Social Innovation in Industry 4.0
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Lecture 41
Rapid Prototyping Laboratory Demonstration- 2

Welcome back to the next lecture on the Demonstration of the Metal X-C D printer. We have seen the demonstration very broadly in the previous lecture, how to set the printer, how to put the components. First in the printer, we get it dwilled, then get it washed. Then, in the sintering, we get it baked properly, so that we get the final component. And, as per the dimensions that we have put, in the printing the dimensions will be little higher, normally, 20 percent higher, those will be taken care by software itself, but definitely, we can scale up and scale down the model based upon our requirements. Now, I will discuss the connection to the eager software, that is how do we connect to the cloud of the software, that is used for metal X printing pair.

So, Printing Using Metal X. So, let me connect to the software. Last video we looked at the metal 3D printer, the software, we only talked about the software, what is the software. So, we looked at the machine in the last lecture, now this is just a Google interface that you could see.

Now, in the Google, how to connect to the software, what is the software and how do we save the files here. We can use the software at from any base, because this is cloud based and we need not to have the big sophisticated systems, we do not need to have 32 GB RAM or may be very sophisticated graphic cards or so. Because this is all cloud based, only a good internet connection, that could help you to see or work using the internet, just like browsing a website. So, in the Google, we put EIGER dot IO, if I click, it will show the first option in the Google that is Markforged. So, Markforged library, so already because we have logged in to this.

Logged means the user ID is already saved in this, so it will just log in here. It is asking the software update, so we will come to the updates later. So, it is Markforged software, it helps here in the search window, to search for the parts, folders, bills, devices. So, first of all, the drawings that we are need to make. So, we have to follow the specific process, how to build the part, we have to see that.

To make any part, we need to understand the location, the position, the feasibility of the part, whether the connection the supports are heavy, or supports are to be put in the minimum possible positions, as far as possible, or the whether it is really legitimate to do it through 3D printing, all the small things we need to see. If the machining has to be there, what should be the thickness given to the component? If threading has to be there, then what strength has to be there? At, threading the infill has to be, maybe more than 90 percent to100 percent, if threading has to be there. Then, we can use this software for all these small analysis, all these small predefined specifications that we have. First we make a job, so we need to see the features of the job and anything that we build in this. First and foremost point is, we need to understand that the bed size that we have of this printer is limited.

So, anything fitting within that bed side could only be build or manufactured using metal less Additive Manufacturing Eager Software. If the component is bigger like you can see a small sections here, down there in the third row of the components. These are all parts of the one big body only. So, these are all developed in a separate parts depending upon our bed size, and these were later welded or screwed or connected using nuts and bolts. So, there are multiple 3D files which are available.

So, there is a library, this is library, you can see multiple files here. And, the left menu in the software, you can say library as first option. And, you can see these 3 rows with 5 parts in each row. So, we have named the file. Then, a maximum of them because MedTech IIT Kanpur is the ID that we are using.

So, it is being saved in this folder only. Next we have the parts. So, in the parts, if I click in the left menu, these parts could be seen here. Each part how is it saved and how different names are there, they are saved in different names. Then, I have my parts, the parts which I have specifically built.

Some of the parts could have been imported from the third party. Those parts were there in the all parts. These are only my parts which I have saved here in my specific folder. Then, we have different folders here. So, these are different groups of the parts like Shivam Sachan is one of the folders that one of these operators have made or saved in this name.

Then, have Epeiment, this is one of the clients file. Then, Ashwin file, McGeek Jobs, so different folders are there. In each of the folders it is showing, in the first folder 18 parts, in the second 123 parts, those were there. Next are the builds. So, any of the parts which are put on the bed to manufacture, to start the printing those are called as builds.

So, if I open any of these files, for example, this file is open. This file is open and it is taking time yes 100 percent downloaded now. So, it is showing the bed size. The complete bed size of the machine is being shown here. So, we can zoom in, zoom out, we can select the component and position it somewhere else depending upon our requirement.

So, there are certain rules to position the components, that I will discuss in the end of this lecture. So, you can see, if this component in this position if I suppose invert this, then it would need to have the supports in between. In this case, you can see the small area just outside the component, this is known as raft. We could have brim, we could have raft, this is a raft, because the whole area, the body is having plane surface at the bottom. So, raft is required.

So, now this is a component, if I need to change the angle of this component or maybe try to reposition it this could all be done using this. The build, it is in the left, you can say estimated print time, it is 1 day and 22 hours like around 2 days, or is it 24 for 22 would be that is 46 hours of the time would it would take. Copper volume because the material that is set is copper only. So, the copper volume, it is 110.29 cubic centimeter of the copper will be used.

Then, ceramic release volume would be 1.39 centimeter cube. Then, the material cost in USD, it is calculating. They have put their own scale because this is a US based printer, it is showing 166 US dollars would be the cost of printing this material. The name of the part is also put here W band final metal 3D printing dot STL.

So, any of the files in 3D printing have to be STL file. This we are now very clear with. Now, in the right detail menu you can see, it is showing build settings, review, and modify your build settings, or printer type is Metal X. So, select printer Metal X, we only have this printer available. So, for this software, this software helps us to build using other versions of the printers as well.

