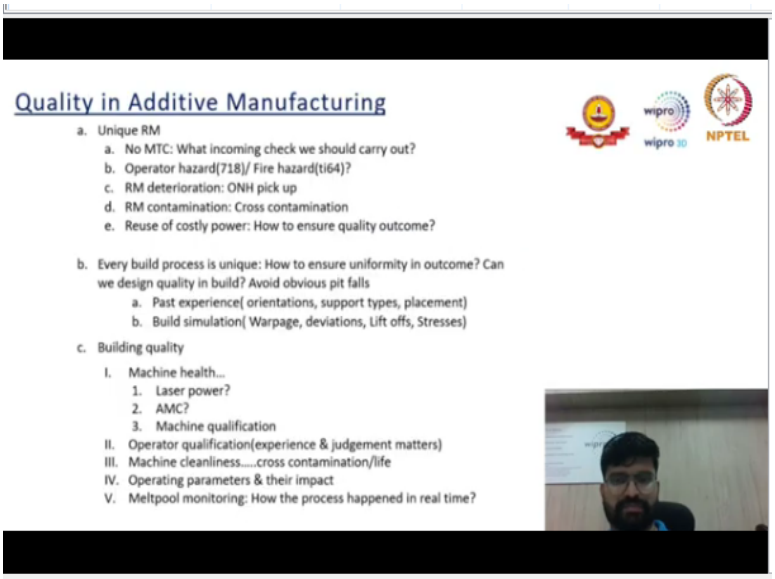

Then, every build process is unique. How to ensure uniformity in outcome over a period of time? So, due to the experience that we had over a period of time; we have identified and realized; we can build in quality during the design stage itself to avoid pitfalls. There are 2 angles to it. One is fast experience, we realized we need to control parameters like orientation. Can we oriented in a way that it does not sit, perpendicular to the re-coater at any height of the entire build?

If it is sitting perpendicular, there is a possibility that it results in liftoff or wrapping, resulting in damage of part, then comes support type. We need to think aspects like can we use soft supports? So, that we can chip off the support easily to reduce the PP activity and want to remove the supports, we need to keep the in-plane cost resulting for machining into remove the supports and additional material added.

Such things to be kept in mind when designing and finalizing the build. Creating additional supports or placing the parts freely to fill the build plate also increases the exposure area. The exposure area is more again this can result in heavy distortion or ware page in undesirable effects like cracks and delamination. Then second thing that we need to see is build quality. When we say build quality, the first thing that we need to look for is machine health.

When we talk about mission health the first thing, we need to take care of is laser power. So, we need to regularly monitor how is the laser power. We have come across a situation where the laser power has dropped during the time of the build. Because the amount of temperature needed to melt the particle for that particular material was more than the amount to which the laser power was dropped, that particular build got rejected.

So, we always have to monitor the laser power. Then comes AMC, annual maintenance charges or contract. So, what we generally suggest, or do is, it is always preferable to have AMC or because all these additive manufacturing machines, laser bed machines are special purpose machines. So, there is a high possibility that if there is any issue in any of the parts, it can result the may expected particular machine output from that.

So, we always it is better to have AMC so that they come into calibration maintenance at regular intervals and see that, machine health condition is good. Then third is material qualification. So, why we generally go for material qualification? In order to ensure that my machine is not deteriorating because of its usage, like we are using it, 24* 7 for almost 365 days. So, this material qualification will give us confidence that the output delivered from the machine is same as the output that it was delivered, when it was newly procured.

So, what we generally do here is we build coupons, some few coupons in horizontal few coupons in vertical, and few coupons in inclined 45-degree angle, in few square coupons for measurement of density and hardness. So, after getting the tensile and structure, all the reports, we correlate it with the first build results and we see how is our machine life. Is it still the same or are we observing any abnormalities like difference in some tensile strength?

If we observe some variations, then we will analyze if they have done any changes in internal inputs. If internal inputs, there is no change then we go to the supplier and see why these results are varying. Then comes the operator qualification. So, as we said earlier, there is a possibility that cross contamination if the machine is not cleaned properly and also there are few decisions where operator needs to decide, like, say for example, if build is stopped whether the build to be continued.

Or it has to be not a part has to be scrapped. There are 2 decisions which he has to take. It also includes things like, say for example, loading the recoater and unloading the re-coater see that there are no edges, damages, or any sharp particulates which are stuck to any edges which could cause line marks or scratch marks on the actual part. Then he also needs to ensure that the build plate is flat and there is no variation.

This could happen if there are some**,** no dust particles or powder particles. Below the build plate, which can result in uneven flatness. Generally, we accept up to 40 microns as acceptance criteria for flatness, or if it goes beyond then he has to know either remove the plate clean it once again and load it or send it for ringling. So, there are a few aspects where operator has to take decision and proceed further accordingly.

Then, machine cleanliness like we discussed earlier. This is very costly mistakes that can happen during the time of powder handling and machine cleaning. So, if even a small particle left out we create unnecessary issues, which will affect the physical and mechanical properties of the parts because of this cross contamination. Then operating parameters and their impact. This is an advanced topic. So, during the time of advanced session we will be covering this operating parameters and melt pool monitor.

