Metal Additive Manufacturing
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Lecture 41
Metal 3D Printing Laboratory Demonstration

Welcome to the session of the demonstration on Metal Additive Manufacturing. I believe that you are now well aware what is additive manufacturing, there is a file, that is a CAD file, we convert that file into the SQL format and layer by layer we try to develop the build ultimate or the body or the object that we might do produce.

So, with additive manufacturing is in various forms, it could be polymer, it could be wood ceramics. Metal additive manufacturing has now taken new leaps. There are certain printing companies, printer developing companies like 3D Systems is there, Ultimaker is there, Markforged is there, those have developed multiple kinds of metal 3D printers. It depends upon the size of the things that you like to have.

So, the size of the printer that it can hold is known as work envelope, it is the maximum three-dimensional size, 'X × Y × Z' it can print. more important point is the sinter. Before that I would like to tell you, there are three major components of the printer, one is we do printing. In printing the method comes through an extrusion nozzle, it is in the form of wires here, the filament.

So, it is printed, it is melted and then the metal, the object is printed. After the printing there is certain support material, impurities which are not required in the final component, those are to be washed. This is done through a washer. Third component is sintering. Sintering is when the component is obtained from actually printing, it is a green component, it is too fragile.

If the component falls or so, see it might even break. So, it has to be now heated to the specific temperature depending upon the material, the certain material, we have stainless steel, copper, inconel is also coming, so many materials are available in big range is developed by our supplier, Markforged.

So, depending upon the type of the material you people might be aware of the processes like annealing, because we have to slow down, we have to heat the temperature towards critical temperature, then it has to be slowly cooled down, so that it is solidify, that it becomes a total solid and the usable metal material, that component or that machine part is known as sintering.

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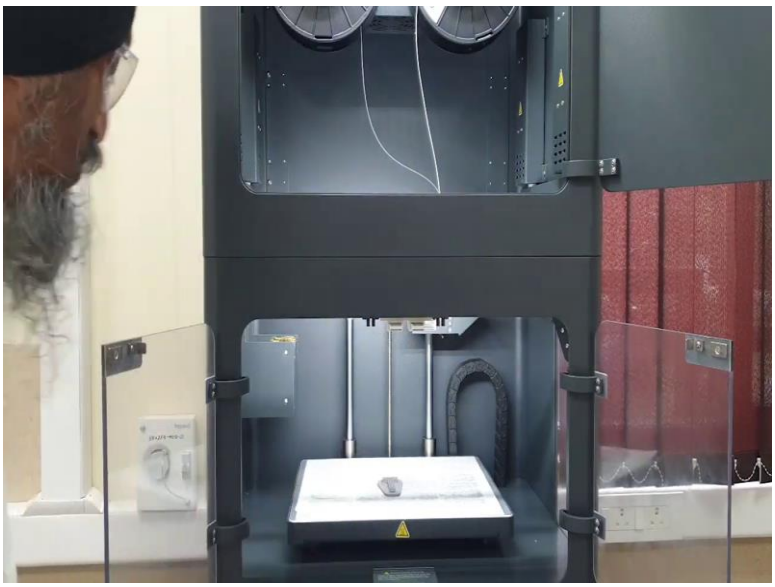

So, let us now see the printer. This is metal 3D printer which is Markforged metal printer. Markforged is one of the pioneers, who is working in now even multi-jet printing. When we say multi-jet printing, in multi-jet printing, the printer is might even overshoot the conventional machine methods.

The only drawback in the additive manufacturing is the processor is still known to be slow because there is single nozzle, it has some limit that up to maximum speed, but it can go and it can build the material. So, when we have a multi-jet printer, in multi-jet printer multiple jets would come and try to print them in one loop.

So then, it will become easier and faster for the printer to print. Cost is another factor that is also being performed by many of the developers. So, let us now see the printer that we have. This is the printer, metal 3D printer. This is a washer I just talked about. And I also have a sinter we will come to that. So, in this printer there is certain recommendations are there and certain instructions are there.

Very important instructions before using the printer. The major, I would say is we have to prepare the bed for that, we have to prepare the material, we have to vacuum that. What is the purpose of vacuum so that there is no impurity, no gases, no whites left in there so that we do not have any kind of the effects in the final build that is made?

When I say build or object or, by that I mean the final print that I am trying to make. So, let us now see closely the components of this printer. This is the beautiful box. It has an extruder setup. It has a bed. This is a work envelope. So, we can just see the two filament spools here. So, you can maybe come closer. So, the two spools, two spool motors I would say, two spool motors are there.

We have, this is the metal spool through which metal filament is coming. Right now, what we have held here is a stainless steel. The stainless steel is specific grade of stainless steel is developed by this company, when I say specific grade, they have developed full parameters for this.

Parameters means what are the parameters to control the temperature depending upon the thickness of the walls, depending for the infield that we have in the material, depending upon the density, depending on the print size and angles; so, all these parameters are to be optimized by the company when they supply this material.

So, this is a filament, this is stainless steel and at certain times, because metal 3D printing. Suppose this kind of print is to be built, it has to have supports in, between because this is a cantilever kind of a beam, which cannot be held in air, so we have to build certain supports so that it can maybe build this thing fine.

To remove these supports, so that this push does not become the part of the main plane, we have to put some coating in between, so that it is removed easily when we put it to the washer and certain support which is removed from that or when we, after this sintering should move, for that a certain parting material is used that is our ceramic.

So, both of these tools, if the software understands what is the shape of the print, what is the size and what is, what are things which we are doing? it takes accordingly. Now, this is the major I would say spool and the extruder setup at the top. I will show you the extruder now. So, this is an extruder, the extruder of the printer.

The extruder has you can see the two inlets, which are coming up. So, most important part next to that is the extruder nozzle. I am opening the door of a printer because there is the green part, we want to run for you because to print in front of you I can say it takes several hours, maybe around tens of hours, maybe 20 hours, 30 hours, that time if it is a small print it might take five hours or so.

So, this is a green part that is ready. So technically or according to the instructions if I say I should not touch this with hand. Right now it is not that hot, I have tested, there are ways to pick, we will show you all the tools as well. So, this is the extruder. Most important point is the nozzle.

The precision I would say or the resolution that is the minimum feature size that we can get in the print depends upon certain factors. One of the major factors is the nozzle diameter. Because what is the nozzle dia, only that kind of the thickness of the material coming out would come and that also determines your precision. So, this is one of the component we have shown.

