Introduction to Mechanical Micro Machining
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Lecture – 24
Components of the Machine tool (Contd.)

Good morning everybody. Welcome again to our course; on introduction to mechanical micro machining. In the last class you have seen some of the components of the machine tool, such as the construction, or the structure of the machine tools spindle system, then we need some type of drive system also, in that way we understood that we have to be very careful in selecting of those components and we have to assemble in a perfectly shape, otherwise you cannot get the required shape out of the machining zone.

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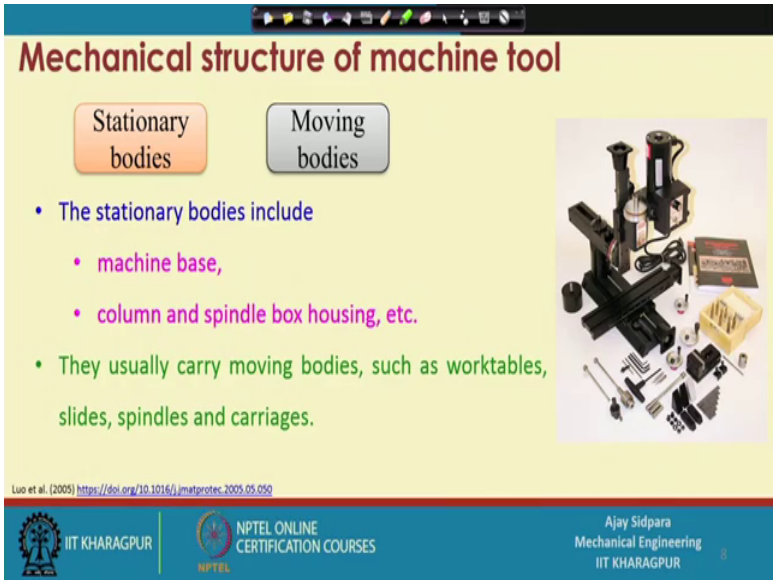

So, let us continue this topic ahead. And we have also seen that there are different components, stationary bodies, and the moving bodies, stationary body will carry the moving body so that they can move from one location to another location to get the things done.

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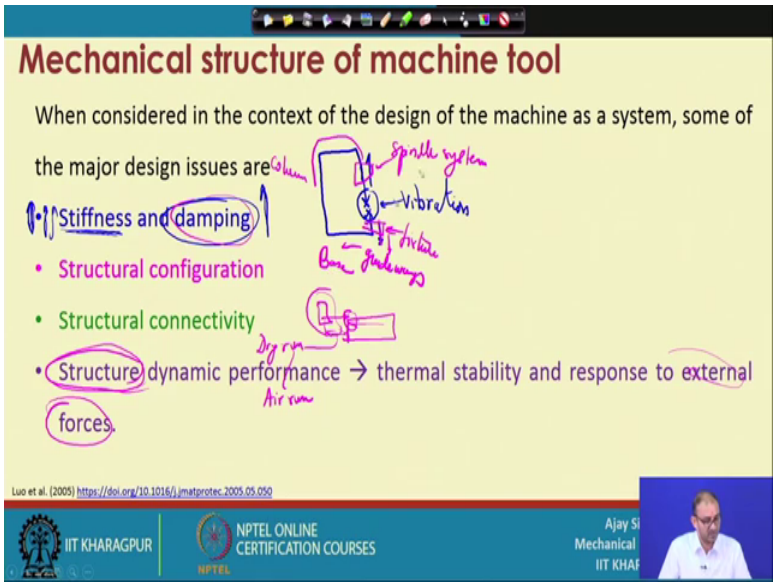

So, when you consider the machine design of a machine as a system, there are some major design issues are available. So, those things are stiffness and the damping, because now, we know that when you do machining at a micro level, your stiffness of the machine tools should be very high.

So, if this is not very high, then we know that it will propagate vibration. It will create a problem in the deformation of the components. Damping is also important, because if it will not damp the vibration within the system, then vibration will be propagated into the different component of the part. So, suppose consider that, this is your tool position and this is your work piece position, this is your contact zone and this is the all things which are connected with this, and this is the location from where you are getting a vibration. So, now, what is going to happen with the vibration? That vibration will move in this direction also, and it will move in this direction also.

