**Metal Additive Manufacturing**
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Lecture 42
Metal 3D Printing Laboratory Demonstration

Welcome back to the next lecture on the Demonstration of the Metal X 3D 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 built, 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 % higher, those will be taken care by software itself but definitely we can scale up and scale down the model based upon our requirements.

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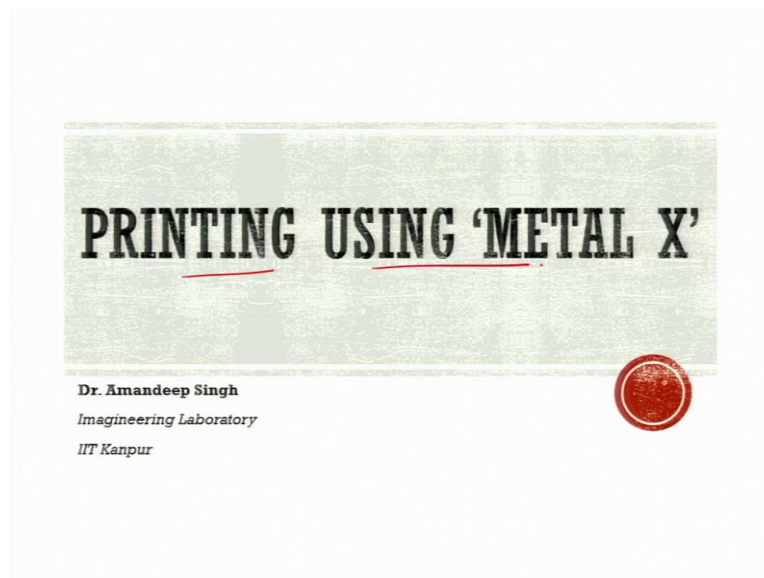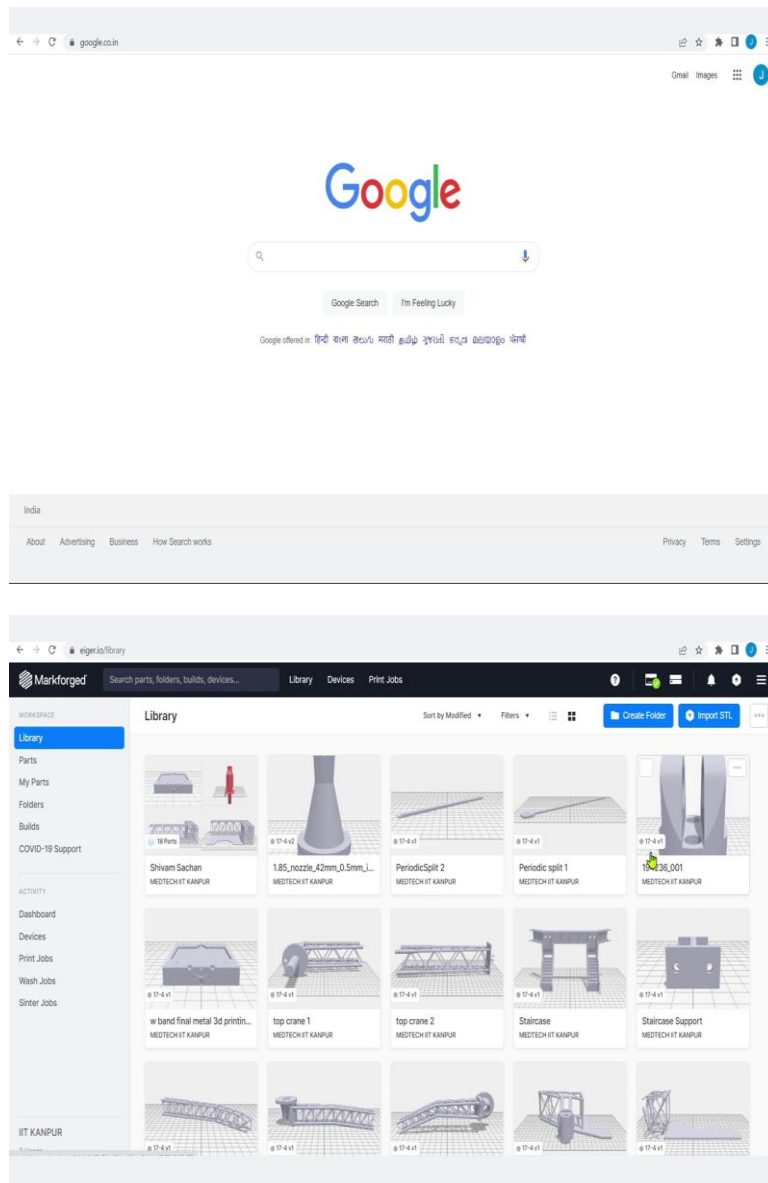
Now, I will discuss the connection to the Eiger software, that is how do we connect to the cloud of the software that is used for Metal X printing here. So, printing using Metal X. So let me connect to the software. So, last video we looked at the metal 3D printer, the software, we only talked about 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 to have the big sophisticated systems, we do not need to have a 32GB RAM or maybe 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.io, if I click it will show the first option in the Google that as Markforged. So, Markforged Library. So, already because we have logged in into this, log 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 you have to see that. So, to make any part. So, 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 whether it is really legitimate to do it through using 3D printing, all the small things we need to see.
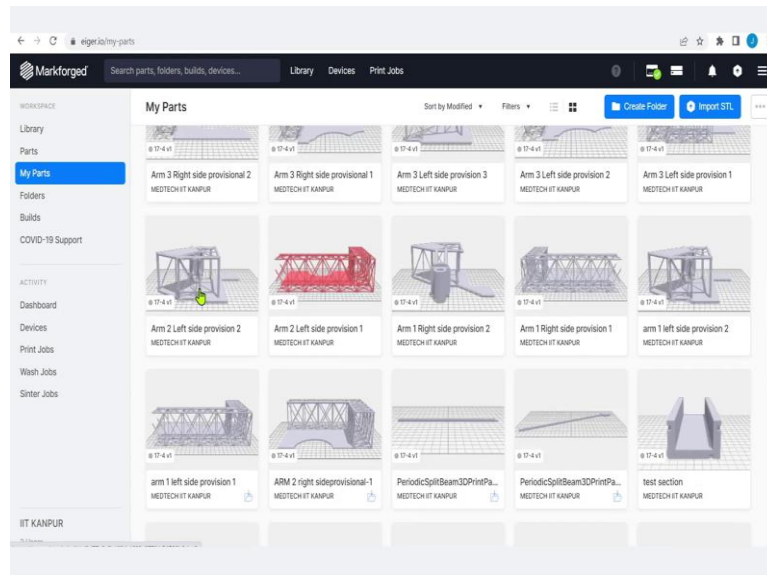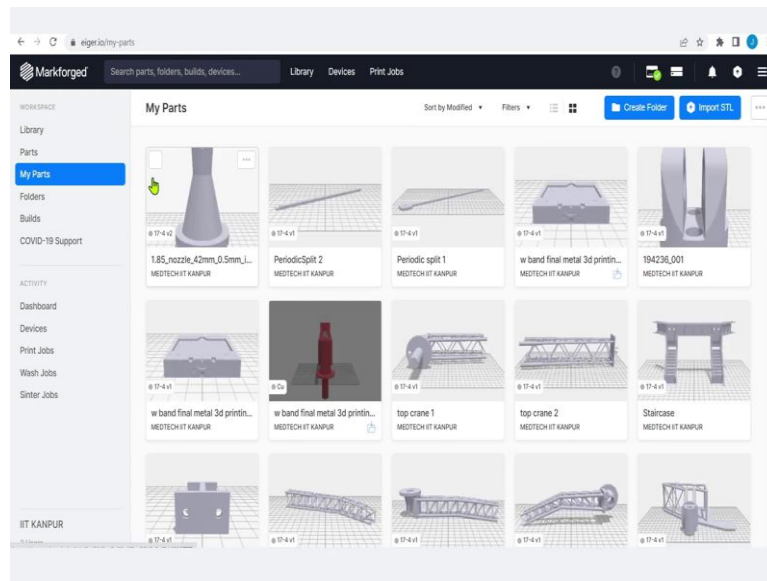
So, if the machining has to be there what should be the thickness given to the component, if threading has to be there so then what strength has to be there, threading, the infill has to be maybe more than 90 % or maybe 100 % if threading has to be there. So, then we can use this software for all these small analysis, all these small predefined specifications that we have.
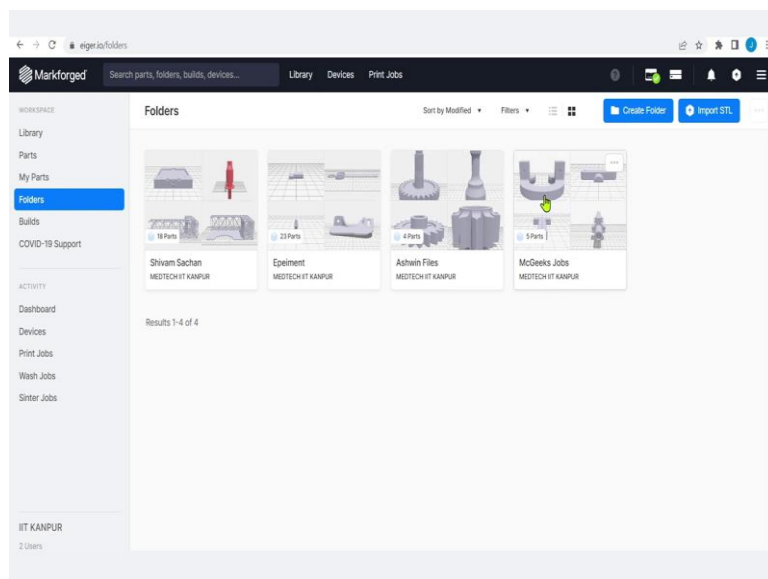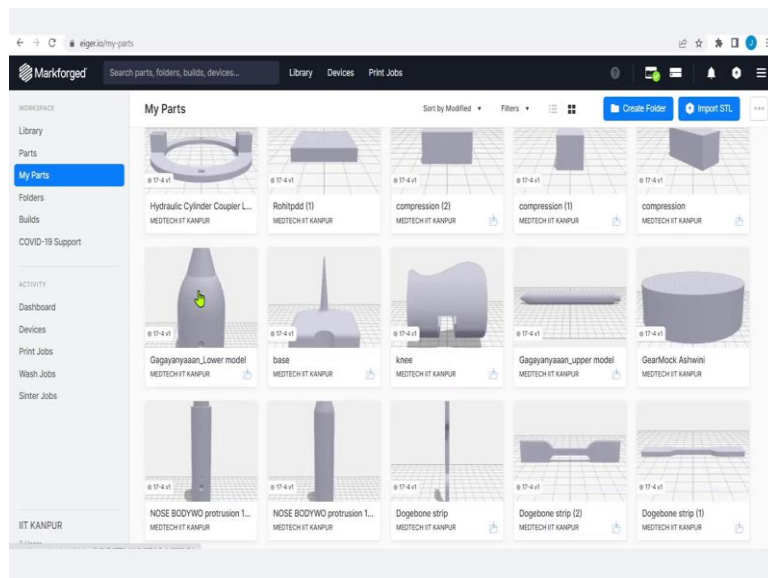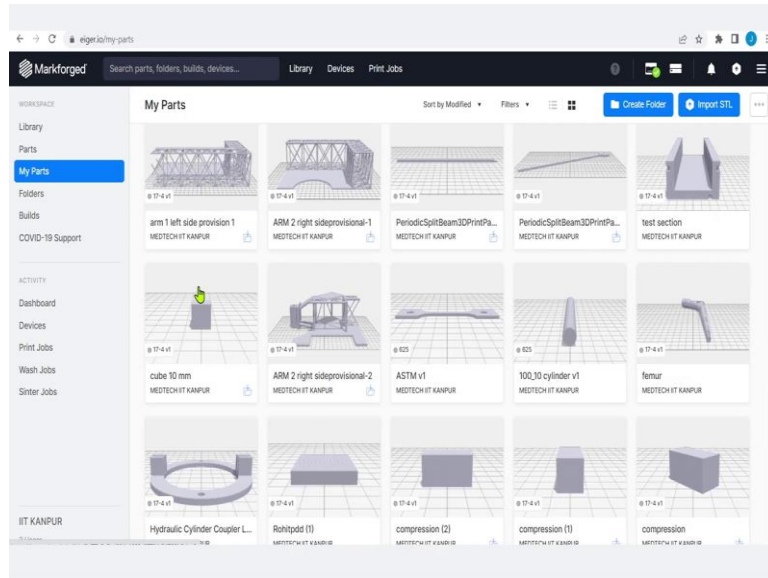
So, first we make a job. So, we need to see the features of the job and anything that we build in this, first and foremost point is we need to understand that the bed size that we have of this printer is limited. So, anything fitting within that bed side could only be built or manufactured using metal less additive manufacturing Eiger 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, in you can see these three rows with five parts in each row. So, we have named the file, then a maximum of them because Med Tech IIT, Kanpur is the ID that we are using so it is being saved in this folder only.