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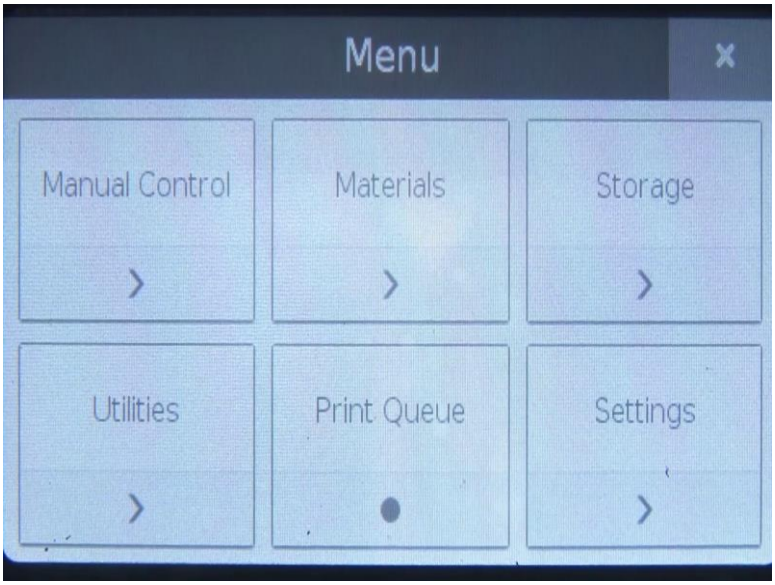
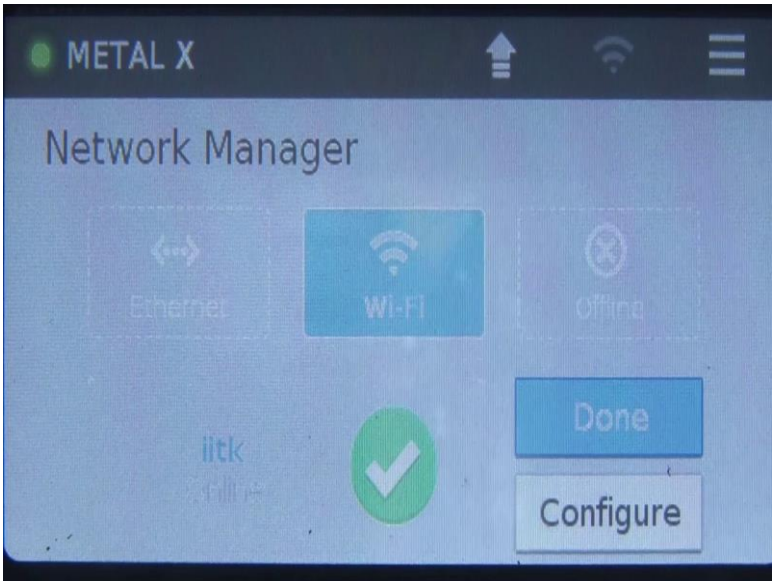
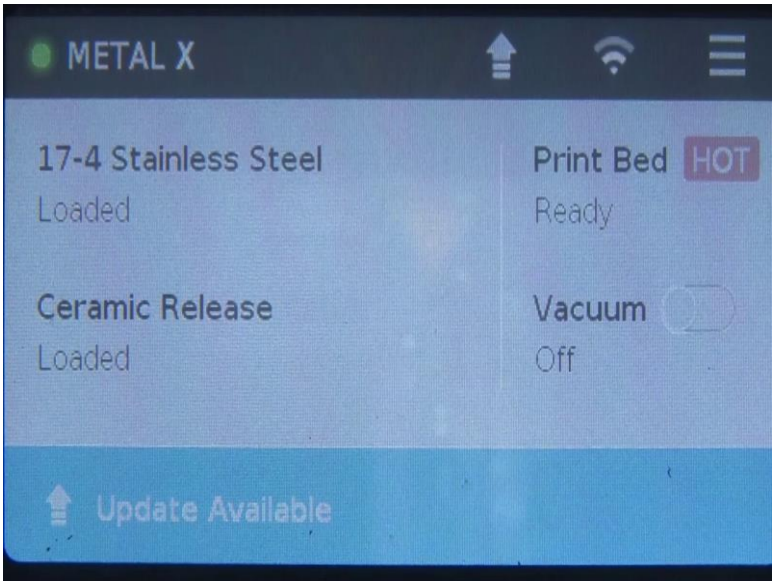
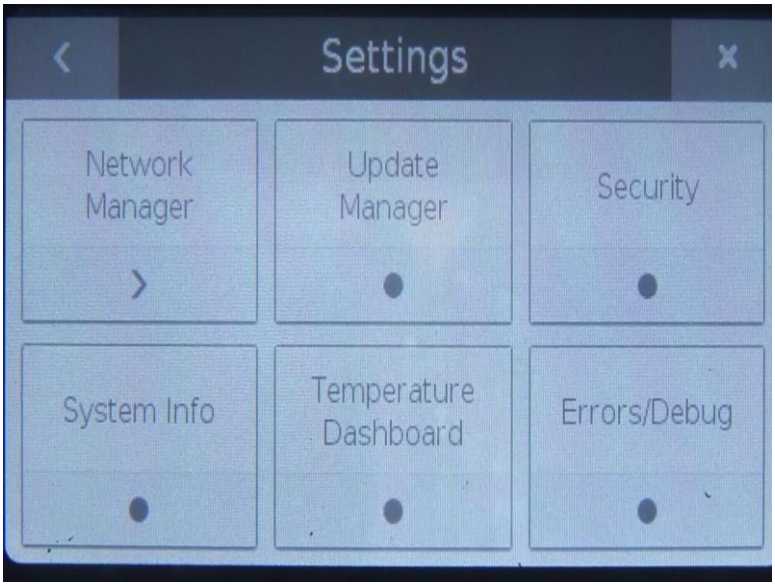
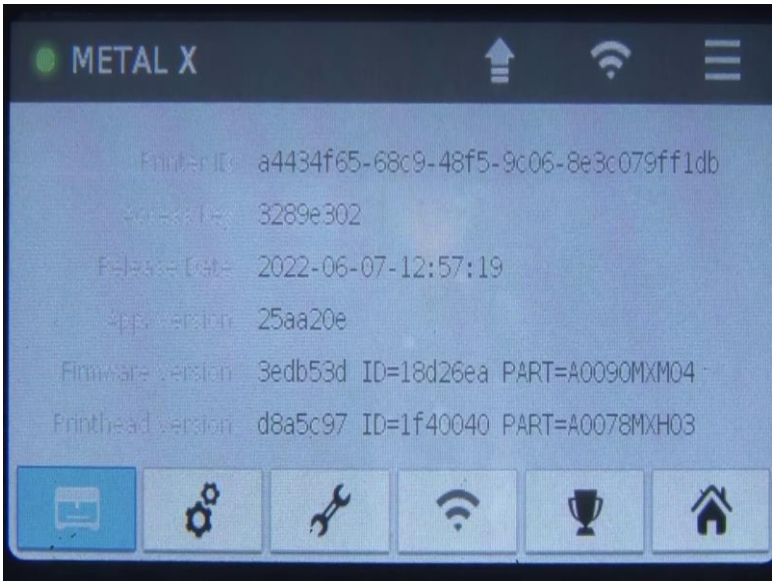
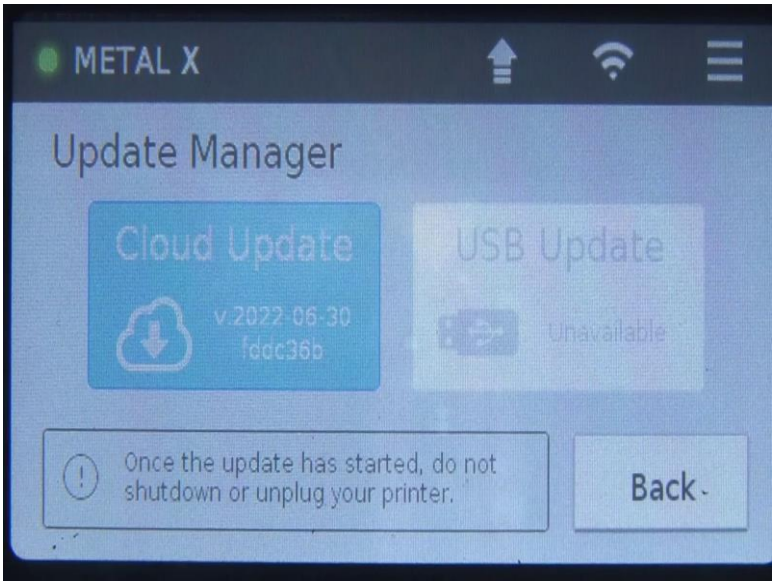


