Design, Technology and Innovation
Prof. Ramesh Singh
Department of Mechanical Engineering
Indian Institute Technology Bombay

Lecture-9
Technology to Solution Part-2

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So, I will just walk you through some of the things, how we designed the machine: the Micro Machining Center. The Micro Machine Center, what we did was we found out what the issues were.

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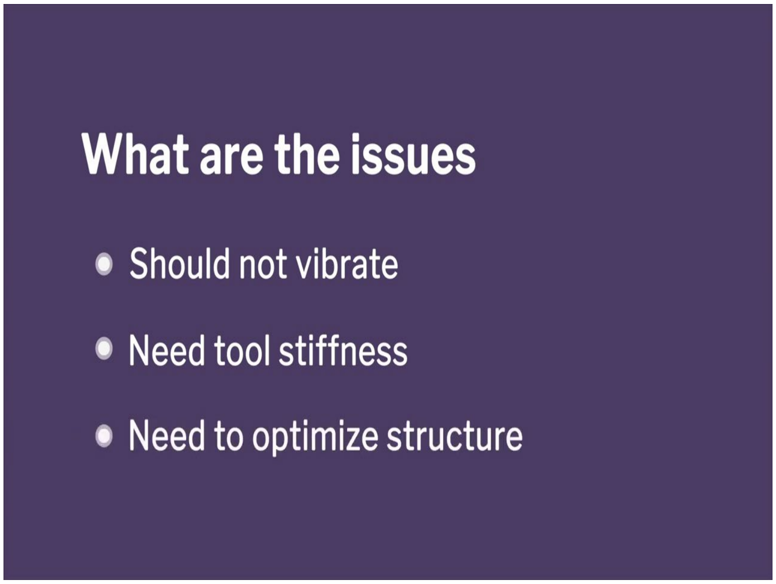

The first one was that we do not want any vibration.

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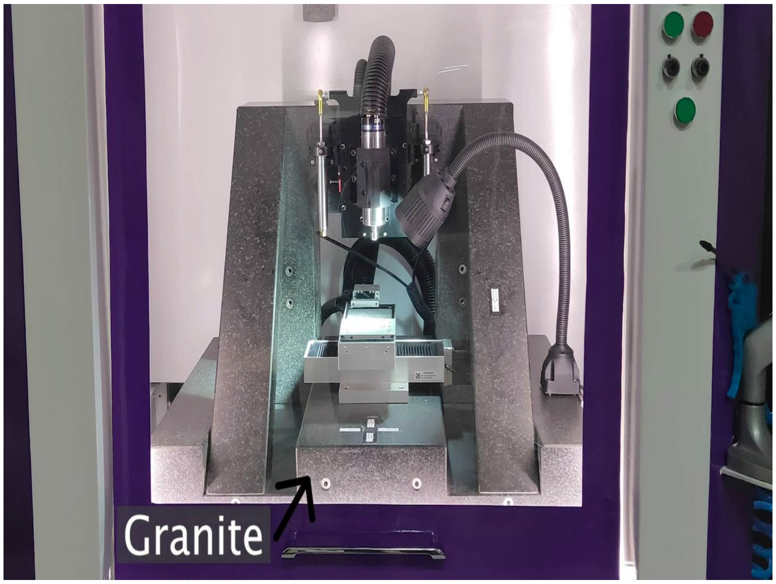

So, we use the entire machine as granite, because granite has very good anti damping properties. Then what we did was, the tool stiffness is an issue that we talked about a little bit. you can go very, very high speeds to make sure that it cuts very small in one rotation. If you get a very high rotational speed you actually cut very, very little, the forces go down. And then I want very high percent precision so we basically have a very good structure, optimize the structure.

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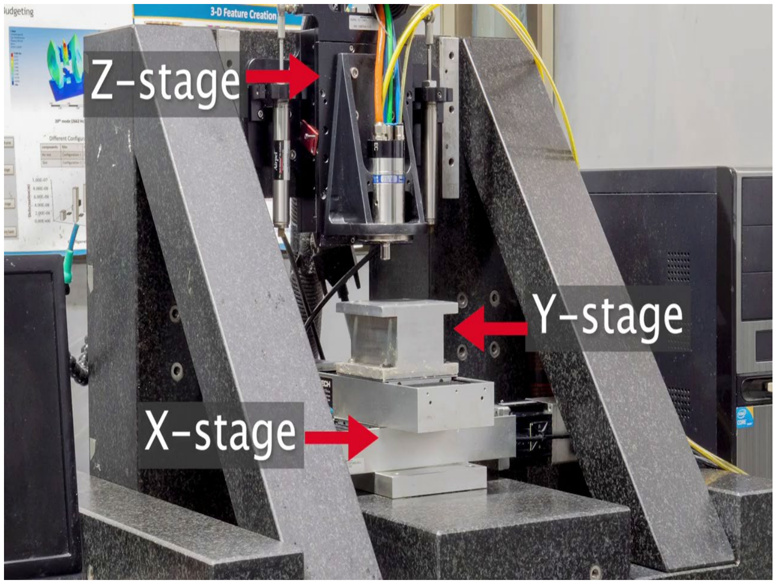

And then I can have a high torque spindle and low-cost because I take a very good Z stage and XY stages that are actually precise but not super duper precise. When I am ding micro machining what happens is,

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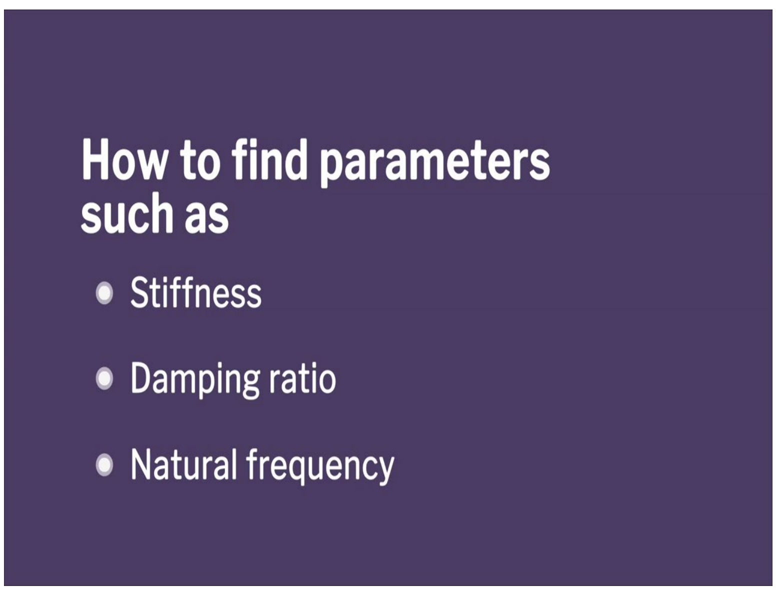

so, if somebody wants to say, the parameter of any, this stiffness, damping ratio or natural frequency, you know, how (do) they get those parameters? They actually excite the structure. So excitation is done either by a shaker to excite it or by a hammer. Take the hammer, hit it and then take something which will measure the vibration.

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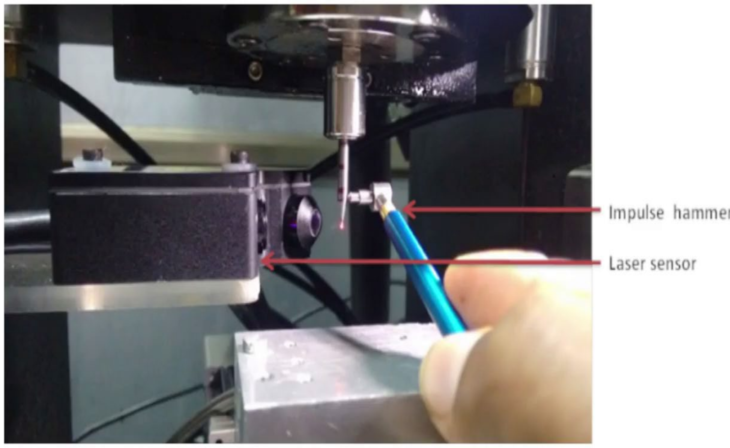

That can be an accelerometer which will measure the acceleration or a displacement sensor. We did not hit right at the end but the shank is thick, shank is 3mm the bottom is 100 micron. So, you do not hit the 100 micron because that will break, so what we did we hit at the shank, measure it at 100 micron. That is a challenge but has to be done.