So, right now we have Metal X here, the parts in build. So, we have put this component here. So, there are two copies of this component. Second component is going to different component here. If I cancel one, if I cross one, it will reach here now only one component.

I can even add the parts, the similar component, the same component could be added, or another component could be added. So, we can add part to a build, add a part to W band like this present file, that we have. This is a stainless steel, first one is a stainless steel component, second one is a copper component. We cannot add separate material components into one printer obviously, because a spool, that is coming, is a single spool. If it is a stainless steel spool, all the stainless steel components could be put here.

Similar is the case with a sintering as well. So, if I say add component done. So, I did not add the component because this component that I wish to add was stainless steel. So, present component is of copper. So, it will add the component, only if the metal component is of the same size.

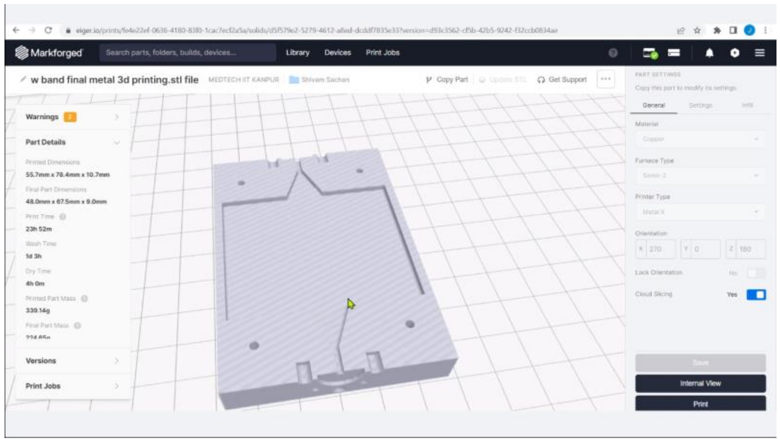
Now, depending upon the, talking about the size of the printers. Sinter one is the first or the base, Sinter that Markforged developed. In that Sinter-1 the volume was around 4760 cubic centimeters, but what we have at MedTech is a Sinter-2 which is a recent version which is around 22000 something cubic centimeter is the volume of the Sinter-2, but one thing is to be definitely taken care of Sinter, the printer is all designed for the specific material.

Sintering for the copper would be different, for the stainless steel would be different, the timing would be different, for the incolen would be different. So, all the components of stainless steel which would come in this volume, 22000 something centimeter cube, that could be put in one go, but it has to be a similar material.

If there is anything required, there is always a support here, there are available get support for the call or for the chat. We can also print here you can see par, view, save, build, print. So, like we look in the machine, how do we connect to the Wi-Fi, the Ethernet, here also, we can just print directly while sitting out there provided the printer is set. Set means the bed and everything is set, and the vacuum is created there, then we can print it from here. Now, it says that yes, printer or the print is ready to execute, it is the Metal X ready.

So, we can click here and see what is ready, printer is ready, that Metal X ready, Sinter-2 is right now offline. So, we can click print button at the right bottom and start the print. So, print will start taking place and it will take this time, one day 22 hours to build these two components. Now, this left menu we have seen, build settings menu in the right also we have seen. Part, view, save, build.

So, we can click the part and look at the view. If I select the part, it will highlight this option part, view and we can view the part. Now, to look at the fine features of the part. We can also see the parts from the different views like top bottom.



So, you can see in the top it has a small groove here, a groove or maybe the negative surface here.

So, that means if I would have put this in upside down, it would have bring supports here. So, this finish would not have come good. So, this is one of the ways that the plane surface as far as possible has to touch the base of the table. So, raft would definitely be used. So, that the final component that we get is having the perfect surface finish, or the surface finish that we require, it would bring accordingly.

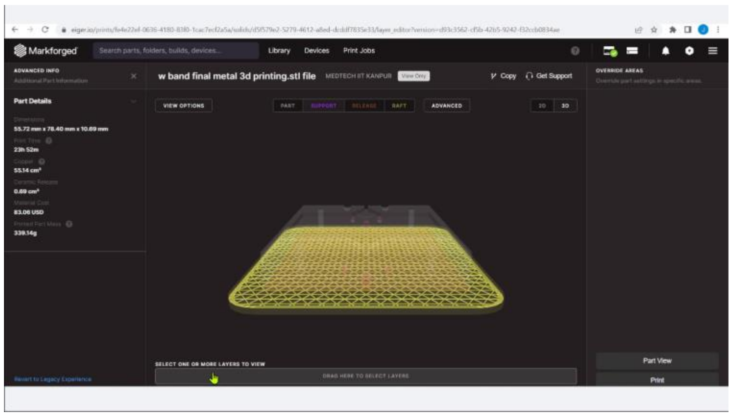
So, whole sizes could also be seen and checked, whether these are feasible to be printed here using this printer, whether the whole size is fit to the resolution of the printer. So, you can also see small grooves here, the sizes of the small half circles, these minor details could be checked. The full detail of the components given in the part details here in the left, there are certain warnings. There are two things, number one is warning, number two is error. Error means, that is vital that is that shall be corrected.

