Social Innovation in Industry 4.0

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Lecture 40

Rapid Prototyping Laboratory Demonstration- 1

Welcome to the session on 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 STL format and layer-by-layer we try to develop the build 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 Kothiri Systems is there, Arti Makers is there, Markforged is there, those who have multiple kinds of metal 3D printers. It depends upon the size of the print that you like to have.

So, the size of the printer that it can hold is known as work envelope, but in the maximum 3D dimensional size x into y into 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 metal 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 are certain support material impurities, which are not required in the following 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 and it is too fragile. If the component falls or so it might even break.

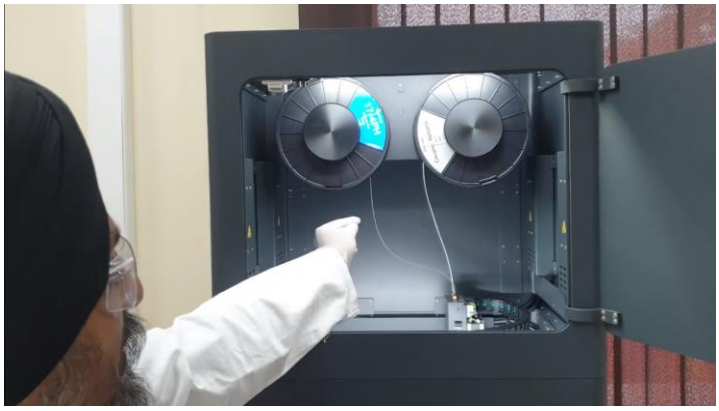
So, it has to be now heated to the specific temperature depending upon the material, there are certain materials, we have stainless steel, copper, inconel is also coming. So, many materials are available in big ranges by our supplier, this is Markforged Sinter-2. So, they depending upon the different 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 solidifies and it becomes a total solid, and the usable metal material that component for that machine part is known as sintering. So, let us now see the printer.

This is metal 3D printer which is Markforged made a printer. Markforged is one of the pioneers who is working in our even multi jet printing. When we say multi jet printing, in multi jet printing the printers might even you know overshoot the conventional machine methods.

The only drawback, major drawback in the Additive Manufacturing is the process is still known to be slow because it is a 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 multi jet printers, multi jet printers with multiple jets would come and try to print them in one loop. So, then it will become easier and faster for the printers to print.

Cost is another factor that is also being worked upon by many of the developers. So, let us now see the printer that we have, this is the printer, metal 3D printer. This is the washer, I just talked about and I also have a sinter 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 operation I would say we have to prepare the bed for that, we have to prepare the material, we have to vacuumize that, what is the purpose of vacuum so that is no purity, no gases, no wires left in there, so that we do not have any kind of the defects 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 the work envelope. So, we can just see the two filament stools here. So, you can maybe control.

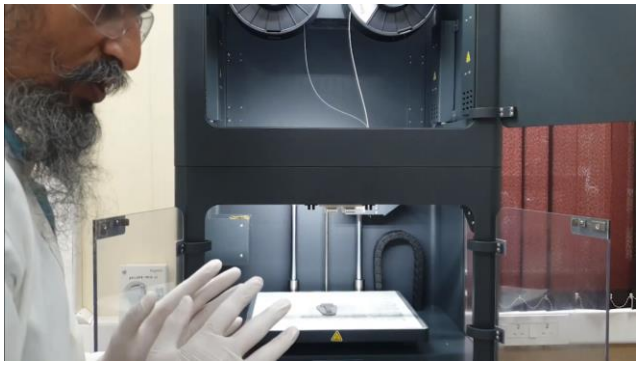


So, the two spools, two spools holders I would say, two spools holders are there. this is the metal spoon through which metal filament is coming. Right now what we have held here is a stainless steel, the stainless steel, specific grade of stainless steel is developed by this company. When I say specific grade, they have developed full parameters for this, parameters means what are the parameters to control the temperature. So, what is depending upon the thickness of the balls, depending upon the infill that we have in the material, depending upon the density, depending upon the print size and angles.

So, all these parameters are to be optimized by the company, when they supply this material. This is a filament, this is with stainless steel and at certain times because metal 3D printing support 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 an act. So, we have to build certain supports, so that it can maybe build this thing.

To remove these supports, so that this spools does not become the part of the made print, we have to put some coating in between, so that it is removed easily, when we put it into the washer, certain support materials are removed from that or when we after the sintering should remove. For that, a certain parting material is used that is our ceramic.

So, both of these spools, if the software understands what is the shape of the print, what is the size, and what are things which we are doing, it takes a body. Now, this is the major, I would say spool and the extruder set up 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 in extruder is the extruder nozzle.

