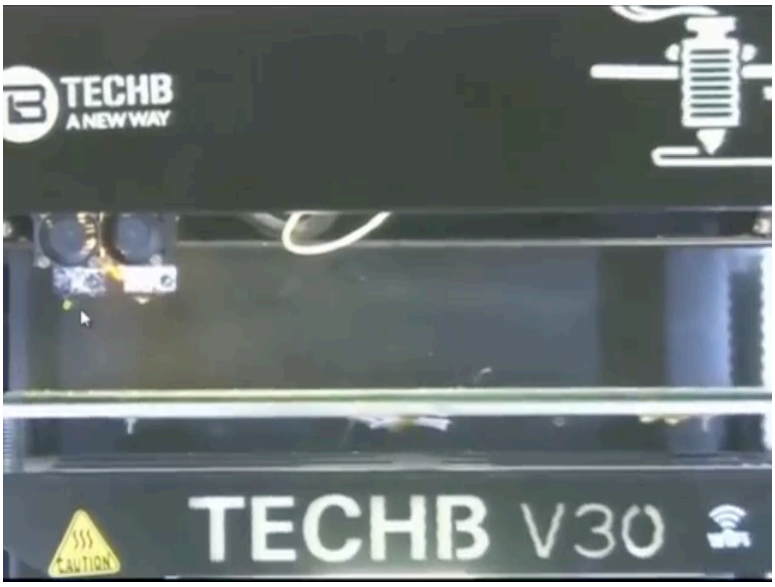
Product Design and Manufacturing
Prof. J. Ramkumar
Dr. Amandeep Singh Oberoi
Department of Mechanical Engineering & Design Program
Department of Industrial and Production Engineering
Indian Institute of Technology, Kanpur
National Institutes of Technology, Jalandhar

Lecture – 27d
Laboratory demonstration: 3D printing (Part 3 of 3)

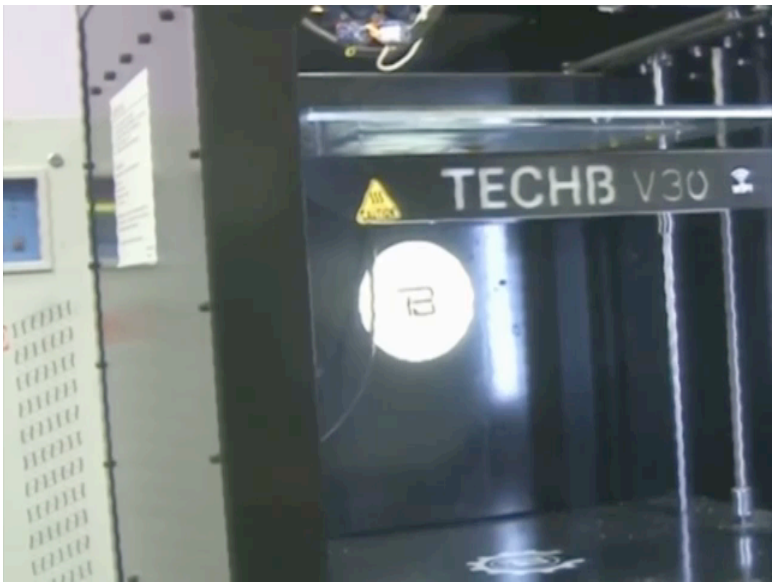
Good morning. Welcome back to the course. In this lecture, we will take you to the lab for the Laboratory Demonstration.

(Refer to Slide Time: 00:22)



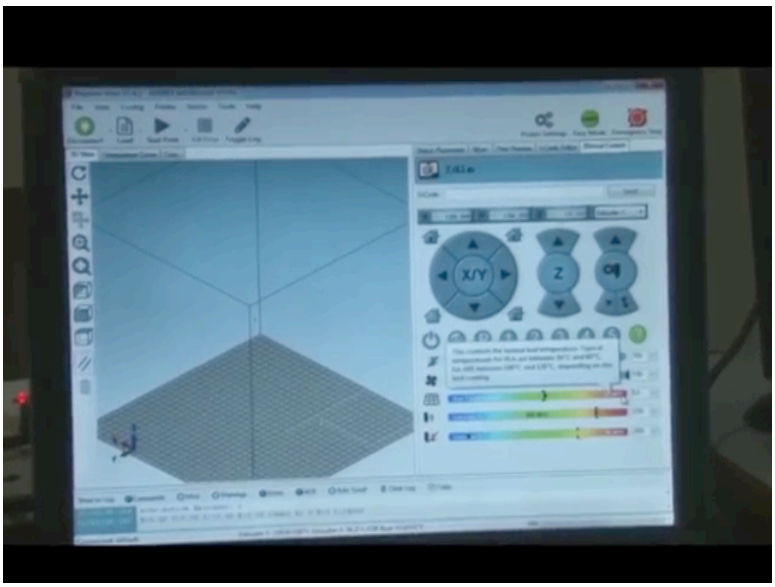
Now this process is you know parking. We are parking like car parking; we are parking like kind of homing. So, it is parking the head at the left side left corner of the machine.

(Refer to Slide Time: 00:39)



Now, after setting the g code and making all these settings we are here to prepare the bed to prepare the bed for machining, ok. To prepare the bed and to set up all the things like spool, filament we will induce, we will in filament through the rollers that would come through the extruder and we will try to see that whether it comes properly or not. Before that the heating is there heating that was done that with the commands that we gave the heating was here the bed is getting hot or it has come close to the temperature that was given 4 to 5 degrees; the nozzles are close to 230 degrees.

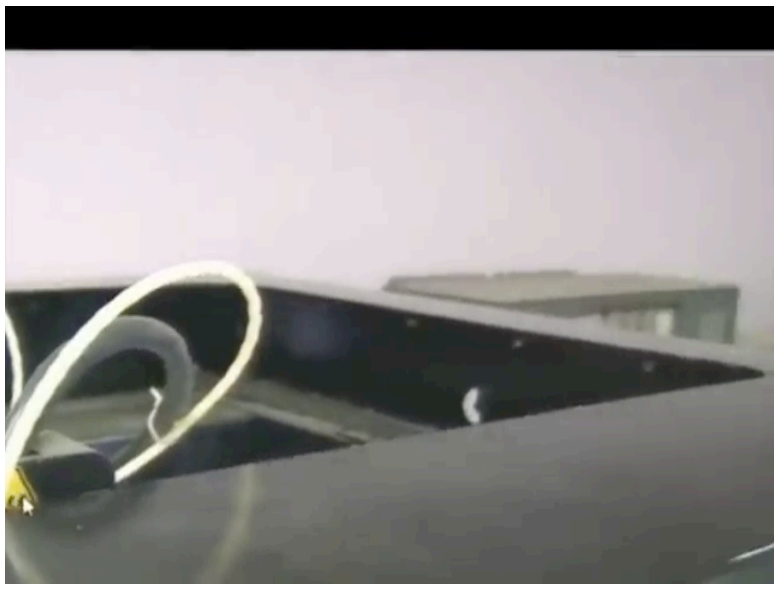
(Refer to Slide Time: 01:22)



So, the temperature is kind of trying to come to this desired input here to 230 degrees for the nozzle, 55 degrees for the bed. It will take about 15 minutes. By the time, we can prepare the bed. So, let us try to start the cleaning and loading and unloading of the material.

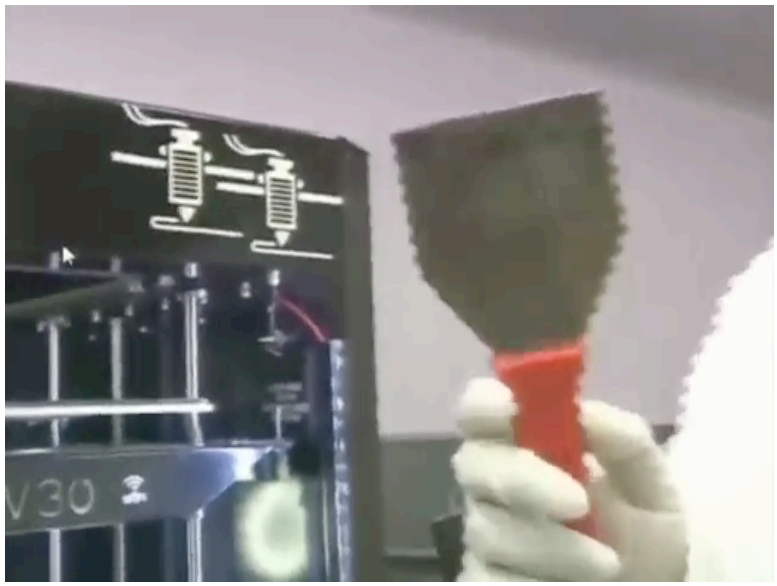
(Refer to Slide Time: 01:50)

(Refer to Slide Time: 01:56)



This is the cutter that is being used to cut the filament if required. So, this is a tube, through which the filament would form through, it provides proper paths to the filament, ok. This tube is it a tubular filament head.

