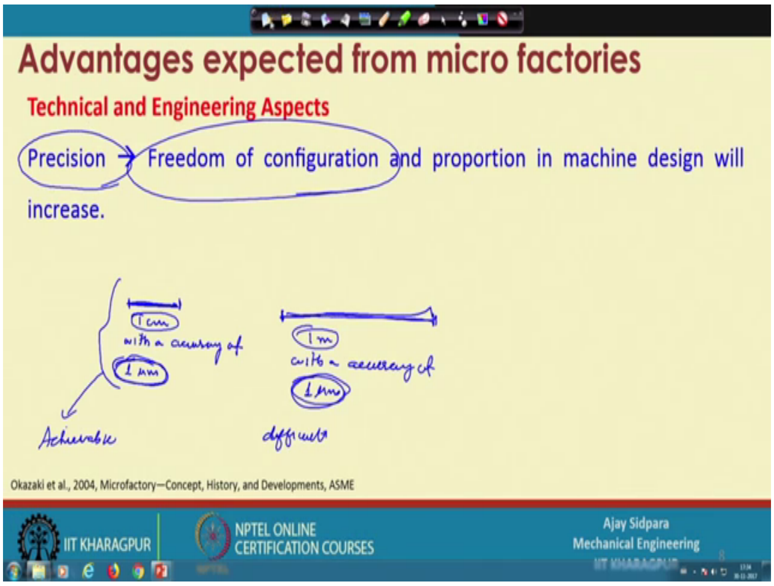
Introduction to Mechanical Micro Machining

Prof. Ajay M Sidpara
Department of Mechanical Engineering
Indian Institute of Technology, Kharagpur

Lecture - 55
Micro machines (Contd.)

Good morning again to our course on me Introduction to Mechanical Micro Machining. In the last class, we were discussing about the micro factories and we have seen that there are lot of advantages in terms of the cost and the different technical aspect also and we continued that what are the things which we have to take care during the use of this particular type of machines. So, let us continue our discussion on the advantages of the micro factories.

(Refer Slide Time: 00:41)



So, we have seen one advantages related to the economic aspect and we were on the technical and engineering aspect. So, what are the things? Other thing is the precision, freedom of configuration; proportion in the machine design will increase.

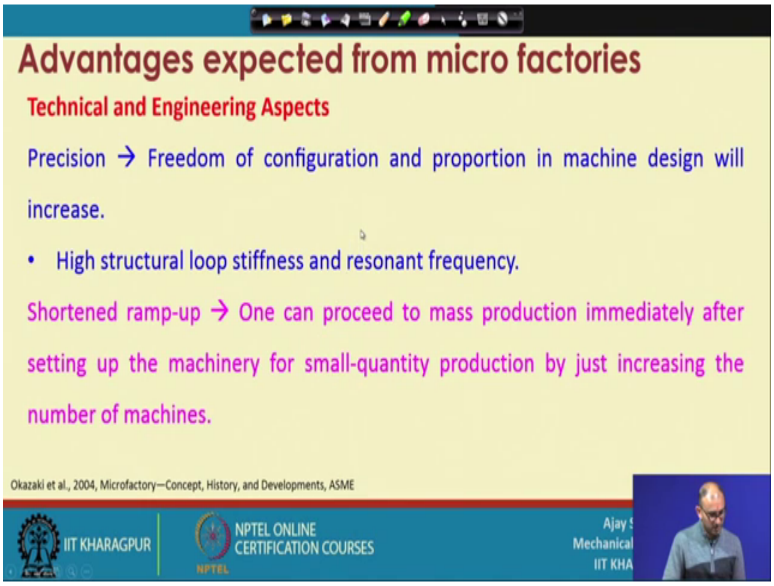
Now, we know that in the last few lectures; what we have seen that suppose you want to move something here to here and this distance is only one centimeter, then actually you have a lot of things that now your accuracy distance is this much with a with a accuracy of one micron right and now this is the one thing and this is the another example.

Where the distance is one meter and again you need the same thing that with a accuracy of one micron. So, here actually it is a achievable and here, it is a difficult thing because now we know that at a meter scale; what is requirement? You requirement is a micron, but here it is in centimeter scale one centimeter and suppose, it is 25 millimeter. So, 25 it is 1 centimeter, 10 millimeter only. So, within 10 millimeter, you need a 1 micron.

So, here what happens that there are many things which available, you can make straight very very finely because straightness is not estimate a smaller scale, but straightens is big issue when you are talking about the large dimension here. So, when you are talking about the small scale where your movement of the x is r in the 110 millimeter or 20 minute kind of thing, then you can actually make the system very very precise and so you do not any type of x is movement problems or any type of other movement things.

So, and other thing is you have freedom of configuration. So, now, you want to make 3 x is component, then you can actually use some type of highly sophisticated small motors and you can actually configure your system very very finely and it is not the case of the bigger size of machines, right.

(Refer Slide Time: 02:53)