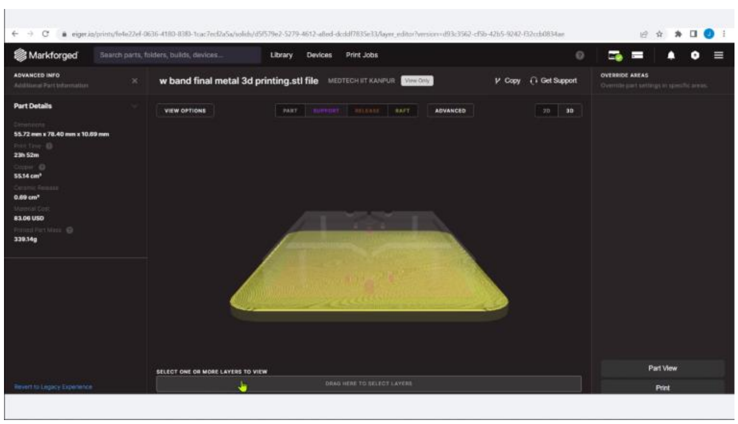
Warning means it may be corrected. This is all it differentiates. So, in the part details, it is showing that 55.7 mm into 78.4 mm into 10.7 mm of the thickness.

This is the print dimensions and the final part dimensions would be 48 into 64.7.5 into 9. This reduction is due to the contraction in sintering, you can see from 48 to 55, around 10 percent or 15 percent of the size is increased to compensate the sintering contraction of this material. The coefficient of contraction is different for different material.

So, this is all calculated by machine itself. Now, the wash time, print time, dry time everything is mentioned here. So, the print time is 23 hours 52 meter, and the wash time for the ceramic and for the small material, that is there in the pores not the support material, the ceramic material also enters the pores of the material the main build that is also to be washed, it will take one day three hours. After washing, we have to put it in dry, that is four hours of the dry time it would take. Then, printed part mass, that is 339.

14 gram of the printed part mass would become. And final part, after taking off all the washing and everything would be 224.65 grams and the metal volume that it is showing would be 55.14 centimeter cube. Release volume would be 0.69 centimeter cube, that will be used as the parting material to separate the supports.

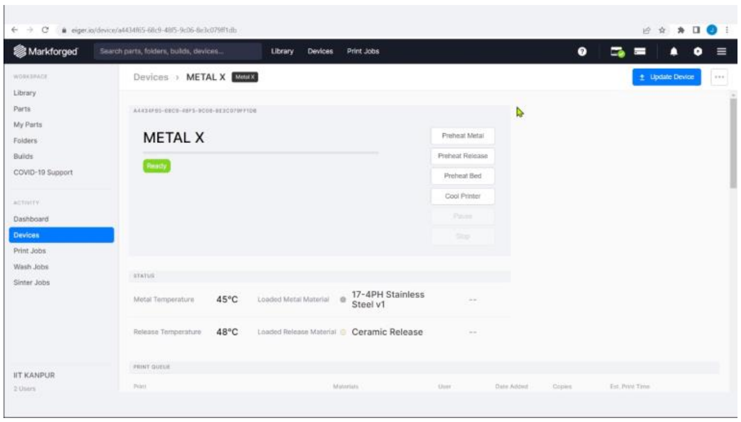




Now, on the right side you can also see, the options here, save, internal view, and print. Let me see the internal view. Now, it is showing the part view, internally how the part would look like. So, you can see this pink color here through the other supports. In the slow motion also we can see, there is a drag bar here, drag here to select the layers.

If I keep on dragging it from left to right so I can manually just select the time frame, at which I would like to see the position or the status of the component being printed. So, at around 40 percent of the time, at around 50 percent of the time, this much component would be printed, it is showing how it would go up. So, here closely it would be 95 percent and around 100 percent of the component printed. You can see the internal not exactly features but internal view of the component and how would it come and you can see the pink color this is support, the orange color is release, green color is raft and the part is white color. In 2D and 3D views could be seen it is showing the screen the black, so that the parts could be seen with more clarity.

So, let me come to the part view once again. So, we can just directly print it from here and it will go to the print. So, we can directly print it from here and it will directly go for the print.



So, if I need to see in the Metal X, that what is the position here or what is the situation here. So, in the screen it is showing that metal temperature is 45 degrees, release temperature 48 degrees of the printer right now. And, the loaded material is this and this is the position or the status of the Metal X printer, that is showing the printer is ready because the stainless steel is already loaded there the ceramic release is already loaded there and the bed is ready, the metal temperature is 45 degree and the release temperature is 48 degree.

So, it is showing the printer is ready and we can just execute or start the print. So, the machine status or machine readiness could also be seen directly from this cloud based software, because the machine is also connected to internet and it is connected through the cloud to this software.

So, let me now come back these are all printing options, like preheat metal is here preheat release is there preheat bed, then cool the printer sometimes if we need to stop or hole in between, we need to cool down the printer that also is option available. Okay, let me come back to the screen where the component is shown already. Internal view is seen, then, let us see the internal structure of the component.

So, let me try to see the part settings at the right side copy this part to modified settings, There are three options. General, setting, and infill. In the general option, it is only showing the material that is to be printed here. Material, then we have the furnace type that is Sinter-2, we have printer type. So, let us try to see the material details in the library once again.