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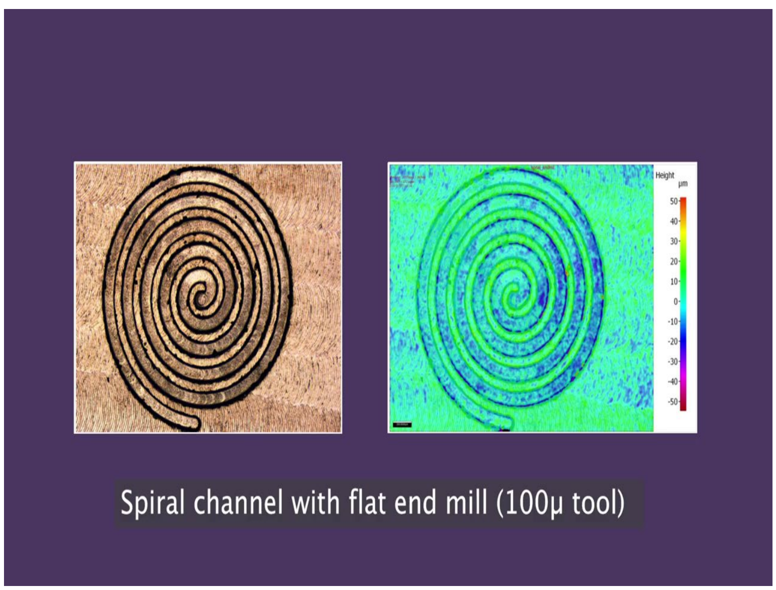

So, then we were able to create all these features. These are 100 micron channels 400 micron channels. Just to show what we can do with this. There are other things which we designed a machine, which would actually just take the laser, soften the material and then machine it. So that way the stiffness can be counted because now the material is softer.

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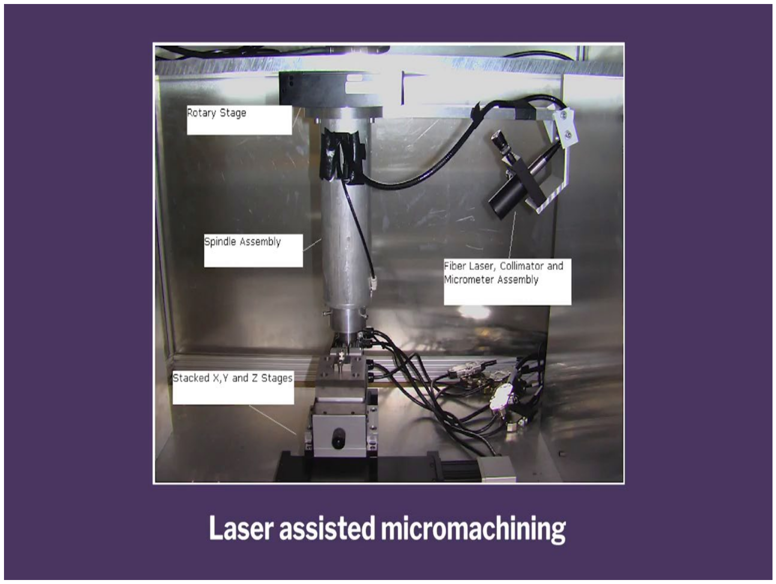

So, we did it in a milling setup.

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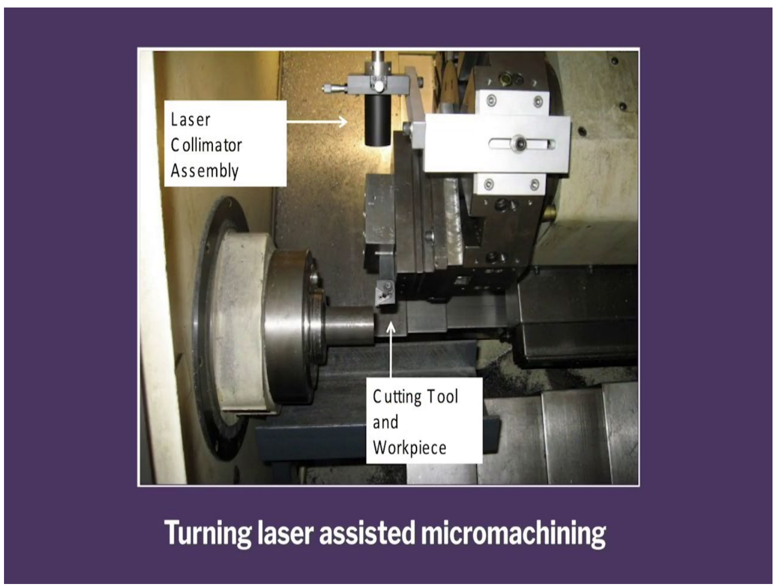

In a turning setup. Then I talked a little bit about additive manufacturing right, but the scientific issue with that is;

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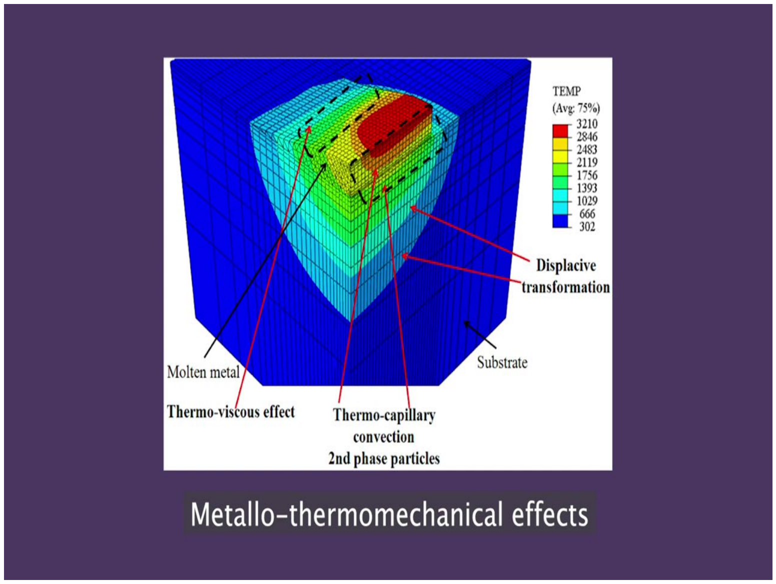

Because when you heat it, there is differential contraction, there are micro structural changes.

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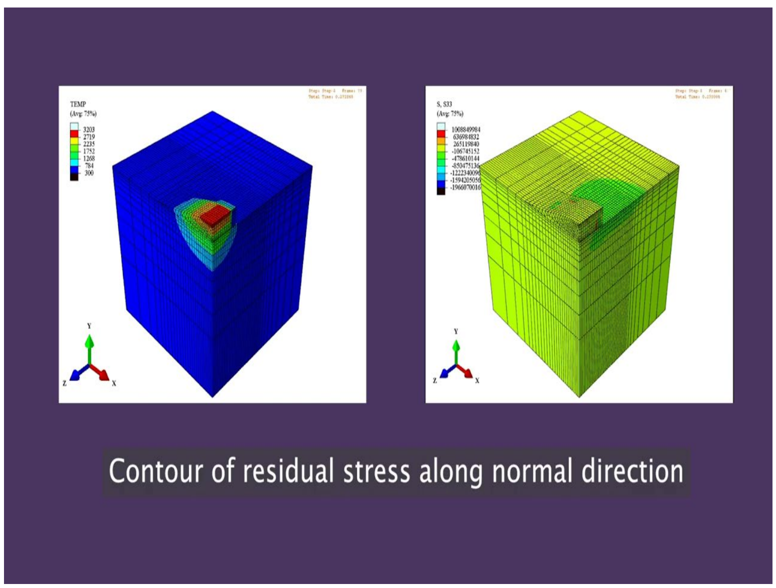

And those induce residual stresses. So, we to understand that. And then we had a nice model and everything. Now I want to build one. Now I understand the process. I have papers. Now what brings me the most happiness is building stuff.