Now, going to that, if it is moving in this direction, there is a spindle system available, and then it will move to the column, and if it is going in downward system, what is happening here? There is a fixture and then it is going toward the guide way and then it is going to the base correct. So, in both the way when it is propagating within the system, at that time it is not good thing for the machining operation. So, what material you have to use for construction of this thing, that is detected by the this particular damping and the stiffness, more is the quality of the damping and stiffness more will be the precision

of the machine, but again problem is the cost; that means, you have to again break even with the cost.

So, that extra thing should not be added without looking in to the cost of the machine. Structural configuration is also important, which type of constable configuration, open, look structure of configuration available, closed loop available, overhang available, we will see those things in next two to three slide. Structural connectivity is important. So, this is called the structural connectivity, because we know that spindle is tool, is connected with the spindle housing to the column and from the work piece side. Work piece is held within the fixture, fixture is move, fixed to the X Y table X Y table to guide ways and guide ways to the base.

So, these things are called connectivities. So, if this connectivities are not completely rigid or not too much tied, at that time, you may get some type of problem during machining, and that few microns here and there will also create the same impression on to the work piece dimensional accuracy, and you will get some error in the final geometry structure dynamic performance; that means, when you are operating the machine, at that time what is happening to the structure.

So, thermal stability is important, because we know that there are many moving component, which are in physical contact; that means, if you are using air bearing, there is no physical contact oil bearing, no physical contact, but when you are using a ball bearing or some other bearing, where there are physical contacts; so, because physical contact an overall emotion.

So, at that time it will create a friction in, because of frictions you will get the increase in the temperature and when this is there, the temperature stability is more important here, because we know that each and every material has the coefficient of thermal expansion at some value and that value is important to understand the stability of the machine under the different variation of the temperature, response to the external force is important external forces; that means, suddenly you are starting machining operation, because now, if you consider that your work piece is here located and your tool is here at this location and this is your tool, has to move from one to this location to start the machine.

So, when it is moving here it is called dry run or the air run right. So, this is called the dry run or air run, where you are not doing any type of machining, but as soon as it is

touching this surface suddenly, it is encountering the material, some material will resist that particular deformation. So, at the time this will consider as an external force also; that means, suddenly your touching the surface and then it is getting deform.

So, what is happening that how; what is the structural stability, when it encounter this type of external forces; that means, when two vehicles are in motion and when there colliding with each other, at that time how much is the stability of the car or the truck; so that you cannot get any type of problem within the passenger, whatever is sitting inside the car. So, same thing happens here also, when these external forces acts, our structure should be rigid in such a way that it should not deform to a very lower level so that, you can further use the comp of machine without any problems.

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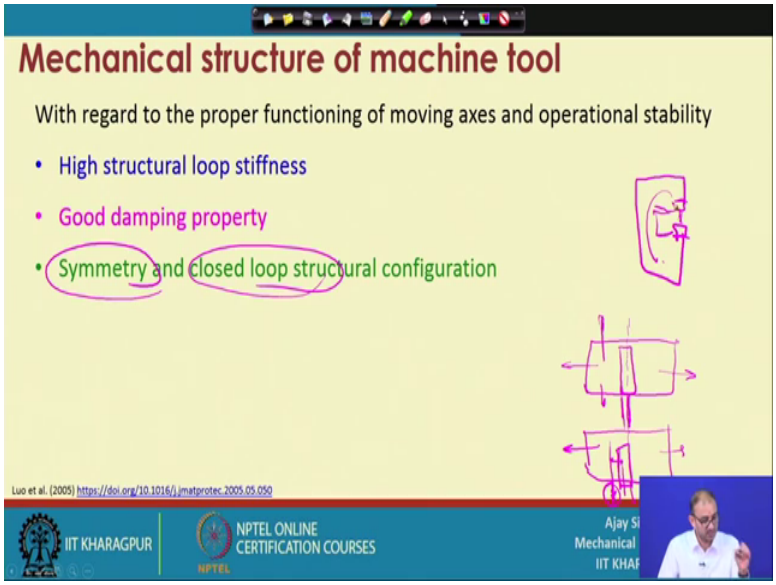

Now, with respect regarding to the proper functioning of the moving axes and operational stabilities, what we need? That we need high structural loop stiffness. We will see this thing what is that will structural loop stiffness. It should be high structural loop stiffness means, whatever the assembly is that from tool side to down side, and tool side to upside, and the work piece side to the down side, all things should be rigidly work against the forces acting on to the tool and work piece good damping property that we have seen, that vibrates once the vibrations are generated. It should diminish within the local area only; it should not propagate within the system. So, that is also important, that

is good damping properties symmetry and closed loop configure, configuration symmetry; that means, when there is a temperature variation

Now, I will show you one video, probably in the next class or during that sensor and monitoring part. Suppose, we have one system here and this is the central line of the component and you have mounted your spindle here, this location. So, when you are coming across the different temperature variation; that means, there is a huge temperature variation. So, what is going to happen?