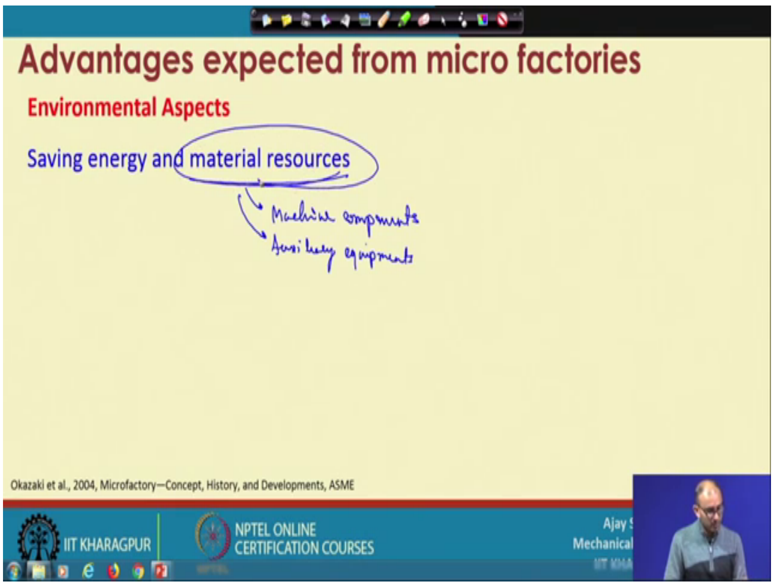
High structural loop stiffness and the resonant frequency; this is actually with the debatable things, here the stiffness is high in terms of the components only because smaller components are very difficult to deform in that way, it is there, but when you consider the loop stiffness of this particular part; that means, when all things are connected with each other and there are some vibration the whole structure will actually the under vibration not the individual component. So, if you talk about individual component, you have a high structural loop stiffness that is the good thing and resonant frequency is very very high.

So, that is the reason that you can go with a high speed and the high translation motion without any problems shortened ramp up time shortened ramp up time; that means, the time you put the machine in to the workshop and then you start installation, then doing some type of preliminary experiments those things called the ramp up time at this particular definition.

So, one can proceed to mass production immediately after setting up the machinery for small quantity production by just increasing the number of machines. So, in that case, what happened that you want to increase the production here, suppose, you want to increase the number of components to be machined by bigger machine, then what you have to do that you have to buy 2 or 3 machines again, it will take some time in terms of the installation and then training and all this thing.

But when you buy a small machine something like that; then what happened that you can actually start the you can actually reduce this particular operation; that means, the installation process and the learning process very quickly in the small machine. So, that is the advantage for this particular aspect.

(Refer Slide Time: 04:30)

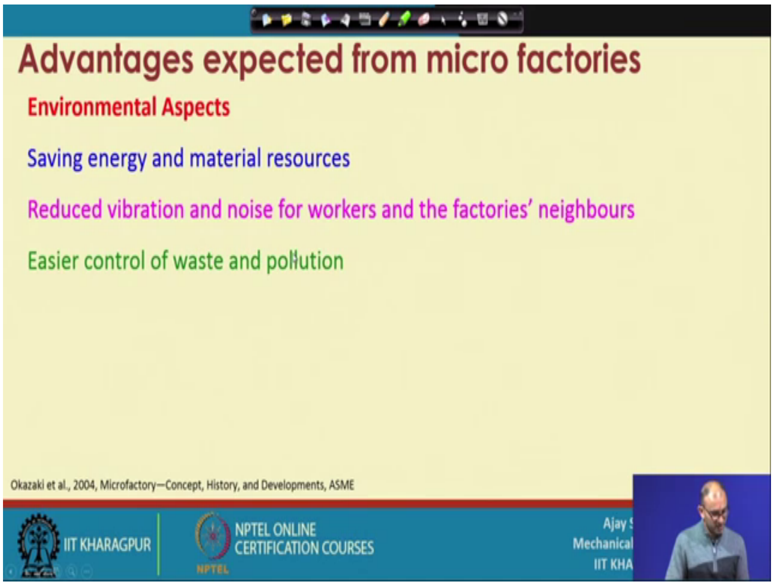


Environmental aspects; what are the environmental advantages first is the saving energy and the material resources.

Because material resources are many material resources are related to the machine components that is the machine component then related to the auxiliary equipment. So, there is equipment of the material related to the coolant what we are using. So, that will be also very very less that suppose, you want to do some type of cleaning operation there.

So, you have to spend less time here because the size of the machine itself is very very small, you can keep the space is very very clean compared not around the on the machine, but around the machines also. So, at that time you required very very less amount of material resources reduce vibration and noise for worker and the factories neighbors.

(Refer Slide Time: 05:28)



So, this is also advantage because if your machine is very very small vibration and noises most rated to the moving components if there are lot of moving components, but we know that our operation will be very very is done by the very very small machine the motors and everything. So, your noise level will be very low compared to the bigger size machine vibration is; obviously, low because we are using very small component and when and also doing a machining operation on a small component.

So, vibration from the machine will be less, but vibration from the outside sources may create some problem at the machining process and factory neighbors because if the machine is very very heavy and very very old, then it creates the noise and the vibration to the nearby places also, but that is not happening in the micro factories easier control of the waste and pollution because we know that suppose chips and everything is very very placed here and there on the machine itself then cleaning is not a problem here because place is very very small and pollution also that is related to the removal of the coolant and some type of other liquids. So, you can easily actually clean without any problem.

So, you do not get so much of problems from the waste and the pollution in the micro machines.

(Refer Slide Time: 06:50)

Human related aspects machine can expand into education and hobby fields opening the door for the new order users now what happens that there are cost is also issue because if you see this first machine which I was shown in the red color that was connive cost is in terms of corrodes, but if you want to learn something in terms of educational hobby; that means, suppose, you want to understand the how machining is being done at the micro scale and what are the problems that we have discussed in the last many classes that how things are different in the macro scale and the micro scale then you actually do not require such a big machine you can buy a small machines which are comparatively very

very cheaper than the bigger size machine and you can actually learn that how micro machining is done.