I am opening the door of the printer, there is a green part we are going to grab for you, because to print in front of you, like we say, it takes several hours, hours maybe, the hours are of the order of the tens of hours, maybe 20 hours, 30 hours, that time, it is to be small print by take 5 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 use hand. Right now, it is not that hard, I have touched it. 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 dia, 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 components we have shown. So, let us now show you that you set up the printer.

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, that is, it is hot and 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 bar at the top, there is a blue bar down there and the blue bar. The lasting updates are available from the previous version 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.

In this menu, we have manual control, materials, 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, the other button that is the network manager.

The network manager, options are Ethernet, that is using connecting a bus or Wi-Fi or either you wish to use it offline itself. So, at this point of time, it was entered Ethernet. So, we have clicked Wi-Fi now. So, it is showing the IITK internet connectivity is there.

We will see it done. Now, it is connected using Wi-Fi to the internet. So, if the internet is not connected properly, it will not work. So, this is connecting to Wi-Fi. This is one of the 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, object manager, security, system info, temperature dashboard, and errors or any debugging if it is required. So, let me click the system information. So, let us click the left bottom option, system information.

This is all touch screen. In the system information, you can see the print information, the release date, the firmware version. It is showing what is our system mode and when is to

be this updated next, sometime after it goes that. Now, coming back to the main menu, using network manager, we can reconnect to the Wi-Fi ethernet, 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 connect that USB to the printer.

So, some errors if this comes to an update, it also says, 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 okay, somewhat touched. Now, let us see next is utilities. In the utility, five options of a bed level, maintenance, print, head alignment, network diagnostics, test prints.

Three options are there which could be done, which could be 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.

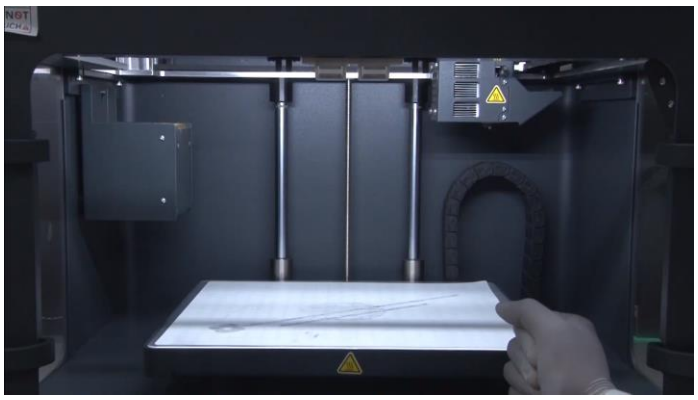
System information is done. Okay, next is temperature dashboard. So, temperature dashboard is showing the bed level, the metal hot-end, the release hot-end, all these temperatures which is right now there, it is showing it here. Again, the menu, settings, errors. In case some errors come, those are to be cleared, then we have to come to the error tab here, and 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 unload materials, reset the metal meter, load release, unload the release and reset the release meter. So, if something is, some material is stuck, 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. So, the 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 or working, so it is stuck for some various reason. So, we can say same spool has to be continued and it starts working. If the spool is consumed in between, we quick load it and try to start the same spool. The meter load is, we try to measure the spool and try to load it, the new spool.

Unload also has similar options. So, when the nozzle is chocked generally, then unload metal is used. We have to unload and the nozzle cleaning has to be taken care of using the small hard tools which are available for cleaning. So, now there is a option storage. 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 bed 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.



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 could work to all the extremities.

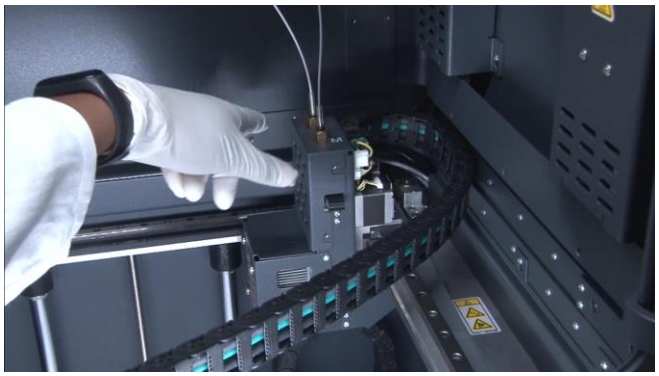
So, to the extreme X, extreme Y, extreme Z. It will make sure that the machine is working properly. This homing is generally one of the processes or one of the starting process or starting tasks that is always there in a CNC system. This is also a kind of Computer Numerical Control, but Additive Manufacturing system. So, XY was all checked, XY it was checked. Then, now, Z axis is being confirmed for the working two activities.