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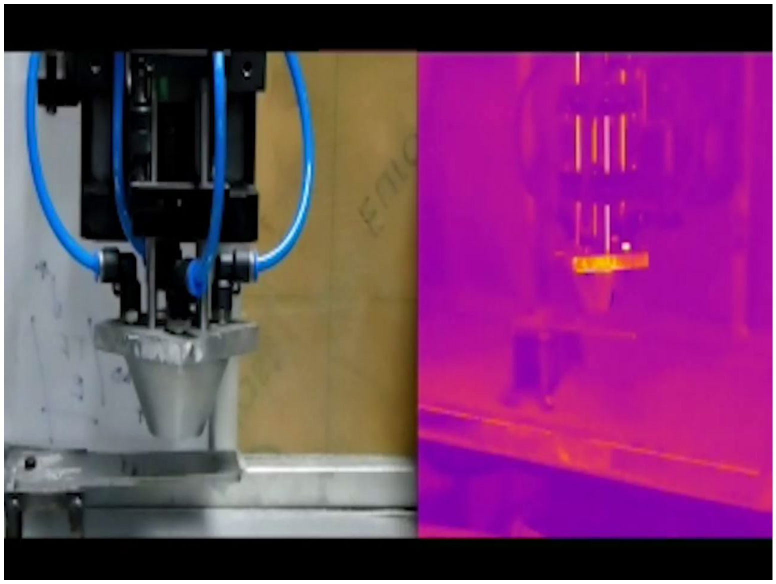

So, there was one student, a good student who actually rigged the machine. He designed his own nozzle. This is a 3D printed one, in the left. Then he actually machined the entire nozzle. He built his own makeshift Powder Delivery system. See, it is in tatters but it works and then he build, he printed some rings, some boxes out of it.

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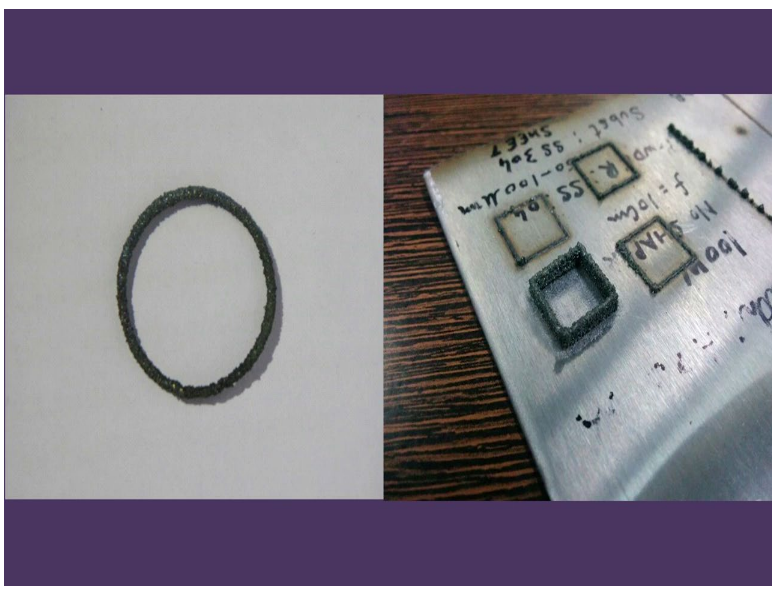

Then we showed these small contraptions and then went to DST, 'Give us money'. They gave us few crores.

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And then the real job started, then we started building the real deal. Got a big heavy-duty robot, got a real cladding head. Cladding head basically means it supplies the material and the laser coaxially. So, this is what we are doing. We are actually doing this for Bharat Forge. We are taking the, we are depositing a very heavy, heavy hard material on top of their molds. So, tomorrow if they use this kind of additional layer the mold life will increase. So it is called hard facing.

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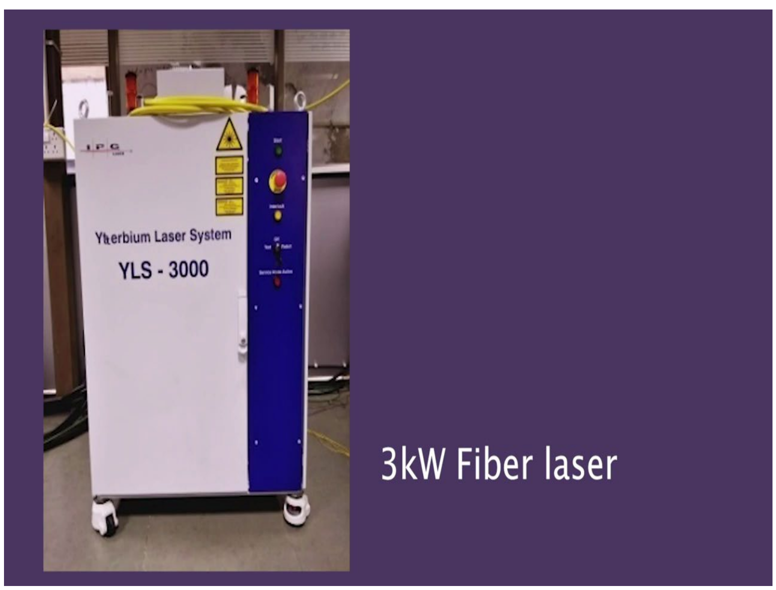

Got a powerful laser, 3 kilowatt powerful laser.

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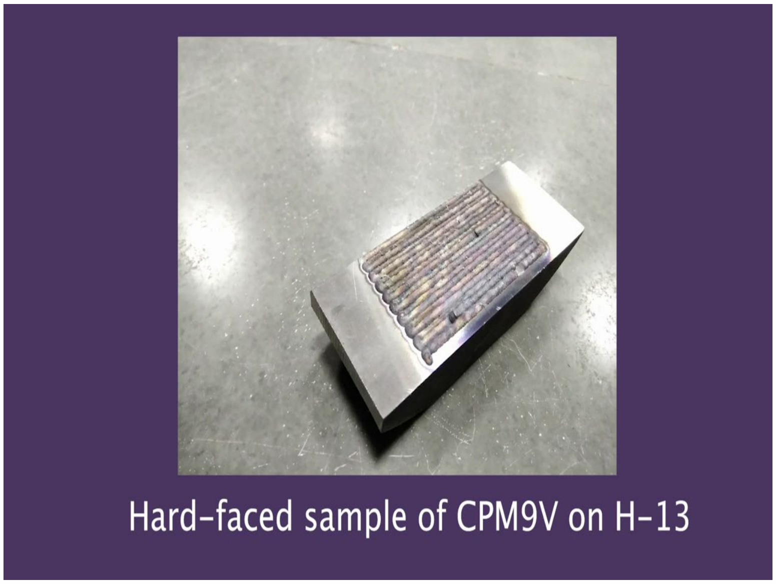

And then we printed something very nice.

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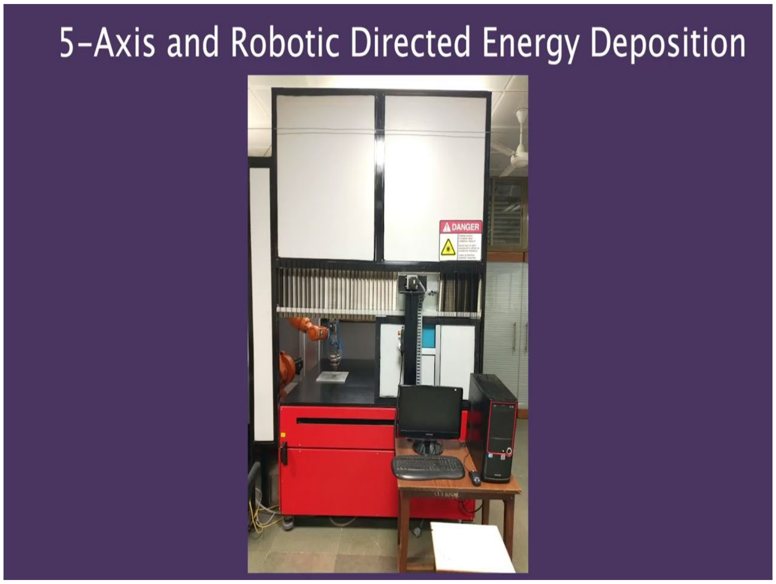

And improved the machine. Now we have 2 stations there. One is the robot. The other is a 5 axis system. Again we have designed this and got it built.