(Refer to Slide Time: 02:07)

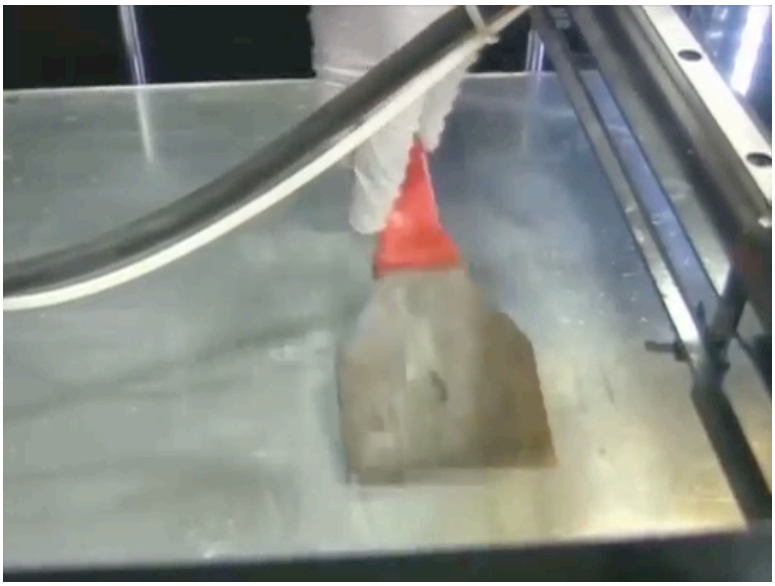


This is spatula, this is used to clean the bed.

(Refer to Slide Time: 02:15)

So, this is a distilled water with some cleansing agent here a few drops.

(Refer to Slide Time: 02:25)



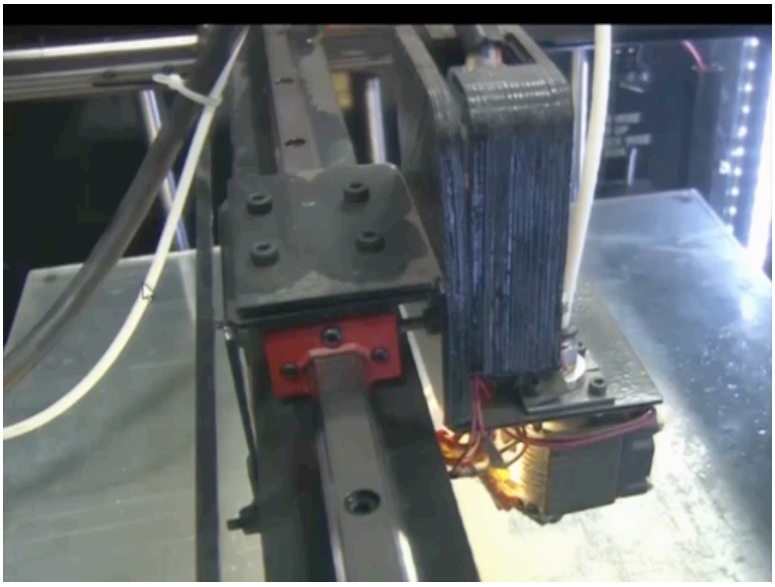
So, some of the liquid cleaner is sprayed and it is cleaned with the help of spatula. So, the whole machine header is actually glass, so we have to be careful. So, what is this white milky material? White milky material it is nothing, but we have used fevistick that is the adhesive material, this Fevistick.

(Refer Slide Time: 03:03)

So, we are gained applying some move Fevistick. So, it will help you lock the first layer. As we said before, we have put our cad at the centre of the envelope. So, that is why we

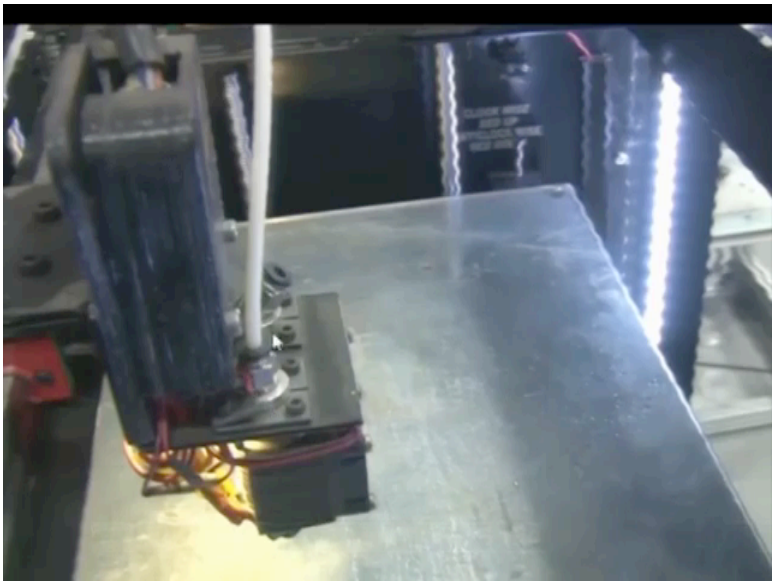
are preparing the portion that is at the centre. So, a thin coat of Fevistick is applied to the centre.

(Refer to Slide Time: 03:37)



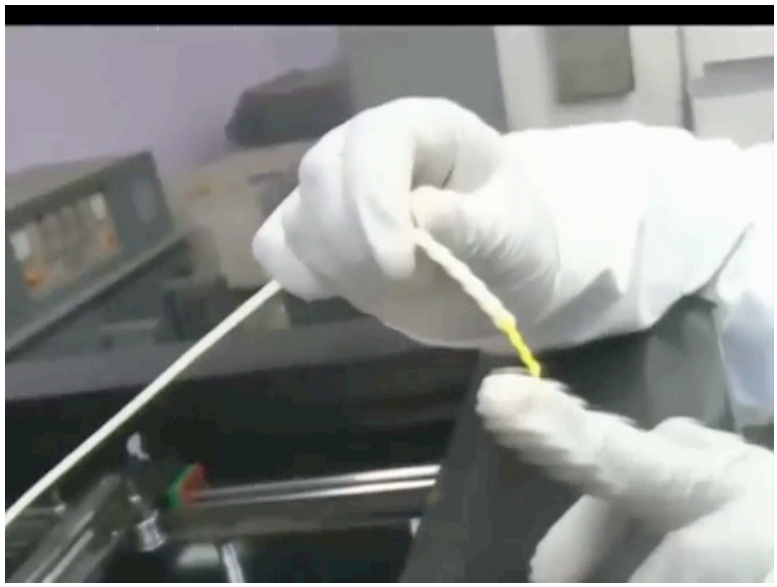
Now, this is our head this is our and there are heaters here that are heating. The filament the spool is coming through this tube, the white tube, the filament is coming through this y tube ok. So, this is the head that can be moved or this is our x and y movement, ok. In z moment that actually bed is moving up and down that movement is controlled with bed and there are two nozzles here. The only one nozzle is active at this point of time.

(Refer to Slide Time: 04:22)



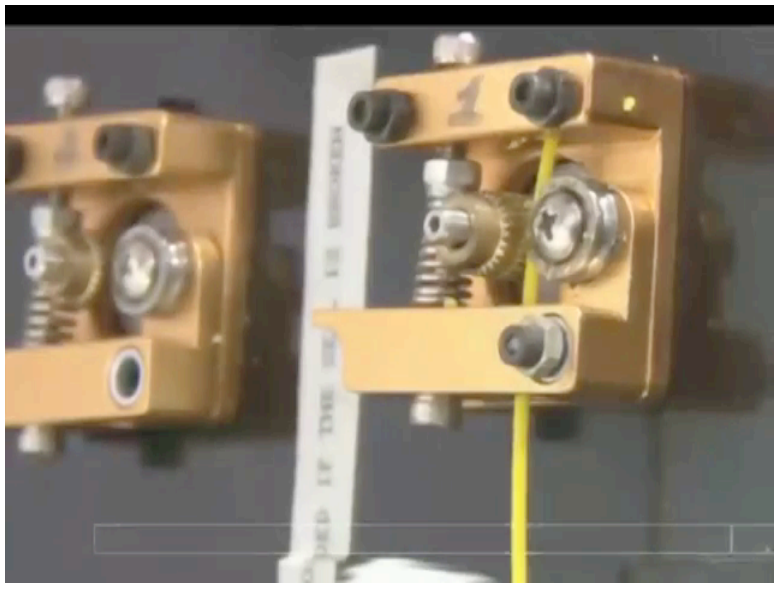
So, let us see how to load and unload the filament. So, this black portion this is a PU connector. So, PU connector can be connected, it can be screwed in and out. So, we have unscrewed it, ok.