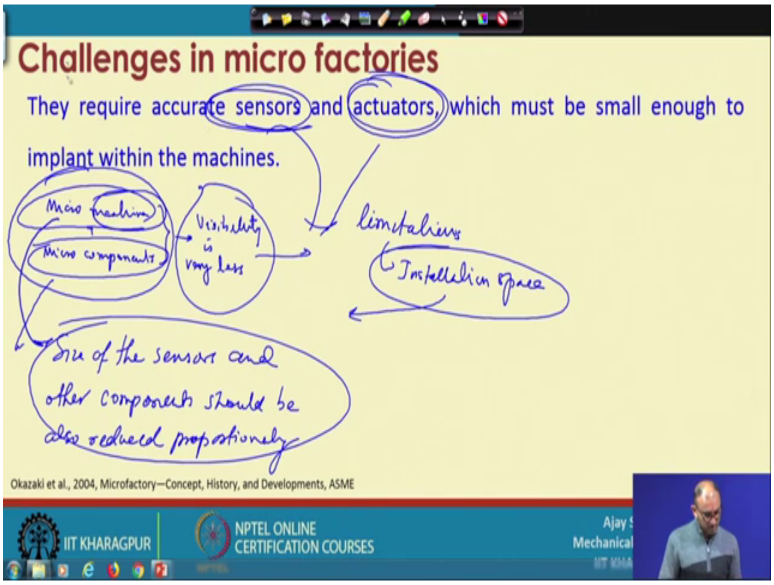
If you are comfortable and you understand all the material related aspect and the process related aspect then you can directly go to the bigger size machine where you can be a expert in the operating those big machine. So, if this is very big advantage because you do not need to do some capital investment for learning the machine you can learn all the things by a small machine with a less cost and then you can do the rest of the part on the bigger machine right, it will help train the people who will take the responsibility for manufacturing the next generation machine. So, training is also very big issue here because when you we know that there are lot of differences between the convectional machining and the micro machining.

So, you can actually do all this things by learning itself, but when unless you do this ends on ends movement you will not understand that how things are very very difficult in the lectures we understand that you should not move your component from one micron to 10 micron very quickly something like that, but telling it is easy, but when you actually operate the machine you do not understand whether you have moved one micron or 10 micron.

So, unless you put your hands on the micro machine it, these things are very difficult to understand. So, training is very important and for training if you actually occupy the big machine which are very very costly, then there is a problem with the production and the cost associated with those machine. So, better you put some micro factories micro machine then train yourself with the different parameter setting that which particular parameter settings are useful for getting the right product out of the machine.

So, parameters; you can replicate on the bigger size machine also because parameters setting will be almost same for both the cases and then you understand that how the different material and different tool materials will play important role in getting the right product out of it. So, training is very important, then you can actually understand this machine as a education or the hobby field and those things are related to the human aspect.

(Refer Slide Time: 09:32)



But these are the advantage, but there are lot of problems in the micro factories; also because we know the advantages are many, but why, but still why this machines I have not come up in the market then because there are many challenges also first things is the they require accurate sensors and actuators which must be small enough to implant within the machines now this is the big machine because we know that we are operating at a micro scale. So, machine is micro scale must micro machine plus micro component.

So, visibility is very very less visibility in terms of; that means, supposed something is going wrong in this one thing is your comp machine itself is very small, another thing that you are cutting something which is also even smaller than that. So, the response or some type of signature coming out of this machines are very very small because we have seen in the bigger size machine also, you cannot understand by means of some noise or some type of other things which is coming out of the machine, but the here, you can you ask further going down into the size of that particular machine. So, you will not understand anything out of that. So, what is the thing that you have to put some sensors and the actuators in this machine?

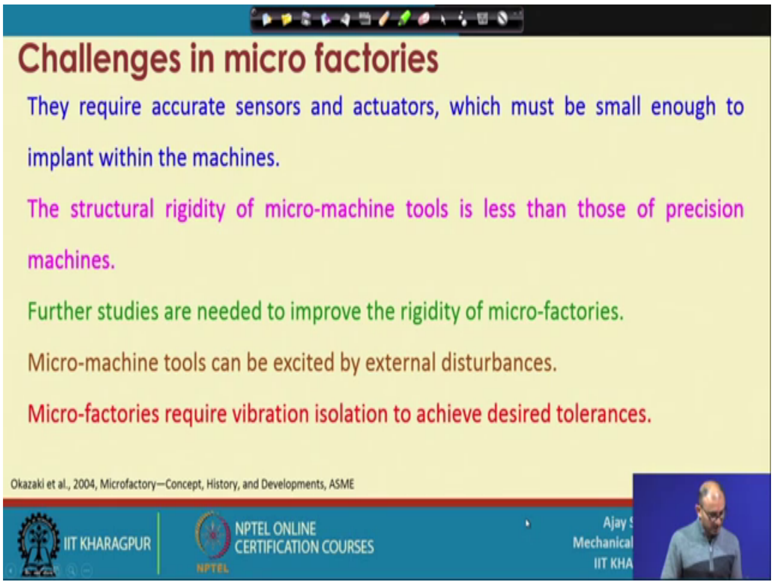
So, now problem is that you have to reduce the size of the component of this also because when you are talking about this thing then the size of the size of the sensors and other component should be also reduced proportionally right. Now, what is problem here that this suppose this is fabricated by some company micro machine you can get some somebody from other company, then you have to actually look for the sensors and actuators from the other company. Now, what is problem that now integration is a big problem. Now, you do not have space here the space is the limitation limitation is the installation space, right.

So, this is the first thing that where do you install that because you have already cram many components related the machine comp machine part also because you have 3 axis motors also moving from one login another location you have z spindle motor also there then you have to put some sensor so that you can put some at least some camera.

So, that you can understand what is going on there then you need actuator also for moving this x, y and z that is sometimes you do not require motor, but you put some actuator in such a way that the where the few millimeter stroke here and there it is easily achievable.

So, space is a big problem here because you have already claimed many compounds here. So, putting some extra component you have to think that where you are putting there another thing that size of this part should be also small, otherwise, if it is not small and it is bigger size of sensor, then sometimes your sensor size is bigger than the component size; what we are machine here.