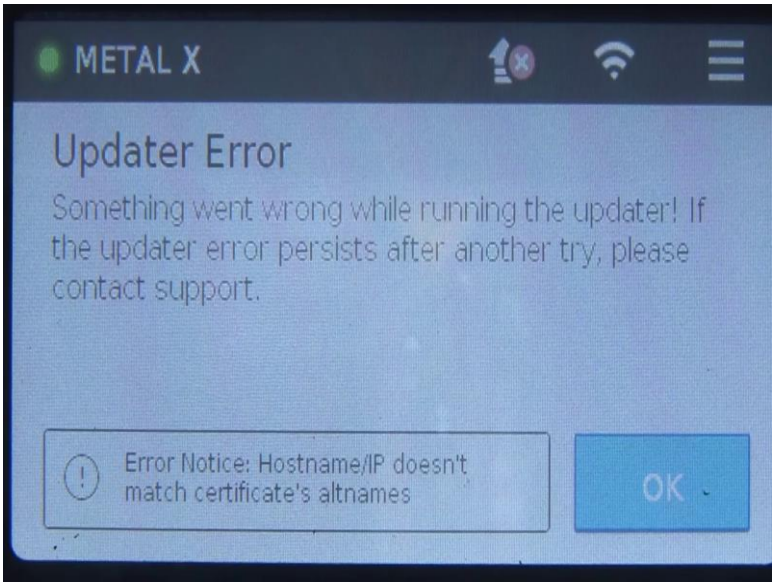


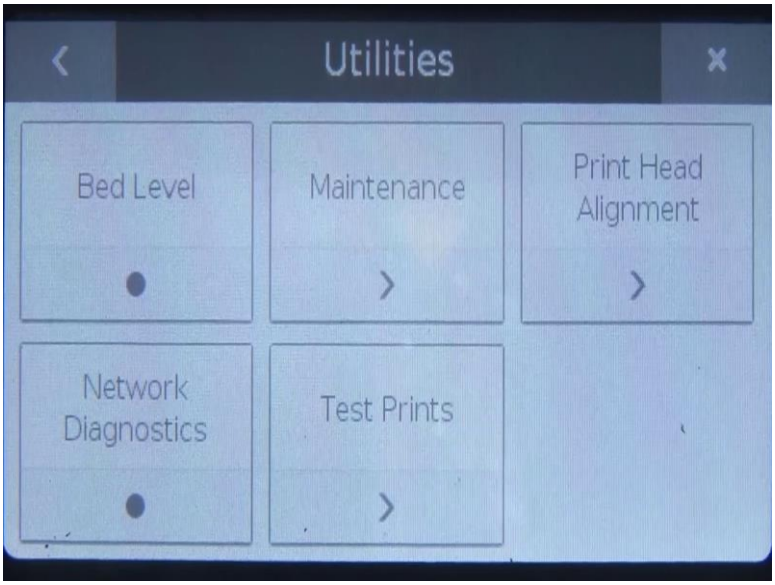

METAL X
17-4 Stainless Steel
Loaded
Print Bed
HOT
Ready
Ceramic Release
Loaded
Vacuum
Off
Update Available

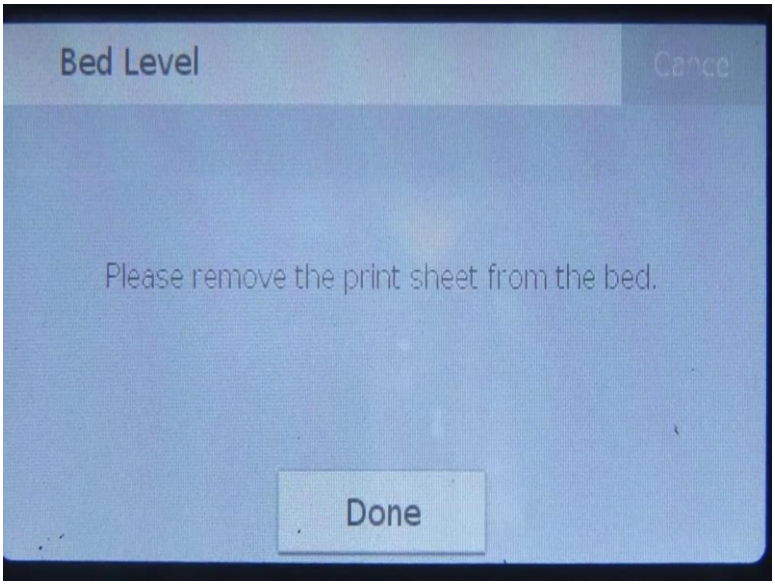

Settings
Network Manager
Update Manager
Security
System Info
Temperature Dashboard
Errors/Debug

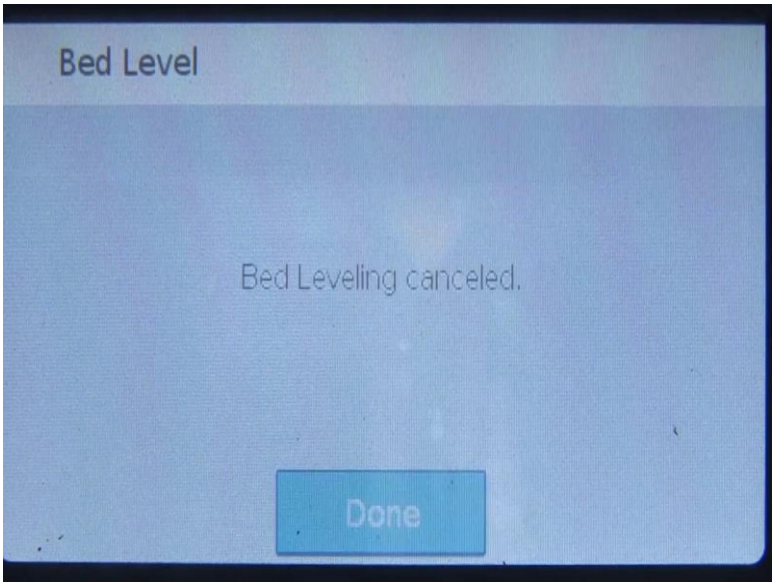

METAL X
a4434f65-68c9-48f5-9c06-8e3c079ff1db
3289e302
2022-06-07-12:57:19
25aa20e
3edb53d ID=18d26ea PART=A0090MXM04
d8a5c97 ID=1f40040 PART=A0078MXH03

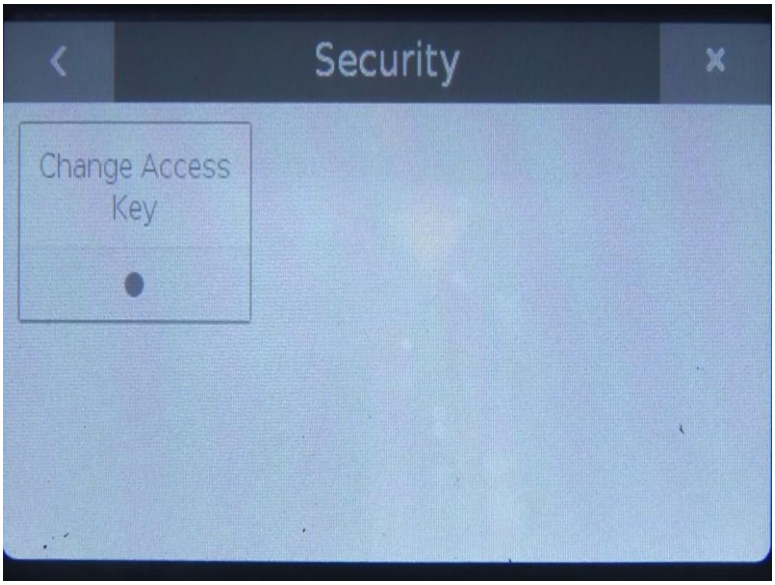

METAL X
Update Manager
Cloud Update
v.2022-06-30
fddc36b
USB Update
Unavailable
Once the update has started, do not shutdown or unplug your printer.
Back