So, this component is there W band, now it is highlighting those options. Part settings in general, then we can review and modify our settings for printing here. So, it was copper before now it is stainless steel here we can select from these materials see how many materials are available. It is nylon white, printer, 17-4 pH steel, V1 and V2, incolen H13 tool steel, A2 tool steel, D2 tool steel, copper, these all different materials could be used. So, this highlighted blue color that is a selected material is 17-4 pH stainless steel.

In the next phase titanium, aluminum these materials are also expected to come. So, this is an ongoing R&D to keep on come bringing new materials. So, people have also worked somewhat in magnesium which is considered to be very brittle material also, but still people have worked upon developing small experiments using the printing in a Rapid Manufacturing using those materials.

So, we can select the printer or the we can set the furnace here. Sinter-1 and Sinter-2 as I told you the Sinter-1 and Sinter-2, because both of them have different volumes the timings would also be different because to heat the bigger volume, to heat the smaller volume, the time would obviously be different.

So, depending upon that, the time for the overall printing including sintering is calculated. So, we have selected Sinter-2, this is only sinter available that we have at IIT Kanpur, then the printer type is Metal X. So, now, you can see the part is now, I kept perpendicular here, just to show you another view. So, we can just put and drag it up and down. If I would have put part like this for the printing finally, the down part would be having printing down there.

So, in the standing position also the printing time would be higher and also the resolution the surface would not be as good as we wanted to have at the base of this. Different orientations could be put here just to see what is the best possible or to have the final best results which position we should be put in. We can move it manually we can put the X, Y and Z dimensions here to rotate the component manually. So, we do not wish to change this.

So, we lock the orientation we say yes, the orientation is now locked. So, with any other option this could not be changed. So, it could be locked here, then we can save this here, it is saved here. Now, it will again show the internal view, the print. So, what you would like to see or you can if you are very confident that this is correct, you can go with the print or if you were to see some more details, you can just look at the internal views.

Now, next is the setting. In the settings, it is showing post sintered layer height, it is showing 0.125 height in millimeters. So, for machining, suppose, if some job is required to be machined. We should know that what is the height, what is the layer of the thickness of the layer, post sintered layer, what layer do we have, so that we can machine the component properly. So, what kind of machine is required, is it only finishing, the grinding only, or do we need to use the lathe machine.

So, this is post sintered layer height depending upon the machining, that we need to have we can put these values here. It is showing two values, 0.050 that is alpha and 0.125, we can change these dimensions here.

Then, original units, it is showing metric and imperial. So, we can scale up and down, scale up and down means this component whatever dimensions are given. For example, the dimensions 100 mm, if I have to scale, if I put scale 2 the 100 mm will turn to 200 mm, and all the dimensions will be double in proportion. But, it is also mentioned here is a note that part is already scaled up for to account for the shrinkage. This scaling up is not the shrinkage one. Now, next is support structure, and change this structure to cubic and again save it is taking time to save.

The clouds I think is in progress feel free to navigate away from this space. So, it is pathing it and trying to create the cubic structure now. Now, again we can see the internal view it is loading a tool pass. Now, structure that is there support structure is this color what is now showing the cubicle structure. If I zoom it more, you can see how the support structure is changed. Now, let us try to see another option for the support structures, that is a radial separations.

Again, the internal view. For the radial, you can see how is it showing now, the support structure in pink color. Now, it has become a single piece and it is radial to the cut volume that is there. So, it depends upon what kind of support structure do we require? How do we fit the support structure properly, so that the part is held in position with as far as possible accuracy, and it has to be an experience of the operator, or it has to be the software decisions itself to put the support structure, because this is a manually put. Depending upon the kind or the size of the support structure, we can select different options cubic, or radial, or so.

So, we have seen the support structure in such settings. How the support structures are support radial separations, default support structure, cubic separations? Depending upon the requirement, we can put different support structures. Whether it is a circular support or whether it is a straight support. What surface do we had at the top of the support? Depending upon that we can have. Then, support, the radial cuts could also be changed, some 2 to 16? How many cuts of the radial do we have.

So, it depends upon how difficult is the support structure to be removed. So, how many cuts do we have accordingly? Then, overlay transform is also there, if it is there, suppose, if something is overlaid how do we transform that into R dimensions. Next is infill. In infill, we have the fill pattern. The fill pattern could be Triangular fill, Gyroid fill, and Solid fill. This is a Triangular fill which we showed. This infill is a Triangular, you can see small triangles are here only. So, these triangles are infill only. So, this is the Triangular fill. Now let us try to see, the another form, that is Gyroid. What is Gyroid? Gyroid is actually infinitely corrected triply periodic minimal surface which was developed.

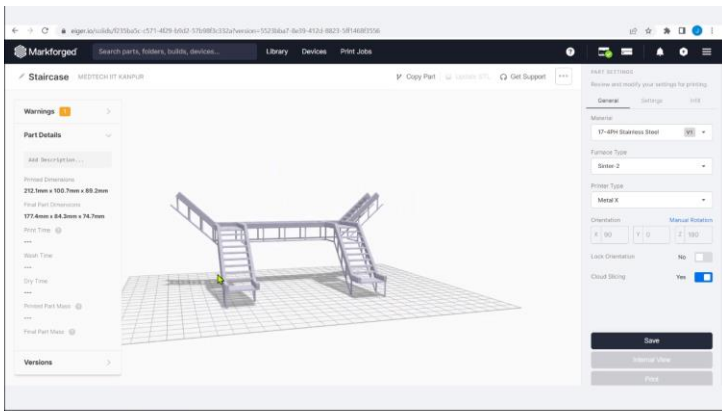
So, Gyroid actually, I would say, is an analogy equivalent to an organic kind of the flow. So, you can see a Gyroid infill here, this is Gyroid, now, yeah, this is Gyroid, this is Gyroid you can see. The flow of the layers, it is completely almost free, So, this is a almost a zigzag motion.