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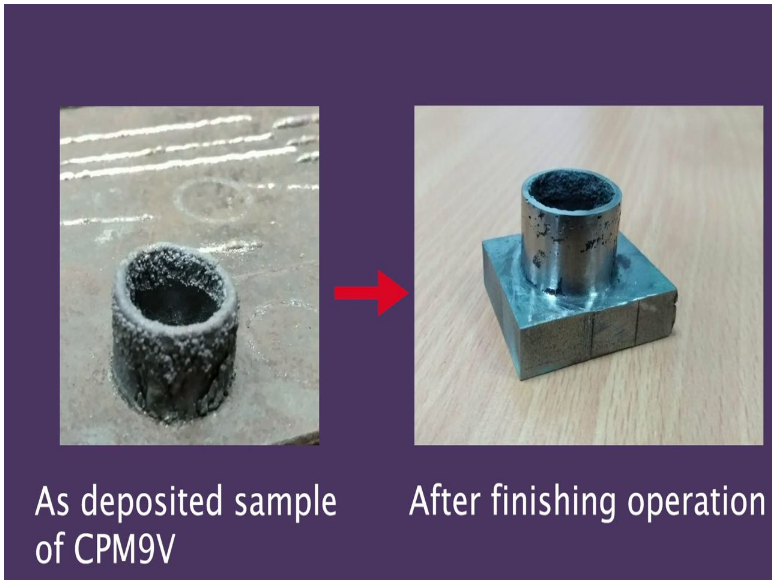

So, if you go ahead you can polish it. It looked ugly right. If you polish it, clean it up, it comes out nice. So, it is 5 times normal steel strength. So, if I were to cut it I would have found a tool to cut it, it is so hard. So that is the beauty that this process can be a process where I can print super hard things which is not possible by using a machine.

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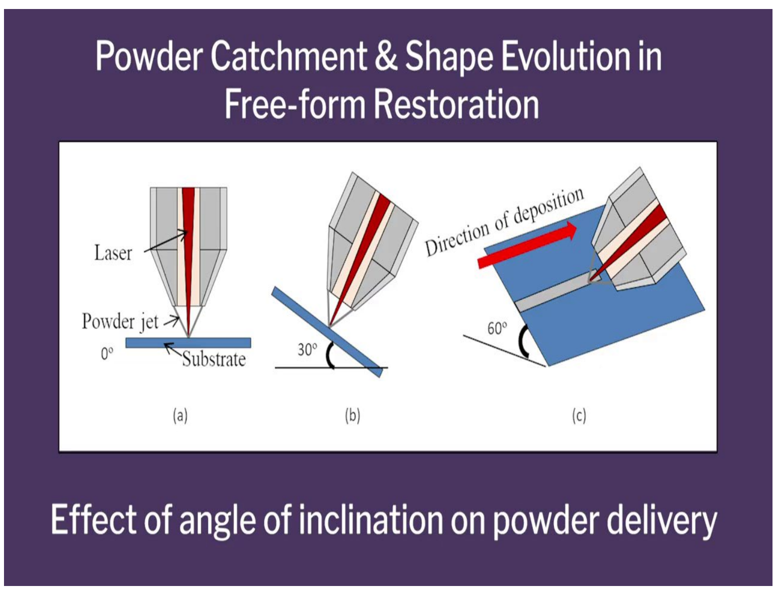

And then we deposited it at different angles because if I do it like this I lose a lot of powder, because the powder gets skewed. We are trying to understand how powder comes because if I have to build in 3D configurations I need to know how the powder, how much powder actually, we call it Powder Catchment Efficiency.

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And how the material flows. So these are actually cross-sections after; so we did it at different angles, and if you do it really, really high angle, you actually lose most of the powder. On the bottom portion, that is what it shows. What a powder is lost. So that was the actual machine part of it. Now if I want to repair it I told you right we also need to scan the defect.

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So, I will show you another video of scanning. So this is what we will propose to do. This will sit on the robot. This is just a dummy, easy to do but this will be done at a real product level. There will be a line scanner which will scan the entire entire product.

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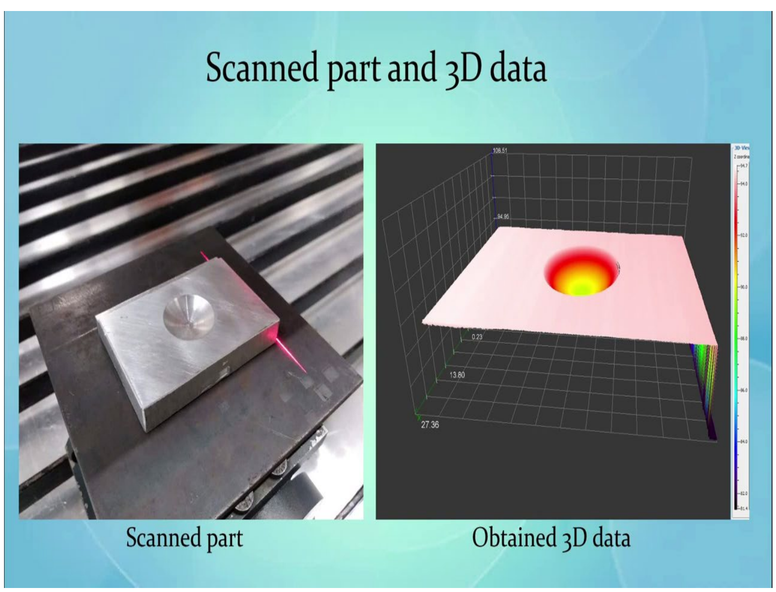

And then build models like this. So right now I know there is a defect right in the center. These robots have accuracy of 50 microns, that is what they claim. It is much higher. The vendor claims that it is 50 micron resolution but I will still take it with a pinch of salt. Robots are not very precise things to do. If you want very precise then you will have to do something (like) what I did with the ball screw stages or linear motor stages. What I have built on the Micro Machining Center.

Those are nanometric stages. So if you have to (be) precise, then you will have to use a different set of kinematics. Robot is not a, it is very flexible but it does not have the same accuracy which you have in a gantry based system.

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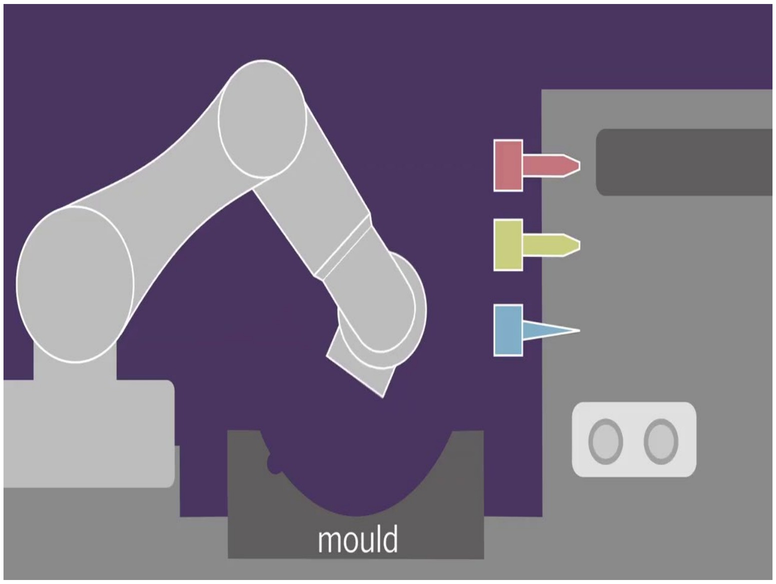

So, eventually our dream is that there will be stations. The robot will go ahead and it will pick, first the scanner, scan it, place the scanner at the holder. Then go pick the printing head, print it. There will be a finishing tool, post deposition you will finish it, keep the thing back. Then take the inspection head, inspect it. So, that is our final dream, totally autonomous, that is our dream. When we make one we will sell one, but that is our final dream that it should be totally automated.