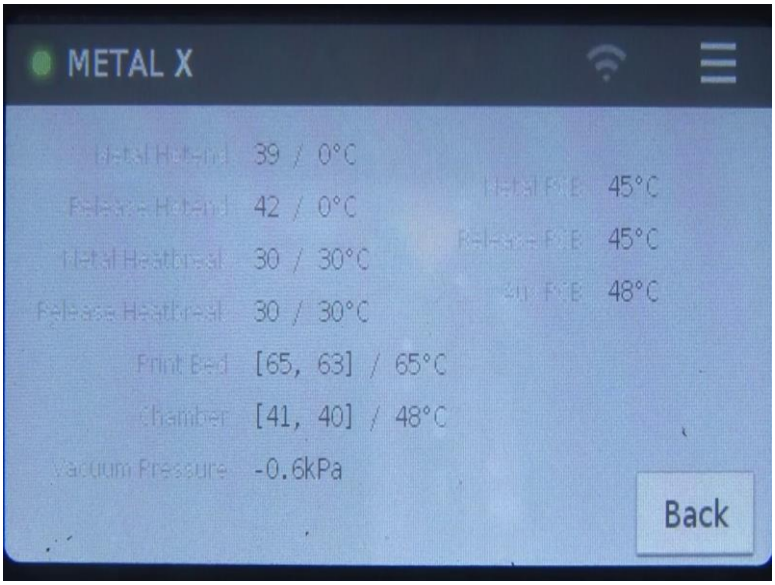

METAL X
Updater Error
Something went wrong while running the updater! If the updater error persists after another try, please contact support.
Error Notice: Hostname/IP doesn't match certificate's altnames
OK

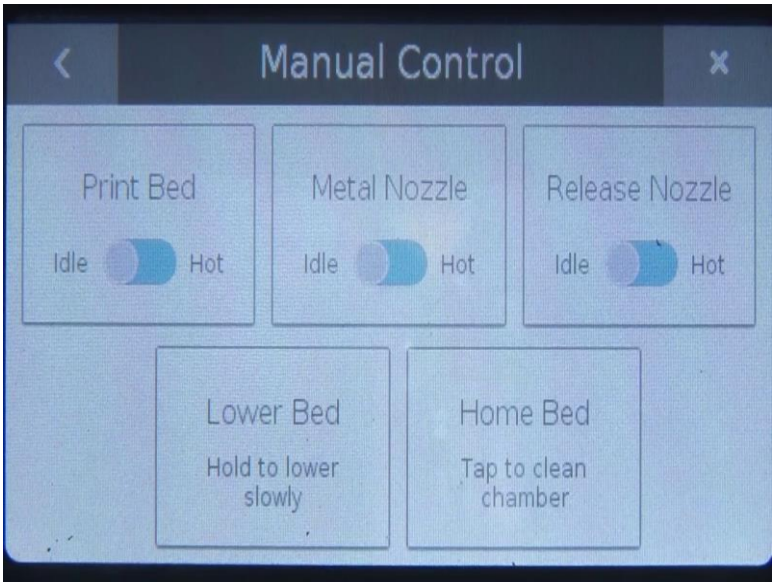

Utilities
Bed Level
Maintenance
Print Head Alignment
Network Diagnostics
Test Prints