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 will now display as operation completed. That is, the bed has now come to the proposition. So, there are screws down there which we just talked about.

Three screws are there. So, using the torque wrench, we can adjust these 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. 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. You can see small serrations here on the bed. A small, I would say, grid is there in which the holes are there.

That is for the use of creating 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 module. Then, this sheet won't move just like it is moving right now. Once the vacuum is generated, this sheet would be fixed and it won't move.



This is the head of the extruder in which two filaments are there, ceramic in a white color and SS in the silver color.

This is a cap. If I open this cap, you can see something here inside. So, both sides we have extruders here. So, there are separate extruders here for metal and for the ceramic. So, we can unlock and unload any of the material if it required.

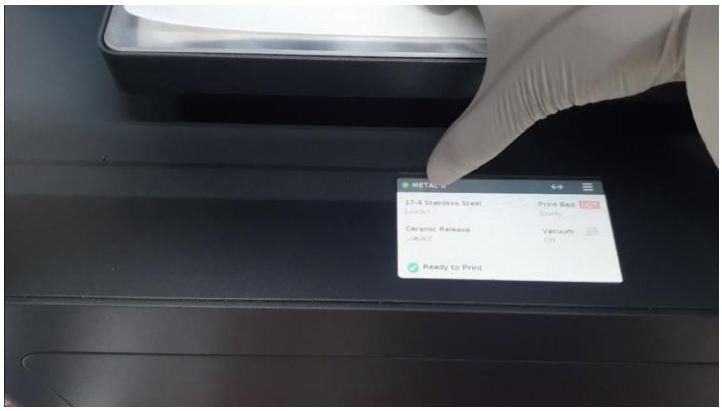
We can unlock and unload using this. So, we have nozzle down there. So, nozzle helps us to extrude the material and we have the heaters here that melts or fuses the material. So, like certain materials, copper, inconel, SS, nylon, all these different materials are being used or could be used using metal excess printer. So, along with this, we have tool tools like A2, D2. Then, we have low tube housing here, then upper tube housing here.

So, low tube housing, if it is to be changed, then this part could be opened and housing could be changed. These all options are available here. So, this is all hard setting or maybe maintenance and repair of the printer. But this is the print head.

I won't say extruder actually this is the print head. Extruder are the parts of the print head. So, this is the complete print head to have a closer view. So, two extruders are there, one for the ceramic, one for the metal. The metal in this case is 17-4 pH, that is stainless steel. So, this is how the printer looks from the inside. So, now we are getting back to that position where we will show you how we open the printer or the operation start and the steps in that.

The first step is creating vacuum. Vacuum is very important for the layer. This material gets stick to the plate. So, we have opened the window now. Now, we will show you the this case of the printer. Now, this is the brush, this is the polymer brush. The polymer brush that is used to clean the printer. Cleaning, this whole process is known as printer preparation. In printer preparation, the first step is to clean the printer for any impurities for the last 3 days that when or maybe some dust might have come.

The printer is recommended to be kept in a closed environment. So, we have air conditioner environment, 25 degrees room temperature, everything is set right here, but still it is to be cleaned. So, now we have put the paper, that is given by the manufacturer itself.



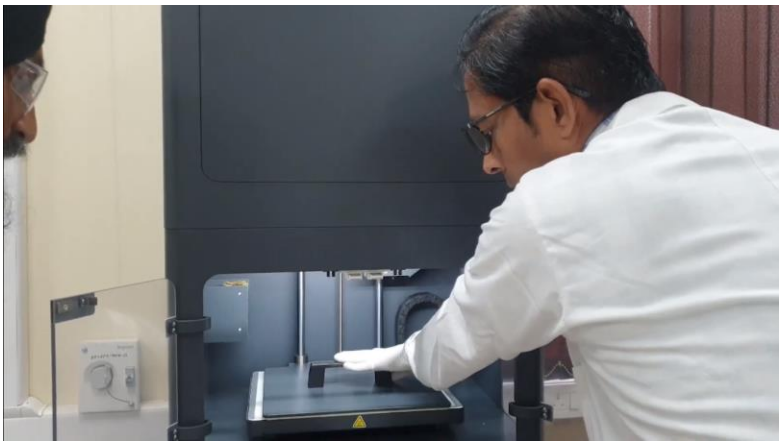
Now, we can see the display what he is clicking on the display. So, it is showing the material that is there.