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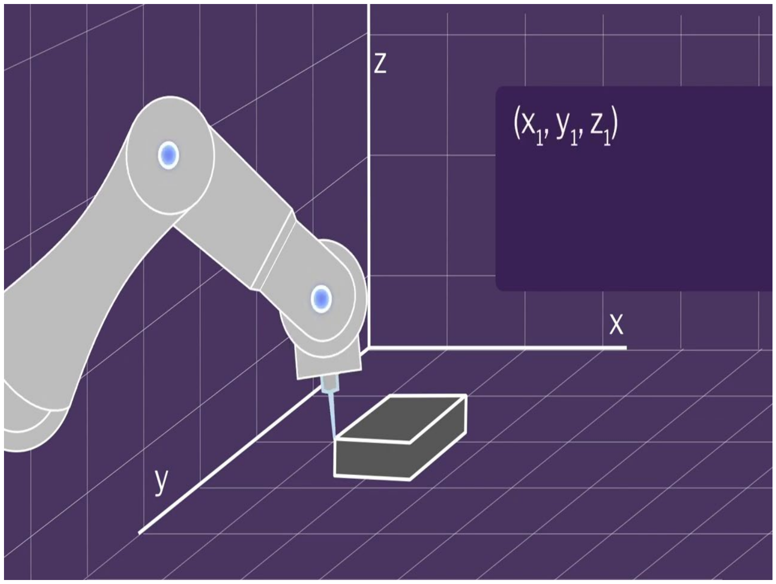

Scanning is not 2D, it is a line scanner, but this line scanner is in space. So I have the data of where these lines lie, right? Where these lines lie in (3D) space. So, this line would give me, but this line, every line has some XYZ of the robot, I can combine all that data. I can get the data from the robot, get the data from the line scanner and create a 3D map of it. So, that is what the student does, the machine which I was talking about, the Vent Cleaning Machine which I want to showcase today.

This is how they do it, in the shop floor. So, he can do in less than a second, one hole he does it. We were doing 1.6 seconds, our machine was doing it in 1.6 seconds. We could do faster. I told him I can program my laser to move faster but then what will happen, all my optics will go away because of the inertial forces. Because if I do very fast there would be acceleration right, and these acceleration will exert forces on my optics and everything.

But then, a lot of the time what happens is the drill breaks. So this is the problem, that if the drill breaks then, and it goes into the tire. So you screw up one tire but the OEMs will return everything. Because OEMs, if you know, I do not know how many people know, how auto industry works. The only people who gets crushed is the is the tyre 1 tyre 2 supplier. Cars are getting cheaper by the day and the only people whose profits go down is the supplier of the OEM. OEM does not reduce its margin.

So if you buy a tire in the margin of 2500 rupees, the OEM buys it for 1000 rupees. That is the price but they still sell it to OEM because they want their tyres to go into Renault or Maruthi.

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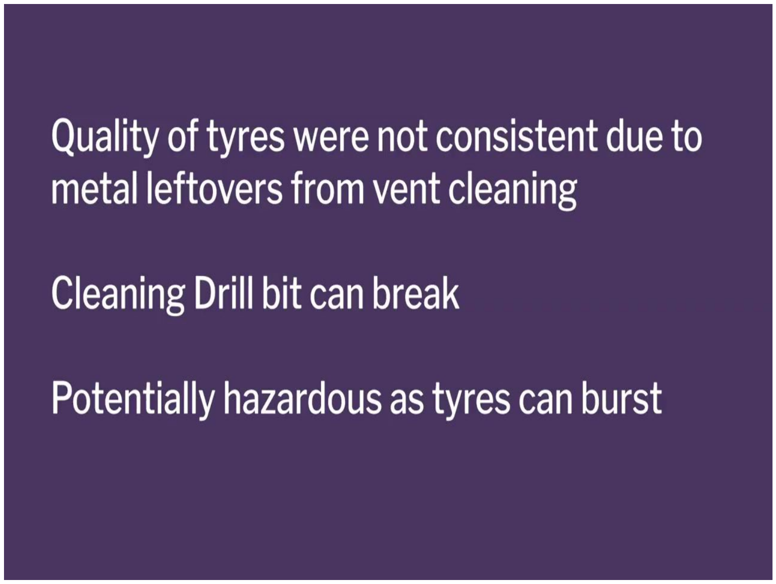

So, quality of tyres were not considered after metal leftovers in the vent cleaning. Cleaning drill bit can be dangerous and potentially hazardous as tyres can burst. right? So, that is how they walked into the lab and said that ‘do it’. So, I asked them first thing is you just send me all these clogged bolts and I will play with it. So, we got those molds in the lab. One of the students came and he fired the lasers. Is it getting cleaned or not? So, that was the first step. We said it is getting cleaned.

We saw, we observed, it was getting cleaned. Then I said, ‘Ok, why don't we clean it with the air jet?’. So, we put up an air jet and cleaned it. Gotten even better. Then they said, let us try nitrogen. They tried nitrogen. Is it improving? Try oxygen. Is it improving? So, nitrogen, oxygen and air did not make much of a difference. So, I said Ok, it does not matter, you do not require an inert gas to improve the efficiency. That was the fundamental idea which,

so people do a lot of experimentation when they sit in the lab. And then they said that how do we correlate how much, how many pulses we need? So, they took a tire piece, kept on firing lasers on it and said ‘How much deep it goes?’

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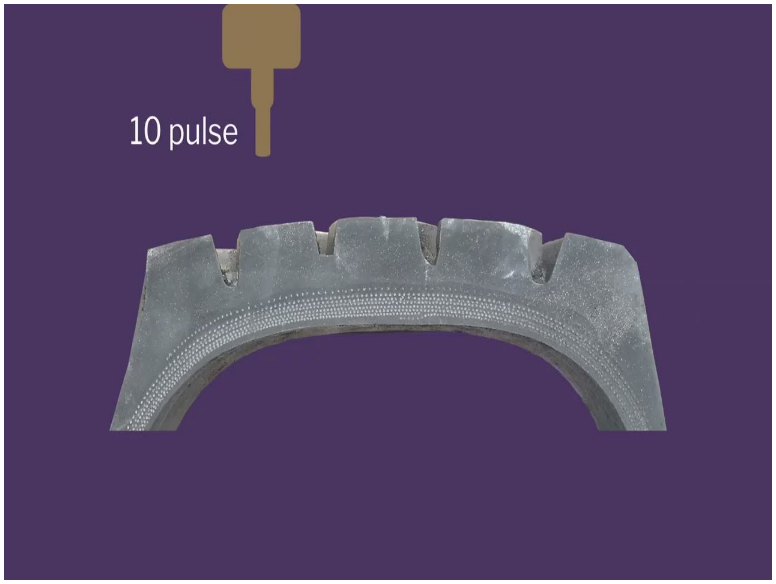

So, they basically did a test by making holes in an actual tyre. They took a tyre and they kept on firing 10 pulses, 20 pulses, 50 pulses, different pulse energies because I needed to know what parameters are required.

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So, this is how the tyre building machines look. This is an actual factory shop. So, this is the final process of making the tyre. First they just make a drum and then they make the side wall. This is a final operation where the side wall is already made.