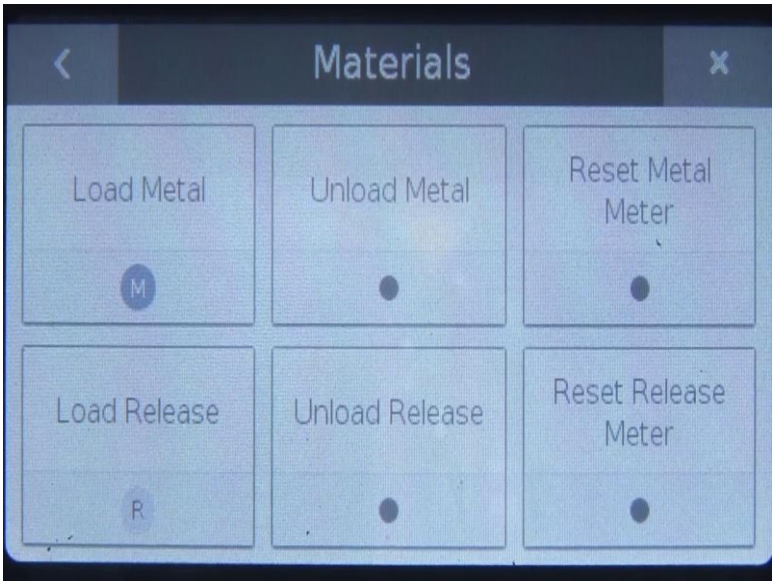

Bed Level
Cance
Please remove the print sheet from the bed.
Done

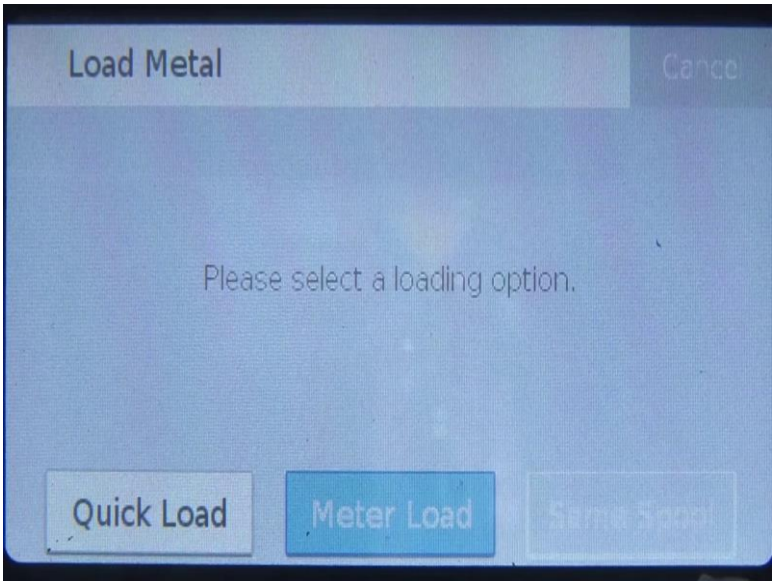

Bed Level
Bed Leveling canceled.
Done

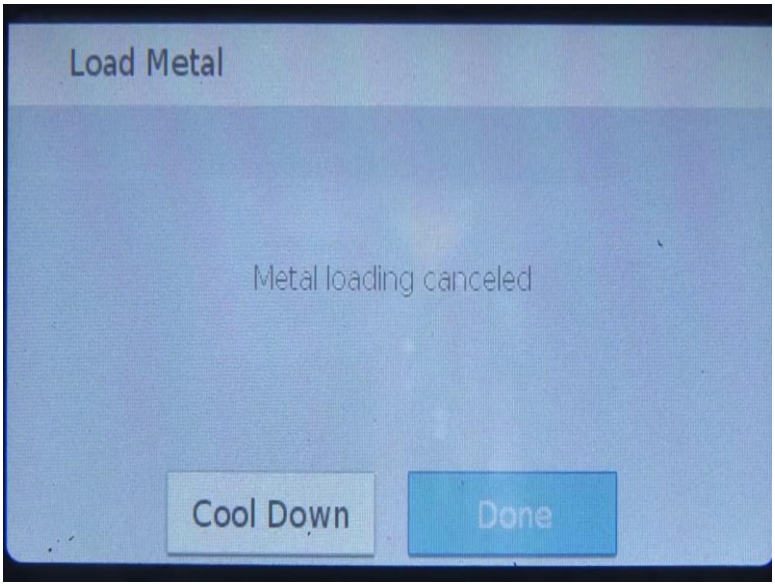

Security
Change Access Key

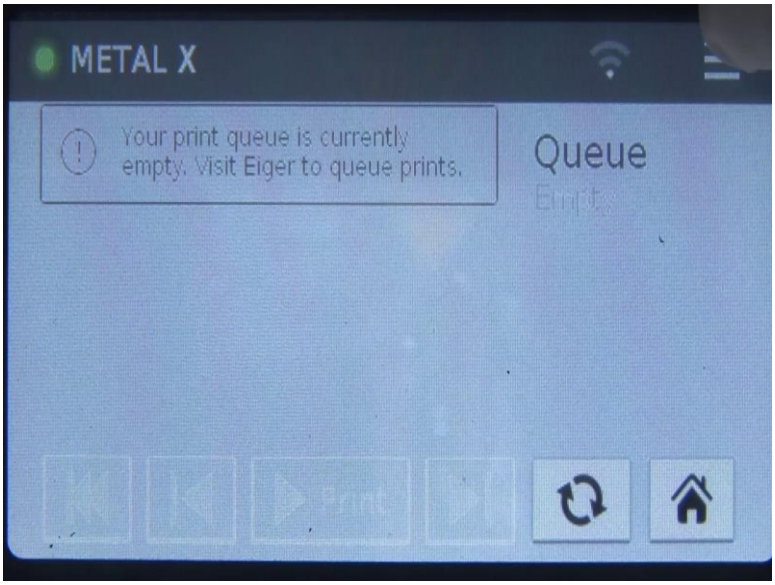

METAL X
39 / 0°C
42 / 0°C
30 / 30°C
30 / 30°C
[65, 63] / 65°C
[41, 40] / 48°C
-0.6kPa
45°C
45°C
48°C
Back


Manual Control
Print Bed
Idle
Hot
Metal Nozzle
Idle
Hot
Release Nozzle
Idle
Hot
Lower Bed
Hold to lower slowly
Home Bed
Tap to clean chamber


Materials
Load Metal
M
Unload Metal
Reset Metal Meter
Load Release
R
Unload Release
Reset Release Meter


Load Metal
Please select a loading option.
Quick Load
Meter Load


Load Metal
Metal loading canceled
Cool Down
Done


METAL X
Your print queue is currently empty. Visit Eiger to queue prints.
Queue

So, let us now show you that to setup the printer. So, this is the closer look to the display of the Metal X 3D printer. So, in this you can see, it is showing 17-4 stainless steel is loaded, ceramic release is loaded. These two filaments are loaded here. Then they say the print bed is ready. Definitely it is hot, when it is ready and the vacuum is off as of now.

So, let us see these options which are available here. You can see three icons at the top, there is a black part at the top, there is a blue bar down there. In the blue bar there are some updates are available from the previous position that you had. And on the black bar it is showing three icons. So, these three lines if I click here, it will show the menu.

Here, in this menu, we have manual control, material, storage, utilities, print queue and settings. These six options are here, so how to connect this machine online using Wi-Fi, so all these things could be. Here then we have this another button that is the network manager. In the network manager options are Ethernet, that is using connecting a bus or Wi-Fi or I believe we could use it offline as well.

So, at this point of time, so it is it was added Ethernet, so we clicked Wi-Fi now. So, it is showing the IIT K. IITK internet connectivity is here. You will see it done. Now it has connected using Wi-Fi to the internet. So, if the internet is not connected properly, so it will not work. So, this is connecting to Wi-Fi, this is one of these steps.

So, again let us come to menu. We have these six options here. Let us see what settings are available. In the settings if you see it is showing the network manager, update manager, security, system info, temperature dashboard and errors or any debugging if it is required. So, let me click this system information. So let us click the left bottom option, system information. This is all touchscreen.

In the system permission you can see the print information, the release date, the firmware version. It is showing what is our system and when is to be this updated next sometimes, it shows that. Now, coming back to the main menu, using network manager we generally connect to the Wi-Fi network or so.

Next, second option is update manager. In update manager it is asking whether you wish to update the system, there is a cloud update available. USB update is also one of the options. So, once the update has started do not shut down or unplug your printer. So, there is a message here. So, USB would mean we have downloaded the update on a USB then we connected USB to the printer.

So, some errors if there is come to in update it also shows, okay the update is not proper, update is still required, it will keep on giving those messages. Again, coming to the main menu, settings, update manager is now somewhat touched. Now, let us see next is utilities. In the utility five options, bed level, maintenance, print head alignment, network diagnostics, test prints.

Three options are there, which could be done, which could have taken care using the screws down there in the bed. So, we can select the please remove the print sheet from the bed because before setting the bed level one has to remove any setup if it is there. So, we cancel it as of now. We will say done. So, it has come to the main menu once again. So, all these options have different sub menus in them.

And in the security if you wish to see we can change the access key, system information is done. Next is temperature dashboard. So, temperature dashboard is showing the bed level, the metal hot and the release hot end, so all these temperatures which is right now there it is showing it here. Again, the menu, settings. Now errors, in case some errors come those are to be cleared, then we have to come to the error tab here, I will try to work on that.

Let us come to the manual control, which is mostly used. So, print bed, metal nozzle, release nozzle, lower bed, home bed, these options are here. Now materials either we can load or unloading materials, reset the metal meter, load release, unload the release and reset the release meter. So, if something is, some material is stuck so how to start from there, how to start or load the filament spool back there.

So, all these things could be taken care using this menu table. To load material, it will be showing now the please select the loading option quick load, meter load or same spool. This spool is already going, working, so it is stuck for some various reason. So, we can say same spool as to be continued that it starts working.

If the spool is consumed then we quick load it and try to start the same spool. The meter load is we try to measure this spool and try to load it the new spool. Unload also has similar options. So, when the nozzle is stopped generally, then unload metal is used. We have to unload and the nozzle cleaning has to take care of using the small hard tools which are available for cleaning.

So now, there is an option storage. So, this is for storing the systems. In the print queue we can also see whether something is already there in the queue and how long would it take, it is

right now, so nothing is in queue. So, setting the bed level number of screws in the bed and positions of the screws and how to label the beds using the screws and using the options here available in the display menu of the printer, all these things could be seen.

So, let me come back home, this is the home window of the display. So, what is loaded here is once again 17-4 stainless steel as the main print material, ceramic release for the parting material wherever the supports are to be removed.

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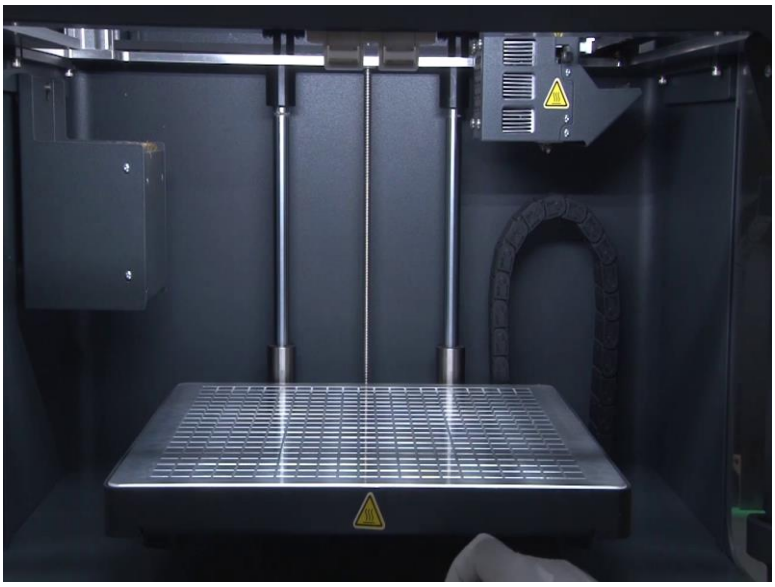