(Refer to Slide Time: 04:42)



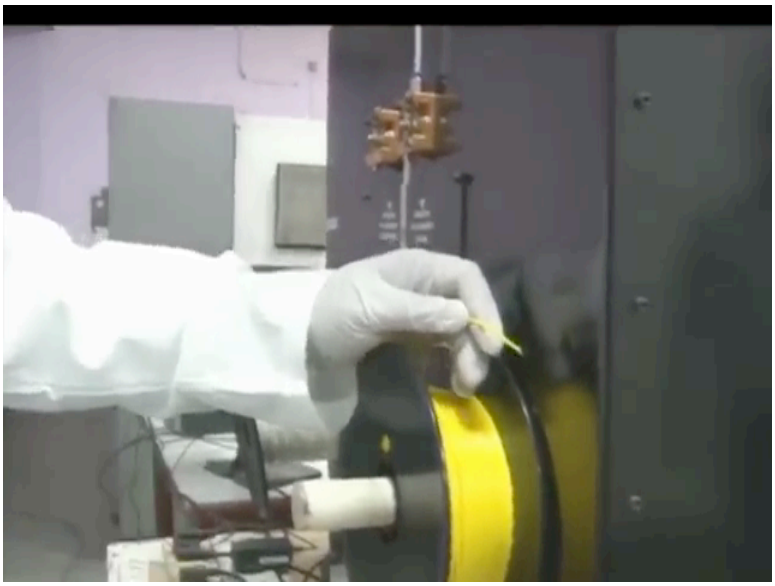
So, in PU connector is according the side of a tube; PU connector is exactly there, the tube would exactly fit into that so this support.

(Refer to Slide Time: 04:50)



So, this is these are our rollers. We are taking it off we are unloading the filament now; unloading the filament you can see.

(Refer to Slide Time: 04:58)

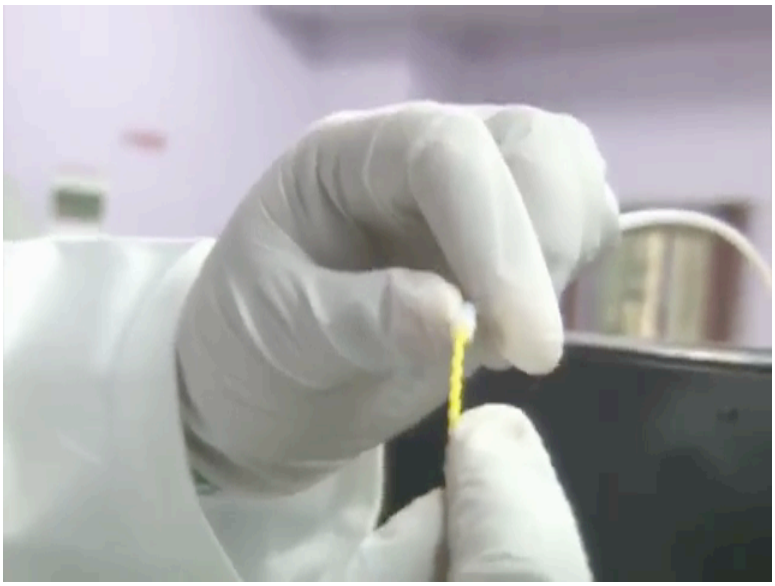


This is, the filament of size 1.57 mm. Now we can see that the filament a little distorted from the tip that is, it would not enter the rollers properly.

(Refer to Slide Time: 04:25)

The tip of the filament or the end of the filament is not proper. So, we are going to cut it, they have cut it, so it is now flat at the end or screw at the end. So, this is the roller. This would help to take the filament forward when this rotates the filament is carried forward in this direction; upward direction.

(Refer to Slide Time: 05:57)

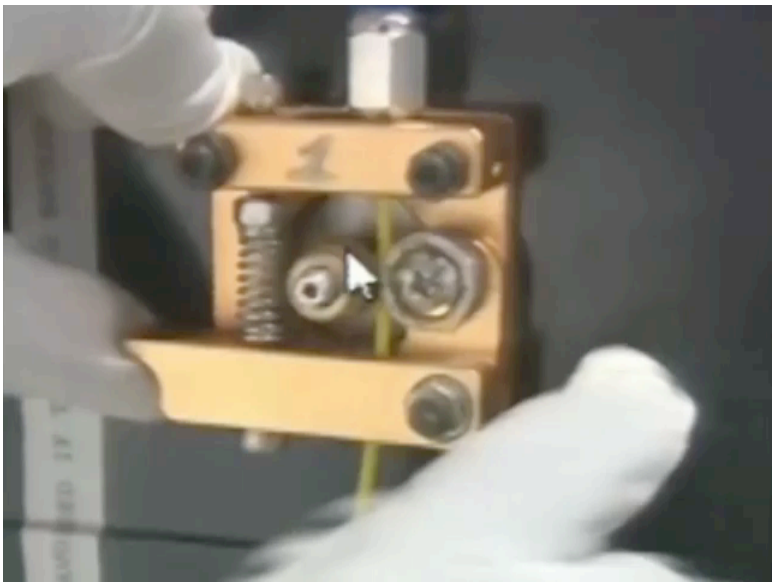


Now, we are entering the filament into the tube that is connected to the PU connector. And this tube is also very much according to the diameter of the filament, 1.75 inside diameter 1.75, plus allowance. Allowance is 0.11 0.85 mm in a dia.

(Refer to Slide Time: 06:15)

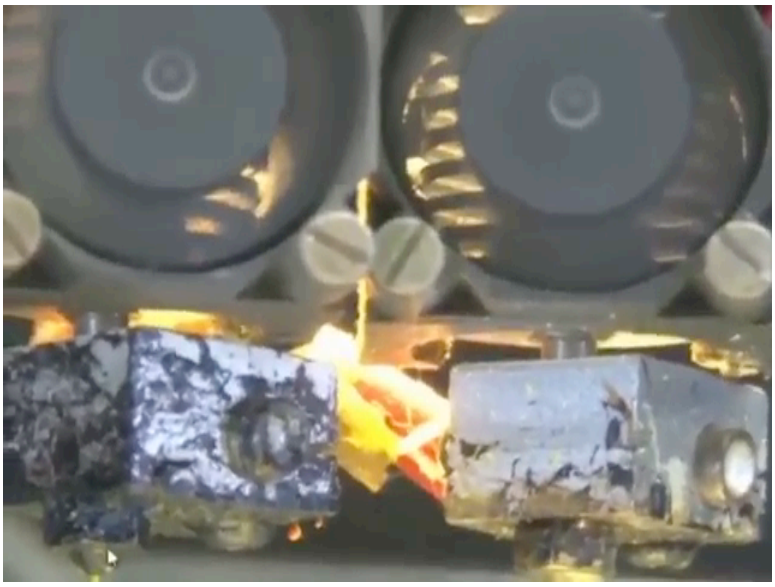
Now this PU supports to, the filament supports is connected to the PU connector, ok. Now we will see that whether it is working properly or not. Now, we will lock the PU connecter, we have locked the PU connector there, we lock this PU connector here as, this is PU connector is locked here.

(Refer to Slide Time: 06:50)



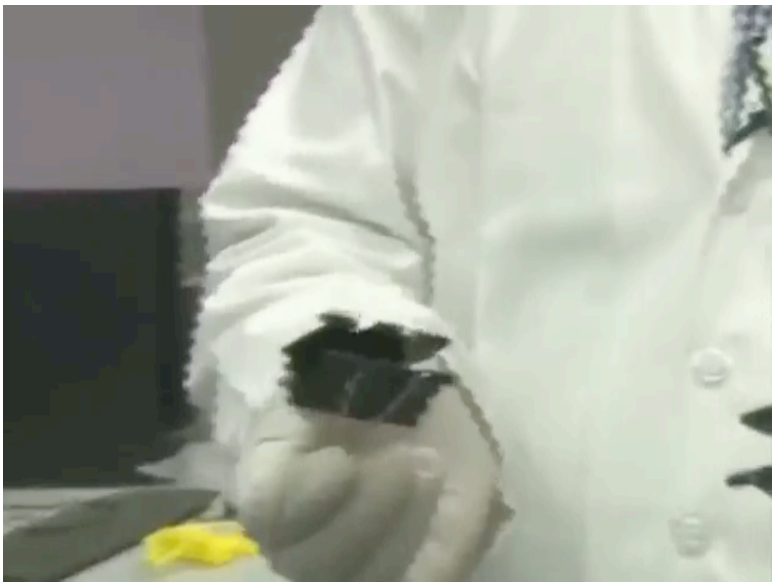
So, this roller that I mentioned that is responsible for feeding; this is also known as feeder. So, we are using this pulley and feeder two rollers. One roller is pulley; another roller is feeder.