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Markforged

Search parts, folders, builds, devices...   Library   Devices   Print Jobs

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ACTIVITY
Dashboard
Devices
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Sinter Jobs

IIT KANPUR

My Parts   Sort by Modified ▼   Filters ▼   Create Folder   Import STL

arm 1 left side provision 1	ARM 2 right sideprovisional-1	PeriodicSplitBeam3DPrintPa...	PeriodicSplitBeam3DPrintPa...	test section
MEDTECH IIT KANPUR	MEDTECH IIT KANPUR	MEDTECH IIT KANPUR	MEDTECH IIT KANPUR	MEDTECH IIT KANPUR
cube 10 mm	ARM 2 right sideprovisional-2	ASTM v1	100_10 cylinder v1	femur
MEDTECH IIT KANPUR	MEDTECH IIT KANPUR	MEDTECH IIT KANPUR	MEDTECH IIT KANPUR	MEDTECH IIT KANPUR
Hydraulic Cylinder Coupler L...	Rohitpdd (1)	compression (2)	compression (1)	compression
	MEDTECH IIT KANPUR	MEDTECH IIT KANPUR	MEDTECH IIT KANPUR	MEDTECH IIT KANPUR

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Hydraulic Cylinder Coupler L...	Rohitpdd (1)	compression (2)	compression (1)	compression
MEDTECH IIT KANPUR	MEDTECH IIT KANPUR	MEDTECH IIT KANPUR	MEDTECH IIT KANPUR	MEDTECH IIT KANPUR
Gagayanyaaan_Lower model	base	knee	Gagayanyaaan_upper model	GearMock Ashwini
MEDTECH IIT KANPUR	MEDTECH IIT KANPUR	MEDTECH IIT KANPUR	MEDTECH IIT KANPUR	MEDTECH IIT KANPUR
NOSE BODYWO protrusion 1...	NOSE BODYWO protrusion 1...	Dogbone strip	Dogbone strip (2)	Dogebone strip (1)
MEDTECH IIT KANPUR	MEDTECH IIT KANPUR	MEDTECH IIT KANPUR	MEDTECH IIT KANPUR	MEDTECH IIT KANPUR

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Devices
Print Jobs
Wash Jobs
Sinter Jobs

IIT KANPUR
2 Users

Folders   Sort by Modified ▼   Filters ▼   Create Folder   Import STL

| Shivam Sachan | Epeiment | Ashwin Files | McGeeks Jobs |
| 18 Parts | 23 Parts | 4 Parts | 5 Parts |
| MEDTECH IIT KANPUR | MEDTECH IIT KANPUR | MEDTECH IIT KANPUR | MEDTECH IIT KANPUR |

Results 1-4 of 4

Next, we have the parts. So, in the parts if I click in the left menu that these parts could be seen here, each part how is it saved? and how different names are there? it is saved in different names. Then you 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 a Epeiment this is one of the clients file, then Ashwin file, McGeeks jobs, so different folders are there. So, in each of the folder it is showing in the first four to 18 Parts in the second one 23 parts those were there.

