Introduction to Mechanical Micro Machining
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Lecture - 25
Components of the machine tool (Contd.)

Good morning everybody and welcome again to our course on introduction to mechanical micro machining. In the last class we have seen some of the definition related to the different type of errors and different type of parameters. So, that we can understand the construction of the machines and 3 very important definition or different important parameters are the accuracy, repeatability and the reliability or the resolution. So, these 3 parameters we started discussing in the last class. So, let us continue further in this discussion.

(Refer Slide Time: 00:50)

So, in the last class we have seen, these parameters are important to understand that how your all the control system, control system; means, the movement in x y z direction, the motor of the controller, how those things will behave when you apply 1 command or when you do a machining operation. So, important things were the accuracy that we started discussion then repeatability; that means, how many times you are reaching to the same position and resolution, we are going to discuss today and by this example we have

seen that there are many ways we can define this parameters, but this is 1 of the example we have taken.

(Refer Slide Time: 01:38)

So, we discussed this thing in the last class that the how it when we give a command to the machine at the time it is going to by position where it has not reached or it has not visited this thing before. So, all the things will play important role that how those accuracy will bring all the machine hardware control so that you can get the required position to a reasonably good accuracy.

(Refer Slide Time: 02:06)

Then we discussed about repeatability. So, repeatability; that means, if you are visiting 1 location and then you again visit the same location that is called repeatability and we have seen there are 2 types of repeatability. 1 is the repeatability only, another is bidirectional repeatability and there we have seen that it is difficult to achieve bidirectional repeatability compared to the only repeatability because there are problem with the hysteresis in the mechanical motion and we have taken 1 example of the backlash, this figure was not there earlier, but this time I have added it.

So, let us see that what things are there. So, here what is happening. So, this 1 is the lead screw and so, this area is the lead screw whatever is this 1 and this upper part is the nut or you can consider the table which is moving because of the motion of the rotation of the lead screw. Now, when you are moving this table or lead screw in this direction; that means, the nut into this direction, your lead screw and the nut are in contact with at this location because you can see this is the location and if this particular area; that means, whatever is this area available, if this area is not same for the nut as well as lead screw, then what is happening that you are getting 1 thing that is called this is the area which is not connected with the lead screw or the nut.

So, this is called the backlash. So, when it is moving in left direction your end up with some space here, but when you are moving in the opposite direction; that means, you are retracting the nut or the table at that time what happened that your table over the particular nut will stay at that location only, but your lead screw will rotate and again it will align your nut with the lead screw at this location. So, that was not the case in that case. So, without any translation motion of the nut or the table, your lead screw is rotated and it will generate 1 signal that is called wrong signal because you have not moved this particular nut or the table, but your lead screw is giving a signal that it has rotated. So, these are the problem with the hysteresis and that is called the backlash and some there are more other examples are also available, but this is very general example for the machine tool.

So, let us go further, now it is a resolution. So, what is the resolution, resolution is the least increment of movement the machine is capable of making. So now, we know that we have different mobile phone and where we have given the HD resolution and full HD resolution. So, at that time what we are doing there, that we are actually dividing the whole screen into small pixels.

So, these are the pixels of the screen, single pixel. Now, it is suppose this is the total area of the screen and then we have to see how many pixel we can add. So, if you add more and more pixel, what happens your image will be divided into large amount of pixel and each and every pixel will give you a real life or the very realistic view of the system. So, higher is the pixel density pixel density, higher is the is the image realistically. So, whatever way you want to see those things, those things very important in this case. So, in same way here it is also resolution, how this resolution play important here because in machine tool we know that we want to move a small small increment and the if that increment is possible in that machine tool; that means, we can say that it resolution is this much.

So, now suppose we have 1 position here and from there to here we want to reach. So, this is your target point and the from here it is starting from a 1 millimetre and we want to move from here to here. 1 point suppose let us say 9.02 millimetre. So, we are talking about the 2 decimal point after 1 millimetre. So, if this is achievable in this particular

machine tool, then we can tell that it has a resolution of a 0.01 mm right. So, in that way we can tell that this is a least of, you can get any number of increment or any number of thing in terms 0.001. So, multiplied by whatever you are getting n. So, that will be the resolution of the system right.

(Refer Slide Time: 08:08)

So, this is that same thing, if the system resolution is n, then all the motions are integer multiple of the n. So, that is what we can see in this particular definition of the resolution right. So, resolution is the least of any system component, but rather the largest. Now, what is the question here that we know that, we can tell that we have many different different type of encoders and the different type of slides available.

Now, if you see our machine or machine has the moment in the x direction then it is in y direction and that is in the z direction correct. So, here we are using different motor, linear motors are available, survey motors are available, stepper motors are available.

Now, out of these old things, now consider the this particular z motion let us talk about the x and y only right now because that will be much better because x and y is mostly located on the table and the z axis is; obviously, the spindle axis mounted on the vertical side. So now, consider x and y tables are, is this here and you are adding 1 particular encoder for measurement of these things. So, now, encoder 4 x 1, suppose it has a resolution of 0.001 mm. So, that is called 1 micron and now consider this y has 0.01 mm, that is a 10 micron.