(Refer to Slide Time: 07:13)



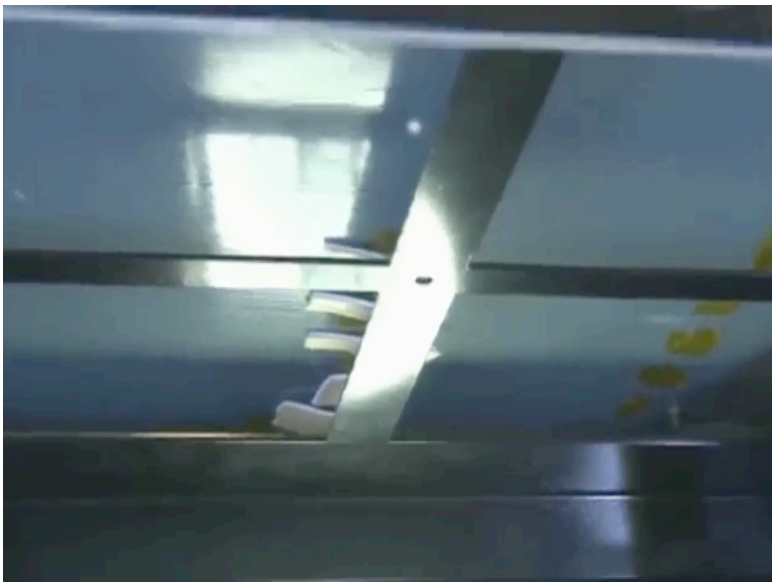
We can see that the loading of filament is properly done. Now we can see that whether the filament is coming through the nozzle or not, yes it is coming. Now this means the temperature is now maintained.

(Refer to Slide Time: 07:31)



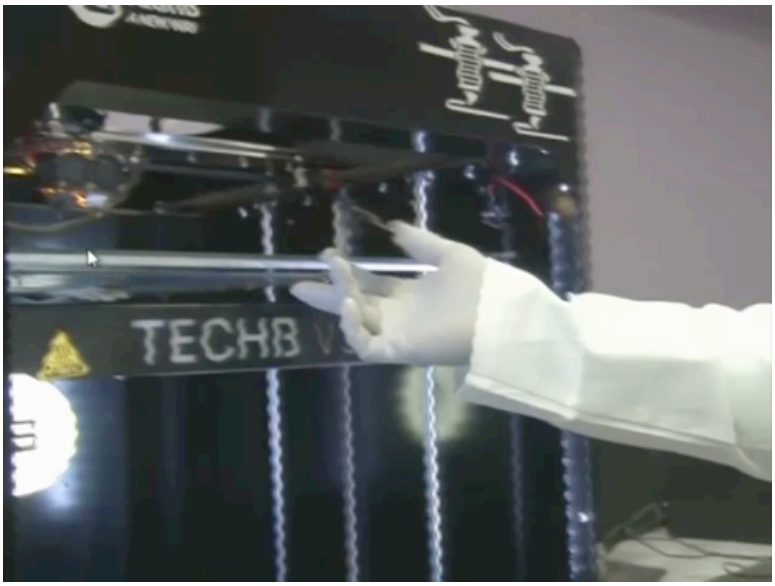
Now, we will use these two clips to hold the glass with that bed, with the table bed, ok.

(Refer to Slide Time: 07:41)



So, this bed is at the temperature of 50 to 55 degree centigrade.

(Refer to Slide Time: 07:46)

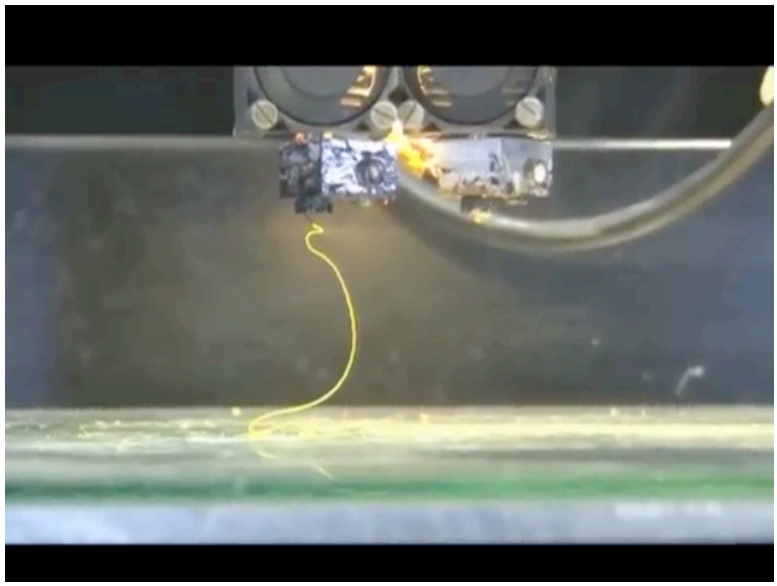


So, to hold them we use these two clips we will put clips here and here. So, that it holds gets properly over here and at the other diagonal end. So, these are the heaters for the bed. Now we can go at the bottom of the bed; let me take camera would go at the bottom of the bed, this is the bottom of the bed a heaters here. We can see their heat is attached here, ok. And the base is aluminium, this bed base is aluminium, they are heaters there and all the aluminium base over and on the top of the aluminium base we have putted glass plate on which the actual fabrication would take place. So, it is that one clip is put here; another clip is put on the other side.

So, everything is in it is place now the temperatures are like, we are see our filament was coming out of the nozzle, the cell temperature is close to what we require. Close to means, if you have put input 230 degree centigrade's as we know that it would not be exactly 230 degree centigrade's all the time it might vary like 2 to 3 degrees or 5 degrees variation, but yes that is the working temperature the temperatures are set 230 degree centigrade's for filament, 50 to 55 degrees for table, the loading of the material is there. The rollers are engaged, rollers, the two rollers means the rollers one is the pulley.

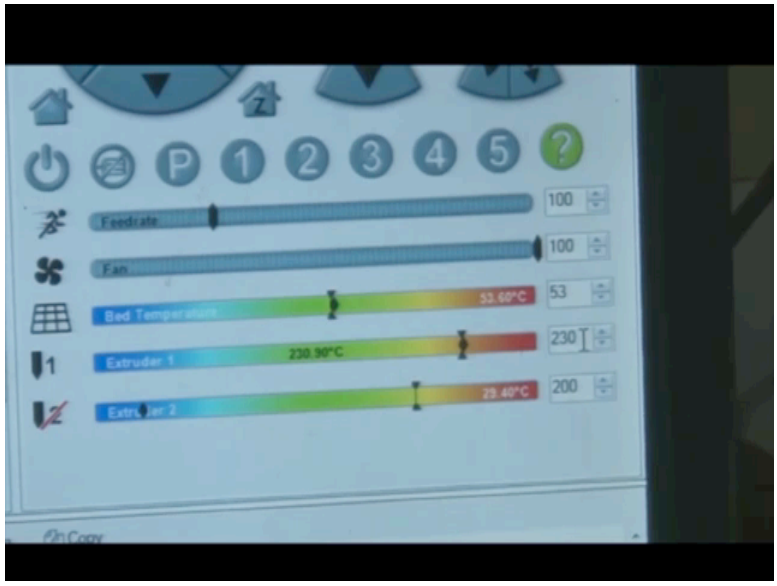
Pulley and the feeder is engaged filament is coming properly the bed is prepared. We have applied fevi stick to make sure that the material sticks there and the cleaning of the bed is, so before a few, we will just come to manual control here.

(Refer to Slide Time: 09:34)



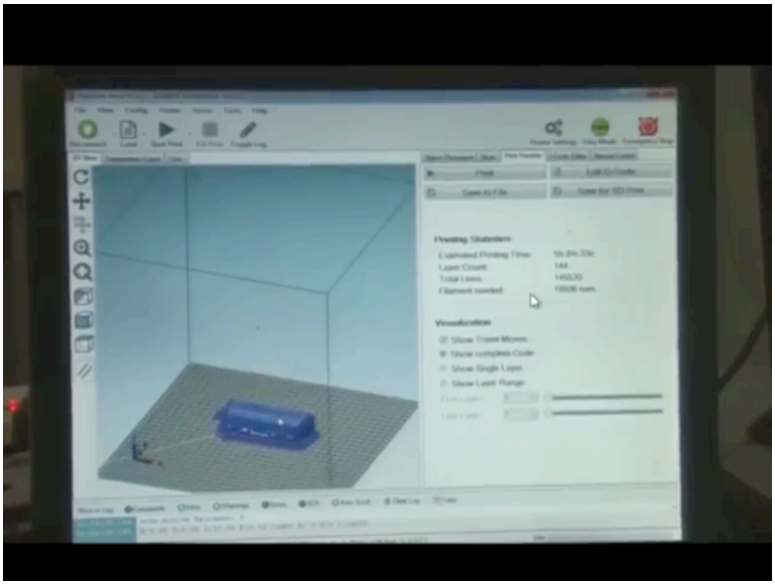
In manual control, so we will we are going to check manually that whether the things are moving. Yes, we have we are checking the material is coming in, material is coming out ,you can see the material is coming out. So, we are manually checking whether the feeder is working or not ok. So, the material is coming out, the extruder is being checked here, for it is proper setting. Again we can see extruder is activated. In this way, we check that everything is quite well or not.