(Refer Slide Time: 12:59)

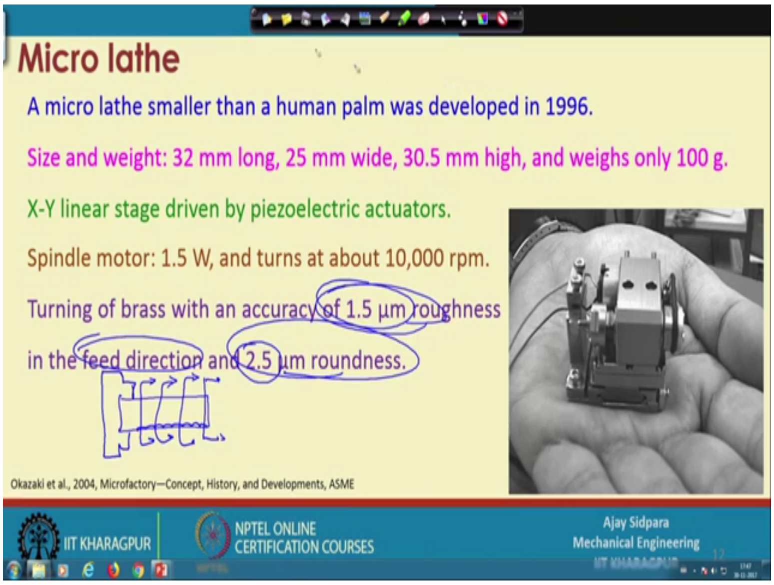


So, this are the some problem associated with the monitoring and the control of the micro machines structural rigidity of the micro machine tool is less than those of the precision machine because earlier, we have seen that it has a high structural stiffness, but this is related to the machines because if you put a bigger size component the vibration coming from the outer surface or the outer environment will not create more problem with the machine is a bigger size; that means, inertia also play important role vibration will not affect in such a small scale, but if the machine size is very very small, then you would will get the vibration for the outer surface in the system very quickly further studies you get to improve the rigidity of the micro factories because mostly this is the big problem here.

So, most of the research which is going on on acceptance of this micro factory in the actual environment, it is related to the rigidity only the how; you can improve the rigidity of the machine and that. So, that you can use this thing more frequently compared to the costly micro machining centers micro machine tool can be excited by the external disturbance. So, that we are this is old things are coupled because small disturbance is enough to get a signature of that external disturbance on the machine surface.

So, that is a big problem here. So, we have to apply some type of vibration isolation. So, that you can actually get the desired tolerance within the in the component vibration isolation; that means, you put some type of pneumatic table at that. So, vibration whatever is coming from the outer surface; that means, from the nearby machine or from the floor that can be actually completely isolated and it will not transferred to the machine if you some vibration isolation. So, now, let us take some example what are the different machines, right.

(Refer Slide Time: 14:41)



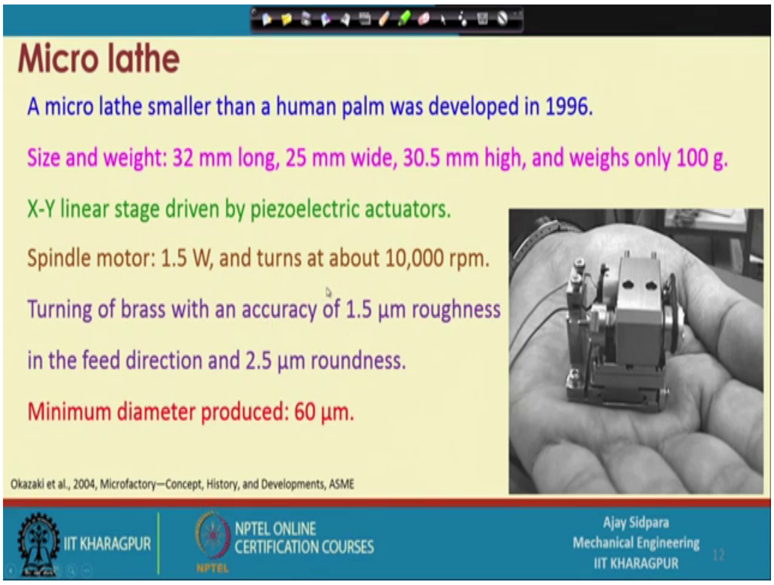
Now, available some of them are the researchers some of them are already in the market. So, this is the micro lathe. So, it is a smaller than human palm was developed in 1996 and see the size, it is a 32 millimeter long 25 millimeter wide and 30.5 millimeter high and weight is only 100 gram. Now we have to see that what this machine can do.

So, it has a x y linear stage driven by piezo electric actuators because why we use actuator here because we do not require lot of travel here when you require lot of travel, then you have to use some type of servo motor or stepper motor and then you use a lead screw or some type of re-circulating bolt screw or something like that, but I was stroke length is very very small. So, you do not require some type of motor, but actuators are enough to give this type of particular stroke spindle motor is one point 5 watt in it can turn about 1000 rpm, 10,000 rpm. So, that is acceptable with a small amount of job and some type of very very soft material. So, example was given little bias material.

So, brass was machine with a accuracy of 1.5 micron roughness in the feed direction and 2.5 micron on the roundness because we know that when you do a turning operation this is the component what we want to machine then what happen that first thing is that this is the 1.5 micron is the roughness. So, this is what we are talking about these thing that is the on the feed direction.