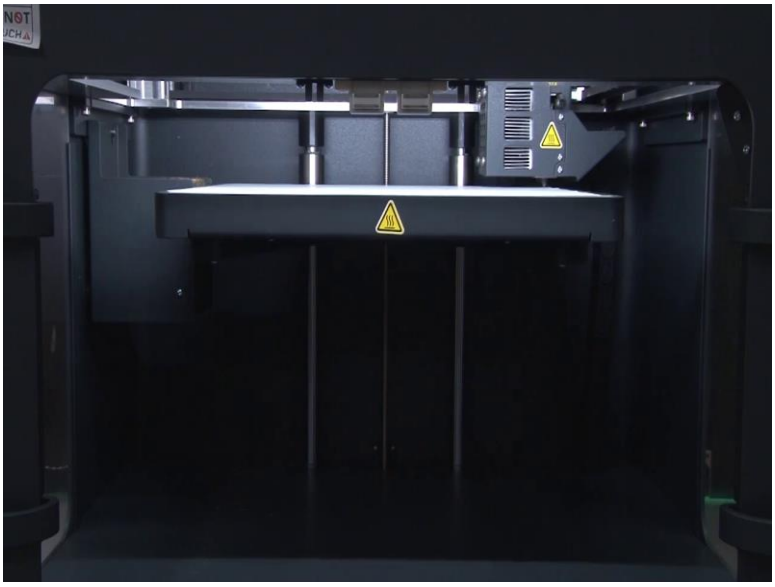

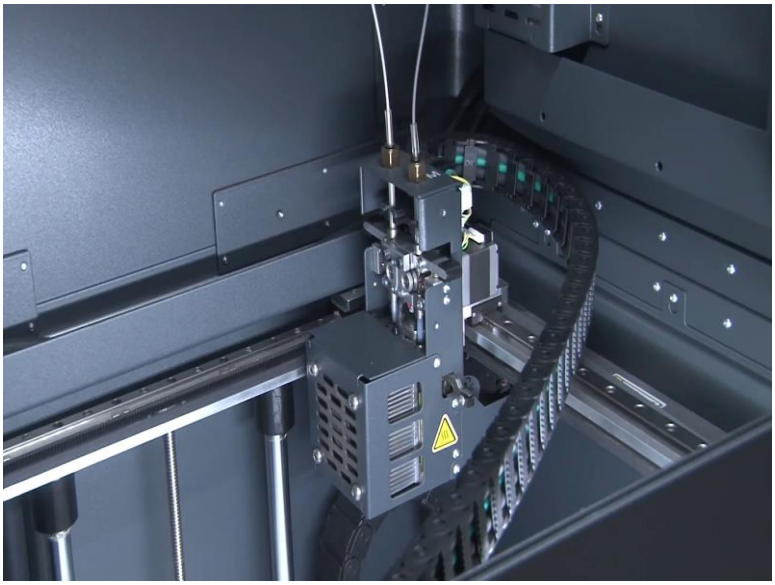

So, let us now come to the main printer volume here. So, if we come to the manual control here it is showing print bed metal nozzle, some options are being shown here. Home bed, if I click home bed here, it will try to do homing for the bed. Homing for the bed means it should try to bring bed to a position and try to see whether the nozzle and the bed head could work to the all the extremities.

So, to the extreme X, extreme Y, extreme Z. It will make sure that the machine is working properly. This homing is generally one of the processes or one of the starting process of, starting tasks that is always there in a CNC system. This is also a kind of a computer control but additive manufacturing system.

So, X, Y was all checked. X, Y it was checked, then now Z X is being confirmed for the working to the extremities. For example, the volume for this printer if it is X Y Z in the Z

direction, it is now checking. So, it is making sure that the nozzle tip touches the bed. In the screen it is now, it will not display as operation completed.

At least the bed has now come to the proper position. So, there are screws down there, we just talked about. Three screws are there so using the torque wrench we can adjust the screws if the bed is not leveled properly. So, this is a manual setting for leveling the bed. This is what is homing of the bed. Now, it is now coming down back. It will come down to the base position where the vacuum could be created.

That means the preparation of the bed has to be there. For the preparation of the bed the temperature of the bed has to come up to the print level, so that the print could be started here. So, bed has come to the low position now. We can stop it anywhere, wherever we think, wherever we find it appropriate. So, you can see small serrations here on the bed, small I would say grid is there in which the holes are there.

That is for the use of creating the vacuum there. So vacuum on and off could be done on the screen. If I say vacuum on, the holes will try to pull the air from there and this sheet will be attached or fixed to the bed using the vacuum and that is, then this sheet will not move just like it is moving right now. Once the vacuum is generated this sheet will be fixed and it will not move.

But this is the head of the extruder in which two filaments are there, ceramic in a white color and SS in the silver color. So, this is a cap, if I open this cap you can see something here inside. So, the both sides we have the extruders here. So, there are separate extruders here for metal and for ceramic, so we can unlock and unload the any activity that we require.

We can load and unload using this. So, we have nozzle down there. So, nozzle helps us to extrude the material and we have the heaters here that melts or fuses the material. So, like certain materials copper, Inconel, SS, nylon, all these different materials are being used or could be used using Metal X printer.

So, along with this we have tool steels like A2, D2 then we have lower tube housing here, then upper tube housing here. So, low tube housing if it is to be changed then this part could be open and housing could be changed. These all options are available here. So, this is all a hard setting or maybe maintenance and repair of the printer.

So, this is the print head. I will not say extruder, actually this is the print head, extruders are the parts of the printer. So, this is the complete print head to have a closer view. So, two of

extruders are there one for the ceramic, one for the metal. The metal in this case is 17-4 PH or that is stainless steel. So this is how the printer looks from the inside.

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METAL X
17-4 Stainless Steel
Loaded
Print Bed
HOT
Ready
Ceramic Release
Loaded
Vacuum
Ready
Ready to Print

So now we are again back to that position where we will show you how we open the printer, how does operation start and the steps in that? First step is creating vacuum, vacuum is very important, so that the layer, this material gets stick to the plate. So, he has opened the window now. We will show you the description.

Now this is a polymer brush, the polymer brush that is used to clean the printer. Cleaning this whole processing on the printer preparation. In printer preparation, the first step is cleaning the printer for any impurities for the last print that has happened or maybe some dust might have come. The printer is recommended to be kept in a closed environment.

So, we have air conditioning warm at 25 ° room temperature everything is set right here, it should be cleaned. So now, we have put the paper that is given by the manufacturer itself. So now we can see the display, what he is clicking on the display. So, it is showing the material that is there. The material right now is 17-4 stainless steel.

So, it is showing certain options that material, yes, material is loaded, ceramic release, yes, it is loaded. The print bed it is hot, that means it is ready. The vacuum it is not yet set, that is what we are trying to do now. So, print bed hot implies the print bed has to come up to temperature of 50 to 70 °. So, the print is easily removable from that. So, that is the temperature of print.

And the temperature for the nozzle I have already told it goes up to 240 °, depending on the material. The temperature is set. When we say 17-4 stainless steel that is already entered in the software phase here, we actually have three, one is the machine that is a material that is a working with the printer, second part is a software, third part is the print.

So, in any of the manufacturing there are always three, any of the CNC or computer involved manufacturing there are three major components, the machine, the computer. When I say a computer that is software, third is the final tool or the print or the job that has been printer. So now, we will set the vacuum here. Yes, it is split.

Then you can see this now, it is giving a warning that make sure that the area under the print bed is clear of all obstructions. Click next to load up, you can see that there should be no obstructions. Now, they will put the print plate over. You say next, this is vacuum plate actually. Vacuum plate has certain weight and it is completely flat or secure with the surface.

So, by help of this weight it will now attach the paper to the surface. Sometimes it does not accept it, once we have to maybe try again. Done. You can see it showed the button is done.

We have clicked that button and the vacuum is also ready, it is green. Now this is now print bed is ready. It is now set there. The paper is set there and the print bed is ready for the print to start.

It has already shown that, yes, your nozzle door or your nozzles, if I say the stainless steel is loaded and the ceramic is loaded, that means the filament and nozzle everything is ready. We need to be a little assured that the printer, the filament, material of the printer, the amount of the filament that is there should be enough according to the size of the print that you are going to create.