(Refer to Slide Time: 10:34)



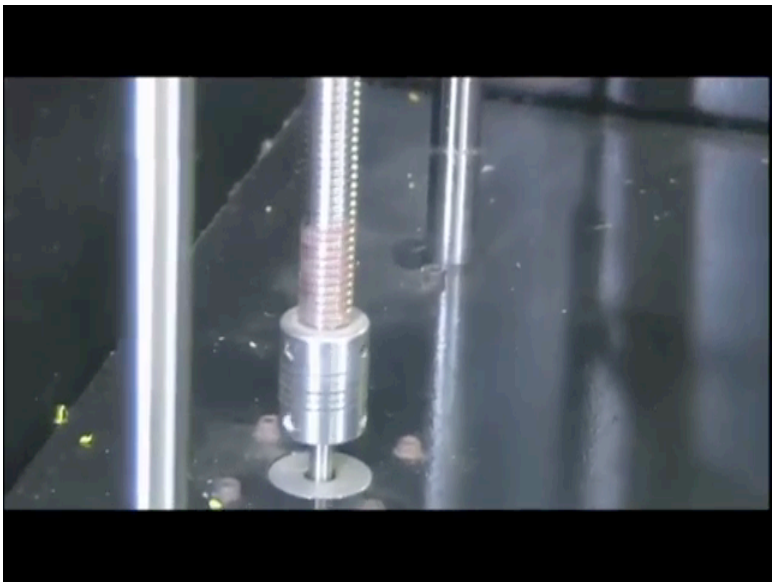
Now, the temperature is actually at 53, 230 degree; yes, the temperature is 230 degree. 230 degrees for the extruder 1, 53.6 degrees is for the bed, yes; that means, as I said 5 degree variation, I will have to correct myself this machine is quite precise or sensitive to temperature. So, the temperature 53 degree was set. So, it is within 1 degree 230 it might be 229 or 231, so within 1 degree of the resolution.

(Refer to Slide Time: 11:07)



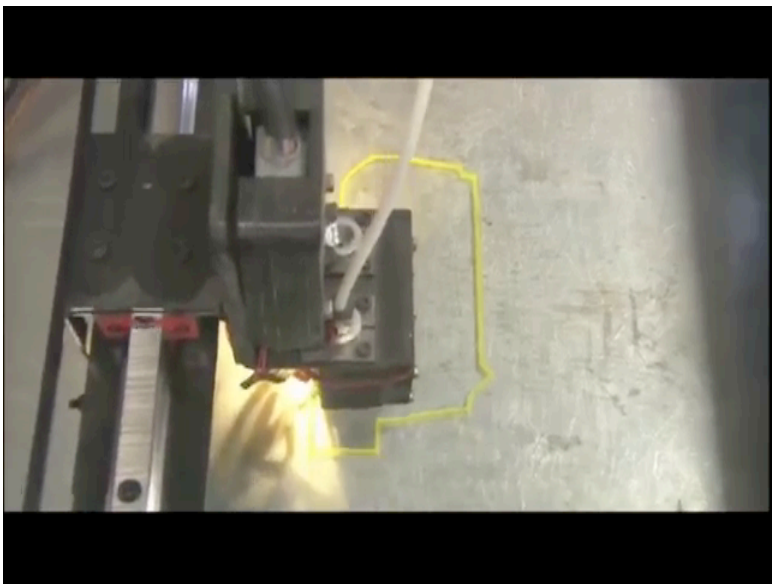
So, last thing left is, we come to print preview and we start the print. Now when we start printing, machine will go and check everything. First it will go at check the starting place, that at the corner. So, this is known as referencing; it is checking the height the height of the job you can see the rotation of the z direction, is moving up, the table is moving up, ok. So, the bed is trying to touch the nozzle top; the bed is trying to touch a nozzle top to set this zero value.

(Refer to Slide Time: 12:04)



Again you can see the rotation the bed is moving up, in a upward direction. Because we do not know what is the thickness of the glass plate that if you put on and also there is there of the fevi stick as well that we have that is there. So, the bed would touch the nozzle end to set the zero value. Now, yes, it has started the printing.

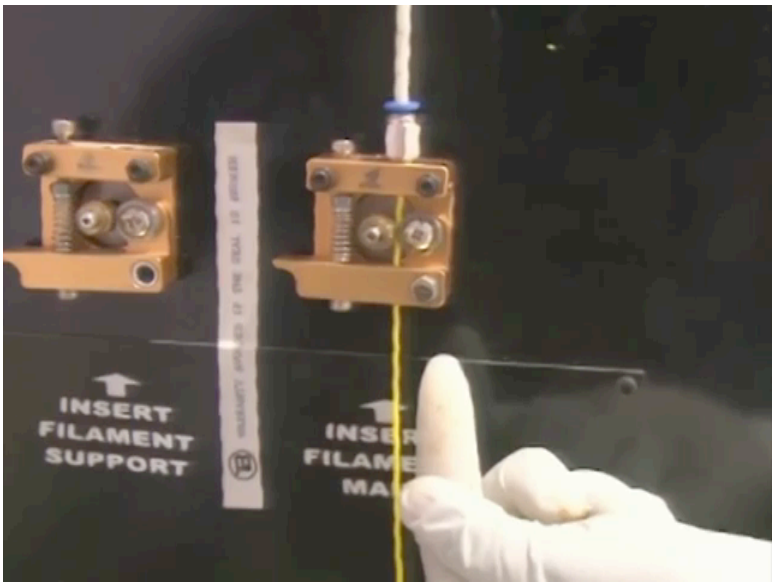
(Refer to Slide Time: 12:34)



The first layer is started here now. It is now printing, it is minting. This is the brim command that we mentioned before and brim is being fabricated before actual model. So, this is a very first line that is being drawn by the machine. So, it is running at the

speed. So, it is actually while brim the, it is actually the printing only, while printing the speed of the first layer was 40 millimetres per second. It will be moving at a speed, but this part would stick with the base again, brim would stick to the base, this is the extra part.

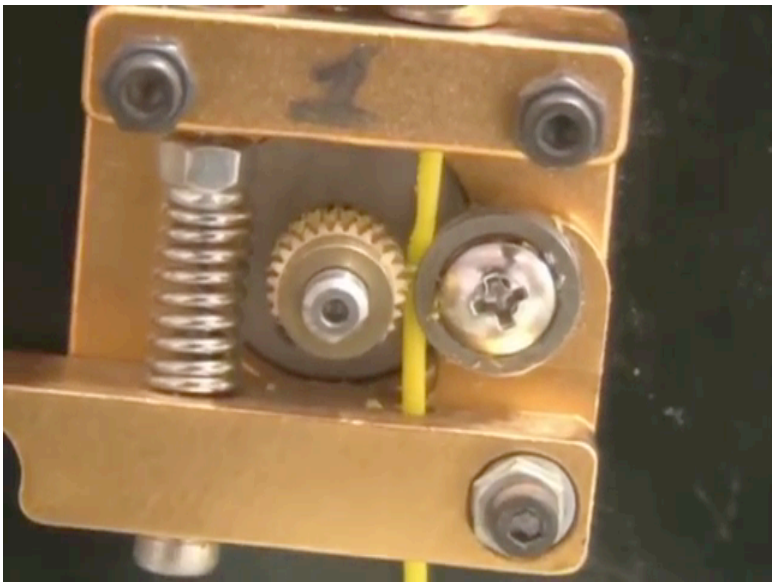
(Refer to Slide Time: 13:31)



Now, we can see here that how the feeder helps to feed the material, this is the feeder; feeder is rotating, ok. This is a roller mechanism here, pulley and feeder, pulley and feeder, is there feeder is rotating to feed the material towards the upward direction, but this is not the part of the CAD (Refer Time: 13:50), but this is used for the deposition. So, this is how the machining is happening, ok.

So, this is how the machining is happening. So, it will make the first layer brim that will start manufacturing the part. For the time for the machining; if you remember was 5 hours and few minutes; it will take this much of time. So, by the time the machining happens let us try to see the different parts different, components which are here in the manufacturing in the 4i lab.

(Refer to Slide Time: 14:39)



Actually we have to wave for 5 hours to see the final production of the final part. You can see the roller mechanism closely, this is used for deposition. So, it will take 5 hours for the machining to happen. So, by the time let us try to see the different components in 4i lab which are fabricated and using the rapid prototyping and other machines as well.