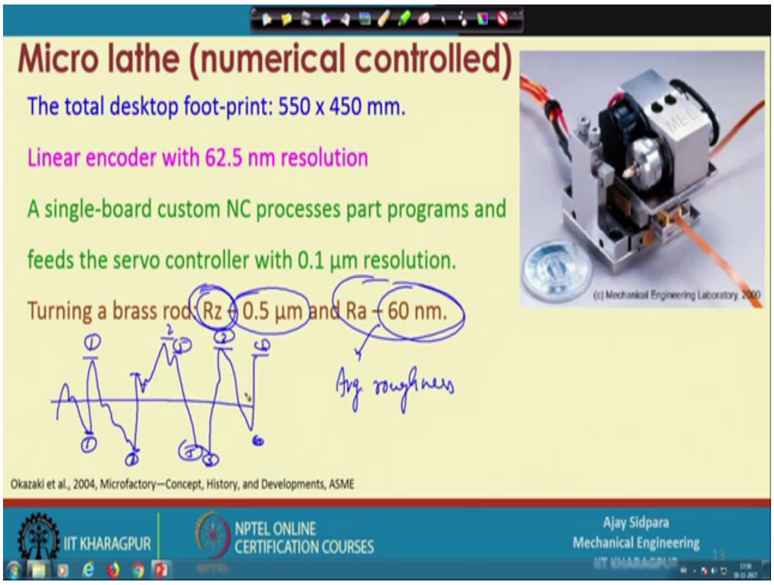
So, this is in feed direction and when you are talking about the roundness then you have to do measurements at the different different cross section that what is the difference in the diameter. So, that is related to the this particular thing. So, that is means you will get the variation within a 2.5 micron dye in terms of diameter and the roughness, you will get the 1.5 micron in this particular direction right minimum diameter was produced of the 60 microns.

(Refer Slide Time: 16:39)



So, you can see that by getting a sixty micron and spending corrodes of rupees that and then the material is same, you can still use this material; this particular micro machine if this accuracy and this particular roundness and the roughness are according to your requirement, then you do not require a very large machine for doing the same job.

(Refer Slide Time: 17:05)



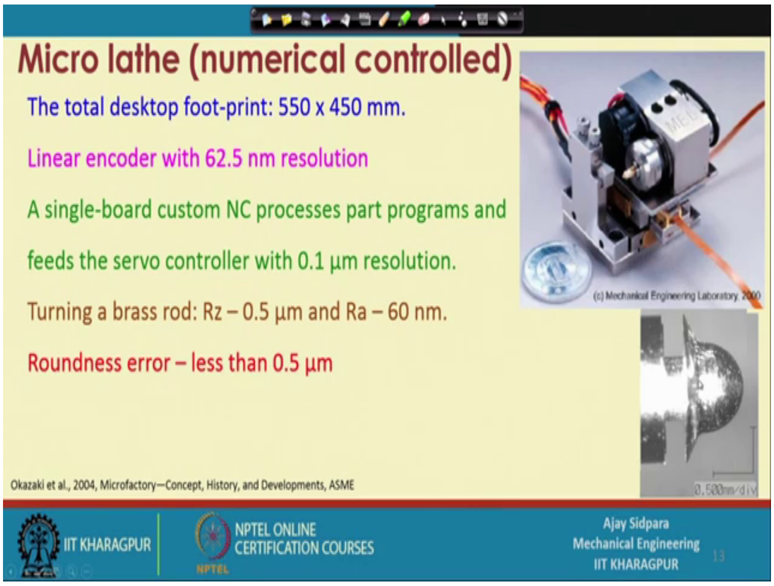
Then the second version of that earlier machine was the numerical controlled machine because here we were using a normal NC program which we are using for routine cases. So, this is the another machine which has a foot print of 550 by 450 millimeter and linear encoders are used here with a resolution of 62.5 nano meter resolution because we have seen that whatever machine has some resolution the resolution of the encoder should be at least 10 times higher than the machine resolution, then only you can extract the maximum benefit out of the machine and it has a single board custom NC numerical controlled which processes the part programs and the feeds of the servo controlled with a 0.1 micron resolution.

Because now, once you have CNC program, then what you have to do you have to process the part also and you have servo controller which will move your axis in X, Y, Z direction depending on the number of axis. So, here that is the 0.100 nano meter is the resolution of that thing and here also the example was the brass. So, they turn the brass and the R z is the point 5 micron R a was the sixty nanometer. So, what is that R z and R a.

So, suppose this is the roughness profile. So, R a is actually the average of this particular signal. So, this is the average roughness and R z, actually, it will find out what are the 5 highest peaks. So, this is the one peak, this is the second third, this is the fourth and this is the 5 and 5 highest peak and 5 highest value. So, this is the 1, 2, 3, 4 and 5, then average of this all 5.

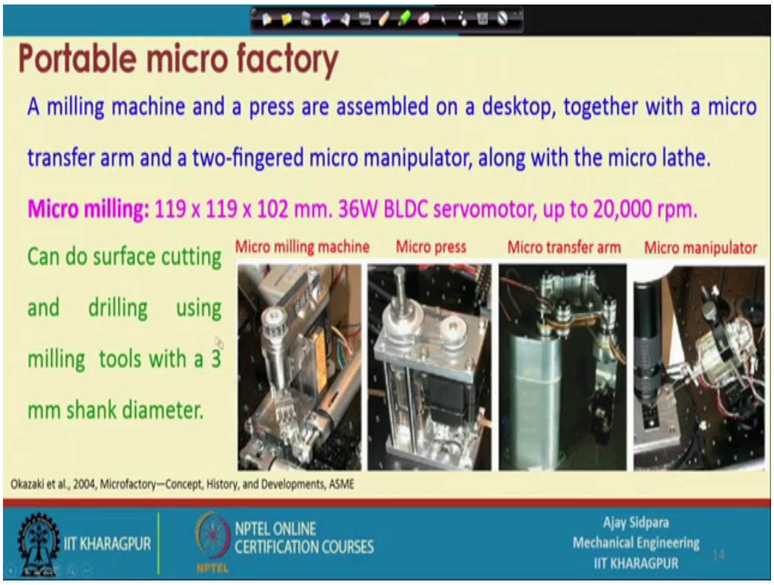
So, you can see that this thing is talking about the highest value only. So, which has a higher rating here so; that means, value of the R z is higher always higher than the R a value because this is the average. So, all the small small peaks also will be counted in the calculation of R a. So, if you want to see the what is the actual picture of this part, then R z is the right parameter compared to the R a because many different surface is here the same R a value because it is the averaging value of the many form components right.