So, these things will expand, if your spindle is located at the centre point of this, even though there is expansion of this, nothing is going to happen with this particular thing, because still it will remain at the same location, but now, consider the same thing is there, consider this is the axes and you have mounted your spindle here, at this location again, there is a temperature variation, there is expansion of this part. So, when there is expansion what happen? This spindle axes will shift in this direction little bit.

So, now your location of the axes, of this spindle is different. So, symmetric structure is very important, you will see that how temperature variation will create a problem, if your structure is not symmetric. Closed loop is important, because overall over hanging structure is something like that, whatever we have seen the most of the cases. So, this is the overhanging, this is a work piece, and this is your tool, and this is over; that means, whatever this part, this part is over hanging, but if you construct in different we will see one figure here, that is, could the close loop configuration of the system thermal elastic structural loops.

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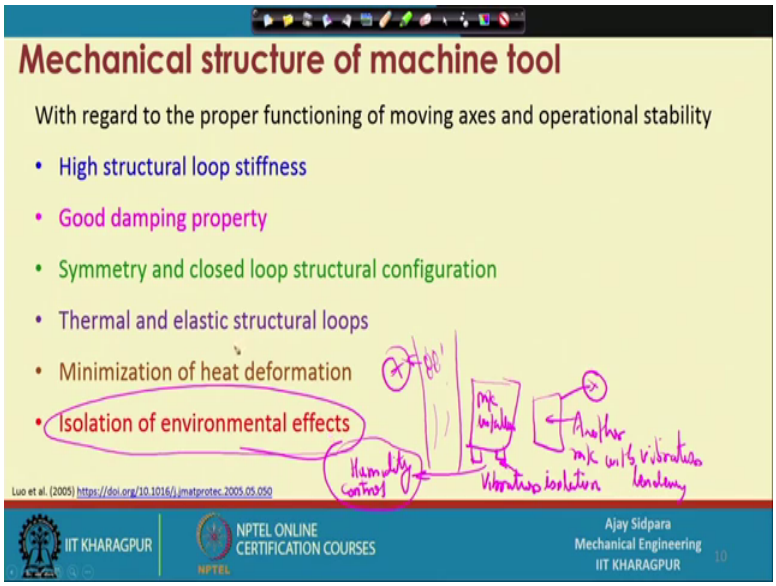

So, thermal loop elastic structural loop we know the elasticity; that means, when you apply the load your structure will deform, but when you remove the load again it comes to it is original position. So, thermal instruct elastic loops are also important, because when you are applying the force it may deform, but your machine tool is intelligent enough by using some sensor that, whatever elastic deformation is there, your machine understand.

It will compensate with the tool and thermal deformation would also know, we know what material we have used for the construction of the machine. We know the thermal coefficient of expansion, then we actually calculate any deformation contraction or the expansion depending on the temperature change, and machine will take it's own decision that how much is the movement of the deviation from the actual location of the X Y Z location to the other location, because of the thermal (Refer Time: 09:55) and the elastic structural deflection that can be decided.

But that will also again comes, again that cost minimization of the heat deformation, because we know the temperature variation is very important and we are working with the physical processes; that means, there is a physical contact between the tool and work piece and once this happens at that time, there is a problem in the actual machining and the dimensional stability of the component isolation of the environmental effect that we have seen, that the machine should be mounted or the installed in such a way that there

should not be any other install. So, this is the machine installation. So, there should not be road passing through this part, where the vehicles are moving. So, this should not be the case, you cannot install another machine with vibration tendency.

So, this thing should not be also there, you need a proper foundation, vibration, isolation. And then another thing is temperature waste, and you have to maintain the temperature also within the one particular limit. So, those things are called the isolation of the environment humidity, also you have to maintain not only temperature humidity control. So, these are the things, which are not directly connected with that machining operation, but these are the external thing, which will also create problem in the dimensional accuracy of the machine.