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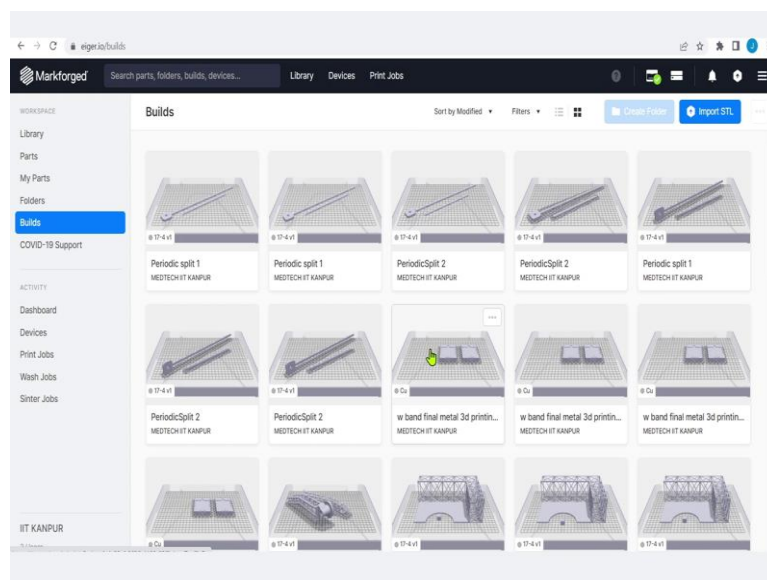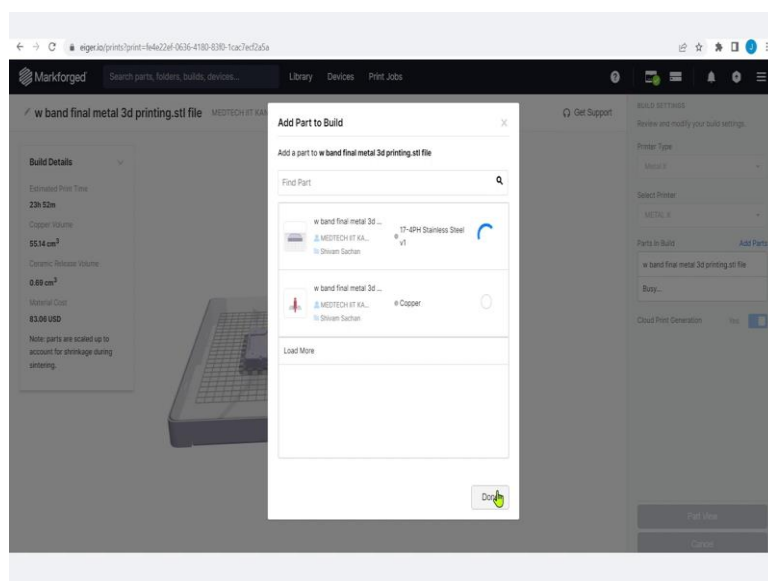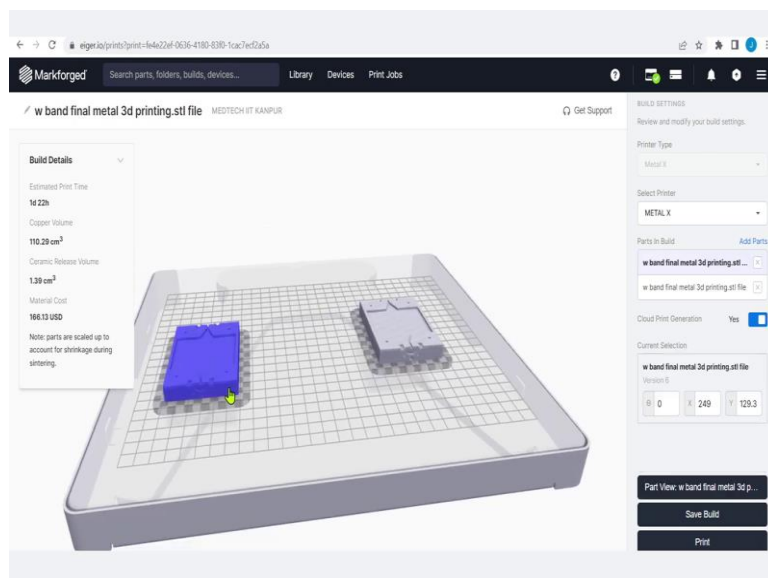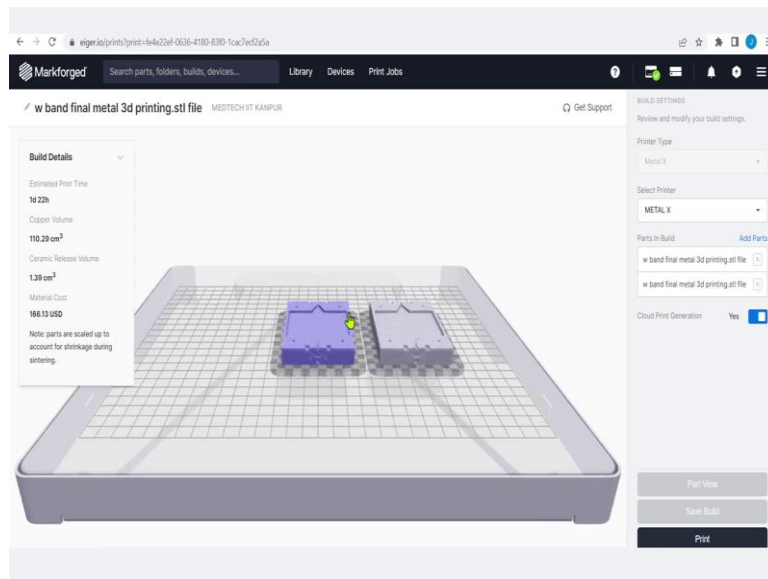
Next are the builds. So, any of the parts which are put on the bed to manufacture, to start the printing those are called as builds. So, if I open any of these files, for example, this file is open this file is opened and it is taking time, yes, 100 % downloaded now. So, it is showing the bed size, the 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, if 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 a small area just outside the component, this is known as raft.

We could have brim, we could have raft, this is a raft because it is the whole area, the body is having plane surface at the bottom. So, a 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. So, builds 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 it would take.

Copper volume because the material that is set is copper only. So, the copper volume it is showing 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.stl'. So, any of the files in 3d printing has to be stl file. This we are now very clear with. Now in the right detail menu we 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 the software helps us to build using other versions of the printers as well. So, right now we have metal X here. So, parts in build. So, we have put this component here. So, there are two copies of this component. So, second component is showing two different components, if I cancel one, if I cross one it will say 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 print 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 at component done. So, it did not add the component because this component that I wished to add was stainless steel. So, the 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.

So, Sinter 1 is the first or the base sinter that Markforged was developed. So, in that Sinter 1 the volume was around 4760 cubic centimeters but what we have at Mech Tech is a Sinter 2 which is an addition version, which is around 22 thousand something, cubic centimeter is the volume of the Sinter 2. But one thing is to be definitely taken care of sinter temperature printer is all designed for the specific material.

Sintering for the copper would be different, for the stainless steel will be different, the timing will be different, for the inconel it will be different. So, all the components of stainless steel which could come in this volume 22000 something centimeter cube that could be put in one go. But it has to be similar material. If there is anything required there is always a support there, there are available get support for the call or for the chat.