(Refer Slide Time: 19:16)



And roundness error was the less than 0.5 micron. So, this is showing much better result compared to the earlier case, but. So, this was the means; what we can say this advance version of the earlier micro lathe and this is the component which was processed here you can see the whatever the features, it was created because of the NC program you can give the curvature also, then you create a slot also.

(Refer Slide Time: 19:43)



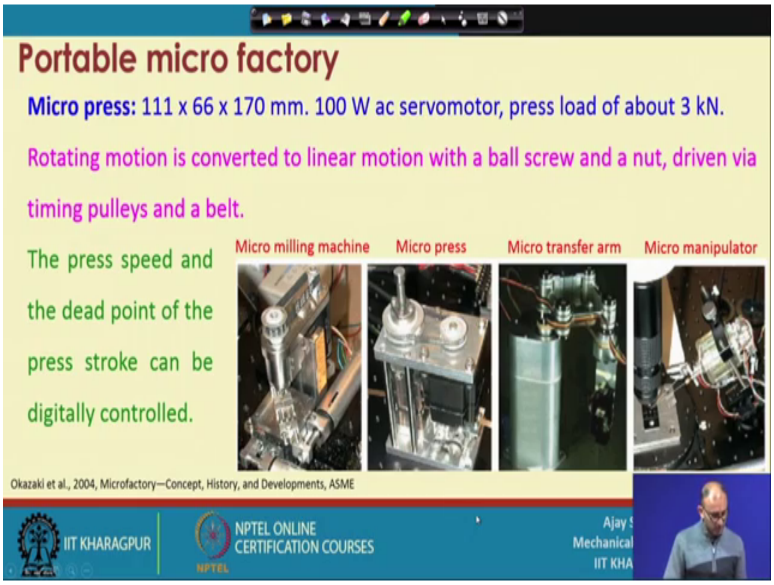
And you can understand the how fine it is produced portable micro factory because in micro factory what we are talking we are using a different different machine at the in a very small group so that you can get different product in terms of the different different processing parameters.

So, here what is the this is the micro milling machine is there this micro press is there transfer arm is the suppose you are doing some machining at this two location and then you want to transfer that thing to other location, then you can use transfer arm this and micro manipulator is there; that means, moving placing a component then there holding force some by some type of griping then you can use this part.

So, if you put this 4 machine together many different type of jobs you can produce without any problem. So, micro milling and a presser assembled on a desktop together with a micro transfer arm in a two finger a micro manipulator along with a micro level lathe is not shown here, but it is also install we will see in the next figure. So, what are the things about the micro milling machine. So, in the area is 119; 119 by 102 millimeter; 36 volt brushless DC, most of using it can rotate up to 2000, 20,000 rpm and can do surface cutting drilling using the micro tools with the 3 mm.

So, 3 mm same diameter is a very very common in all the micromachining cutting tool which are available because this is very standard, you can easily get the collate with a 3 millimeter of diameter compared to related to the press.

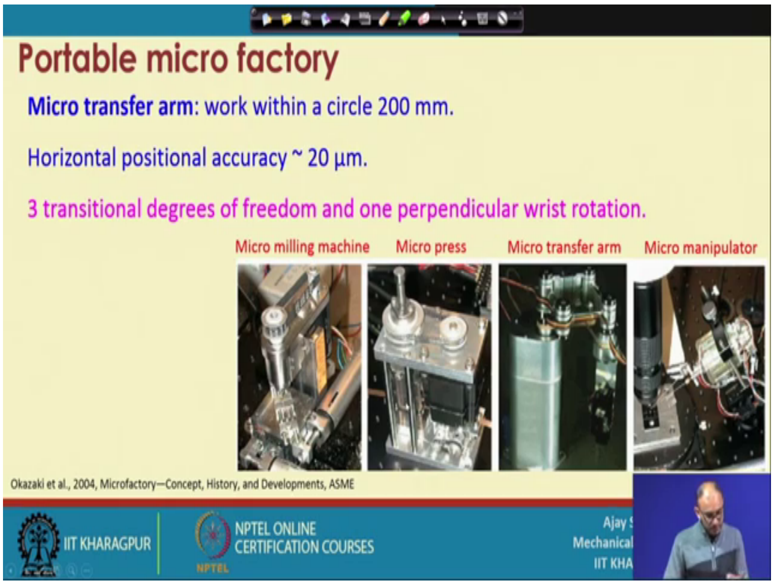
(Refer Slide Time: 21:11)



Now, press has this much area and hundred watt ac servo motor is used and you can get the 3 kilo Newton of load on the particular press and rotating motion because now here you have to press something. So, pressing getting that much amount of force is a very very difficult.

So, what they are doing they are actually converting the rotational motion in terms of a linear motion. So, they are using a timing pulley belt and then you by rotating it your pressing punch on the down surface and then you can get the required geometries the press speed and the dead point of the press stroke can be digitally controlled.