Now, what we should tell to this system that what is the resolution of the system. Now, suppose because this whole thing is a system, now somebody will ask you the question, what is the resolution of your system? So, whether we tell them that our resolution is 1 micro or we can tell them it is a 10 micron. So now, that question is very important to ask. So now, what is happening here that we have to go with the largest 1, not with the least 1 because we know that our system is working with a 1 micron resolution, but it is only 1 axis, but another axis is the 10 micron resolution here.

So, ultimately whatever is the largest value of the resolution that will be the resolution of the system. So, for this particular thing we can tell the resolution is 10 micron. Even though 1 of the axis has 1 micron of resolution, but still you can go with that 1 only because that is achievable at 1 location only, but still there is 1 another axis which is giving the very little bit large resolution, large resolution; means, the higher value and that is met means it is in worst condition not in the good compared to the first 1. So, in that way you have to select the things which is giving the largest value in terms of resolution and then that that is the resolution of the system.

(Refer Slide Time: 11:22)

Now, let us take this example that a machine controller can calculate a movement of 0.1 micron, but the feedback control only has the resolution reliability of a 1 micron, so not able to reliably move the machine with increment of 0.1 micron. Now what is this thing machine controller that whatever we have seen that there is a was full screen available

where we had lot of things here that there was x y and z axis and there are some values here 0.001 and here some value seven and there are so many buttons were also available. So, that is the controller screen and, but other thing on the other side there was a velocity controller there are other feedback controller is available.

So, here suppose your machine is able to move with a 0.1 micron. Suppose you are giving something let suppose you want to move from here to here, this is a 0.1 micron this is a 0.2 micron and this is a 0.3 micron right, but now what is the problem that your resolution; that means, you are getting a feedback from the controller; that means, how much you have achieved.

This is the things which you are moving in the direction, but you have another encoder which is give the feedback of the system that where your tool or the workpiece is moving. It has a reliability or the resolution of a 1 micron. So, this 1 is counting, how it is counting, it is counting 1 micro then 2 micron and 3 micron, 3 micron this is in terms of this 1.

So, now this both thing has a difference of a 10x. So, there is a 10 times of difference between this system and this system. So, what is problem here, that when you are moving your tool from 0.1 to 0.3 or 0.9, your feedback system will not able to detect that change. So, when you are moving from 1 micron, suppose this is the 1 micron and then you are reaching to the 2 micron, then only your encoder will give a signal because now this is the range in which it is working or it has that particular resolution, but suppose you want to reach to the here point 1.5, then it is not possible here.

So, that is the resolution. So, even though you have a linear motor which can move with a point 1 micron, but if you have added a encoder for measuring all the giving feedback of the controller, that is a resolution of a 1 micron then your system resolution is actually the 1 micron and not the 0.1 micron. What is the problem with that; that means, here problem is you are not able to extract the complete capability of the controller which is a capable to do any machine you are any movement with a 0.1 micron, but you have added 1 not reliable or the less specification of the feed in back feedback controller which has a 1 micron. So, here if your movement is this 1 then it is better to go with at least a feedback control of a 0.001 micron.

So, feedback controller should be at least 10 times better, 10x better, not the 10x lower, then we can really very comfortably get that particular signal or the whatever movement is giving here that is possible to get this thing.

(Refer Slide Time: 15:17)

Now, how all this parameter or the all this characteristic things are connected with each , the accuracy will be affected by the resolution. So now, you can see the how this thing a working that all moves are integer multiple of the minimum of the worst machine resolution that we have seen that, we can actually define something in terms of the which one is the worst resolution and then only you can tell that this is this is resolution of a system. Now, this is the thing that a linear motor with a high resolution fed by the low resolution encoder feedback, that is what we have seen in that earlier slide. So now, we can consider that suppose this is your target position or starting position you want to reach to this location target location.

Now, when you are moving this thing, we know that we have a very high resolution linear motor, but our feedback encoder is a little bit less. So, it is moving precisely at that location, but it may not give that location because that location is a in terms of 0.002 or 1.02, if that is the case then your encoder will not find that location, but when it is finding a location in terms of 1, 2, 3 micron, then actually it will be useful in this particular case.

So, your accuracy is actually sacrificed because of the low resolution of your system, high resolution moves, but low resolution of known position. So, that is what is happening because your linear motor you can move with the 0.1 micron very easily or 0.01 micron also depending on the what is the stroke of the length of the stroke, but again you have position whatever you want to know from the controller that is actually faded by the lenders encoder feedback which is bit low or so, you are end up with the low accuracy. So, in we have seen in that encoder, that instrumentation that we can actually give many type of digits. So, when you say that encoded design or that controller part. So, in the controller screen we have seen that x y and z it was giving 0.0001 in terms of that and this was also giving 0.001 and that is also same thing,0.0001 and there are lot of other buttons also available. So, that you can get some specific operation from this control panel.

So, now what is this, in these are all the digital values. So, when you are move when this controller is calculating. So, this controller has a very high resolution, but you are end up with the another feedback system. So, feedback system may be giving something which is in terms of the 2 values only, it is giving up to these only suppose up to these only. So, actual movement is the 0.001 only, actual movement, but your controller is showing 0.0001 correct.