So, the printer is now ready to get the print command from the software. Now before we go actually give the command I just like to show you certain tools. There are certain things which are over here, it looks like a simple injection. This is used for lubricating. I need 1mm syringe hole here. It is used for lubricating.

And lubricating of what? Lubricating the lead screw or the components that helps the pitch nozzle to move. I would like to also tell you that the nozzle can move in X direction, Y direction and Z direction, the overall system that is holding the extruder moves. The printed precision is better in X and Y directions always. In the Z direction the precision of the resolution is lower.

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So, So, wherever we need more precision or more close features or small features that orientation of the print is always put in X and Y direction. For example, if I have to print this injection, if I need better resolution on this side, a bit on the height side I will put it in this direction because in X Y, X and Y direction the resolution or the precision will be better, in Z direction the precision is little lower.

So, this is one tool, yes, anti-seize whenever we close the frame this is an anti-seize material that we put on the tip of the nozzle. So, the nozzle does not cloth. So, it is anti-seize the name itself tells that it does not let some other seize or cloth. There certain nozzle cleaning as well with the copper brushes.

So, these are known as viper brushes, these are used to close, clean the nozzle, clean the nozzle for the ceramic and the metal tube. We have this top driver, this is a top driver that is used to close and open the nozzle, it is a top based driver. Depending upon the number when we click it, when you rotate it you we hear the sound of click tick, tick.

It will deliver the similar or the proportion torque to the novel how tight do you need. It is recommended to have a single click to nozzle. These are certain major tools that I am showing you. There, multiple tools are there when the printer comes, it comes with a big box. Definitely when this printer was received it was a big loader Vega 404 truck and big nozzle was there, big loader was there and also we have, maybe quickly the nozzle these pins are there. So, many things are there.

So, now we will try to put the print over. So, now, let us consider that the print is ready we have set the vacuum the printing started through the software itself, software gives a

command and a nozzle in the extruder start extruding the material, both of them the print material that is the stainless steel in this case and the ceramic. So, now the print is ready. Now it will remove the print from the printer. It is ready and also it is cooled out, we will remove the print and take it to the next section that is the washer. He is removing the print while wearing gloves.

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Where is taking straight to the wash section. You can see Markforged wash one, wash one is the well section. He is wearing mask, why, because wash has two major sections, one is the dry section, one is wet section. Wet cleaning is done to a chemical that is known as Opteon SF79. It is a liquid that is put. In that wet section this component is left to be dipped to be completely soaked for several hours.

Depending on the material the time is decided. It has this Option SF79 that is a liquid, it has NPB, that is a N-Propyl Bromide, then PERC that is Perchloroethylene, then TC that is Trichloroethylene. So, the mask is to be worn and the gloves are to be worn so that it is safe to the skin. This is a basket and he is holding the basket from the basket holder.

He will now keep that material. Yes, just let you know that basket is held, he will keep this material that is ready, be very careful because it is fragile. So, the one has to be expert, very slow, patient. Now it is dipped into the liquid, the Oteon liquid. This is the better position. Yes, close it. Now this it will be kept for several hours.

After it is kept the display will show that, yes, it is done. We will set it; we are not setting it right because we are not doing it. It involves so much the use of the material in the process. So, when he, again he will remove the materials, suppose the material is now washed it has taken several hours of it is process.

Now, it can move to the dry section. We will remove it. This is after several hours depending on the material. He removes the material and put it in dry section. Wet section part is over. Now he will put the material in dry section, that will dry the material and make it completely ready, put in the sinter. Now, what has happened in the wet section, all the ceramic, all the other impurities and whites they have removed everything. His gloves are only required for the wet section only.

So, those are removed now. Now the material is put in the dry section and again depending on what the material type and the size and the build of the material they are certain time that is fixed after which the material is removed from the dry section and it is put in the sinter. Now, we will move this sinter part. Now consider that the wash has completed this process and the material is ready to be now transferred to the sinter.

So, we have kept the print outside. The certain places, there is a big print sizes and we also have kept certain trays to keep the prints, they are not. So, many prints already kept in the wash. So, we can put multiple prints in one go in the wash and in the sinter.

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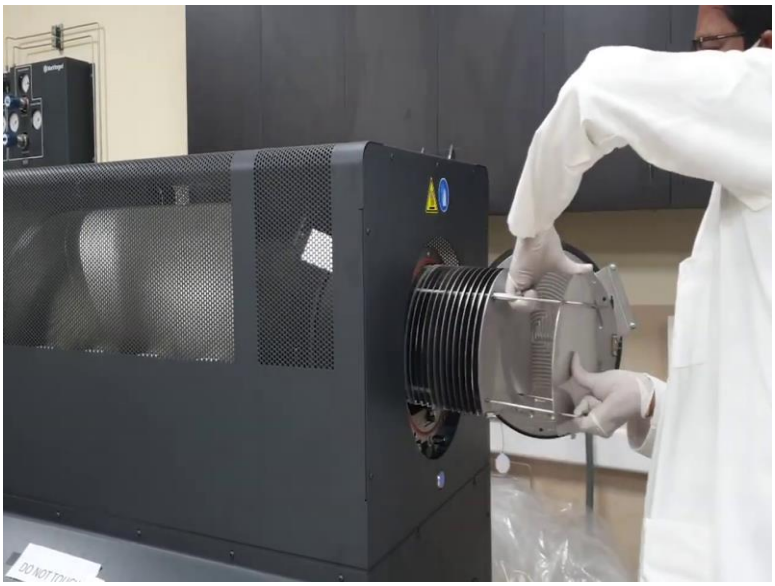
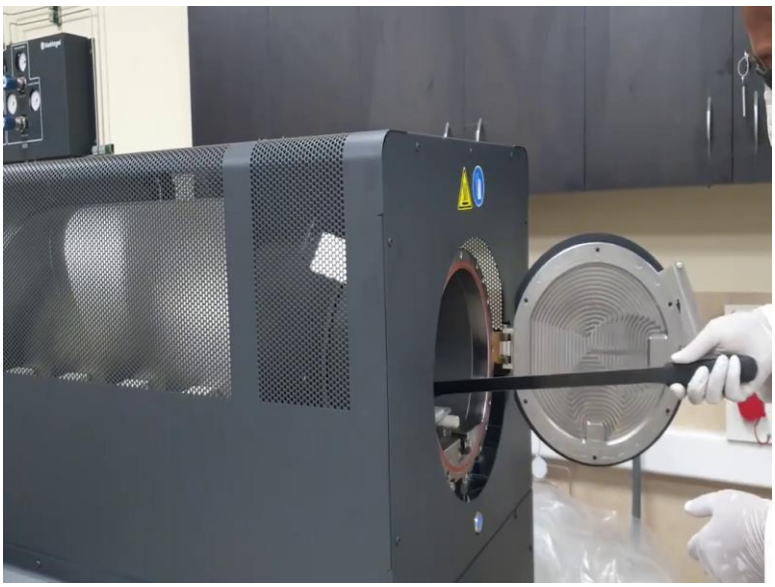
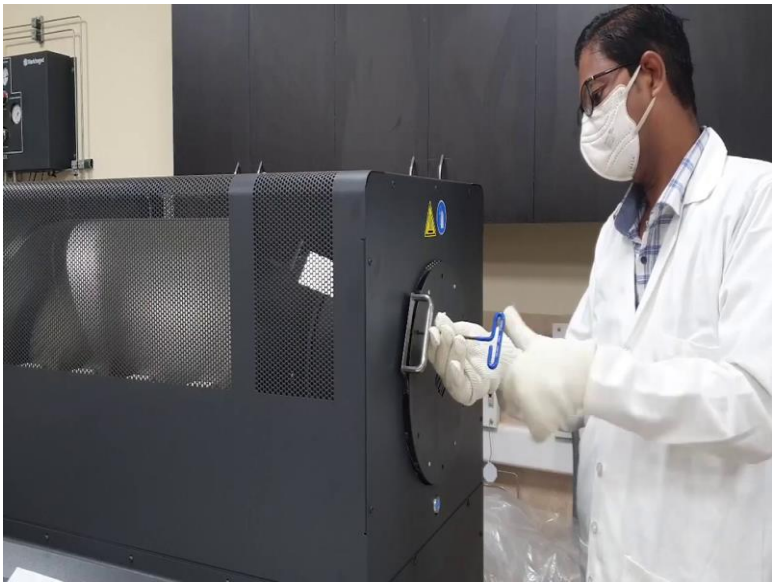





Markforged
INERT
MIX




Gas And Materials
Mix Gas
Inert Gas CLC
Inert Gas Reserve
Replace
Replace
21.194 kPa
Tube
Supply Filters
Exhaust Filters
Total Runs: 10
Runs Left: 35
Replace

Sinter now we have move to the third section of the printing setup, that is this sinter. We have Sinter-2 setup here, which is the biggest sinter that the company has produced till date. Now, we will show you how do you open this sinter. The sinter is a big furnace actually. Its temperature can rise up to thousands of degrees.