We can also print here, you can see part view, save, build, print. So, like we looked in the machine how do we connect to the Wi-Fi, the Ethernet. So, here also we can just print directly while sitting out, they have provided, the printer is set, set means the bed and everything is set and the vacuum is created there. Then we complete 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, Metal X is 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 1 day 22 hours to build these two components. Now, this left menu we have seen builds settings menu in the right also we have seen, part view save build.
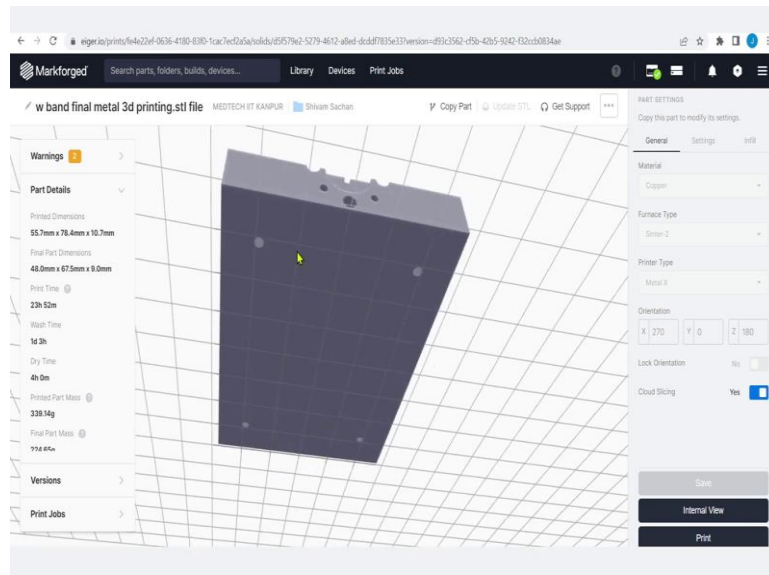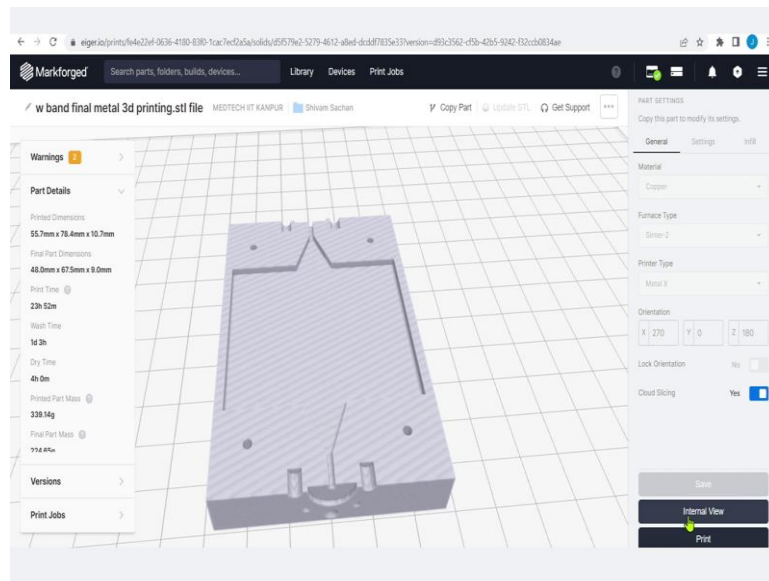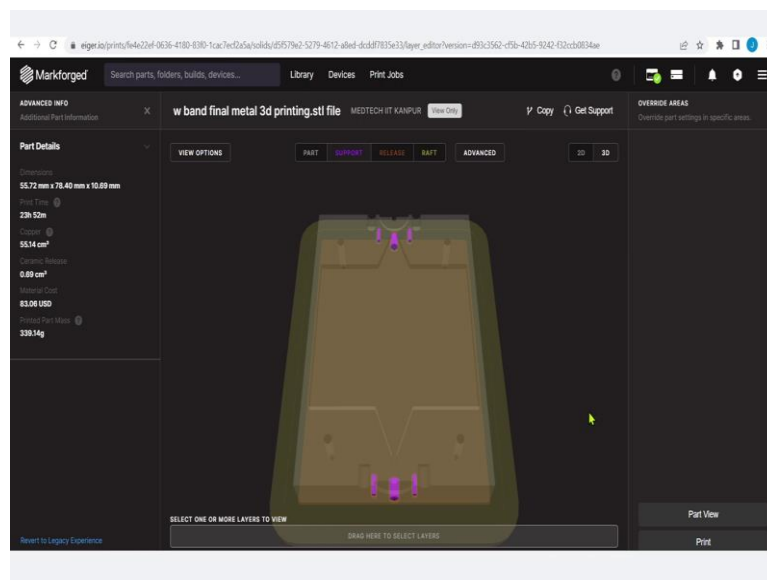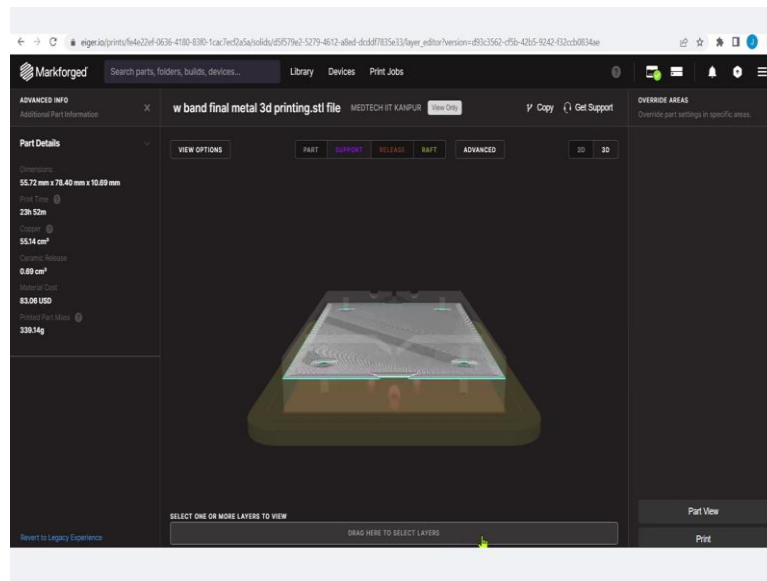
So, we can click the part and look at the view if I select the part it will highlight this option part view and we can view the part. Now, to look at the fine features of this part we can also see the parts from the different views like top, bottom. So, you can see in the top it has a small grove here; a grool or maybe the nectar surface here. So, that means if I would have put this in upside down it would have brought 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 print accordingly. So, hole sizes could also be seen and checked whether these are feasible to be printed here using this printer.

Whether the whole size is switched to the resolution of the printer. So, you can also see small groups here, the sizes of the small half circles, these minor details could be checked. So, the full detail of the components given in the part details here in the left, there are certain warnings, the two things, number one is warning, number two is error. Error means that is vital, that shall be corrected.

Warning means it may be corrected, so this is how it differentiates. So, in the part details it is showing that 55.7 x 78.4 x 10.7 of the thickness, this is the print dimensions and the final part dimensions would be 48 x 67.5 x 9. this reduction is due to the contraction in sintering. You can see from 40th to 55 around 10 % or 15 % 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, note the support material the, ceramic material also enters the pores of the material, the main build that is also to me wash, it will take 1 day 3 hours.

After washing you have to put in it dry that is 4 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 of it 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 patting 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 to 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 % of the time, at around 50 % of the time this much component would be printed it is showing how it would go up. So, here closely it would be 95 % and around 100 % of the component printed. So, 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 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 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.