(Refer Slide Time: 21:55)

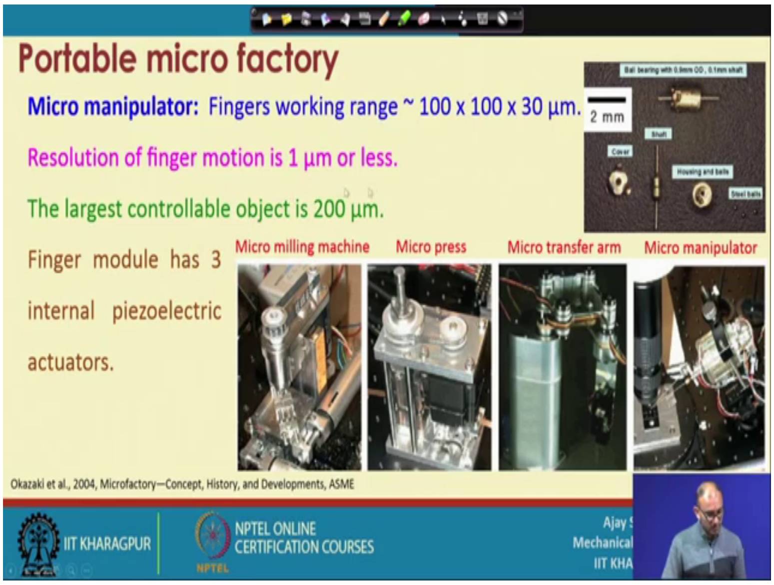


So, there are some micro control available which will do all this parameter settings micro transfer arm. So, it this is the third component it has a working old area circle in the 200 millimeter. So, it is very very large compared to the area of this. So, you can actually move one component from one machine to another machine very easily because you can see it is a twenty millimeter 200 millimeter is very very large.

So, you can you sometimes you do not require so much of space between this two. So, you put this R micro arm transfer in between these 2 machine without moving any of this thing, it will take out the component from here and then it will place at the micro press or other way around also and the horizontal position accuracy is 20 micron because now when you place component from one location another location, then it has a 20 micron.

So, within a 20 micron of a position accuracy, you can get the machining done it has a 3 translation degree of freedom and the one perpendicular wrist rotation. So, you can move in a circular wave also and then you can move in a 3 translation directions.

(Refer Slide Time: 22:58)



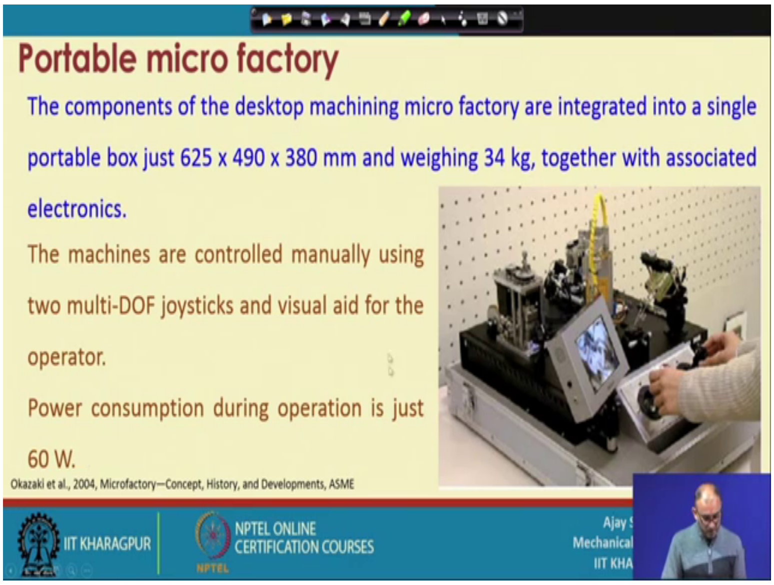
Now, coming to the last one that is a micromanipulator; so, it has a finger working ranges 100 by 100 by 30 micron. So, within that area you can actually give any component from the resolution of the finger motion is one micron or less. So, when you want to pin pointly, you want to target something, then you can go with a one micron. So, that is the advantage of one micron largest controllable object is 200 micron.

That means how much amount of things you can move from here to here that is the object; that means, if the object size is 200 micron, you can actually easily place from one location to another location you can manipulate the movement of that component and finger module as 3 integral piezoelectric actuator because when you look at the very very small area or something at the time, it is better to use some type of actuators which are energized by means of some type of electrical supply instead of using some motors and this are this is the component; these are the different components which are fabricated using this particular set up.

Now, you can see that ball baring with a 0.9 millimeter OD and 0.1 diameter is the shaft diameter. This is another staff, this is a cover and this is housing and the ball is there still balls are available here.

So, one bearing assembly is completely fabricated by sequence of different operation by this particular micro factory area.

(Refer Slide Time: 24:21)



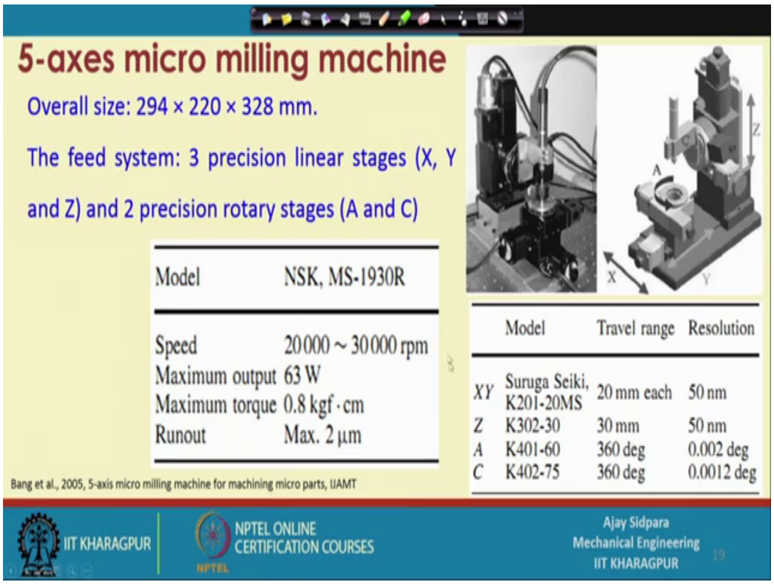
And if you assemble all this thing in a single part. So, this is the pool assembly of all that component now you can see that this are the this is the press is there then this is the manipulator is there then in the transfer arm then this is micro milling machine now once you do machining here what is happening that you cannot see anything by necked eye. So, here there is a visual look on instrument is available and you have a joy stick.