So, this is Gyroid fill. We can put different percentages for different kinds of the fill. For example, for Gyroid fill, we can put exposed infill as no or yes. Then, roof and floor layers do we require, how many layers in the roof and the floor. Do we require 0.50 mm post sintered layer? How many layers of 0.5 mm post sintered are required 4 6 8 10 12 14 16. Then, wall layers could be increased here, it is 1 mm post sintered layer. The post processing that is required, that is a machining or surfaces required, setting is required, based upon that wall layers could be increased here. This wall layer could be increased 1 mm post sintered 4. So, in the Solid fill, we can just say, it is only asking the wall layers here.

It is again calculating and computing the path. So, in the Solid fill, let us again try to see the internal view. So, it is a complete Solid, you can see it is almost a Solid and completely filled Solid. So, this is, how a Solid fill looks like. So, Solid fill and the status at different percentages.

50 percent, when we have 40 percent, we have around 25 percent of the print completed. You can see, how the Solid fill is completely showing it filled with the metal. Now, let me come back to the part view once again. So, we can save this whole data. So, let me come back to the Triangular fill and save the file. It is again computing the path, fine,

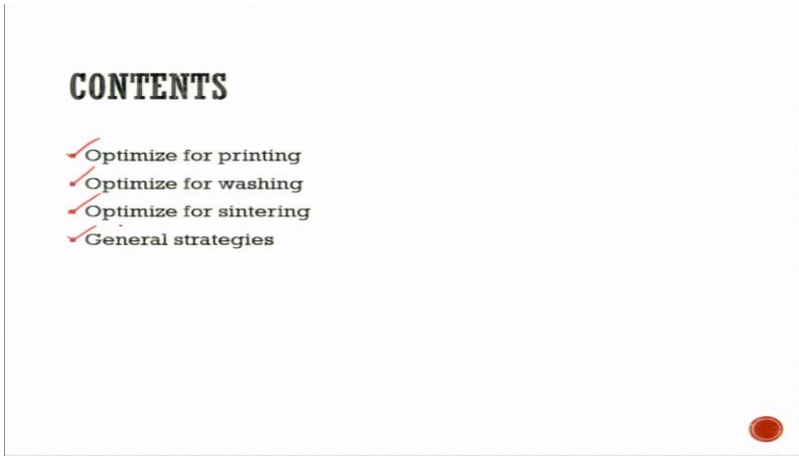
uploaded, and it is all saved in the Triangular fill once again.So, this is the general settings, the general options which are available, the settings options and infill options. And, part details, again, it is mentioned in the left hand side. So, we can copy the part, we can update the STL file, we can rename it, or we can save it in different name, we can download the STL file, we can delete the parts here. So, in the library. In the EAGER software again, we have come to the library once again, where we have seen the components which are saved here and let me open another component here.



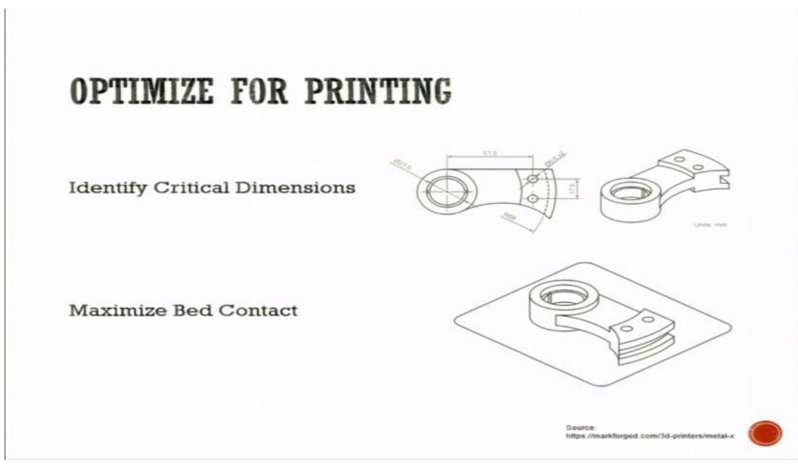
This is a drawing suppose this is a drawing. So, this is a big drawing and this is a little complex drawing. If I put it in this direction, you can see what heavy support would it require. And, definitely, this could also be one of the options to put it and print it, but suppose, if I put it in different orientation that would require even more support. So, it will calculate the support the software will calculate the support and the time itself, and wherever the minimum time is we can put it accordingly.

Sometimes, the component is also put in an angular position as well. So, we can calculate the details here, this is another way we have inverted it. We can put it in a vertical position.