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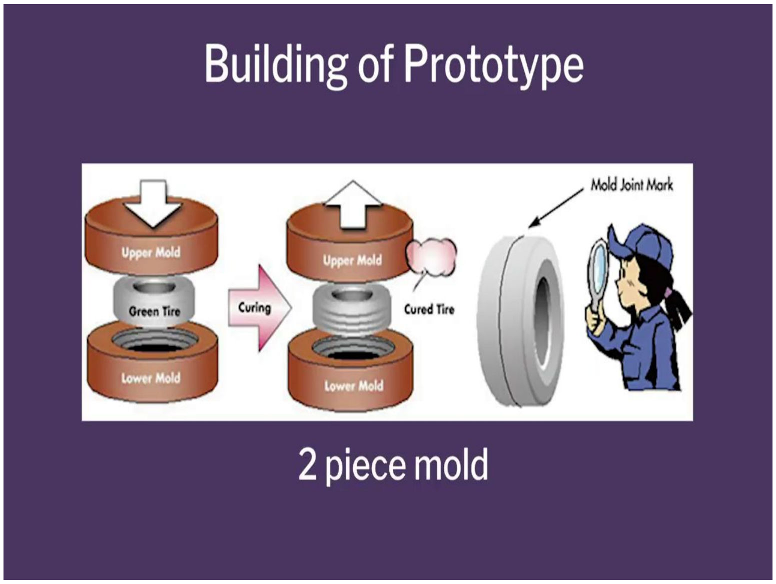

So, prototype building, what we did was, this is a two-piece mold. There will be one piece at the bottom and one piece at the top.

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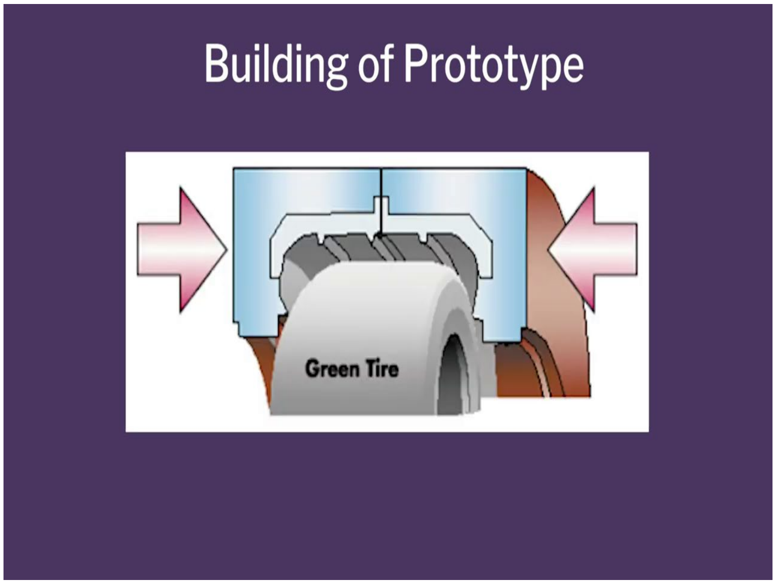

It takes something called a green tire which is not cured yet. It is called a, pre shaped tire is there with no treads or anything. It will come into the mould, all the treads, all the features which you see the tyre comes in the tyre mold. They will take steam and they use the steam to heat it up and hold at certain temperature and the temperature tolerances are very high. The entire thing should have few degrees, one or two degrees, within 2 or 3 degrees to make sure that the difference is not very high. Otherwise the quality will be compromised.

So, they want us to do another project now. They want an induction heating based system for curing the mold, but if I do something like induction heating, there is a gradient. So, they actually want us to redesign the entire thing. So we will said that we will actually reengineer the induction coil design. We will do some physics based modeling to figure out what would be optimal coil design and then do a conduction study of the mold, and then make sure that we design the mold with a combination of studies and some control.

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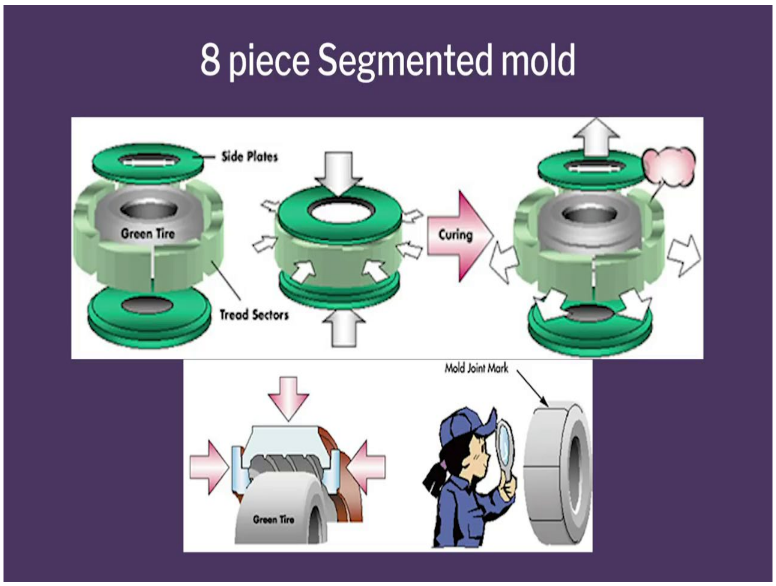

So, these are 8 piece molds. It is an 8 segment molds, made of aluminum.

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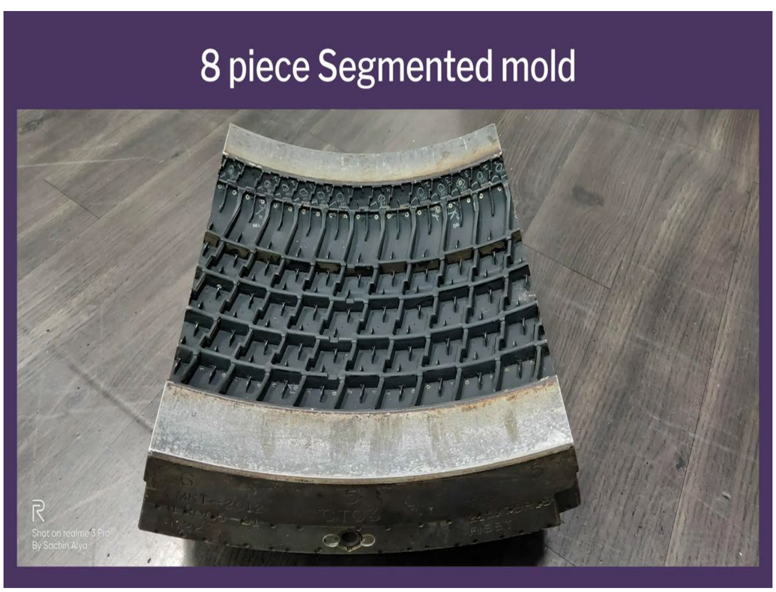

So, those are assembled and you see the vents will be somewhere here. There are all these vents are there. These are the vents which would have to be cleaned.

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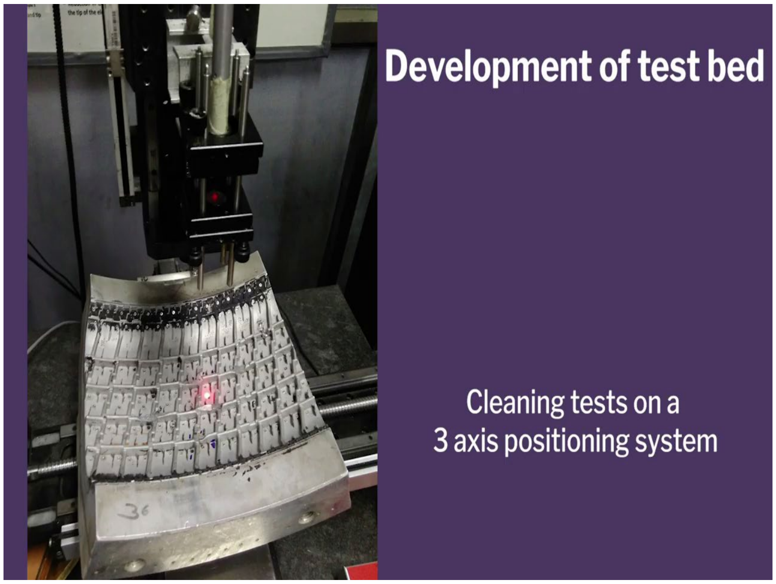

Now the ultimate test bed is, initially I did not have the position to, position accurately, right? So, we would do the alignment by, the usual degree, you see it is right at the normal vector is there. So, we did not have a robot or you did not have a positioning system of 5 axis, right? So, we managed to do it using some tilting, something like that and then trying to make sure of that. Our idea was just to see the proof of concept, whether it is cleaning or not and then get to the kinematics of it.