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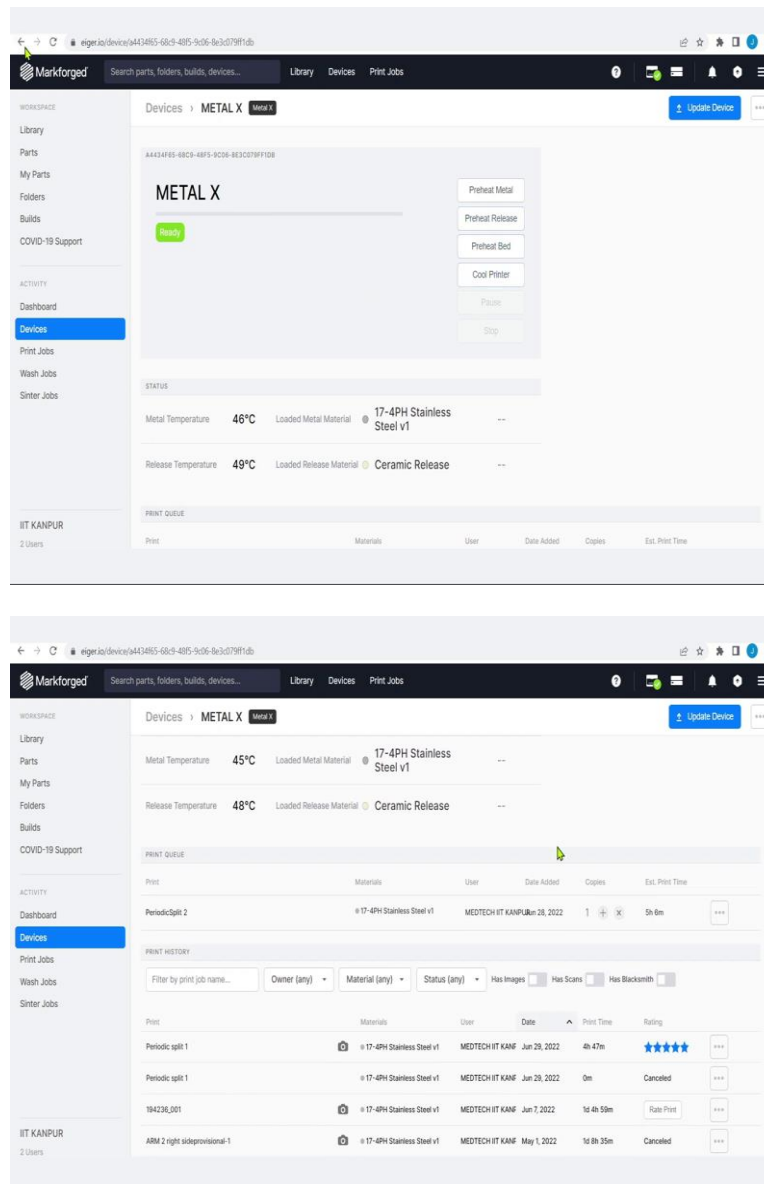
So, if I need to see in the Metal X that what is the position here or what is the situation here. So, in the screen it is showing that temperature metal temperature is 45 °s, release temperature 48 °s of the print right now and the loaded material is this and this is the position or the status of the metal X printer that is showing the pattern 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 ° and the release temperature is 48 °. 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.
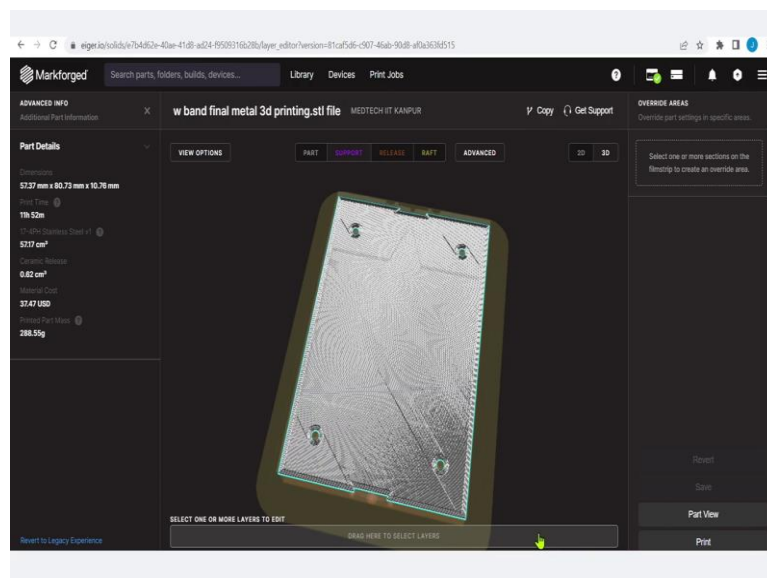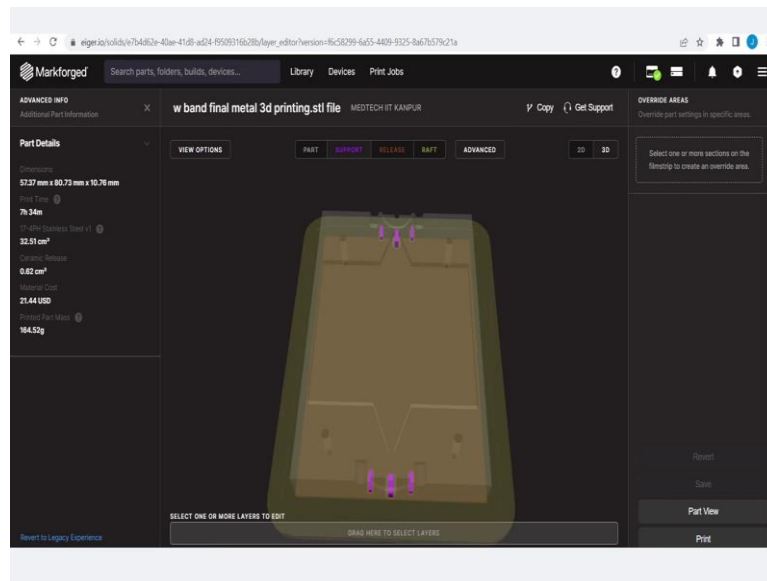
So, let me now come back these are all printing options like preheat metal is there, preheat release is there, preheat bed, then cool the printer sometimes if you need to stop or hold in between we need to cool down the printer that also is option available.