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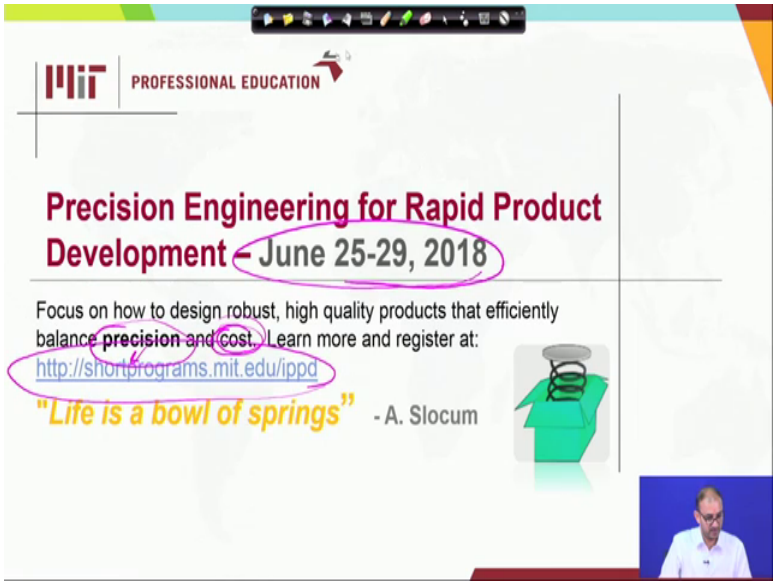

Now, before we go further in this thing, I have taken some of the material from professor A. Slocums slides, because now, I got one information that he is proposing one course on the precision engineering, for rapid product development, where you can find out that what we have to do to get the break even between the precision, and the cost, because we have seen in early slide, few slide before that if you increase the level of precision or performance, your cost will also go very high. So, you have to find out that how much you have to spend on to the precision with respect to cost; that means, cost should not be so high that you have to do a compromise with the cost of this. Course will be floated on the in July 25 to 29 and you can register this course, on this particular website.

So, these some of the things I have included in this particular. These are very limited, but for more detail and more rigorous understanding about the robust design and the high quality products then you have to go through this course, that is very useful to understanding this precision, machining and the error (Refer Time: 13:11). So, some of the slides I have taken here. So, this is a Professor Alexander's website where you can find the kinematics couplings and this is a website you will get it a lot of information about those things. I have taken something which is more relevant to this course and you can understand rest of the things from their website.

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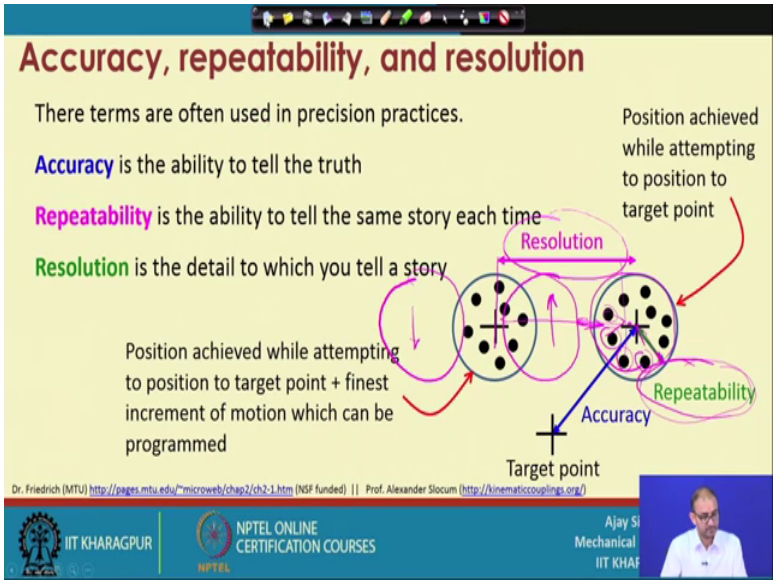

So, what are this accuracy repeatability and resolution, because we know that when you are working with a micro domain, you have to understand that how each and every parts are affecting the machining operation. So, we know this particular things in terms of metrology or the instrument part; that means, what is the accuracy of the particular instrument that suppose, you want to measure temperature variation, you want to measure dimension of any component by means of vernier caliper were something. At the time, you have to understand accuracy, repeatability and resolution and these things are important in all the measurement. So, here let us say that how these terms are connected with the machining operation or the micro machining operation. So, there is their term.