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So, we did some experiments. This is the very first few experiments that we did. The first one we needed with the Continuous Wire Beam Laser (CW). CW laser is not the right tool because with a pulsed laser I get a lot more variables. I can do a number of cycles, I can give a lot more energy in small times, I can ablate the material very fast. So then we switched from CW to Nano-Second Pulse Lasers and the Nano-Second Pulse Lasers are much cheaper, 1.5 lakhs, and this 20 watt is continuous power, peak power can be 20 kilowatts.

So, it is actually, the peak power in Nano-Sseconds, if you see because 20 watt is the average power. If I keep it on for only a few Nano-Seconds, 100 nanosecond, 20 nanoseconds, the peak power is very high. It is actually in kilowatts.

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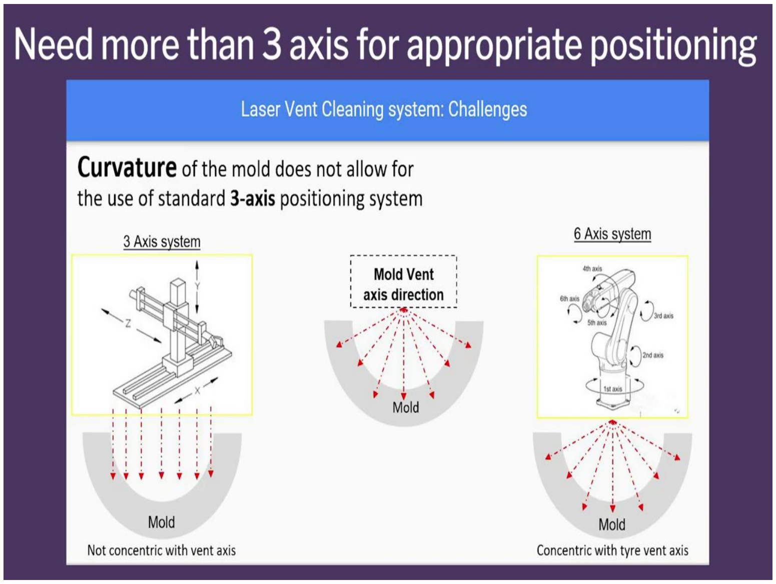

So that was the basic thing that 3axis pointing system does not serve the purpose, because I need to be normal to the surface. Whatever the surface is, I need a normal vector to the surface. So, I need a flexible position system, preferably a 5 or 6 axis poisoning system.

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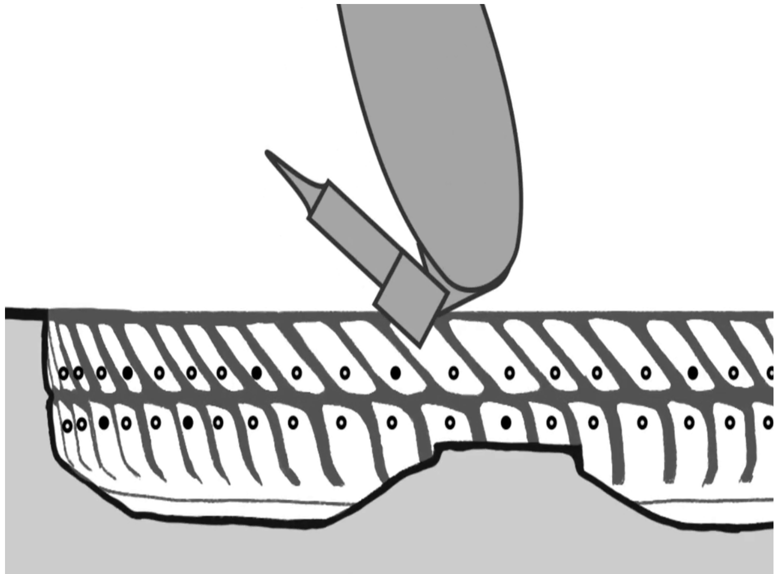

So, that is how we built a, we zeroed in on a robot. So this is just the kinematics now, right? I need to be normal to the surface. But the primary challenge is how do I know where the normal is? That is a bigger challenge, right? and now I know I can position it. I have a machine to do it and I can clean it. What do I do, how do I know where the normal lies? So, a robot can do two things. I can teach a robot. The simplest would be I go ahead and teach, this is one, and this one, and teach one mold completely.

And it records all the locations and goes and fires there. That is the easiest way to do and the stupidest way to do. Because if I move it here, everything is gone.
Student: The position of the holes everywhere is the same?
Sir: Ideally, so they have drilled more holes. And the thing is the moment, if I train it, right, I need to either make a very good fixture or a registration system to make sure that every time it knows where exactly it is, where the zero is.

I move a little bit, everything is gone. This is the first robot CEAT got actually. Before that they have never seen a robot. And that is one of the bigger companies in the country. You teach the robot and then we will give you a registration algorithm. So, you will put some markers in every mold you get those markers right and then transform whatever data you had with respect to those markers. Every time you load, register the thing.

A month later they said, ‘Why don't you build us the detection system?’ After taking the machine. We showed them, trained them, we showed the registration thing, gave them the machine and said why don't you build it. And they said give it in three months. I said look, three months, I think nothing can be done. I cannot even put a purchase order to build anything. So, you know what, my student has a company, he will build it for you.

So, two months later they come back again. ‘Why don't you, you are right, why donot you build this, build us the software for that’.

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So, we actually built a software which detects the holes automatically. It has an algorithm built in to identify where the molds are, so it is a camera system and it has also some sensors. So, it knows the location, so it knows where the normal lies. This is the Vent Detection System. We actually built a software, a vision based software for that. And identifies the holes and then goes and fires. So it records the data of the holes and it goes and fires it. So that was a second iteration.

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So, you understand what the problem was that you need to position it right. So we use the robot for that because we could not build a, right now we have, we actually have a 5 way system so we can use that plate form, for Vent Cleaning System.

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So, now this is how we built it. We actually designed an enclosure. Mounted the robot on that enclosure. Did all the electrical subsystems, PLC controls because the laser, the robot, the air supply, the camera everything has to be on one platform. This is how it looked and then we gave a nice window to do that.

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This is how the machine looked. Even all the, all the electric lighting was also, we did it.

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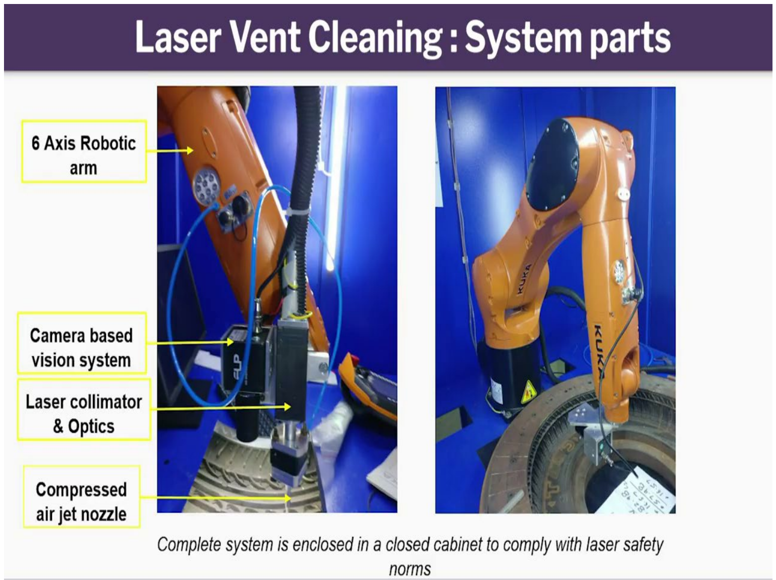

So, these are the main components here. The robotic arm, the camera, the laser collimator and the compressed air jet. So, there is a solenoid valve for the air jet also. The air jet, yes, air jet, with this is ablated, brings out debris, this debris gets blown out. So, you actually need an air jet to blow the debris away, what you have ablated.