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Then build observations. So, when build is running operator has to see how the powder spread is? What I mean by powder spread? For example, if the flatness of the build plate is 40 microns. Then what happens is that top most surface of the build plate will have less exposure of powder spread due to a recoater rubbing, than the build, which has a shorter. Say for example, I am just making it very exaggerated to just say what I am trying to say.

So, recoater moves in this way, because it is rubbing here, more amount of powder will be accumulated here, and less amount of powder will be accumulated in this area. So, when we increase the powder spread what happens is automatically more powder will be accumulated here, then our, the required amount of powder for the first layer would be compensated with the help of powder spread.

Then comes the recoater rubbing. When it comes to recoater rubbing there is always possibility that even after taking full precautions. The recoater could be rubbing and creating vibrations, sounds, or landmarks. So, operators should be attentive. In case if he absorbs any vibration or sound like recoater is getting rub. Then he needs to reduce the speed of the recoater moment or he depending upon the observation he needs to respond and take actions.

So, once again the qualification of operator becomes very crucial here. Then particulates. There is a possibility that particles could be stuck onto the recoater edges or anywhere onto the machine areas and get mixed up with other particles. So, operator has to ensure that he is ensuring that no particles are left out on the machine after completion of the build. So, what we generally suggest here is, he applies, isoprobe to the tissue paper.

And he claims, he should not be able to see any black marks or any powder marks on the tissue paper, he will be doing this until it is confirmed that no more particles are found on to the machine bed or its powder exposed surfaces. Then comes the proof of build quality. Proof of build quality is something most of our customers are concerned about. It is like, I do not know your builds looks okay alright but how do you ensure quality?

Many times, they say, how the test coupons? How multiple test coupons? have them in different directions, different orientations, some may be horizontal, some may be vertical, some may be inclined at 40-degree angle. Some square coupons for testing density and hardness, to check if there is proper fill and was proper all the requirements have met, as per customer expectation.

They want to be sure, in many of the customers ask why you build the part, build the coupons, along with the part. So, that I am sure that same type of properties that are attained on the coupons will be present on my part as well. They do not want separate build for test coupons. They ask okay. Some customers are okay with establishing parameters on the coupon.

And then, using the same force and parameters to run the part for producing the actual finished part. Many customers also asked for dummy parts. Dummy parts in the sense, the same platform build with some dummy parts, which is similar to the part, but may not be a complete part, then we do a microstructure study and tensile coupon study, made from the dummy parts and show the results.

So, some customers go to that extent as well. So, these are like proof of the build quality. There cannot be any questions beyond that, either we pass or will fail. In most of the cases if things are done properly there is no reason for failing. Then comes, post processing, by conventional method. So, in post processing what we generally do is, we always do stress relieving in order to remove the residual stresses that could have generated during the time of actual part build.

Then few customers asked for solution treatment, few customers ask for precipitation treatment, few customers, depending upon the stock or you know dimensions criticality. We may choose to go for machining. Then some customers asked for surface treatments like solution, surface treatment like anodizing, primer, Nickel coating or any other type of surface treatments.

Some customers ask for short blasting. So, it depends upon customer parts function, then measurement. In measurement what we generally do is we scan the full part with Faro 3D scan, and we compare this with model.

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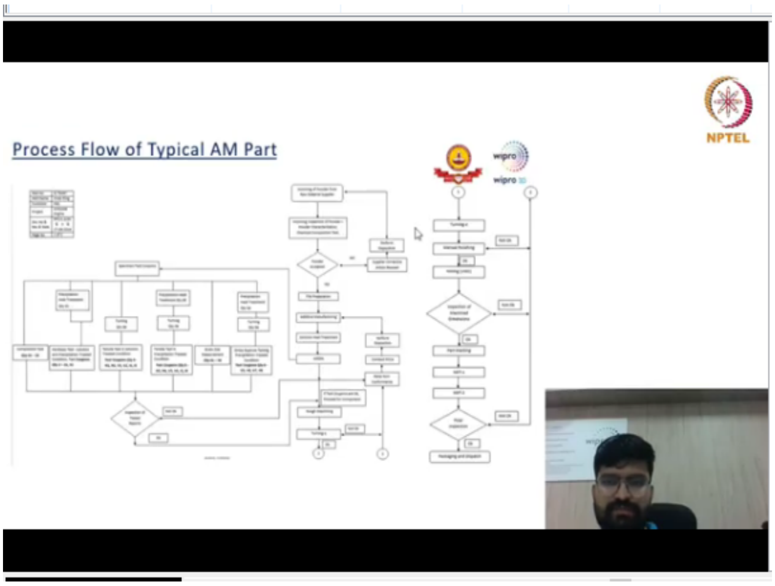

So, this part also consists of non destructive testings both radiography and fluorescent penetrant inspection. This is our airworthiness part. So, it is very much exhaustive. You can just go through it.