This is surely not a recommended position, it is showing big errors. Errors means, it shall be corrected, warning it could or could not be, at an angle how would it look like. So, different components have different orientations and depending upon the minimum possible orientation minimum possible time that we have, we can put the components. For that, let me have a quick look on the recommendations which are there.

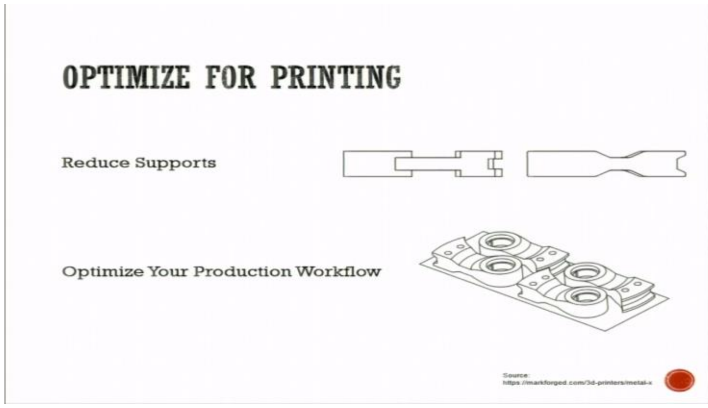


So, there are small suggestions like how to optimize for printing, how to optimize for washing, and sintering, and general strategies, specifically in metal X 3D printer.



Some suggestions in optimizing for printing, first point is identify the critical dimensions. You can see the hole that is 6.6 millimeter into 2 holes are there, these holes are put here horizontal. So, this is my print bed here, and on the print bed it is just kept horizontal, because the precisions in the planes parallel to the build are higher in 3D printing and that is discussed previously in the previous lectures as well.

Along the XY directions, the procedure is higher, this is how it is kept. So, identify the critical dimensions and try to see where the strength is required higher. So, that would be kept on the bed accordingly, this is, how do you do. And, maximize the bed contact, you can see this flange, this protruded surface, this is connected with the bench.

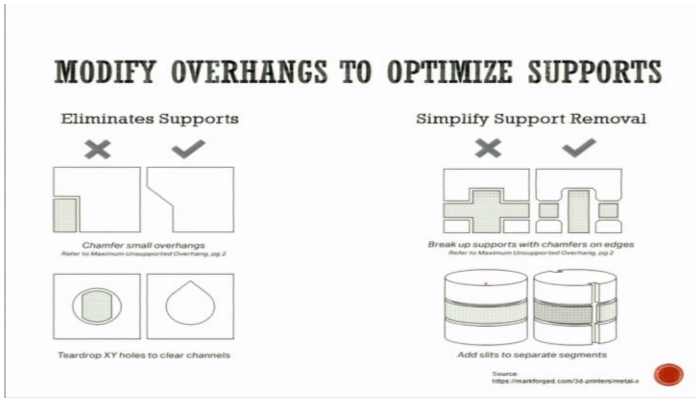


So, we maximize the bed contact because the more surface area with the print bed, it reduces or minimize the supports and improves the bed adhesion as well. So, which phase of the part would contact bed, which orientation would be best for this, this is to be taken care of.

Then, we reduce the number of the supports. So, in this case you see the fewer supports are required. So, this is one, this is another orientation. So, number of supports which could be reduced. So, fewer supports means few or the less wastage of the material how do we design to minimize the supports. So, are the supports in our part completely accessible or not, this has to be taken care of.

Then, optimize your production workflow. Production workflow means, how do we align, how do we set the components. so that the raft that is required is connected, and the maximum utilization of the surface is there. It is a general setting or the casting or you may be in stamping as well. These kind of settings the proper layout of the components is always there. So, it is considered the overall throughput of the component, like in the one go of the printing in the single run of the print, what maximum number of the components could be produced.

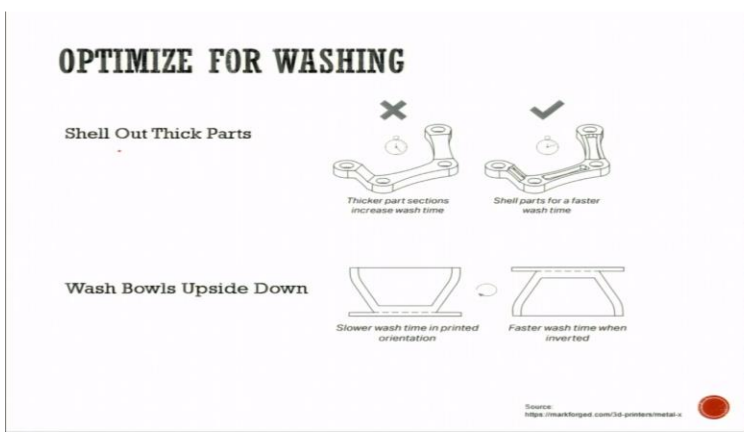
This will maximize the batch size, this will minimize the batch cost, this is how it goes. And, the infill also could be designed here like solid infill is required or not, or do we need 90 percent or lesser infill, what kind of infill would we have. So, this also minimizes or optimizes the cost of the printing.



Then, we modify the overhangs to optimize the supports. Overhangs means, for example, in this case the support is required, this will be overhang, this is a kind of a cantilever. In this place suppose, if I provide this kind of the angular feature in my component, what would this help us to do, we will chamfer the small overhangs, and it will bring more strength here because this part, strength, would be lesser here.