These terms are often used in the precision practices. So, first thing is the accuracy. So, now, what is the accuracy, how we can define? Accuracy is the ability to tell the truth; that means; that suppose, you are at one locations; you want to identify that location; that means, how closely you are going that location. So, that is given by the accuracy, what is the repeatability? It is the ability to tell the same story each time; that means, it one person is asking something then you are telling something, if other person ask in same question you, how to tell the same story if you are not telling the same story? That means there is a problem with the repeatability. There is a third one, it is called the resolution. What is the resolution? This is the detail to which you tell the story.

Now, how small you can go inside it that will be decided by the things and that is very important in this case. So, these three terms are very important in machine tool also. So, we will see this each term very detailed in this part. So, now, consider this is a target point; we want to go to this location instead of that what we are getting? We are reaching to this location somewhere.

So, here important thing is that once you get this location, you are away from the target location and this is creating a problem. So, now, you are away from the target. So, what things is that? So, this is a position achieved, while attempting to position to a target point, we want to go to this location, you are reaching to this location and these are the black dots, are the different points; that means, instead of that you have done around ten types of operation and everything is paired around this location.

So, this is the centre point of this particular variation or the distribution of that part, what you are getting here. So, this is called accuracy. So, more is this being away from that less is this accuracy, more this thing close to the target point more is the accuracy correct. So, this is the way you can define, the accuracy is the ability to tell the truth. So, how close you are reaching to the target point that is their thing. Now, repeatability that how much time; you are getting this result here?

So, we have many readings here. So, this all things suppose, you considered this within the tolerance limit that whatever dimensional you are getting, which is within the tolerance limit. So, that mean this is the repeatability. So, all things are falling within this particular band. So, if you create a radius out of it all things are within that part. So, this is called the repeatability. So, how many times you can tell the same story?

So, this is the centre point of that, you are telling everything around that part. So, if this is acceptable, your system is repeatable. Now, once this part is over suppose, you have done a lot of readings here, you are changing the component and then you are doing same operation, then you are getting some other location by chance, you are not getting the same location. So, what is this thing? So, same thing, again the position achieved, while attempting to position to a target point, same thing is your position achieved, while attempting to position to target point, but plus the finest increment of motion, which can be programmed correct.

So, now what happened that; this is the one thing, you are getting in first operation. You are getting this thing and next operation what you are getting? You are not going to this location, but by chance you raise to this location. So, now, this is also a different from this part. So, now, you consider this accuracy is still same suppose, you consider distance between this point, this point, this point, this point are same then accuracy is same, but problem is that how far it is located from each other. So, this is called the resolution. So, this is the finest increments.

Suppose, it is within that range, then this is the location of this particular part. So, you are getting something within this part and this is called resolution, if it is this particular circle is close to this thing; that means, it is high resolution; that means, within a small moment it can detect the things of whatever things are changing, if it is located, here is this location. The resolution is low, here the resolution is very high. So, I think now, it is very clear in terms of the machining operation, micro machining perspective, that accuracy repeatability resolutions are very important during the construction of the machine also and during operation also.

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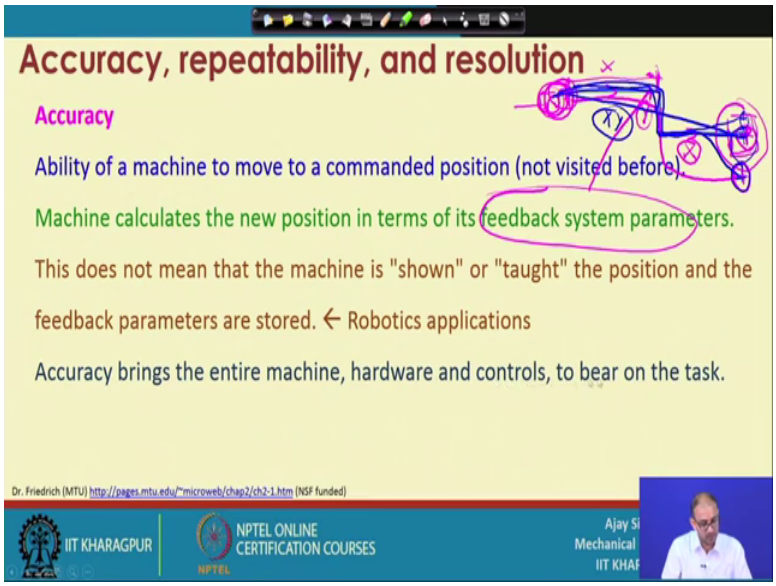