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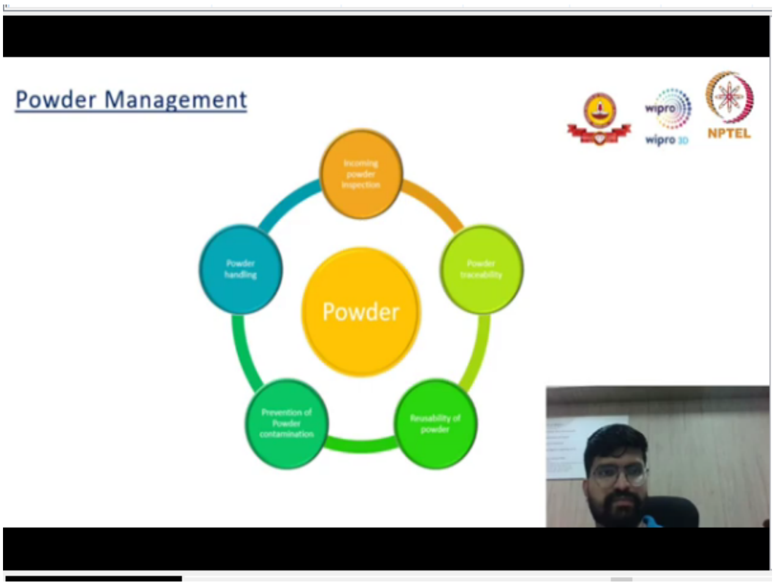

Now comes powder management. In powder management we come across things like incoming powder inspection, then powder traceability, then reusability of powder, then prevention of powder contamination. Then powder handling, incoming powder inspection.

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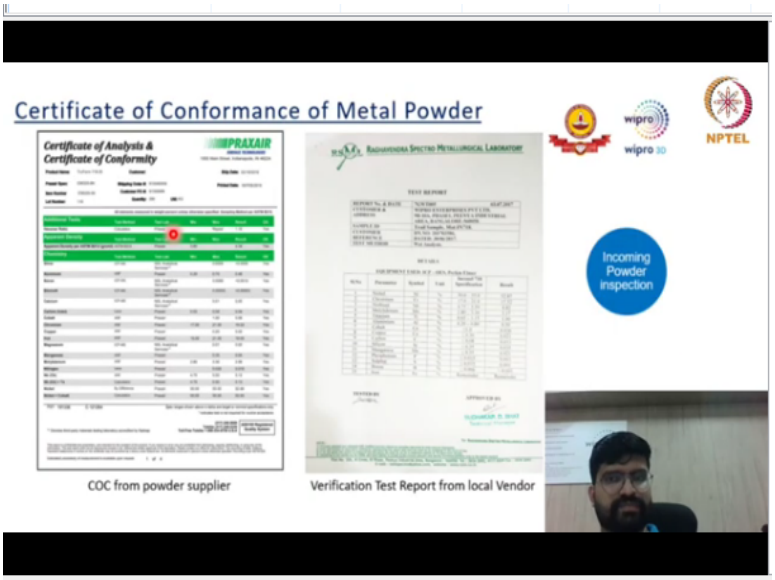

So, what you can see here on the left is the certificate of conformance received from a supplier PRAXAIR. like I showed earlier we do all the expected requirements for the powder in the purchase order itself. So, when the supplier shapes the certificate of conformance, he provides us the actual values of all the test results in the respective test certificates. So, what we generally do is instead of blindly laying on the report provided by the supplier.

We individually, test the orders and do all the testing, few we do in house and few we do it at outsource, what you can see here is the report generated by outsourcer supplier. Then we correlate both the results. Only when both requirements are met and are acceptable, we issued a part for production, saying that this is acceptable. Because powder is a very important aspect of the process that will decide all my physical and metallurgical properties.

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We check particle size distribution. So, what we generally do here is we check how is the powder distribution? As we know, if we ask, for example 0.063 micron powder product size, every particle may not be 63 microns, it may fall anywhere between 45 to 75 microns, the distribution is generally calculated by saving the powder. Weighing them, and then deriving the proportion of particle size.

Then we check flow rate. In this we lead the powder flow from known predefined cylinder and see the time it takes to pass through it and determine how much powder will be flow rate generally determines how powder will be spread during the build. Apparent density. Here we check the density of the known volume of powder and derive the apparent density. This determines the mechanical properties that can be attained.

Tap density, in this we tab the powder in a predefined time and check the density. We continue this till we see there is no more change in density, then the density where this powder can be acting depending upon the density, we decide whether this powder can be accepted or not. These parameters govern the mechanical properties, or the part. Then we do ONH analysis to check the ONH levels in a powder. We also do microstructure analysis on the specimens.