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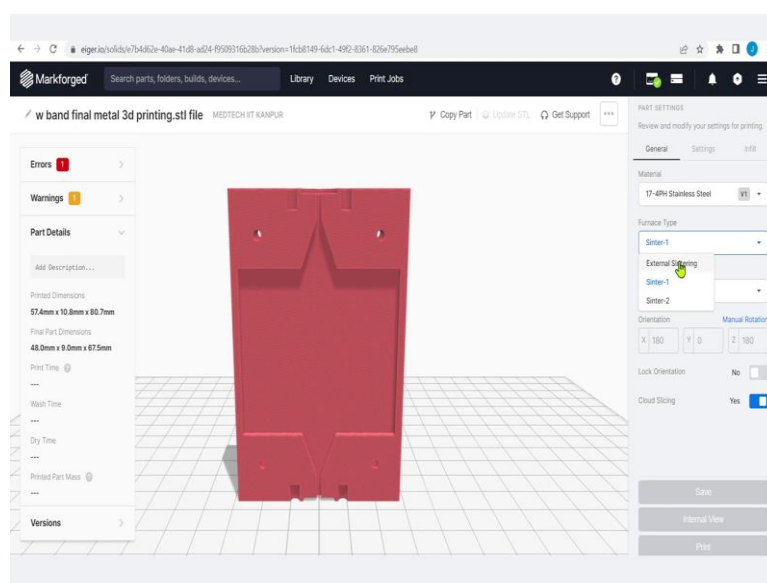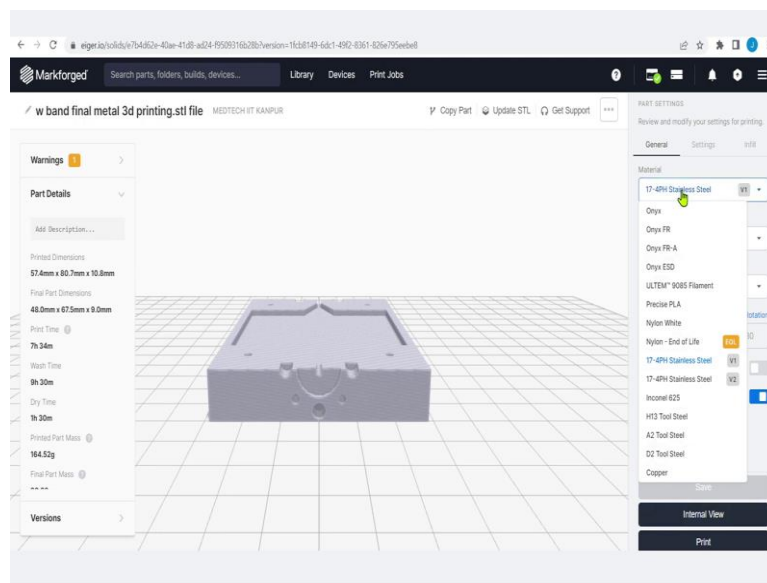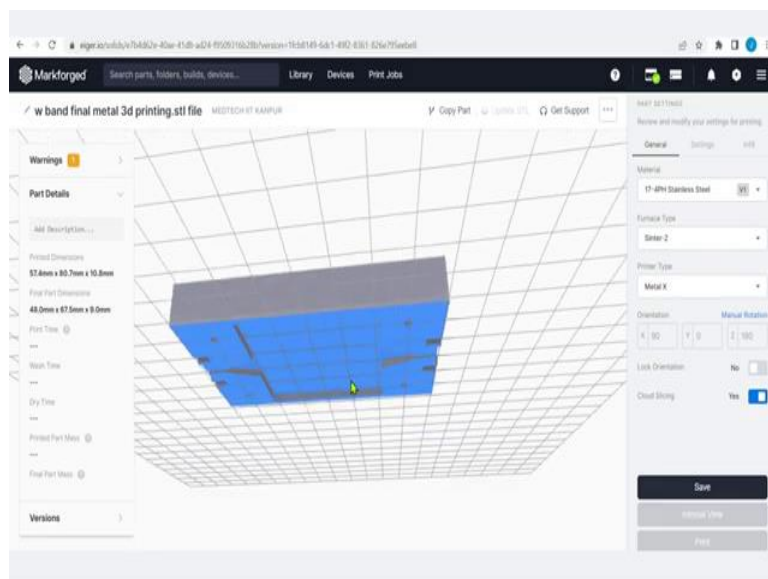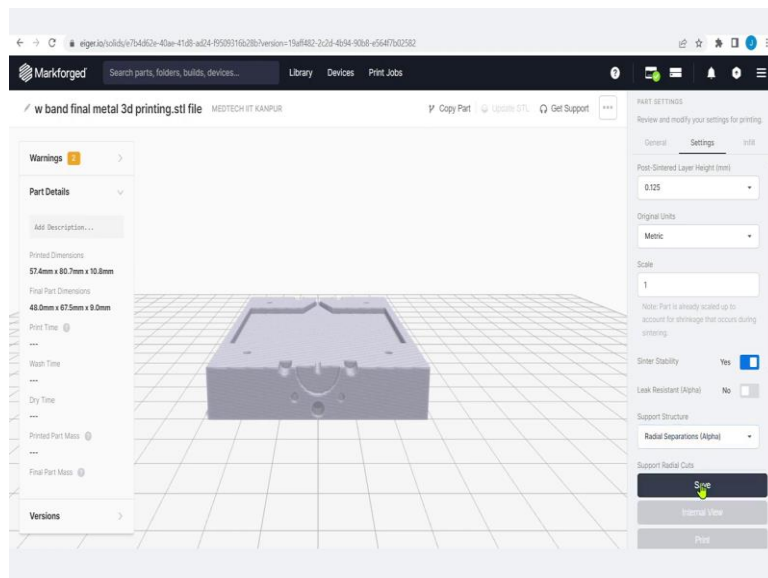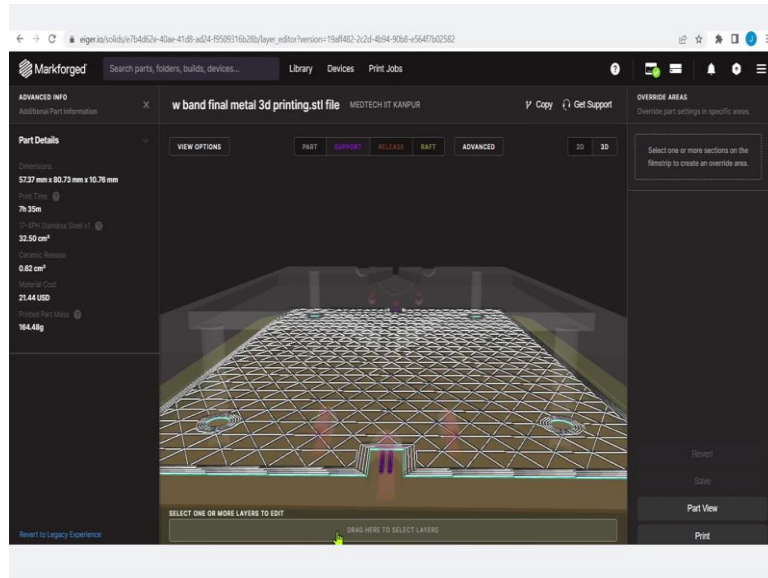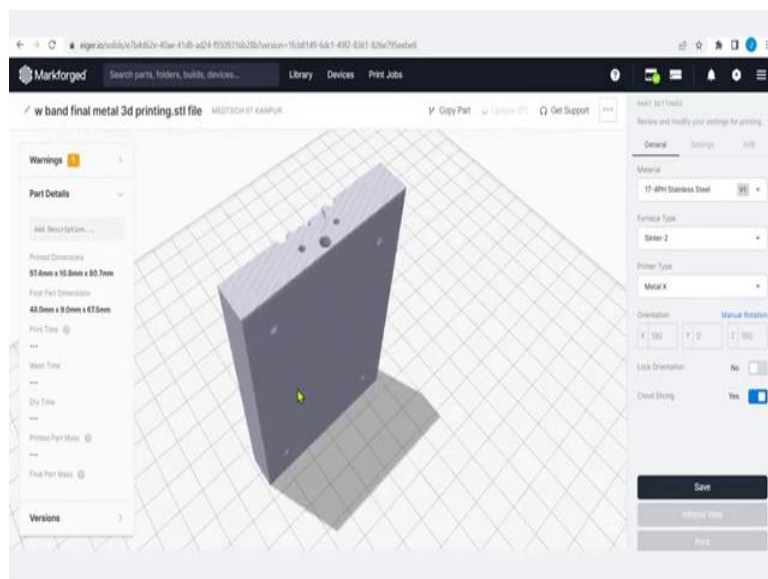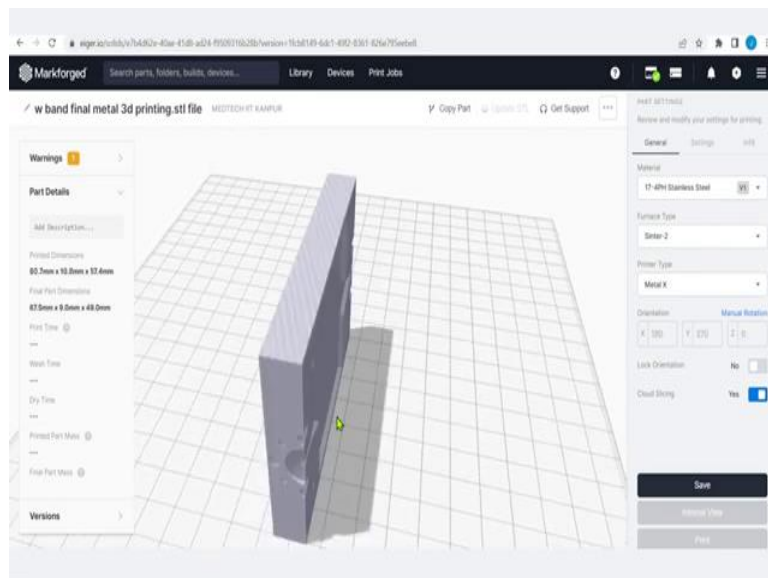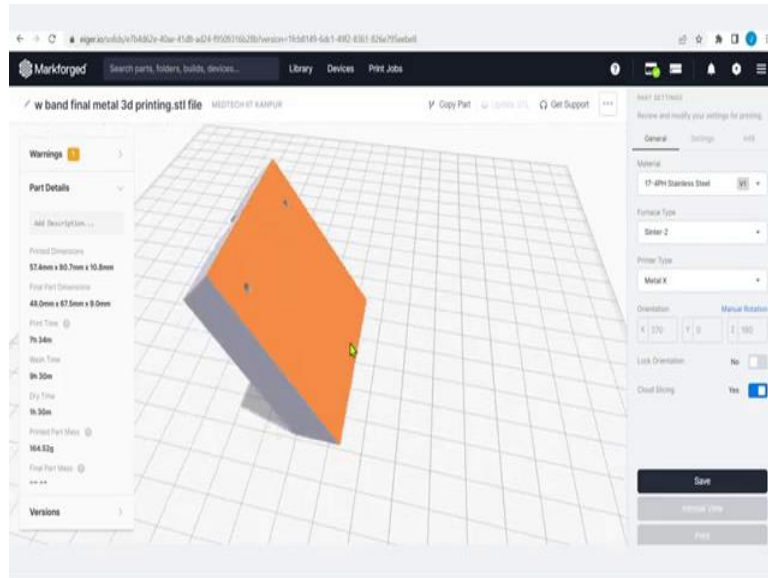
Let me come back to the screen where the component is shown already internal view is seen and then print is well, let us see the internal structure of the component. So, let me try to see the part settings at the right side. Copy this part to modify its settings. There are three options general, setting 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, yes, 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. So, it is nylon white, printers 17-4 PH steel, V1 and V2, iconel, H13 tool steel, A2 tool steel, D2 tool steel copper, these all different materials could be used.

So, this highlighted blue color that is the 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 and D to keep on 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 additive manufacturing using those materials.

So, we can select the printer, we can select 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 kept perpendicular here, just to show you another view. So, we can just put and drag it up and down. So, 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 will not be as good as we want it 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 not 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 will have to see or you can, if you are very confident that is it is correct you can go with the print or if you need to see some more details you can just look at the internal views.

Now, next is the settings 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, 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 determination is 100 mm if I have to scale if I put scale two the 100 mm will turn to 200 mm and all the dimensions will be double in in proportion. So, but it is also mentioned here is a note that part is ready but is already scaled up to account for the shrinkage this scaling up is not a shrinkage one.

Now, next is support structure and change the structure to cubic and again save it is taking it time to save the cloud slicing is in progress feel free to navigate away from the space. So, it is parting it and trying to create the cubic structure now, now again we can see the internal view it is loading the tool pass now the structure that is there suppose 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 the radial separations, again the internal view. So, for the radial you can see how is it showing now, the suppose structure in pink color. So, now it has now 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 the manual input, 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. So, how to how the support structures are, support radial separations, default suppose structure, cubic separations, depending on the requirement we can put different suppose structures. So, whether it is a circular support or whether it is a straight support. So, what surface do we had at the top of the support.