The material right now is 17-4 stainless steel. So, it is showing a certain options that material, yes, material is loaded. Ceramic release, yes, it is loaded. The print bed, it is hot, that 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 degrees. so that the printer is easily removable from that. So, that is the temperature of print bed when the temperature for the nozzle, I have already told, it goes upto 40 degrees, depending upon the material, the temperature would be set. When you say 17-4 stainless steel, that is already entered in the software phase here.

So, we actually have 3 sets. One is the machine, that is material that is working it through at the printer. Second part is a software, third part is the print. So, in any of the manufacturing, there are always 3, any of the CNC or computer involved manufacturing. There are 3 major components, the machine, the computer, and when you say computer that is the software, third is the final tool or the print or the job that is being build.

So, now we will set the vacuum here. Yes, it is click. Then, you can see the sound, 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, it is say that there should be no obstructions.



Now, they will put the print plate over it. We say next, this is vacuum plate actually.

Vacuum plate has certain weight and it is completely flat or secured to the surface. So, this by help of this weight, it will now attach the paper to the surface. Sometimes, it does not accept it once we have to we will try again. You can see it showed, the button has done, we have clicked that button. Now, vacuum is also ready, it is also green. 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 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 we are going to create. So, the printer is now ready to get the print command from the software.

Now, before we go actually print the command, I just like to show you straight to just a few things which are available, it looks like a simple injection, this is used for lubricating. It is having one and a syringe over here it is used for lubricating, and lubricating of what, lubricating the lead screw or the components, that helps the print nozzle do.

I would like also to tell you that the nozzle can move in x direction, y direction, and z direction. The overall system, that is holding the screw moves. The printer procedure is better in x and y directions always. In the z direction, the procedure on the resolution is lower. 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 do print this injection itself. If I need better resolution on this side when on the height side, I will put it in this direction because in 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 ok anti-seize, whenever we close the print this is an anti-seize material, that we put on the tip of the nozzle, so the nozzle does not clocks. So, it is anti-seize the name itself tells that it does not let the nozzle to seize or clock there.

The certain nozzle cleaning to there as well with the wafer brushes. So, these are known as wafer brushes, these are used to clean the nozzle. Clean the nozzle for the ceramic and the metal both.

Yeah, we have this top driver, this is a top driver, that is used to close and open the nozzle. That is a top based driver depending upon the number when we click it, when we rotate it, we hear the sound of click, tick, tick, tick.

It will deliver the similar or the proportional dock to the nozzle hot or tight do you need. For it, it is recommended to have a single click to tighten the nozzle. But these are such a major tool that I am showing you. Multiple tools are there. when the printer comes, it comes with a big big box, you know. It is actually when printer was received, it was a big loader, big 4O4 truck, and big nozzle was, there big loader was there, and also we have a maybe clean the nozzle.

These pins are there, so many things are there. So, now, we will try to put the print over it. Now, let us consider that the print is ready we have set the vacuum, the printing started through the software itself. Software gives the command, and the nozzles 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 we will remove the print from the printer, it is ready, now it is cooled down.

We will remove the print and take it to the next section that is the wash section. He is removing the print while wearing gloves. Now, he is taking this print to the wash section. You can see Markford wash one, wash one is the section, that 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 Optium SF79, it is a liquid that is put in that wet section. This component is let to be dipped, to be completely soft for several hours. Depending on the material, the time is decided. It has this Optium SF79, that is the liquid, it has NPV that is N-probyl bromide, Then, PERC that is Perchloroethylene, then TCE that is, Trichloroethylene.

So, the mask is to be worn and the gloves are to be worn, so that it is safe to the needs. This is a basket and he is holding the basket from the basket holder. He will now keep that material, yes, let you know that all the basket is held. He will keep this material, that is ready, very carefully it should be, because it is good for your time. So, the one has to be expert, very slow, patient.

Now, it is dipped into the liquid, thickening liquid. This is the wet portion, close it, now, from the largest, 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. Because we are not doing it, it involves so much of use of the material. So, when again he will remove the material, suppose the material is now washed, it has taken several hours of process, now it can move to the dry section.

We remove it this is after several hours depending upon the material. We remove the material and put it in dry section. Wet section part is over, 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 voids.

They have remove them, these gloves are only required for the wet section only, those are remove now. Now, the material is put in the dry section, and again depending upon the material type, and the size, and the period of the material, there is 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 to the Sinter part. Now, consider that the wash has completed this process, and the material is damaged.

Now, to be transferred to the Sinter. So, we have kept the print outside. There is certain place in the big print sizes, and we also have provided certain tris to keep the prints. There are so many prints already kept in the wash. So, we can put multiple prints in one go in the wash and in the Sinter.