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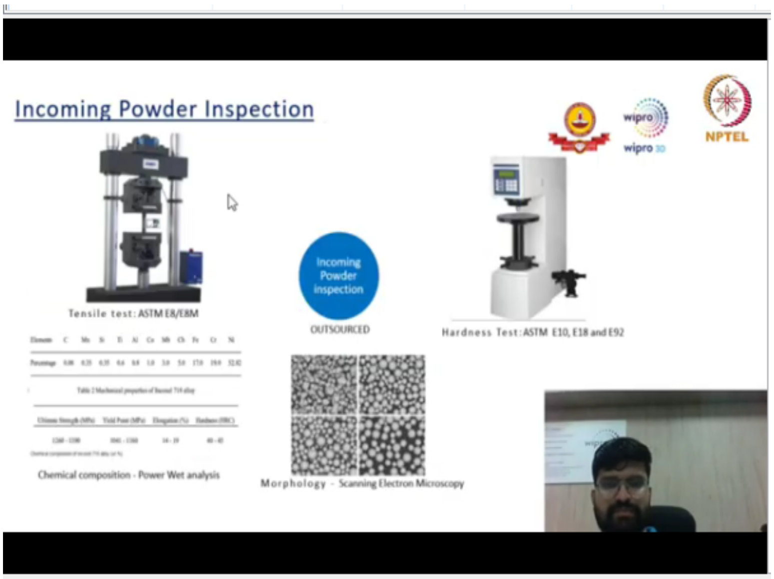

Then we do tensile test and hardness test for the specimens that have been produced along with that part. Then we also test morphology. We do not have in-house facility to we outsource it and get this tested. So, in scanning electron microscope, it uses how is the powder morphology. Depending upon the result we decide whether the powder can be used or the powder to be put on hold in to be discussed supplied.

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Then powder storage and traceability. Like I said earlier, we have powders which have a possibility of catching fire. So, we store all the powders in un-flammable cupboards. If you look at here the yellow colour cupboards. These are un-flammable cupboards, or so all the powder boxes will be stored in these cupboards. If you look at here on all the boxes, we stick the serial number of the box, so that we can maintain the first out on the powder boxes.

So, initially when we receive the powder, it is received along with the supply sticker which has the supplier name, the powder type, the lot number, a heat number of the supplier. So, what we do is we place one more sticker. It has all the details like, what is the lot number? What is the material? Then how many times this particular powder has been used? So, we visually we made something called visual management system by looking at the box visually we can say, what is the powder inside it.

So, what is the quality of the powder, in the sense, is it accepted or not, then how many times this particular powder has been used, then what is the lot number of this particular powder. So, all these details will be captured. We maintain a internal tracker, as well as a sticker on the both, with the help of but we are referring anyone of these we will be able to track and say the details about this particular powder, which is lying inside the box.

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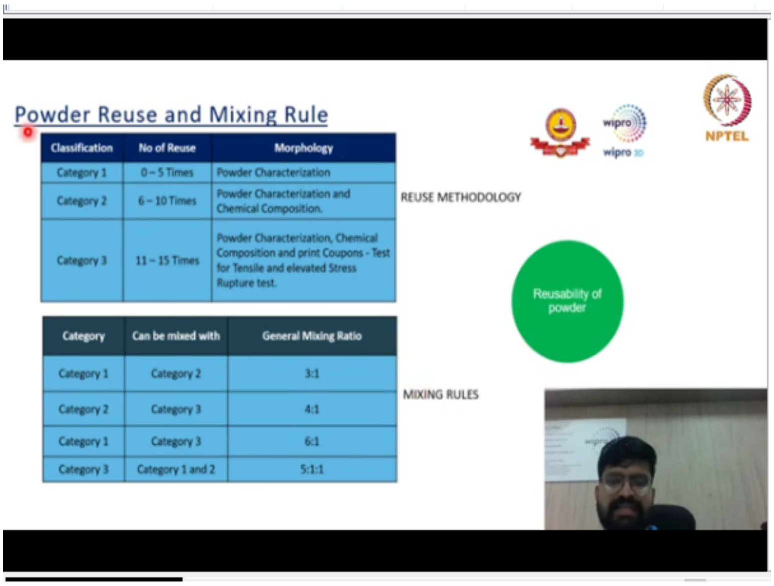

Then comes the reuse methodology and mixing rules. Say like I said earlier, for building a 10 kg part we need almost, like 50 to 60 kgs for building the part. So, it is not always possible to have virgin powder or you reuse one powder or a particular reuse type of powder in that much high quantity. So, it is always we have to mix the powders with, say, 0 to 1 virgin to reuse 1 or use 1 to reuse 2.

So, what we generally do is we have to classified them as into categories depending upon the number of times they have been used. Say for example, if a particular powder has been used from 0 to 5 times, we will be checking the powder characteristics of the particular powder.

Now what I meant by powder characteristic is the flow rate, the tap density, the apparent density and all other tests.

Then in category 2 where powder has been used for 6 to 10 times. When powder has been used for 6 to 10 times what we check is all the powder characteristics in the chemical composition of the powder. Once again this is done from 11 to 15 times use, we check powder characteristics, chemical composition. They also print the test coupons and do all the tensile structured tests and confirm that all the parameters are meeting the requirement.