(Refer to Slide Time: 15:23)

Specifically for the prototyping, there are certain components. We are going to talk about a few beautiful and important features that we talked before as well. These are produced

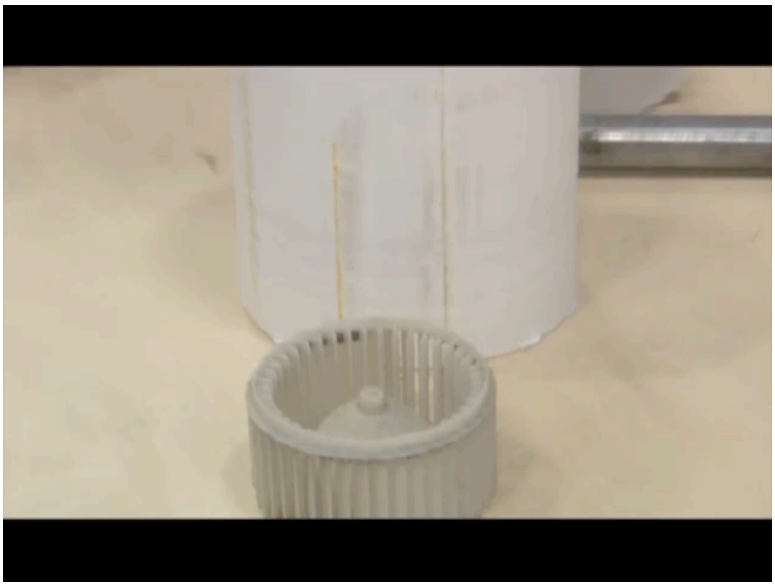
using FDM technologies; that is Fuse Deposition Method. Now with 3D printing that is this specific machine TECHB V30.

(Refer to Slide Time: 15:42)

(Refer to Slide Time: 15:49)

This 3D printing machine we have produced this geometric crank, ok. This is produced with this machine. Now this kind of hollow cylindrical job can also be produced, but this is pipe shaped with lock, but with the locking device sometimes we get very challenging kind of jobs.

(Refer to Slide Time: 16:05)



For instance, this is a propeller, this is a propeller fan ok. So, what it does? This you can see you can see the number of fins here, the number of very fine fins. The gap between the fins is very less; the angle is very important here. So, this is impeller. So, it is impeller, just sucks and throws out the fuel, so here angle is very important. So, this is a complicated job, so its fabrication is really complicated, really tough. So, it is typical to fabricate it with any other machining like a milling, turning or the conventional machines always may be bit CNC, general machining.

(Refer to Slide Time: 16:57)

So, now this technology FDM helps us to work freely to produce these kinds of parts, ok. So, and medical sciences know you know we have this foot, you know we can produce artificial limbs. For instance left leg, right leg and we have to fabricate artificial limbs for instance; for a particular man or lady and we are not able to copy.

If for instance someone has lost his limb if it is he has lost his left leg, but we can, we can just scan his right leg and by using mirror command we can produce the left, leg this can also happen. So, this is artificial foot that is produced, ok. It is actually the spectrum for the shoe here, so there are certain other components kept here.

So, 3D painting, what we need? We need to have the scanned model sometimes or the cad model has to be there. The cad model can be produced by someone, by the engineer or it can be even scanned model which can be then transferred into the cad model, ok. So, also you can see another model here. This is a beautiful feature; this impeller is a beautiful feature you can see the angle, you can see the accuracy, really very good. So, scanning helps in a way that you don't put any extra efforts for cad, modelling, designing, putting all that in the scanning helps in that.

(Refer to Slide Time: 18:35)

So, this is a pen stand; this is a pen stand and the now we need to if we need to model the same, we can scan it. We can scan it using a 3D scanning. 3D scanning means from all the directions from the different scanners are there like different degrees of freedoms of all the scanners are there and we have produced this similar model.

So, the scanning took about 2 hours and the printing this printing of this model took about 2 hours. So, within let me say 2 hours for scanning, 2 hours for scanning and 2 hours maybe, I will say 2 hours for printing. In within 24 hours, we can produce the same product or we can copy the product. This is re-engineering; this is reengineering like scanning and producing iron.

So, it has produced in a very fast pace within 4 hours as I said. So, that is why this machine is also known as rapid prototyping machine. So, we can produce very rapidly the scanning and producing, scanning and producing, that is why the term rapid prototyping and rapid manufacturing's comes into play.

(Refer to Slide Time: 19:49)

Also a few creative items are kept. So, this is a complicated model of maybe some holy person; this is a human skull. So, with scanning we can just scan the model and produce it again, ok. So, scanners are highly capable to scan anything, even we can scan the live humans and after scanning, we can produce the replica and the same scan data can be used for printing when we scan.

So, white light scanners are there like white light scanners are used to scan the human body. So, in general cad, we have to draw, we had to input to the machine and all those things have to be there. The 3D scanning helps the threading now the threading mean is a very used in engineering and mechanical background. So, in 4i lab, it is a High lab at IIT Kanpur. We deal with this kind of unconventional manufacturing methods.

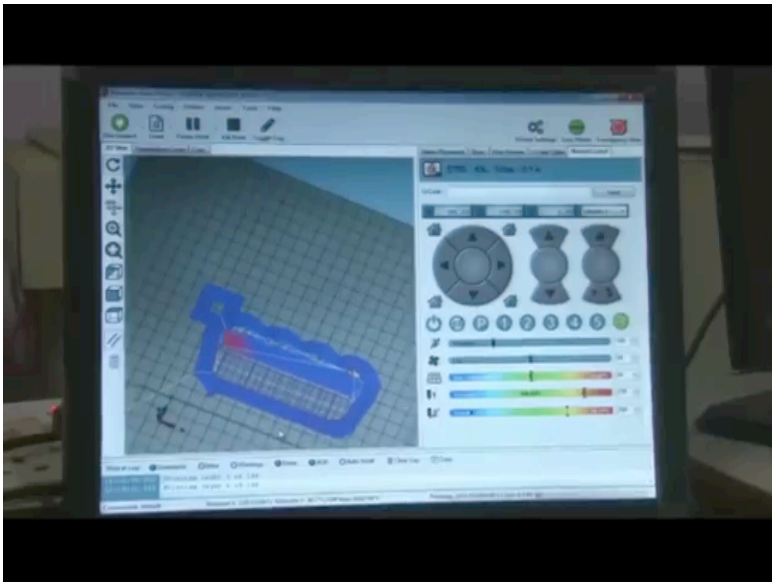
(Refer to Slide Time: 20:54)

So, FDM is quite possible in the, prototyping is very unconventional method of machining with 3D printing technology. We can print this kind of creative jobs like this hollow cylinder this kind of hollow cylinder. Now the beauty of these two models is that this model this skull is solid and this is hollow, this is hollow from inside ok. This is lightweight in this is solid; this is quite heavy. The beauty is that we have scanned and printed them, the interesting thing is that whatever we scan we got the components exactly matching the features of those were scanned.

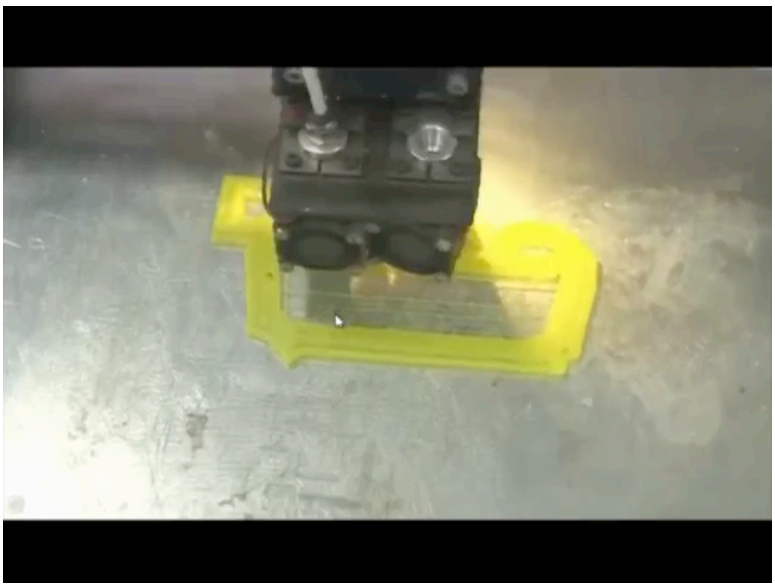
(Refer to Slide Time: 21:43)

So, there are other machines as well you know like CNC milling, CNC turning, so this is a metal part. Now this is a ball inside a metal cage. This is not the prototyping, but we are just mentioning a few components which are here, it was a cube. And it is machined with milling machine, with a CNC milling machine from all the faces and a ball is left inside. So, this is this is example of subtractive method not additive manufacturing. So, it is subtractive manufacturing with milling. So, same kind of job, we can manufacture with 3D printing.