Sinter, now, we have moved to the third section of the printing. Sinter, that is the Sinter, we have Sinter-2 set up here, which is the biggest sinter, that the company has produced till date.

Now, we will show you how do we open the 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 we will put it under the table separately. Now, I will show you the Sinter, the plate in the Sinter.

There is a flat plate on which the material is to be kept This tool, that is holding, is a blacksmith tongs. These are blacksmith tongs or blacksmith wrenches because the temperature of the Sinter is too high. So, we have to put the gloves on, So, these are insulating gloves before touching that we have to put these gloves. That temperature for stainless steel, this stainless steel is for thirty minutes is 1066 degrees centigrade.

So, this is a stainless steel. So, right now the temperature would rise up to 1066. This is a ceramic plate on which all the Sinter parts will be put. Sintering process is too expensive. In one go Sinter, the cost of that go up to may be 4000 rupees or so, depending on, because lot of gas is consumed.

You can see at the back-end on the wall, there is a gas control panel. In gas control panel, there is certain control walls you can see, certain display dial gauges 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 the mixes of the argon and hydrogen. So, we have to have the Sinter banks we have 12 cylinders in the line. Two mixed cylinders of argon and 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, suppose if the plate is to be removed once again. However, this does not happen normally suppose if in between the process is to be stopped, and due to certain reason may be power cut or certain catastrophic failure happens, the position of the printer has always been 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 those will be kept at 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 is 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 the 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 dia 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 degree centigrade. The sintering cycle again goes for the hours of the order of the 10 to the 10 to the hours.

So, he is clicking certain the gas and materials, he can do certain options in the menu available. Gas, and material, utilities, settings, storage security. In gas and material, he says, yeah, mixed gas it is already there inert gas is already there. Inert gas reserve ,he said yes, it is at this pressure of 21000 kilo Pascal. 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, reserved part of the cylinder 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 are, utilities what are available, do we need to control the gas walls, do we need to have thermal controls, pressure systems, then firmware recovery, only if suppose some default or may be re-run of the system is to be done. The 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, the certain settings have the pressure, certain errors if those are there, we need to clear the errors. So, so many options can be put there, what is the storage, all these settings. The major point is, we already have put their input at the material 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 power out. It will show you, maybe 28 hours are left, depending upon the sintering size and everything depending upon maybe 14 hours. So, whenever the

sintering, it is actually the annealing process. Annealing, if you know again, we go to the critical temperature we cool down at a certain rate, maybe 2 degrees per hour, 10 degrees per hour, time temperature reduction. It is too long process. But just annealing, normalizing these two or three processes run, and within the Sinter setup and what we obtain from, that is a sintered part.

Now, this sintered part, you see the base of the part also had a plate. That plate is removed and we get a Sintered part complete with optimal print that we get. With the optimum size that we have put as I need to put in the software, But 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.

So, this is the components which are ready this is a nozzle that is used for this is actually model of the nozzle that is used to draw for the impellers 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 braze the material from here, it is the top is dwellers separately this component is dwellers separately. Then, brazing has to happen this we get certain projects from certain agencies like DRDO itself, as 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 benchy that is given by Markforged. It gives us certain angles, what are the angles, to which the printer can be used, and certain holes which are made, you can see the Markforged is printed here properly, then with the Markforged their logo is also printed here. So, there are certain components which are printed and I will have to show you how the plates, you could have seen certain plates were there, for all the plates.

These are the plates which are the removable material. So, 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 of small attach. Here, we had ceramic which was removed using a wash liquid itself. Now, these you can see the small points are there, these are support materials which are all removed this is the missile, you can also see this part can also be removed that 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. This part is only the support to produce the height of this missile. So, these are certain examples that how these, this is now complete metal, even if I throw it will not be. Completely strength, having full strength, stainless steel just certain test for that mechanical engineering test, like impact strength, tensile, compression, all the test can be done. On certain you know papers are also published itself, papers are also published in this, how do we test it, what orientation to be have we printed. It is just printed like this only have we have, it printed in that 45 degree to have better orientation.

Now, it has lesser strength in this direction. If I try to bring in this direction, the tensile instead of I see here it will be lesser, if I printed in the 45 degree angle, the entire strength would in this direction will be much higher. Depending upon the size of material, this is all mechanical engineering and the material engineering that you study. This is all the components are produced. The major components, the major steps in metal

3D printing for the Markforged Sinter-2 and wash 1 set up, we have now demonstrated for any queries, you are open to come to MedTech IIT Kanpur, where this is printer installed and thanks for your time. Thank you.