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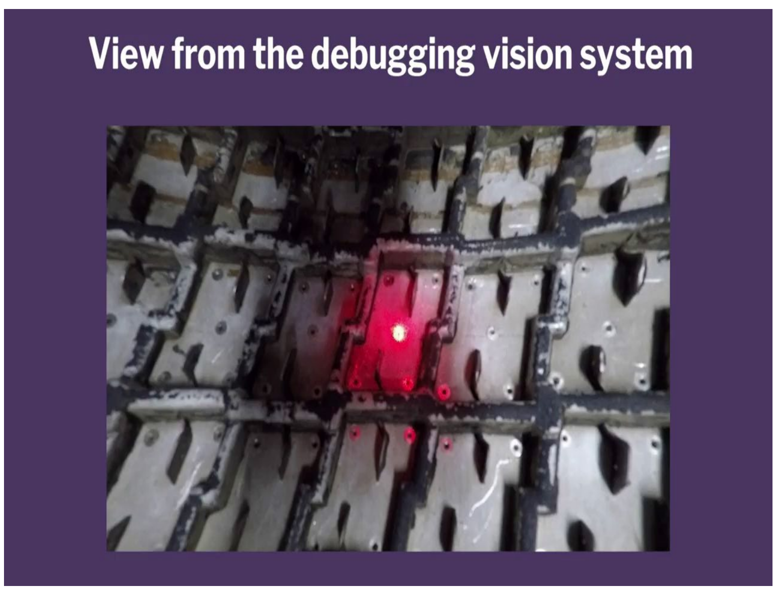

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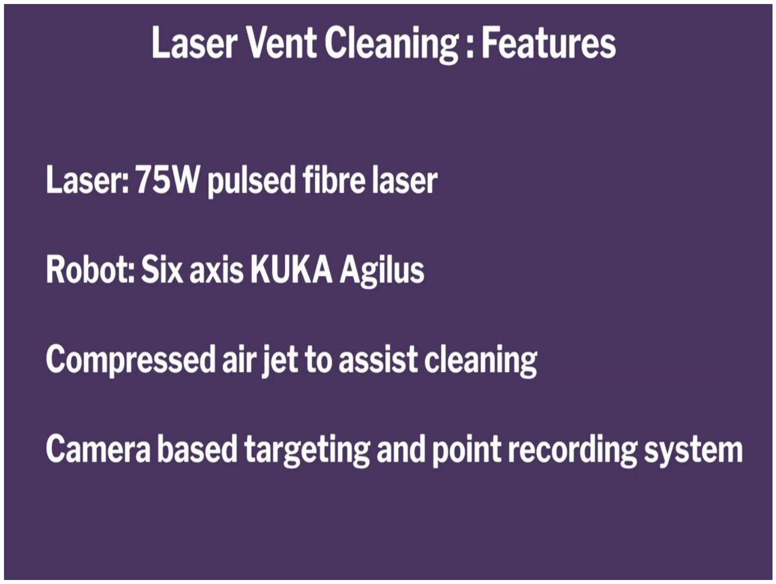

So, we use a 75 watt Pulsed Fiber Laser, robot, compressed laser, and a camera. So, this was the entire thing, entire components which were there.

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So, this is the final, finally those guys came. We trained them. This is how the lab looked before. So typically what happens is, these lasers have 1.1 milli joule pulse energy. So, the power which it will give you is 1.1 milli joule for 150 or 180 nanosecond. So, you can do the math 1.5 milli joule divided by 150 nanosecond. What comes out of, it should be close to 20 kilowatts or so. Give or take if you do the math. So, this can do 100 kilohertz frequency.

So, it can do very fast frequencies. Otherwise what happens is if frequency is very low then I will not be able to do it very fast. So, the pulsing frequency is very high.

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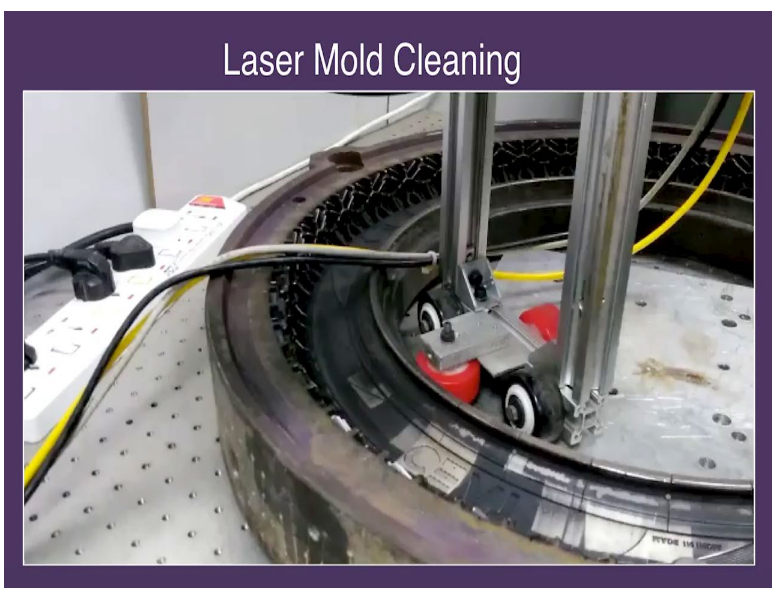

And then we also, we are trying to develop in press cleaning for the mold. No, not the vent, not that deep vent cleaning but just the mold cleaning.

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See. There is a line laser based thing with the Galvo scanner and it will clean it. So right now it is a very cheap laser. that is why the cleaning quality is not up to satisfaction because as I said, the laser and the Galvo cost me 1.2 lakhs the student went and bought from their own money. And they build a lot of toys with that. So, see there it will clean. It comes out pretty clean. So, actual laser cleaning applications require a much higher per pulse. So, right now I have 1.2 milli joules. Ideally, I would require 1 joule.

(Video End Time: 19:39)

But 1.2 milli joule cost me 1.5 lakh rupees when one joule cost me 114,000 dollars. Do the math and it $114,000 is what 75 lakhs plus as these days, yesterday it was like 71 or 72 (rupees) I do not know, it is again skyrocketed, 71 something, so you do the math plus, 25% loading if it comes to India. And here I just go and buy, actually it was not one, for 1.2 lakhs they just dragged everything, with the laser, controller, scanner, Galvo scanner, F-theta lens, which is actually doing some cleaning.

So that is the thing. But if you really want to do good work, it costs money, but then some compromise if you do you can actually do it really cheap. That is the moral of the story. I want to give you, that if you are smart enough and if you understand little bit you can actually do a few things at a much, much cheaper price. But again, if you really want to do it good. So a German laser cleaning company says that do not contact if we have anything less than $200,000 budget. Do not even talk to us.

It actually says on its website. Laser Cleaning is not cheap and this is what we counter. It has to be chap. Otherwise who will buy it right. So, any questions I think, I think we are coming to close on this topic.

Student: Sir, there are no poisonous fumes or anything?

Sir: That is a good question. You actually need a scrubber here, there will be fumes. So there are systems where you can have a scrubbing mechanism that we can make. But it is a very good point, if you really want to have a good product, if I want to sell it in a European country, I need a scrubber here.

So there is a very simple way to do it. What you do is you actually take a heavy gas and scrub it from the bottom. So, you take a heavy gas which will actually take all the fumes and you can extract it from the bottom. So, we can actually design something like that. I have some ideas to do that.

Student: Argon?

Sir: Probably argon you can do. Whatever is slightly heavier than the nitrogen because air *se heavy hona chahiye* (should be heavier than air). If it is heavier than air you can actually scrub it from the bottom. That is the typical, safest way to do it.

We should be, we should be very, very cautious. When we design products, one of the important component is that we should also have a very strong idea about whether there is a, a health hazard and environmental hazard, both, your personal health and environment as well, which unfortunately I am not shown, but I think that has, that is a component we should go into as an engineering design. Thanks!