So, 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 transformed is also there. Overlay if it is there, suppose if something is overlaid, how do we transform that into R dimensions.

So, 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 connected 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, as you can see a gyroid infill here, this is gyroid. Now, here this is gyroid, this is gyroid. You can see the flow of the layers it is completely almost free, but this is almost a zigzag motion. So, this is gyroid fill. We can put different percentages for different kinds of the fills.

For example for gyroid fill we can put exposed infill, as node, yes then roof and floor layers will be required, how many layers in the roof and the flow do we require, 0.50 mm post sintered layer, how many layers of 0.5mm post sintered are required 4, 6, 8, 10, 12, 14, 16, then wall layers could be increased here that is 1mm post sintered layer, the post processing that is required that is the machining or surface is required.

Setting is required based upon that wall layers could be increased here, this wall layer could be increased 1mm post sintered for. So, in the solid fill we can just say it is only asking the wall layers here, it is again calculating and computing the part. 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.

Now, this is how a solid fill looks like. So, solid fill and the status at different percentage is 50 % when you have 40 %, we have around 25 % of the print completed you can see how this hollow 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 part, fine uploaded, and it is now saved in that 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 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.

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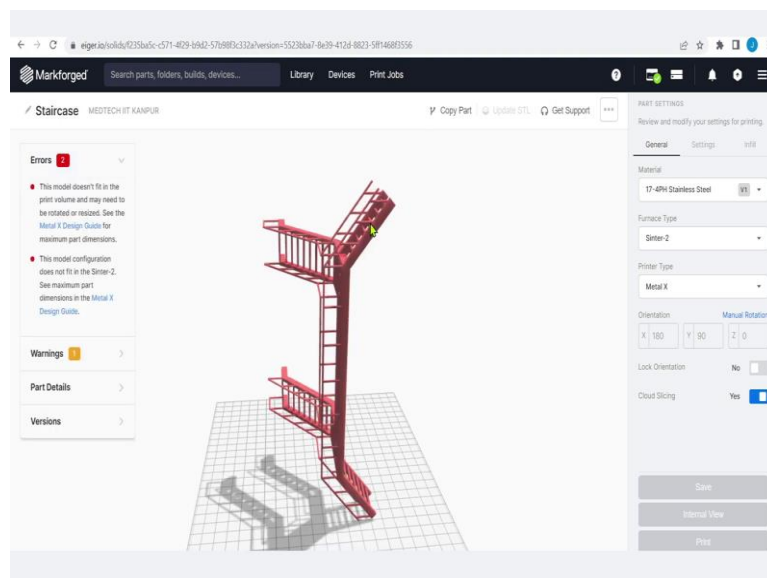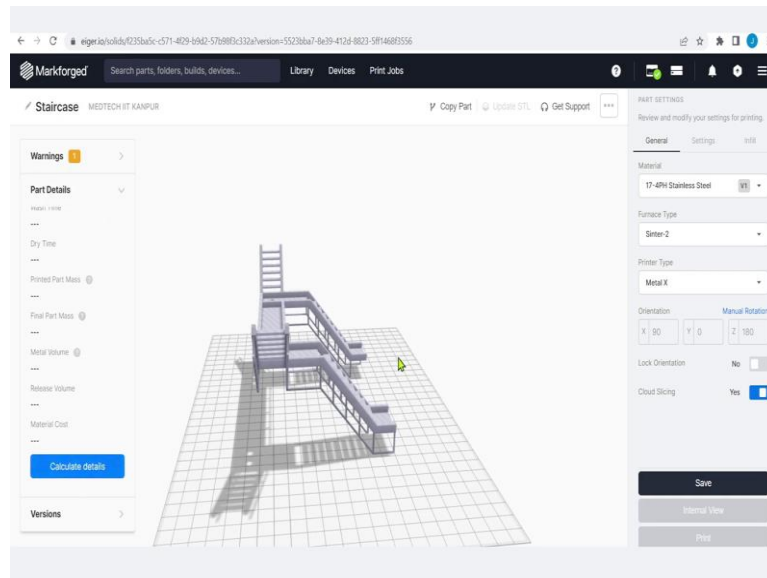
So, in the library. So, in the eager software again we have come to the library once again where we have seen the components which are saved here and let me open another component here this is the drawing suppose this is a drawing. So, this is a big drawing and this is a little complex drawing if we 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 supports and the time itself and wherever the minimum time is we can put it accordingly. Sometimes the component is also put in in angular position as well. So, we can calculate the details here this is another way we have inverted it we have we can put it in the vertical position, this is 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, a 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.

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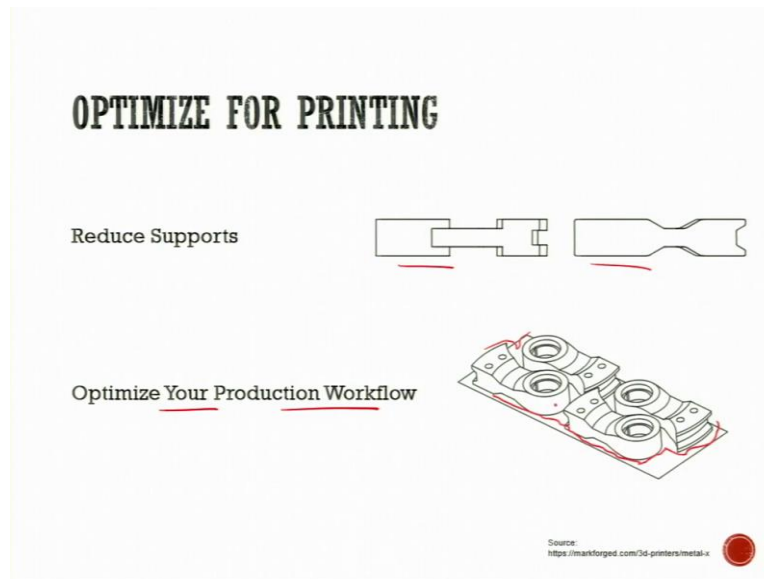
So, there are small suggestions like how to optimize for printing, how to optimize for washing and sintering and general strategies specifically in Metal X 3d printer. Some suggestions in optimizing for printing, first point is identify the critical dimensions. You can see the hole that is 6.6 millimeter into two holes are there, these holes are put here horizontally.

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 X, Y directions the precision is higher, this is how it is kept. So, identified critical dimensions and try to see where the strength is required higher. So, that would be kept on the bed accordingly.
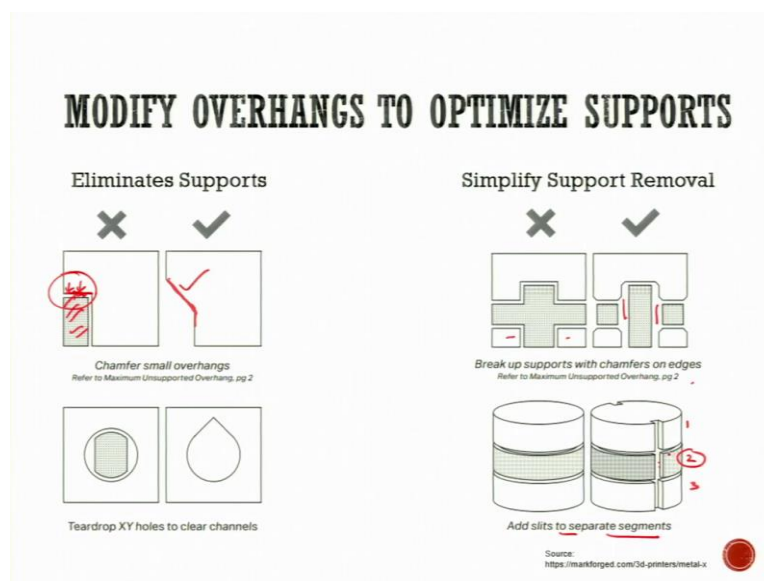
So, this is how do you do and maximize the bad contact, you can see this flange, this protruded surface, this is corrected with the bench. So, we maximize the bed contact because the more surface area with the print bed, it reduces or minimize the supports and improves the bed adhesion as well. So, which 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 for 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. So, this is a general setting or the casting or it may be in stamping as well these kind of settings the proper layout of the components is always there.