(Refer to Slide Time: 22:15)



(Refer to Slide Time: 22:28)



In that case, we will have a support any modern materials you know now this is happening this first layer was brimmed. And after first layer, the other layer, the second layer is now being manufactured. But it is preparing support; you can see it is preparing support here because it was an angle in the component.

Now what this component is? This component is actually a key, it is to be kept in the machine, a key that we will set it and that will lock the two different parts of the assembly. You can see the machine moving. So, other components are here like we work in additive manufacturing and subtractive manufacturing both in 4i lab, so in both the modes we work.

So, let us see the other parts which are manufactured here. See all these white components are manufactured using 3D printing, ok. All these white components are from these 3D printing. So, let us see some other components and other models which are manufactured.

(Refer to Slide Time: 23:58)

Now, this is the model they were machining this is actually the printing on the wood that is IIT K lobo IIT K lobo and FDM Titan Knife Set whatever it is before I have a 4i laboratory IIT. This you know you can see the complication of the deep features in the part, this is manufactured using the laser machine that is here.

(Refer to Slide Time: 24:27)

This printing in teak ply, and we print and cut when we assemble. So, this is a printing and cutting of wood, this is teak ply, the 3D model is made. Now this is actually a very old technology cut and paste cut and paste there was no 3D printing, or no advanced machines were there. So, this was the way to develop the model.

So, we had to cut the faces and then assemble it and then fabricate it, but with the help of FDM we can do this entire shape without putting any effort. So, it can be manufactured directly and also with laser machine that we have, we are capable to etch and cut, as well as, many materials like acrylic, wood, mica, teflon and so on and we can etch and cut both the things can happen.

(Refer to Slide Time: 25:42)

Few materials can be etched only like this; this glass; this glass it is here, you can see it is etched here. And the image is produced, we can etch any image any alphabet.

(Refer to Slide Time: 26:01)

So, with this fine features and profile, the capability of machine is that it can etch and create a groove, or channel at a micro level. So, with this, our capacity is that we can work at micro level machining and we can go for both creative as well as engineering aspects of job with this machine, with the laser machine, ok. The capability or the resolution or I can say accuracy better, but accuracy is up to 40 microns.

(Refer to Slide Time: 26:42)

So, we can print on flat as well as cylindrical shaped jobs, like, when see the glass, we have printed the 4i laboratory name and logo IIT K logo. So, with this machine with the roller attachment facility, we can etch we can print, we can make a mark, we can groove slot or any kind of non machining, like any kind of non contact machining can happen using this machine.

So, in general when we say word machining the first thing that comes into the mind is ok. There might be some to some cutting might happen, contacts would be there, scrap would be produced tool; tool will deteriorate. But here the with laser light, it comes from the source that is, and it is a non contact method and the light from come from the source and it hits the work piece surface and the material burns out and sometimes it get is evaporated. So and by means of this non contact method pitching, printing, cutting, machining; these things take place. Now in this lab we have number of machines; cutting, printing or like this is ok this is cutting and printing on leather.

(Refer to Slide Time: 28:08)

(Refer to Slide Time: 28:12)

So, this is mica ok, on mica this printing is happening here, between then, happen on this mica here ok; the etching on mica, then testing on teak ply.

(Refer to Slide Time: 28:32)

Again with laser and cutting also as I have done with laser in this component. Sometimes this kind of cutting is also to be carried out on metals, ok. This is carried out with the a machine known as abrasive water jet machining.

(Refer to Slide Time: 28:56)

From with water jet cutting machine, we can cut any metal and in non metal. We can see this is a marble and this is granite, this is granite, ok. It is a brittle material to cut; this is a Chinese dragon shape, it is cut with abrasive water jet machining. So, this is aluminium and we cut it from rack, like this is a rag gearing, this is rag gear actually.

(Refer to Slide Time: 29:24)

So, there is one more job of brass; this profile is called as aerodynamic profile. So, our students at IIT Kanpur of working on this high pressure air, this specific component is used to there. So, this kind of job also is carried out with the subtractive method of machining only, with milling machine.

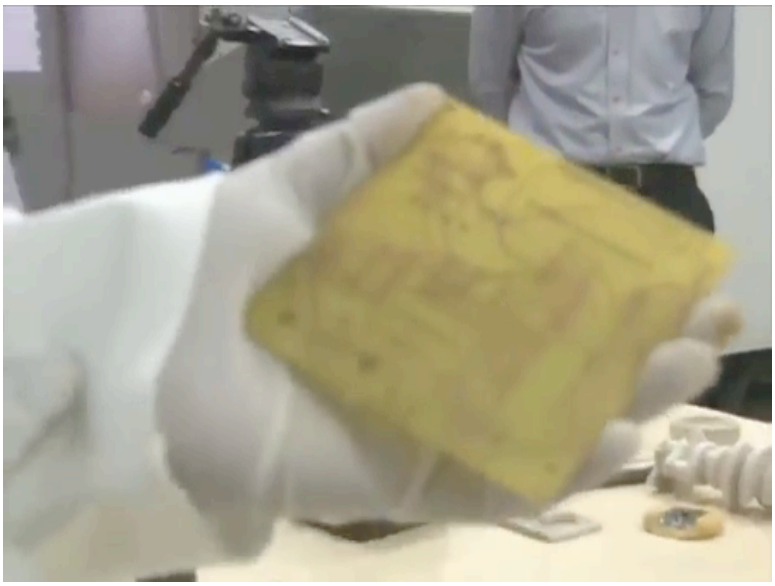
(Refer to Slide Time: 29:56)

So, this is 3D printed, but it part that is the outer covering of any shape ok, outer shell covering. So, this is manufactured using vacuum forming machine; this is not with 3D

printing. This is one more machine that is able to produce the outer shape covering. So, it has a specific feature in that so this is vacuum forming machine.

So, with the help of vacuum forming, we can form the sheet of any shape as per our part or a die board, according to that, ok. We can make a hollow geometry as well as 4i lab, we support mechanical as well as electronics here; so in electronics we have a number of machines to fabricate and to manufacture PCBs.

(Refer to Slide Time: 30:54)

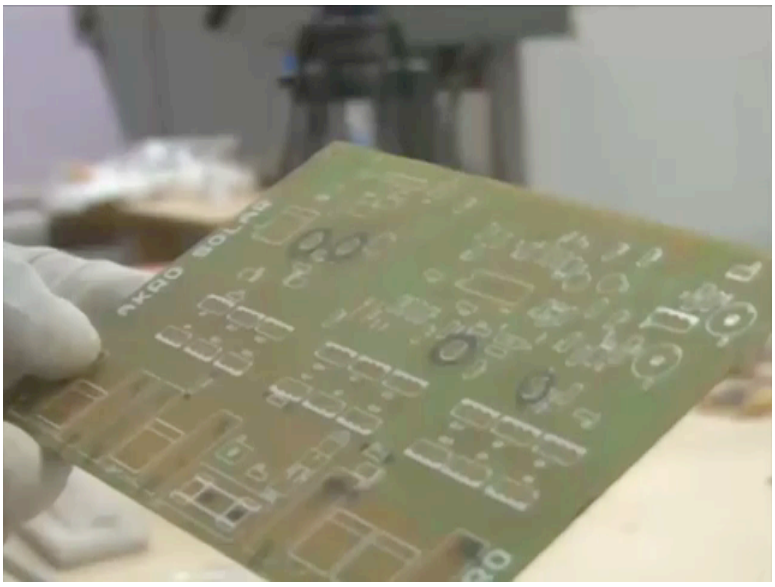


This is printed circuit board. You can see this is the raw PCB, these are the tracks. We have asked a material from the yellow surface area where yellow area here. This is this brown one is copper bead here.

(Refer to Slide Time: 31:09)

And then we have the chemical coating also to make it green coated at all and the copper tracks are there. And to prevent it from oxidation, we use green coating and green liquid is here to make it free from oxidation that is, green coating is happening.