So, he is opening the door of the sinter. There is a table for putting this. he will put in the table separately, Now, he will show you this sinter, the plate in the sinter is a flat plate on which the material is to be kept. These are, this tool that he is holding in hand now is a blacksmith tool, it is a blacksmith tongs or blacksmith ranches because the temperature of the sinter is too high.

So, we have to put the gloves on. But these are insulating gloves, before touching that you have to put these gloves. The temperature for stainless steel, this stainless steel is for 30 minutes is 1066 ° Centigrade but this is a stainless steel only. So, right now the temperature would rise up to 1066.

This is a ceramic plate on which all the sinter parts will be put. The sinter sintering process is too expensive. In one go sinter, the cost of that maybe to go up to maybe 4000 rupees or so depending on, because lot of gas is consumed. You can see at that back end on the wall, there is on the wall there is a gas control panel, the gas control balance, there are certain controlled valves you can see, certain display dial edges are there.

So, those are controlling the supply of the inert and the mixed gas, when I say inert gas that is the Argon. Inert gas is Argon and with the mixes of the Argon and hydrogen. So, we have to have the cylinder banks. We have 12 cylinders in the line. The mixer and there is hydrogen and other all are argon.

So, now he is putting the plate into the sinter machine. He has put it to the last end and we have to be very assured, very certain that the position of the components, if suppose if the plate is to be removed once again, so however this does not happen normally. Suppose if in between the process is to be stopped and due to certain reason, maybe power cut.

So, if certain catastrophic failure happens, the position of the printer has always to be the same, all the time print which are kept there. The three components kept, at what dimensions are they kept, at what distance from the end of the plate it is kept, those will kept all the same places all the time.

Now, he is closing the door of the sinter. He completely close it using this Allen key because the temperature is too high. So, it has to be completely safe for the environment as I said the room with air conditioned, the outer environment of the room should not be affected at all. So, it is insulated properly. So, that it can be used in this kind of environment.

So, what he has put in the sinter is green part. When we will sinter it and we will take out what we will get is the completely ready part that is a solid part, there is a size reduction always when we heat that. It is the contraction in the material, the final dimensions of material is obtained only after this sintering.

Suppose if I have a rod of a dai 10 mm and length 50 mm, this 10 mm would be produced as a green part as 12 mm. Generally, 20 percent more size is produced in green. So, the final print would be the dimension that we have actually required, that we have put as an input in the software.

Now, we can show you the display of the sinter. It is right now showing 28 ° Centigrade. The sinter cycle again goes for the hours of the order of the 10 to the, tens of hours. So, he is clicking, setting the gas and materials, he can do, certain options in the menu available, gas and material, utilities, settings, storage, security.

In gas and material here says mixed gas it is already there, inert Gas is already there. Inert gas reserve yes, it is at this pressure of 21000 kilopascals and we have tube runs 10, then we have supply filters left 35. Then we have exhaust filter. If they say replace it only means that the reserved component, reserve part of the sinter might have to be replaced. However, it has the enough gas to run this sinter run.

So, next we can go back through this error in the top. Next utilities with what are available, do we need to control the gas walls, do we need to have thermal controls, pressure systems, then from web recovery only if suppose some default or maybe rerun of the system is to be done.

There certain diagnostic are there, system diagnostic, whether the printed completely the system is running fine or not. Then we have network diagnostic, whether the network is connected to that or not. We will go back again and show you the other options like certain settings, we cannot move to all the settings right now.

So, there is certain settings of the pressure, certain errors, if those are there we need to clear the errors. So, many options can be put there. So, what is the storage? All these settings. The

major point is we already have put their input at the material is this grade of the stainless steel, the sinter will understand that.

The software is intelligent enough to understand that what temperature would it go. When we switch it on it will show the time left the time left, that is the number of hours which are left to finally get the printed part of; it will show you that maybe 28 hours are left depending upon the sintering size and everything, depending upon maybe 14 hours.

So, whenever the sinter, it is actually the annealing process, annealing if you know again you go to the critical temperature, we cool down at a certain rate, certain rate may be 2 ° per hour, 10 ° per hour, temperature reduction. It is too long process. But this annealing, normalizing these two or three processes run and within this sinter setup and what we obtain from that is a sinter part.

Now, this sinter part, if you see the part the base of the part also had a plate that plate is removed and we get a sinter path completely with optimal print that we get, with the optimum size that we have put as an input in the software. So, this is how the 3D printing setup happens all the three. Now I would have to show you some 3D printed parts that we have already developed through this setup itself.

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So, there is such a component which are very, this is a nozzle that is used for, this is actually model of the nozzle that is used for the impedance in the aerospace industry. So, generally to develop this kind of the material, this kind of the component using the conventional machining, it takes a lot of time and we have to also brace the material from here.

This is the top, top is developed separately, this component is developed separated, then brazing has to happen, we get certain projects from certain agencies like DRDO itself, they want this whole component to be built up, this kind of the components to be built up as a single part.

So, this kind of things are developed. Also, this is a bed sheet that is given by Mark forged, it gives us certain angles, what are the angles at to which the printer can be used and certain holes which are made. You can see the Mark forged is printed here properly. Then with the

Mark forged their logo is also printed here. So, there are certain components which are printed.

And I will like to also show you how it plates, you could have seen certain plates who are there for all the plates, these are the plates which are the removable material. So, this is this is a missile that is produced. So, in this missile this plate is removed, this is after the complete sintering. So, you can see certain marks are there.

These are the marks or small attached, here we had ceramic which was removed using our wash liquid itself. Now, this you can see it is a small point are there, these are support materials which are all removed, so this is the missile. You can also see this part can also be removed. So, this part was only a support.

This was not required, but to develop this kind of the component, at this place it is being held in the air itself. So, we have to support something, so this part is only the support to produce the height of this missile. So, these are certain examples that how are these, this is now complete metal, even if I throw it will not be broken, it has good strength, having full strength stainless steel.

There are certain tests for that mechanical engineering test like impact strength and soil compression, all the tests can be done, certain people have also published, some people have also published this how do we tests, at one orientation we have printed, it is just printed like this only, have we it printed in that 70 to 45 ° to have better orientation.

Now, it can be, it has that is the strength in this direction, if I try to break in this direction, the tensile, inside if I see here, it will be lesser, if I printed in the 45° angle the tensile strength would in this direction will be much higher. So, depending upon the size material this is all in engineering, mechanical engineering and the materials engineering that you study.

We will see how these components are produced. The major components, the major steps in 3D printing, metal 3D printing for the Mark forged Sinter-2 and Wash 1 setup we have now demonstrated. For any queries you are open to come to MedTech IIT, Kanpur where this printer is installed and thanks for your time.