So, only when the parameters are met then we accept this powder. Otherwise we will let quarantined and discarded. and we will proceed as per the powder dispersion procedure. Then comes the mixing rule. So, like I said, it is always not possible to have a single type of reuse quantity in more amount. So, what we generally do is; we sometimes how to mix category 1, which is 0 to 5 items used with category 2 which is 6 to 10 times.

So, when such scenarios arise, we have defined, depending upon our experience, our experiments and few literature's. We have delayed to this issue to see that the amount of mixture, more amount would be of a better quality and the amount of less quantity will be of, a little bit deteriorated quality.

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When compared it to the, the better one. So, this is how the machine looks like. This side is called the dispenser side. This is the collector side and the part will be loaded here even if my part is up to here, I need to fill powder to this full cross section. So, that I can build the part, my order should be above to the required height. So, in order to built 10 kg of powder I need to have not just 10 kg lot more, so that this full area is being compensated when the part is being built.

So, once when the build is completed, then we remove the part in the build. Then the powder will be left out in the dispenser. It goes up to the bottom, so up to here in the dispenser area and in the collector area. So, powder will be left out here, then they bring the IPCM and then we collect powder from here, from here and on the powder exposed surfaces of the machine.

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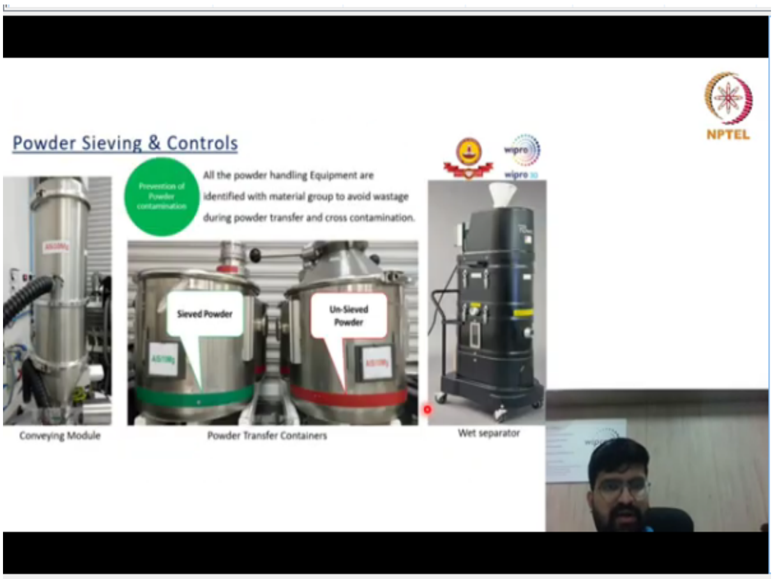

Then on the guide ways here. So, from all the areas of the machine we collect the powder into the IPCM, and our IPCM will do the sealing, where it will filter out the unnecessary contaminations and it will give you the acceptance powder at the bottom. So, when we are collecting the powder, we collect all the powders into un-sleeved bins, which are identified in the form of red stickers.

So, with that the powder is collected, it gets collected into un-sleeved bin there once when un-sieved bin is collected, it would be our conveyor module will do the sieving of the powder, and it will sieve and give the accepted powder, which has passed through the accepted sieve, which will be collected in this sieved powder. We have dedicated bins for different materials for laser.

What you can see is ALSA 10 mg dedicated as per powder bin, and ALSA 10 mg dedicated un- sieved powder bin. These are dedicated so, there is, we will not use ALSA 10 mg bin for some other material. So, with the help of this we will see that there will not be any cross contamination, then one more thing what we do is, these **c** bins are covered with the lid. So, there is very much less exposure to atmospheric atmosphere and so there is very less chance of ONH pick up, as we discussed earlier.

Then we use something called wet separator. We try to use maximum IPCM if in case where we are unable to clean the particles with the help IPCM. Then we go for a wet separator. Wet separator generally we try to avoid it because anything that goes into wet separator has to be scrapped. This cannot be used anymore.

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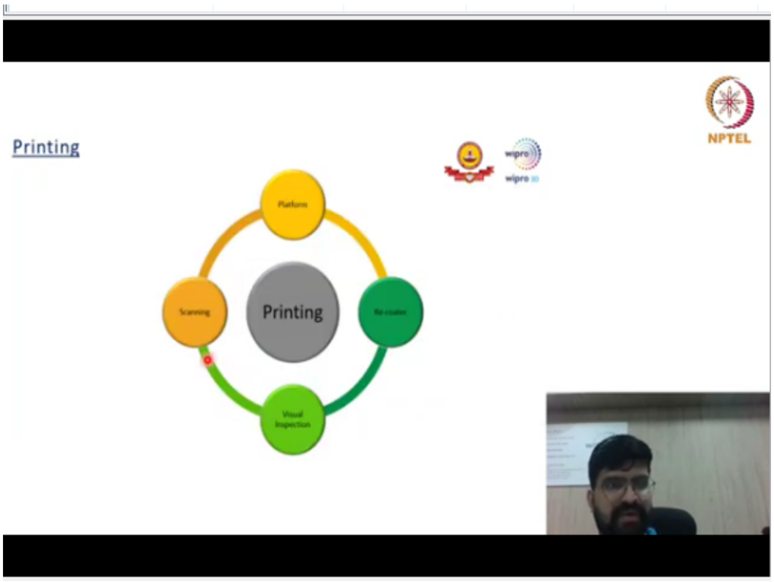

So, we try to use IPCM in cases where we cannot clean with the help of a IPCM, then we go for wet separator.