(Refer to Slide Time: 31:33)

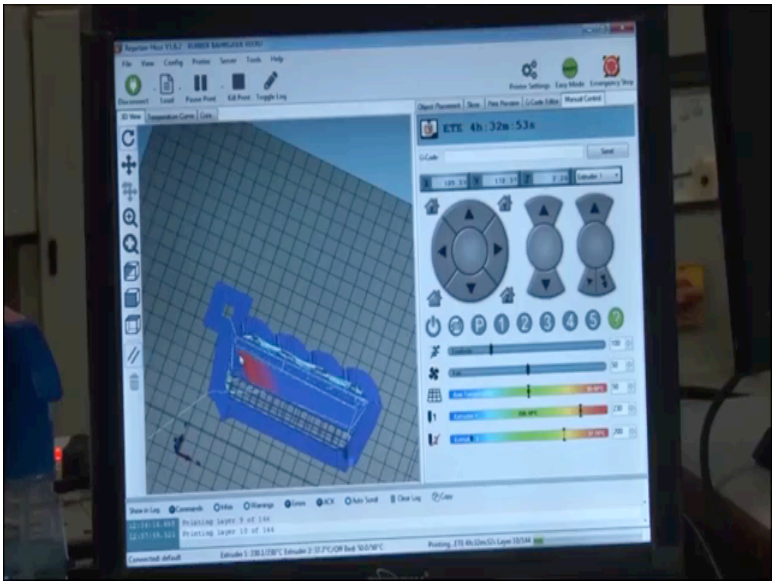


So, this printing of white here, this printing of white material here; this is called as tin coating. To print some alphabets some numeric's like it is showing the circuit diagram here to clear the IC numbers at all to be put on. So, we can put what kind of soldering has to be, you know, product has to be soldered.

So, all those symbols for transistors symbol for , input output, then printing the kind of all the things, that we will taken care within the white colour that is called as tin. So, here we help the students to or the industries those come here, to in mechanical as when in mechatronics, mechanical plus electronics.

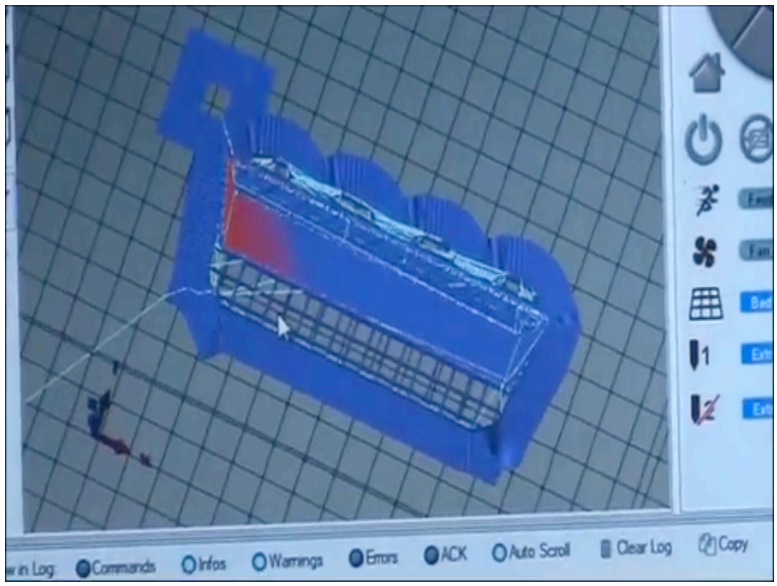
So to help our students to develop their own prototypes, their own setups and experiments machineries. So B. Tech project students also we support and we give classes people are training to the people who come here for the faculty development programs. We provide hands on skill towards students and the guests who come here for learning and support to fabricate their job. So, especially support people from industries and all those things are here.

(Refer to Slide Time: 32:51)



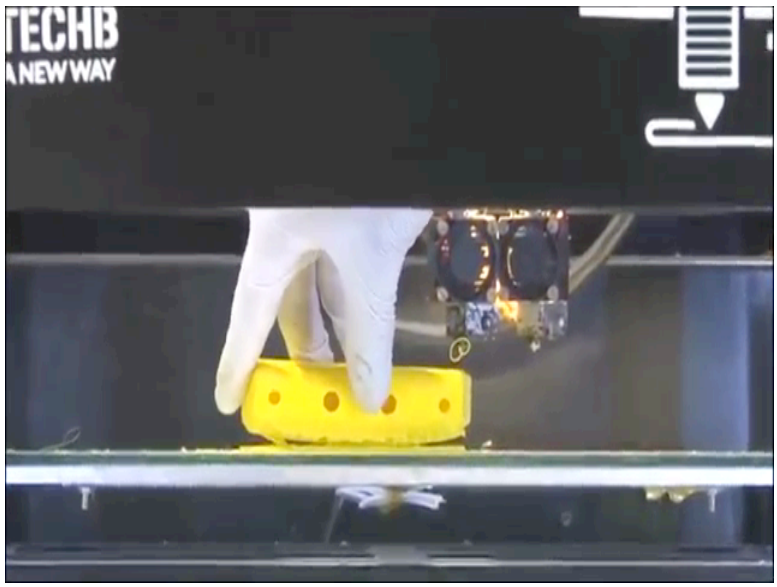
So, what we can see here is the machine is running we can see the simulation of the machine as well as the actual machine is running here. So, the stimulus is happening, you will see the material is being deposited here. So, all these layers that you can see as mesh here, these are supports.

(Refer to Slide Time: 33:14)



These supports would make the material to deposit over it. So, when the machine, it has not completed on this side now it has made one line here. So, it would not waste time to restart the machining from this point, when it has done it has machining here means adding material. So, when the material is added over, here it will restart from this point only and keep depositing the material here. So, this is total 144 layers would be made to manufacture the part where that we have designed and estimated time here is 4 hour 32 minutes that is the total time there is left here.

(Refer to Slide Time: 33:50)

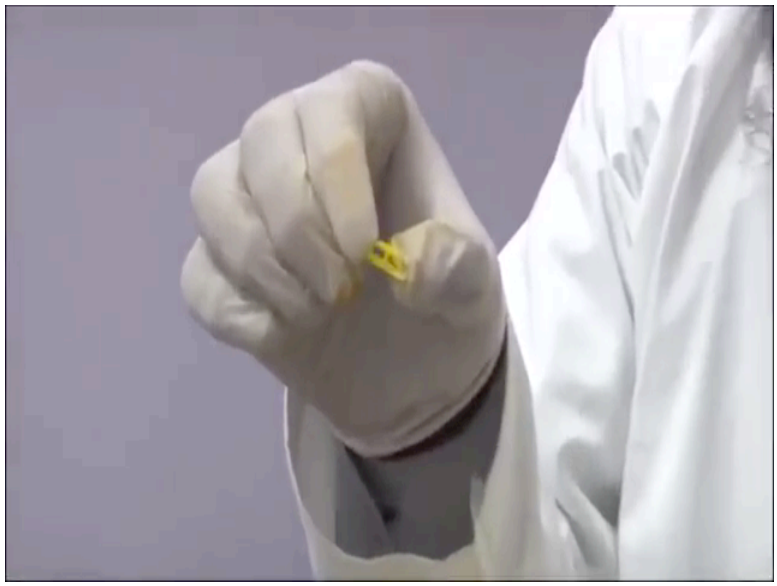


So, it has been an hour that we have manufactured this product. So, I can pick this products from here, I will just pick it up.

(Refer to Slide Time: 34:01)

So, this part this support I am removing. So, the brim part is there on the machine only. So, this is the final product that we have manufactured. So, we can see here that on this support that complete material deposit is not, it is only the mesh. So, as the minimum material is deposited that can support the main material, that is the main filler material that is we used here. So, here as we are using single spool the same material is being used as support and main material.

(Refer to Slide Time: 34:40)



So, these supports you can see this was the final component that was desired here final feature of my component here and this is the support that is removal, so it is hollow from inside. So, this is the product that we have manufactured in our demonstration in rapid prototyping or we also call it additive inspection here. So, this is TECHB V30 machine fused deposition method machine.

Again we are talking about, this is 3D printing machine like we have multiple additive manufacturing or rapid manufacturing or rapid prototyping technologies like steel lithography, digital light processing, stereo lithography and fused deposition method are the major ones. Then also we have laser methods like selective laser sintering, selective laser melting, electron beam melting, then laminated manufacturing like laminate object manufacturing, all those methods are there.

This is a theory printing machine out of the types of the 3D, 3D printing machines. This use Cartesian coordinates there are certain types of FDM machines. It is specifically 3D printing fused deposition machining methods that use different kinds of coordinates. The Cartesian, Cartesian uses the x y z this is the Cartesian method. Other methods or other kinds of machines are delta FDM printers.

The printers use 6s axis 3D printer which are based upon delta technologies machines, operate with they also played with Cartesian technology. But there is more freedom in that then the polar machine is there, polar machine, the polar 3D printers in the in that the

positioning is no determined by x y and z coordinates, but by an angle like the polar coordinate system.

So, another with 3D printing machine can be with the robotic arm different robotic arms can come and keep printing at one point. So, they are with the four kinds; Cartesian, delta then polar and robotic arms. So, this is Cartesian FDM machine. We have gone through a demonstration of this machine in the 4i lab and I hope you have enjoyed the demonstration and please come up with the questions anyway.

Because this was produced in three or four phases, we made the setup we had produced, we the recorded the video in the lab when then we had tried to see that video and then I have put my voice over here. So, there might be some mismatching, so pardon for that, please come up with the questions wherever you think that things are not clear. And we will meet in the next lecture; we will discuss further about the course.

Thank you.