Now, let us go through one by one. So, what is the accuracy in terms of the machining operation let us not talk about the instrument point of view. So, ability to ability of a machine to move to a commanded position, which is not visited before now consider that your tool right now located here. So, this is the first location and you have instructed the machine by a part program that you want to go to this location.

So, this is the target location. Now, it is starting from this and it is moving and this ligand, this location actually it was not visited before that. So, how close it is reaching at this location that is decided by the accuracy; that means all the components. What are components? You are using over this drives, X Y Z drives, then you are using encoders. So, everything will work in such a way that you can reach to that particular location. So, machine calculates the new position in terms of it's feedback system parameters.

So, now, when you command this particular tools so that, your tool is moving from here to here. So, first thing is that it has to move up to this dimension, consider this is in X direction. So, your program or the G N M code will command your tool to move X direction up to this location, then move into the Y direction and then again move into the Z direction. So, when you are moving and you are reaching to this location your feedback system will give you information to the controller that it has reached to the X position there. Now, it will move to the X line, then it is moving in Y line, Y direction again, your feedback system will give information that your tool has reached to the Y

location and then it will move to the Z X axes X axis again, but that does not mean that the machine is shown or taught the position and the feedback parameters are stored.

Now, seen robotics application many times, what happened that there are ways of doing this thing suppose, you are you are right now at this location you have one work piece and your robotic arms want to pick up. This is the work piece and this is the robotic arm location and your work piece is located here and your ex instructing robot to pick up this arm, pick up this work piece from here. So, many times what happened that these locations are already known to the robotics application, then what it will do? It will do a back calculation there, which is the easiest way to get this thing done, but that is not done here in this, because in our case, it is altogether opposite direction, that these things is not known, where is this point located is not known.

So, that is the reason that you are moving in such a way that you are reaching to this location in an efficient manner. Now, it is showing is this location, but this direction, but you can directly reach to this location by this way. So, at that time you are to move X and Y simultaneously, if you want to move X independently, Y independently, than this is the way of reaching to this location, but how closely you reached to this location that we have seen here, the target position is different and when you are reaching that maybe different, but then whatever accuracy of this thing, that will decided by there.

So, this is not working in terms of the robotic application, where you already have information about this particular point and then your robotic arm will follow one particular optimise part to reach to this location. It is not like that, our case, it is an open loop thing; that means, we know our control only to reach to this location, this position is not known.

So, accuracy brings the entire machine hardware and controls to bear on the task. So, now, what is the important thing here that again we want to reach to this location? So, we know that each and everything is important. Now, what is the task of the components? So, this is overall the task; that means, machine entire machine; that means, the construction of the machine is important, because if there is a deformation, then your end up with the wrong location at that part. Hardware is important, because hardware related to the all the X Y direction movement; that means, whatever it is, things you are adding,

this turbo motor you are using, stepper motor you are using. So, those things a hardware controller; that means, what things are rotating or moving this particular motors.

So, those things are what variable frequency drives and those things are there and this all things were will work and if all things are working 100 percent of the capacity, there is a high chance that you will reach to the target point. If even one of this things is not working at 100 percent capacity, high chances are that you will end up with the wrong location, may be here, here, here, or here any direction it may happen.

So, that is the problem. So, what is the importance of accuracy, there if you tell your machining accuracy is very high, you can understand that all parts are working fine, if one part is not working fine, you will not get accurate machining during the operation. So, this will bring all the system whatever is included within the machine tool, all things are sees possible for getting a high accuracy of the machining operation.