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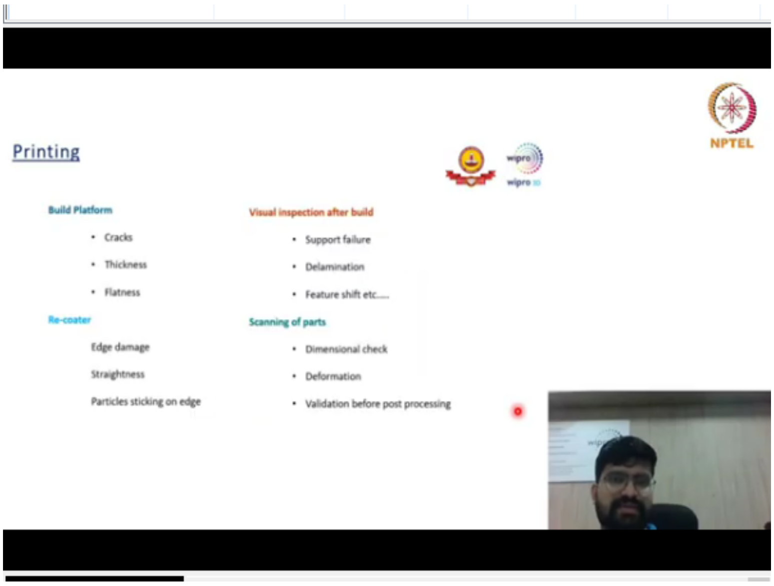

Then come in to build. In build we come across platform, re-coater, visual inspection, and scanning. Build platform generally when we are choosing a build platform, we need to see that it does not have any cracks. After simulating the build, then the software will tell us what is the minimum thickness that is expected in order to build a part, without any stresses, and thermal stresses.

So, depending upon the thickness they spread by the software we will decide which thickness built to be used, then flatness, generally our acceptance criteria is 40 microns. After loading the build plate, the operator just dials the top most and see what is the flatnees, that is obtained after loading the build onto the bed. Then comes recoater. So, generally, operator has to see before starting the build how is the recoater. Are there any edge damages?

Is it loaded straight? Are there any dust particulates that are got stick to the recoater because these sorts of things can cause a line marks or, step marks onto the recoater due to rubbing. So, once again the role of operator codifications becomes key here, then visual inspection after build, what we generally see here is how is the supports. Is there any failure observed? Is there any cracks or delamination observed?

Then how is the feature shifts. Are there any step marks, line marks, or dent mark on the part? So, we do all the visuals, it is the defects that we are talking about here is only the defects, which can be seen visually with naked eye. We are not talking anything about the defects, which are not detected during NDT. Here we are talking only about a defect can be seen with a visual naked eye. Then comes the scanning of part. So, in scanning of part, we generally do dimensional check.

We compare this with the model and see if there is any deformation on your profile variation. Generally, for experimentation and for better understanding what we do is we check the part immediately after build. Then we check it once again after stress relieving or to just see if there is some dimensional variation which is resulting after we relieve the stresses from the actual part. Then validation of post processing activities, like if you are done any conventional machining.

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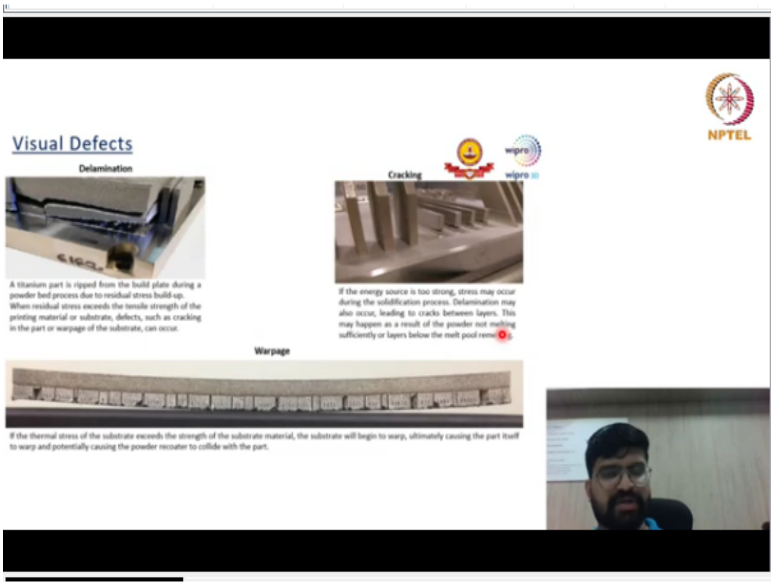

Or some primer or different features check, whether everything is within that acceptance you need to have. So, these are the different visual defects that can arise when residual stresses exceed the tensile strength during printing, the deflamation or heavy ware page or distortion can occur. So, this is what happens when the delamination happens, the material gets liftoff from the actual build print cracks. If the energy sources too stronger stresses will occur during solidification process, resulting in cracking.