So, we have to be very careful in the interpretation of this particular thing. Whatever is showing on the display screen that has no connection with the control, but first we have to see that what is the resolution, accuracy and repeatability of the machine where we are getting the feedback. So, that is the actual thing, but not this thing we will see in some demonstration class also, in the machine tool that you want if you change a one particular digit still you are not able to get the last value change, if both the things will change simultaneously so; that means, your controller has the capability of 0.001, but your machine is actually not capable to give that much amount of resolution.

So, now what is also problem, the machine cannot interpolate between the least count of the resolution and therefore, it will stop as soon as the commanded position is met.

So, now, what is this. So, this is the encoder. So, now, here there are 2 encoders we have given here. So, this is the low encoder, lower resolution encoder and this one is the higher resolution encoder. How this encoder work, that will cover in the later stage, but here what this dark colour and the white colour is just. So, this are actually 1 type of film or 1 type of grading is available. So, there are 2 light sources suppose, let me show you here little bit about those things.

So, this 1 you considered the black 1 and this 1 is the remaining is the light one. So, in the one side there is a light source and there is a receiver at this location. So, this is a light source and this is the receiver. So, wherever this black portion comes, at that time light cannot pass through this and it receiver not get the signal, but whenever this white portion comes at that in light will pass through it and then it will get the signal. So, what when you are moving this table here and there, your light source will be also, light source all these receiver is attached with the table and depending on this thing they you are getting a 1 particular signal.

So, this 1 is a fix on to the table slide, but the base slide. So, when it is moving in this direction or this direction, when you are moving this thing in this direction at that time every time you encounter this particular black colour and white colour thing. So, you

will get the signal. Now, what is the what way you can tell the low resolution high resolution because everything depends on the what is the width of this black colour and white colour portion. So, if see this is a thing, then suppose this particular distance right now you consider 0.1 micron. So, every time when you are moving a 0.1 micron, at that time you will get 1 signal because you are white colour is a 0.1 micron again 0.1 micron is the black colour.

So, you will get a signal from the receiver, but now you consider this particular thing and this one is a 2 micron consider right. So, unless you are close this 2 micron your light source will not able to pass the signal to the receiver then only it is getting a signal from this location. So, this is called the low resolution the encoder because you are not able to identify the location of the table or the tool within a less than 2 micron of distance, but here it is called the high resolution because here the distance is very small. So, even if you move here and there within 0.1 little bit higher then 0.1micron you are able to get that position done.

So, now what is the problem here, now suppose this is condition you considered the this is the position; that means, the motor which you are using this is your motor and you know that a your motor is able to move with a 0.1 micron of a distance, but what your problem that you are actually end up with low resolution encoder, but encoder is able to identify that location only. So now, consider that when you are moving your table from this direction.

So, that is what is in the last known location moving this direction. So, what is happening that this is the 1 location where your light is able to get, receiver will get able to signal get the signal from the light. So, this is the 1 location and then this whole system or the whole travel will not get any signal and then the next one what you are getting, your getting a signal at this location because in that white colour came into its way and then your receiver will get the signal from the light.

So, within this duration you are not able to get anything. Now coming to your position where you want to move to this location because now this is thing where you want to move that location, but that location is not available. So, this is your desired position that is what we want to know this thing. So, this is a problem. So, what it is written the machine cannot interpolate between the least count of the resolution. So, this is the least

count that is what our encoder can measure that is the minimum it can measure is the 2 micron. Then what it will do that, if still you use this thing what is that is doing that if you want to do if you want to reach to that location your actual machine will not reach to that location, but either it will go to this location or this location.

So, that is the therefore, will stop as soon as the command position is met. So, whenever you give anything even if you give this particular thing you want to go to 0.5 micron, but you are not reaching to 0.5 micron it will go either this location or this location, but still your control will tell you that you are reaching to this location also, that is a big problem when you are working with a some encoder which has a least resolution low resolution, but your position on and positional that is all the motors are capable to operate at a very high resolution.

(Refer Slide Time: 25:40)

So, what is the problem, that this can cause repeatability error depending from which direction the commanded position is approached. If it is moving from this direction it will give something different it will moving if it is moving from this location it make give you something different part.

So, what is a conclusion resolution should be comparable for the high efficiency. So, if your motor is capable we have seen that if it is a something like that, whatever is the x this is called x resolution. Let me clean, let us give some value, suppose it is able to move with a 0.1 micron then your encoder should have at least 0.01 micron correct.

So, at least it should have 10 times higher resolution of encoder than motors or controller and so, this way you can actually get the complete capability of this machine because without that, whatever sophisticated motion controller you are using, but if you end up with a lower resolution encoder, ultimately your operating a one particular things which is extremely low we have extremely high in terms of the resolution low in terms of the resolution because low resolution; that means, you are end up with a very large amount of motion steps, but when you are telling a high resolution; that means, step size is very small.

So, let me finish this lecture here and we will continue this topic in the next class.

Thank you very much.