So, it is considered overall, the overall throughput of the component like for, 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 make minimize the batch costs. So, this is how it goes and the infill also could be designed here like solid infill is required or not or do we need a 90 % or lesser infill what kind of input would we have. So, this also minimizes or optimizes the cost of the printing.
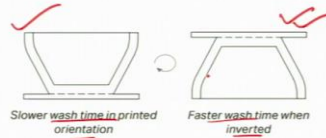
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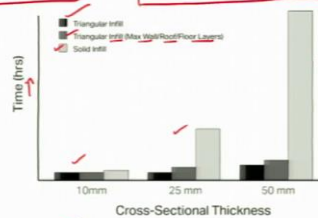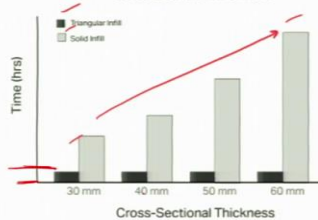
OPTIMIZE FOR WASHING

Shell Out Thick Parts

✗ ✓

Thicker part sections increase wash time

Shell parts for a faster wash time

Wash Bowls Upside Down

Slower wash time in printed orientation

Faster wash time when inverted

Source:
https://markforged.com/3d-printers/metal-x

TRIANGULAR VS. SOLID INFILL VS. THICK WALLS

Solid triangular infill wash time

Triangular Infill
Triangular Infill (Max Wall/Roof/Floor Layers)
Solid Infill

Time (hrs)

10mm   25 mm   50 mm
Cross-Sectional Thickness

Solid triangular infill dry time

Triangular Infill
Solid Infill

Time (hrs)

30 mm   40 mm   50 mm   60 mm
Cross-Sectional Thickness

Source:
https://markforged.com/3d-printers/metal-x

Then we modify the overhangs to optimizes 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, how 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 X Y holes to clear channels. So, to create channels the X Y holes you can say those are also connected in this way. The simplify support removal, support removal this support is difficult to be removed, for example these components here down there. So, we try to divide the supports into different parts. So, that it could be removed simply.

And also slits are also made here, slits are also separated here. Slits are there to separate the components this is one, two, three. Two is my support. So, to separate the components again a delineation proper has to put in between them. So, that is also here. Now to optimize the washing, the shell out the thick part is the 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 oral volume that is to be washed. So, the thicker rubber part is, it will be 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 my time would be minimum that will spend in the wash.

So, also we need to maintain the consistency in the wall, it is to be also taken care of. So the wash bowls upside down. So, slower wash time it is having faster wash time because when it is kept upside down and the washers solvent by weight is lighter than the binded 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 X only that floral triangular infill wash time this is a triangle full black one the dark grays triangle fill with maximum wall roof or 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, it 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, it is a really critical decision that needs to be taken now solid triangle infill dry time as well. So, saw the triangular infill, solid infill you can see for the different cross sectional thicknesses again the time for 30mm, for 40mm, 50 mm for all for 60 mm the time for triangular thickness is just this small units only but as the thickness is increasing.

Because it is solid infill here the time is increasing. And this time again moving more than 10 times of the time it is taking for trying 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.
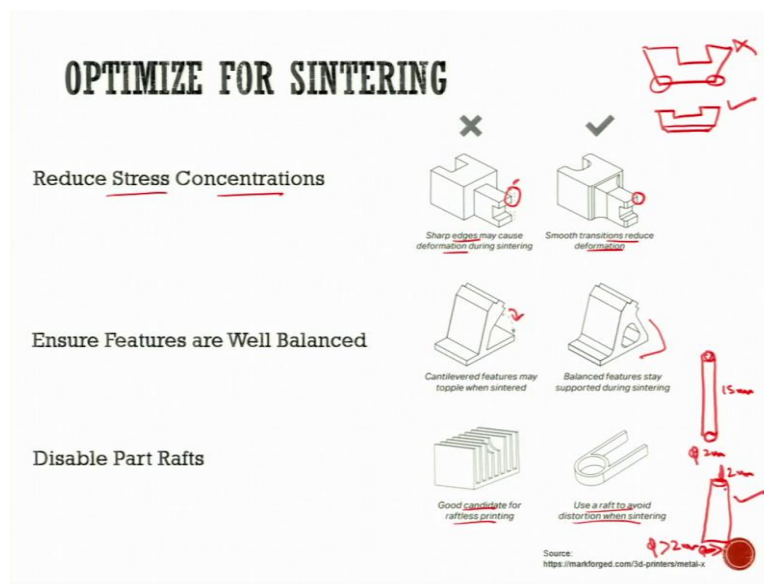
Now, for sintering there are certain suggestions, reduce the stress concentrations because in the sintering contraction has to happen, in the contraction the edges here you can see this, this edge here and this edge here this is a chamfered edge. So, we smoothen the transition to reduce the deformation, in the sharp edges may cause deformation during sintering because this sharp edges would induce in themselves, the thermal stresses.

And when sintering happens the contraction happens, they pull themselves together as they shrink. So, to reduce the stress concentration, so 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. So, 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 disable part rafts, the part raft for example, there 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, 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 the rock 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 lag 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 like, for example, this is one component, it is let me say this is the component it is sharp at the bottom, in the shrinkage this will also induce stresses just like this, just like this. So, it can also have a chamfer here, chamfer for fillet here, this is correct, this is not correct. So, the bottom edges could be chamfered, fillet could be provided and suppose if they are some components in which heights to width ratio is very high, it is 6 times of it and this is a component of example.

And this is let me say 2mm, phi 2 mm and this height is 15 mm. So, in this case it is suggestible to have a component something like this, this is phi 2mm. This is phi larger than 2mm, larger than 2mm. So, that the tall or thin features which are more than 6 times of their cross section height should not be freestanding. So, for these free standing features a raft 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. So, this could also be one of the suggestions.
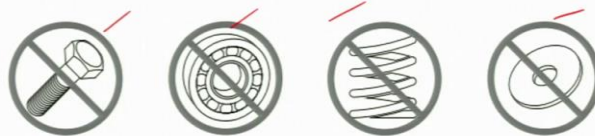
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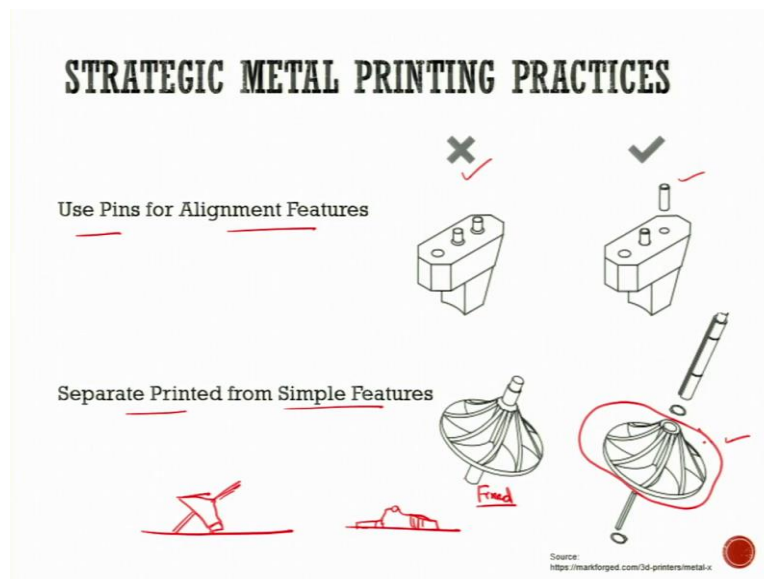
STRATEGIC METAL PRINTING PRACTICES

Isolate Properties with Modular Features

Source:
https://markforged.com/3d-printers/metal-x
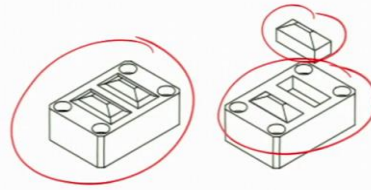
DON'T PRINT YOUR HARDWARE

Source:
https://markforged.com/3d-printers/metal-x

So, 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 a 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 one's part or using shoulder bolts for the location. So, doll pins pressed into the gripper jaw located onto a robotic arm.

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

So, it can be only 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, 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 1 and module 2. This was a single component. So, to separate the component with modules means we can isolate the metal insert and separate the part that localizes metal properties to only the region where they are required.

So, then also it is suggested that do not print your hardware like bolts bearing, springs, washers, these are available generally in the library. So, these are not suggestible to be printed directly. So, with this 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.

We will meet in the next week and try to discuss more on the costing, the safety features in metal additive manufacturing. Thank you.