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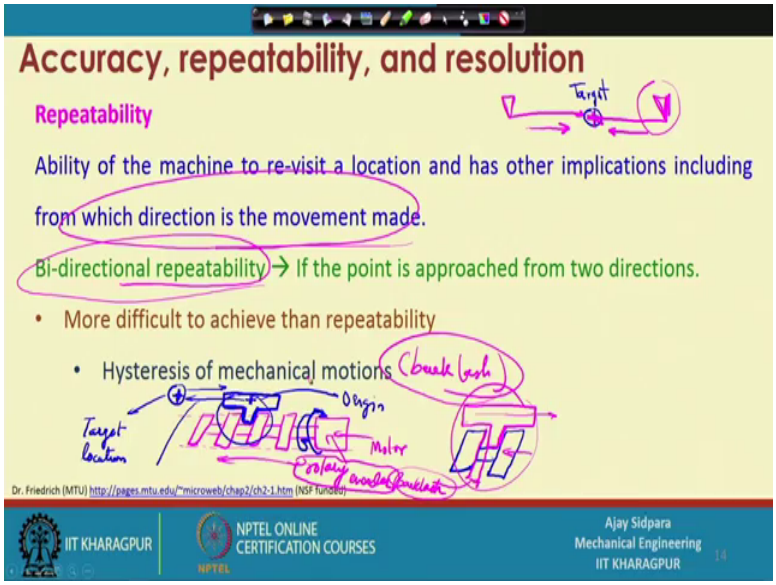

Another thing is the repeatability. So, what is the repeatability? It is the ability of the machine to revisit a location and has another implication, including from which direction it reaction is the movement made. So, now, let us see this thing. So, now, this is our target position, when our cutting tool is right. Now, at this location this is our cutting tool, let us consider our cutting tool is this location. So, it is moving in this direction. Now, in next operation; now, this is depending on that revisit location and has other implication including from which direction movement is made. So, right now one

direction of movement is this one correct. So, now, it has reached to this location, consider this is your reference point, through which you are actually making a different machining operation.

So, this is your reference point and second part suppose, your tool is located here, in this location. Now, you are machining or the direction of movement is in opposite direction to the earlier case. So, now, consider that if your tool is moving from these to this locate is reaching to the target location, if your tool is moving any direction other than this direction, then again it should, these to the target location.

So, how it is defined here? So, this is depending on there. So, now, there is a two thing; one is the repeatability and other thing bidirectional repeatability. So, if the point is approach from the two directions. So, whether you move from this direction is any other direction, it should reach to that particular location or revisit the location again and again.

So, that is called the bidirectional ability repeatability, but this is very difficult to achieve than the only repeatability, why? What is the problem? Because there is a problem with the hysteresis motion so that is creating a problem and other thing we can write, it is a backlash. What is this backlash here? Because now, consider, suppose, you have this screw something like this. So, this is connected with a motor and we have one table which is mounted on the top of it.

So, this is considered as a table. So, when you are rotating this screw at the time, what happened that your table is moving in this direction? Suppose, you are rotating the screw in this direction, your table is moving in this direction. So, at the time when it is moving in this direction, you have contact at this location correct. So, when it is contact, it is moving in this direction continuously. So, you are moving your tool from this location of this location, this is your target location.

So, now your starting position is this one and you are reaching to this location, you have reached there. Now, you are rotating your motor in the opposite direction in such a way that you want to move to the original location. So, this is the target location and this is the origin. So, when is moving in this direction, this is called repeatability. Suppose, you are reaching this location a one direction then you are calling this back to this location now what is the problem now consider this particular zone part. I am zooming this thing

little bit. So, this is the lead screw and now this is, because when it was moving at the time there was a physical contact here when it is moving in opposite direction what happens at this is creating a problem. So, whatever this gap is there between the inner face of this lead screw and the this known whatever is there this is called backlash right

So, when it is rotating in opposite direction for a small amount of rotation, your lead screw is rotating, but your table is not moving in this direction and suppose, your added here rotary encoder for feedback getting, feedback out of it, when motor rotates. Your rotary encoder will tell you that your motor is rotated. So, your table has moved from this location to this location, but actually your table has not moved in that direction.

So, because of the backlash, your rotary encoder will calculate wrong position and, because of that your end up with drilling or doing machining at the wrong place. So, this is the problem of the bidirectional repeatability. There are many ways, you can actually avoid, you can minimise this thing that by using a different recirculating bolt, screw mechanism or using linear encoder in place of rotary encoder, but this things you will discuss in the few class later.

So, let me finish this class today and this topic will continue further in the different aspect of the machine tool in the next class.

Thank you very much.