So, this is correct. Similarly, in the teardrop XY holes to clear channels. So, to clear channels, the XY holes, you can see those are also connected in this way. The simplified support removal, this support is difficult to be removed. So, example is components here down there. So, we try to divide the supports into different parts, so that it could be removed simply.

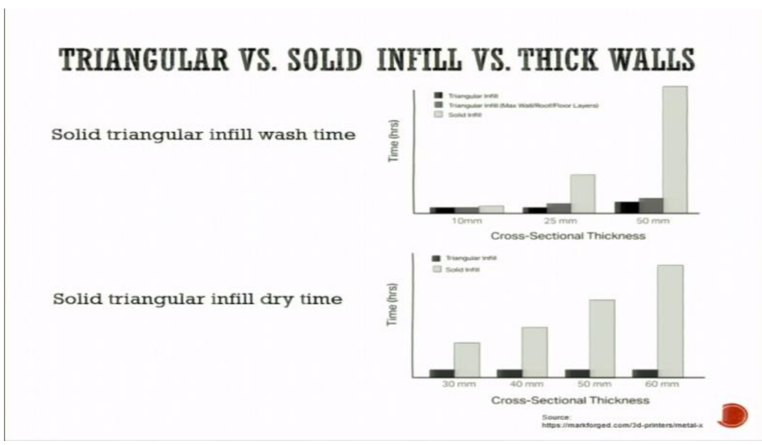
And, slits are also made here, slits are also separated here. These slits are there to separate the components, this is 1, 2, 3, 2 is my support. To separate the components, again a delineation proper has to put in between them, that is also here.



To optimize the washing, to shell out the thick parts, this is a complete thick component. In this case, in the second portion, you can see small slots are provided, small cuts are provided, what does this help us to this minimizes the overall area, overall volume, that is to be washed.

So, the thicker our part is definitely, longer time it will take to wash. So, we cut down the volumes to increase the surface area. To increase the surface area here, surface of contact to the wash liquid would be higher. So, this will also help us to spend time in the wash, and the time would be minimum, that we spend in the wash.

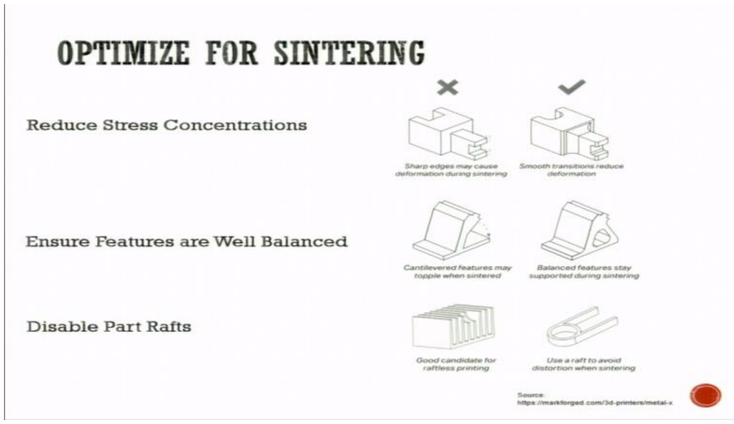
So, also we need to maintain the consistency in the wall, it is to be also taken care of. So, wash bowls upside down. So, slower wash time it is having faster wash time, because when it is kept upside down, and the washer solvent by weight is lighter than the binder material. So, it permeates into the bowl if it is kept upside down. So, regarding printing, printing can be done in this way only, but washing has to be done in this way, so that the wash time is minimized.



Then, a small data that is provided by metal actually that solid, triangular infill wash time.

This is a triangular infill black one the dark grey is triangular infill with maximum wall roofer floor layers. Then, solid infill, you can see for 10 mm for 25 mm for 50 mm, how the cross-sectional thickness is varying and the time it is taking. So, for the 50 mm, for the complete solid infill, in comparison to the triangular infill, it is around looks like 10 times of the time it is taking. So, it depends upon, really do we need the complete solid infill or can we reduce it.

So, this is a really critical decision that is to be taken. Now, solid triangular infill dry time as well. For the triangular infill, for solid infill, you can see for the different cross-sectional thickness is again the time for 30 mm, for 40 mm, for 50 mm, or for 60 mm, the time for triangular thickness is just this small unit only, but as the thickness is increasing because with the solid infill here the time is increasing and this time again may be more than 10 times of the time it is taking, for drying of the infill. So, this is in the wash, how do we select between the triangular and solid infill, and how do we compare them with the thickness of the walls.



Now, for sintering, there are certain suggestions, reduce the stress concentrations, because in the sintering, contraction has to happen, and the contraction the edges here, you can see this edge here, and this edge here, this is a chamfered edge. So, we smoothen the transition to reduce the deformation, and the sharp edges may cause deformation during sintering.

Because these sharp edges would induce in themselves thermal stresses. And then, when sintering happens, the contraction happen, they pull themselves together as they shrink. So, to reduce the stress concentration, filleting or chamfering is suggestible. Then, we ensure that features are well-balanced because the contraction has to happen.