This can also happen if this face is perpendicular to the recoater moment, then there is a possibility that liftoff can happen because of recoater regular rubbing and heating. So, we generally avoid the part, being in perpendicular to the recoater movement. Then warpage. If thermal stresses generated during process exists the strength. Then, heavy distortion occurs on the part, this is generally due to the thermal stresses which are generated. If this thermal stress exceeds beyond the strength of the material, then this type of warpage can happen.

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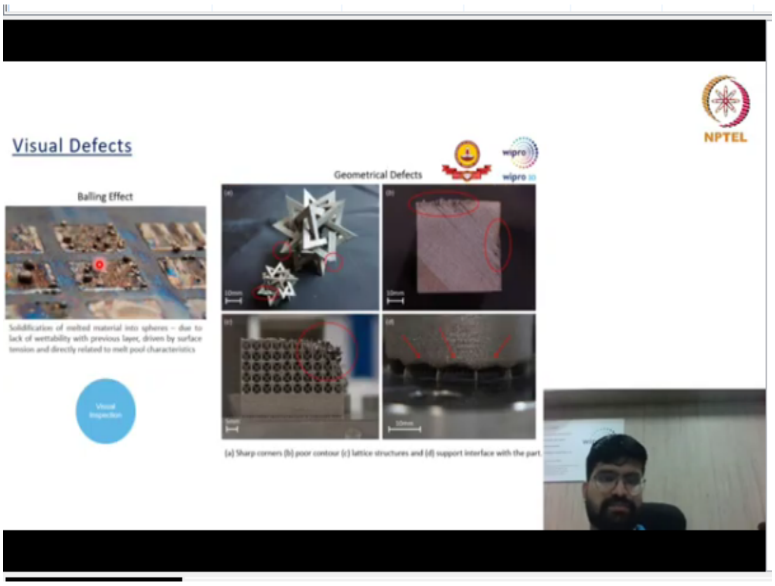

Then bailing effect. Due to lack of weldability, with the previous layer, which is generally driven by the surface tension, this sort of bailing effects happens. Then geometrical defects damage of sharp corners. This can generally happen if the recoater continuously rubs with the sharp edges. So, operators should be attentive when they observe some sounds of rubbing or vibrations, due to recoater rubbing.

Then poor contour formed, if you look at here, the contour is not formed properly. Then, lattice structure. Generally, when you are building lattice structure it is always preferable to have brush type of the recoater. So, that will be soft material and does not create any damages to the sharp edges or lattice because the thickness will be very less. Then support interfering with the part. So, when you are providing support, we need to say that it is not interfering with the part.

If it is interfering with the part then we need to spend more amount of time in post processing like finishing the part to remove this additional support that we have provided. So, while deciding the supports we need to keep this in mind that the any extra supports that are added will have a direct impact on cost that is needed in order to do the post processing machining activity to reach the dimension called that drawing, then post processing.

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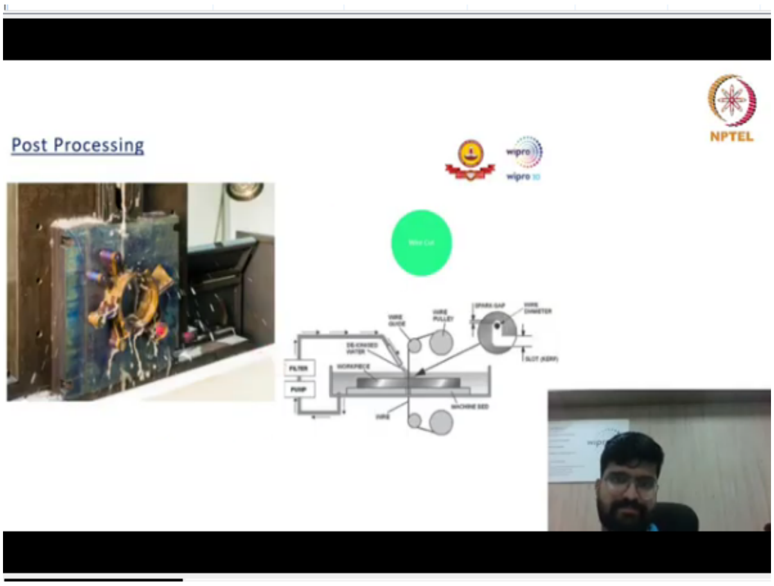

So, these are the 4 activities that we will be covering, wire cutter. So, in our case, we use wire cut, only to separate the build separate the part from the build. In no case wire cut is a finishing operation. So, after cutting we immediately do machining and finish that particular phase and maintain the dimension as per drawing.