So, by joy stick; you can operate the machine because we know that by operating or moving component by means of hind it is very difficult to here because you cannot sense also there how much force you are applying or how much is the component size is there. So, if you assemble everything in a single parts. So, total box size is the 6; 25, 490 and 380 millimeter is the area and weight is 34 k g only.

So, that is the advantage many machines you are putting together in the same look same size same part. So, machines are controlled manually using the 2 multi degree of freedom joystick and visual aid for the operator. So, this is a visual aid because you can see the these machining is being done.

So, you put one camera here. So, camera will tell you that what happening; what is happening at this location then power consumption during a operation is just a 60 watt. So, you can see that many things can be done without actually spending lot of money and the resources for the bigger size of machine.

(Refer Slide Time: 25:41)



Now, this is the one thing about the 5 axes micro milling machine now you can see that this is the another part. So, now, you can see that if you want to increase the what we can say the capability of the machine, then you have to put more and more amount of axes on the top of that.

So, earlier we whatever we have seen that maybe that 3 axes machine or the lathe and other things are there, but here it is a 5 axes machine and here what you can do that you rotate the work piece here and then you can give the inclination to the Z axis in that particular C C direction.

So, that you can do some type of tapper cutting also without any problem and this are the standard X, Y and the Z axis are there and this is the actual photo where you can see that this is the spindle available spindle can rotate in this direction and this is the thing in the work piece is the second rotation because now suppose you have a one job here and you want to drill at this location this location.

So, what you can; so, here that you can actually instead of moving your tool end that direction what you can do you can index the surface right. So, first you hold drill over here drilling is over then you rotate your work piece at this location. So, this part will come here and then you do indexing.

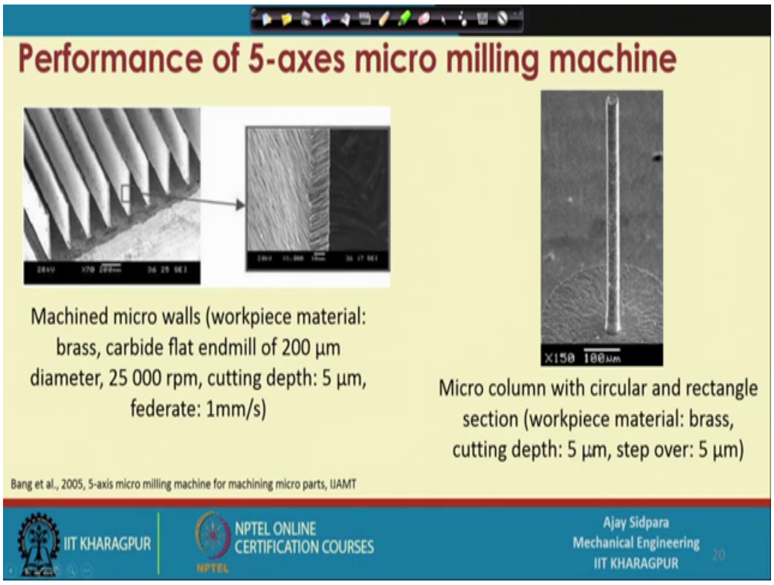
So, indexing is much precise compared to the movement of the cutting tool. So, that is the advantage of using the A axes that is rotation around the X axes very very easily. So, all overall size is the almost 1 feet by 1 feet in the in terms of height, but it is 294 by 220 is the width and the length. So, what are the feed system is the 3 precision linear motions are there for X, Y, Z and two precision rotary stage are there that is for A and the C X is here. So, this is the specification of the spindle.

So, spindle can rotate up to twenty thousand to thirty thousand rpm power is sixty 3 and the torque is pointed kilogram 4 centimeter and run out is 3 my two micron now you can see the when you go with a down and down with the size the maintaining run out at the lowers case also very easy because here you do not require a you are actually working with a very very small amount of component and you will not get to hide generation or the different problems also compare related to the axes specification.

Now, it has a X, Y, Z and A C axes, X Y has the total travel range 20 millimeter. So, if you want to do machining within 20 minutes, you can do that resolution is 50 nanometer z means vertical travel, you can accommodate a component with a 30 meter millimeter of height with a same resolution and A and C X is what you are required that you required the rotation of the; so, you can see here the c axes is a very very high because if you want to in maintain the tilting angle with a very very highly precise motion then it has a 0.0012 degree and it is a 0.02 degree.

So, by making this particular system, you can do lot of different type of jobs.

(Refer Slide Time: 28:39)



So, let us see those things what are those things. So, this is the one of compound which was fabricated by that earlier machine.

So, machining of micro walls material was the brass carbide flat end mill of 200 micron was the diameter of the end mill cutter and 25,000 was the rpm cutting depth was the 5 micron and feed that was 1 millimeter per second. Now you can see that how find features, you can create at the cost of this machine will; obviously, small lower than the bigger size of micro machine.

So, if you see that this are the find feature there is no bending of this part also there because we have seen that if you reduce the wall thickness at the later stage at one instance that you are wall will be in bending list because it will not take the lot of forces from the cutting tool and this is the dignified view and you can see that this are the very very finely features and the size you will you are also not getting lot of amount of burst.

So, that is the advantage of using these particular part another example that you can see that this is the very very circular long circular micro column is there. So, it is in the square section and there was one another one that was marinated by this rectangular section also.

But not shown here again the material is brass cutting depth is 5 micron here. So, every time you are going 5 micron and with a step over of the 5 micron. So, 5 micron, then again go 5 micron down and down and that way you can fabricate the big component. Now, you can see that there are lot of advantages associated with this type of micro machining processes and if this particular requirement is full filled by your smaller machine, then it is better to use this smaller machine compared to the big machine.

So, let me stop it here and we are finishing this micro machine lecture here itself.

Thank you very much.