This is a cantilever feature. So, it will try to fall down, this is topple down. And, this balance feature, so that this kind of the flaw does not come in the final print. Then, we have the disabled part rafts. The part rafts, for example, they are different rafts, a good candidate for raftless printing, use a raft to avoid distortion when sintering. So, when Metal X parts are printed with a raft.

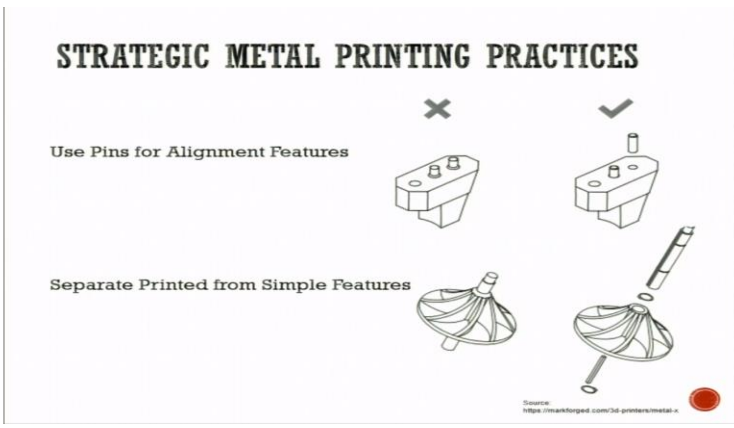
For rafts, always make sure that a good adhesion to the print sheet and uniform part shrinkage during the sintering is there. Though, this is clearly labeled with the material to help prevent mix ups. So, one might consider disabling raft for smaller parts, and to have good first layer contact, so that raft, even if it is not there, the first layer of the print bed, that would cover its absence. So, the good first layer contact with the print bed, and lack features that require a raft to prevent distortion in printing, that is also taken care of.

And, disabling the raft will produce much smoother surface at the bottom at certain times.

And, also small things, for example, this is one component, let me say this is a component, it is sharp at the bottom. In a shrinkage, this would also induce stresses just like this. So, it can also have a chamfer here, chamfer or fillet here, this is correct, this is not correct. So, the bottom edges could be chamfered, fillet could be avoided. And suppose, if they are some components in which height to width ratio is very high, it is six times of it and this is a component.

For example, this is let me say Phi 2 mm, and this height is 15 mm. In this case, it is suggestible to have a component something like this. This is Phi 2 mm, this is Phi larger than 2 mm, so that the tall or thin features which are more than six times of their cross section height. It should not be freestanding. So, for this freestanding features, a draft angles should be provided like this angle is provided here.

So, this will help them to not to topple or lean when they are printed. This could also be one of the suggestions.

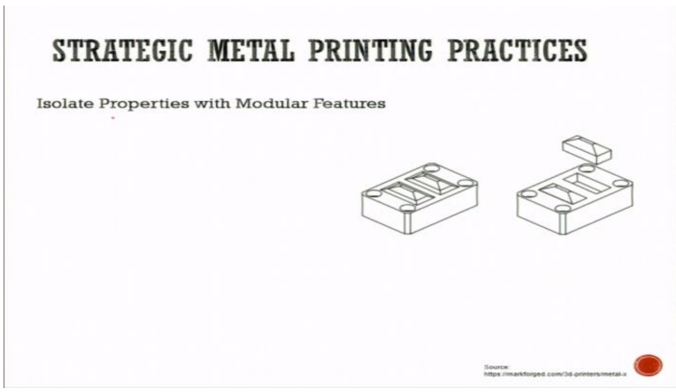


Then, some strategic printing practices which are again suggested here. In general are use pins for alignment features. Example, these pins are provided, this is a straight or fixed component, these are the pins which are used for alignment. So, to improve the alignment precision and save material, and print time by pressing doll pins into once part or using shoulder bolts for the location, doll pins pressed into the gripper jaw locate it onto a robotic arm.

This small changes in design reduces the supports and it also simplifies the print orientation. Similarly, we can separate printed from simple features. For instance, this is the impeller in which the simple shaft is here. The impeller within an integrated shaft is one option, impeller with a separate shaft is another option. So, when we get an impeller with the integrated shaft, this will sacrifice the optimal print orientation for the reference orientation.

So, it can be fit in the Sinter sideways only, because it is impeller, this is fixed here. Now, if this is printed in a separate part, this becomes a single component. Now, this could be put in the Sinter directly like this. In the Sinter, it could be put directly and we can just Sinter it.

Otherwise, in the Sinter base, it would have been put like this. This is a shaft, this is a shaft, only in this way it could have been put. So, to separate the components so that in the Sinter we can put them properly.



So, we can isolate properties with modular features as well. This is a component which is now again developed in modules. Module one, and module two. This was a single component. So, to separate the components in modules means we can isolate the metal insert and separate the part, that localizes metal properties to only the region where they are required.

Then also, it is suggested that do not print your hardware like bolts, bearings, springs, washers. These are available generally in the library. So, these are not suggestible to be printed directly. So, with this the demonstration on the Metal X 3D printing is completed, and we have seen how do we set the printer, how do we use the software for printing and general suggestions to put the component into the print, into the washing and into the Sinter that we have discussed in this lecture. Thank you.