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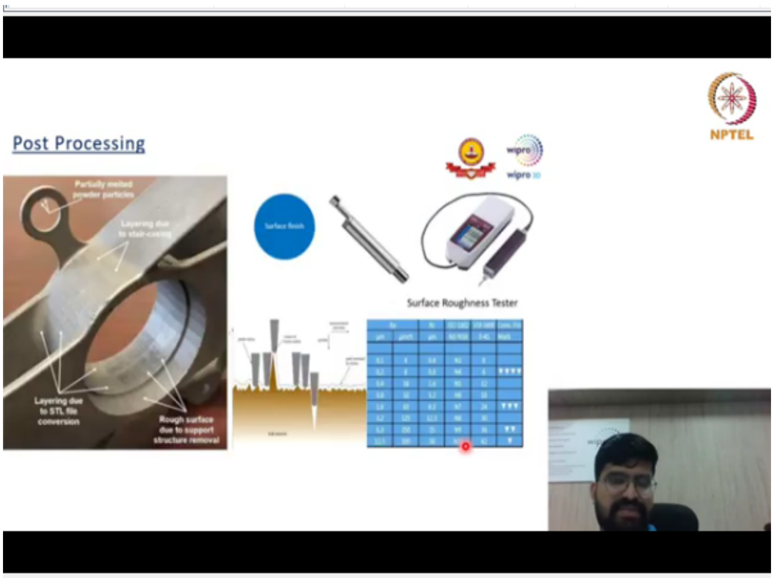

So, we use wire cut only to separate the part from the build, then these are the different issues that are observed like partially metal particles. So, this can happen when the powder particles are elongated where one end of the particle gets melted, and the other end is left out the projecting in this way. Then layering like I said earlier, when we are initially loading the model there if we do not do the slicing properly the sort of stair casing effect, or this sort of rough surface occur if the slicing of the model is done properly. Generally, surface finish of 8-15 RA is generated from additive manufacturing.

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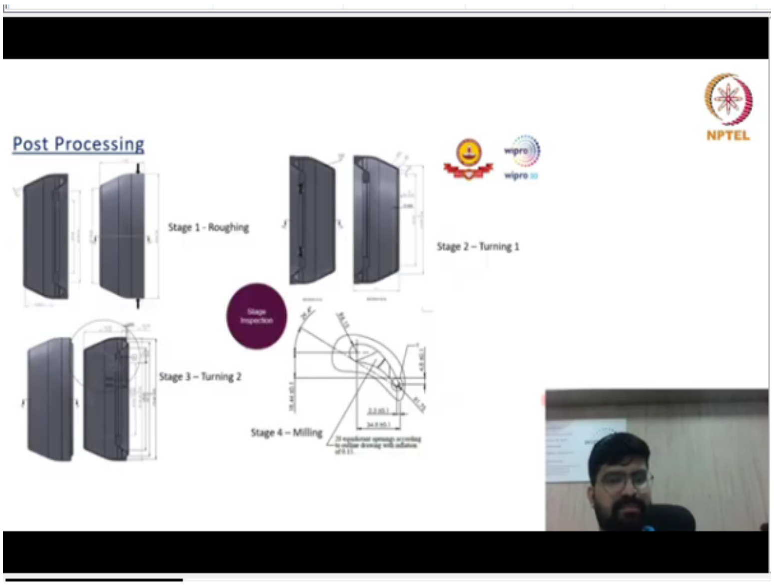

So, this is a strange drawing, which involves the roughing, turning and. So, it is similar to any other conventional method. So, I am not covering much about these details here. So, if you look at this particular part. This is the part that we have printed. The issue with this part is that after almost completion of 90% of activity only say some 10% of activity was left out.

Because of the recoater rubbing and collision, this part got rejected. So it is always preferable to simulate the build, and ensure that all these sorts of issues will be addressed even before starting the actual build. So, if you look at this resulted not just customer satisfaction is missed. We also observe issues like he could not meet the customer on time delivery, then this particular part has got rejected.

The amount of time, for which the machine was running in order to create this part, even that is become waste now. The powder used for producing this part that is waste now. So, all these things will impact so we need to be very sure before starting the build to ensure that it does not stop in between the process before the actual completion of it, then one more thing that we need to look is.

If you can look at this part, we have provided supports here. So, we need to be very cautious when we are providing supports, because we have provided too many supports the time of post processing it has become very complicated. So, we have provided this supports so that we do not get any distortion, in order to remove this support in machining distortion was observed.

So, you need to know partially take a decision how many supports are really required. So, that this will not increase my post processing time and increase of post processing cost. We need to consider all these aspects when we are actually designing the build. So, this is just an overview in the advanced session we will go in detail about the simulation.

Then other defects that can occur, then how to control them the what additional controls we have introduced. All these details will be covered in the advanced session. Thank you for joining this session