Introduction to Mechanical Micro Machining
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Lecture – 27
Errors in machine tool

Good morning everybody and welcome again to our course on Introduction to Mechanical Micro Machining. In the last class we have started a topic related to the structural loop of a machine tool. And we have seen that the structural loop consists of different different components; which are connected from one side from the tool and other side from the workpiece. And when you have force acting between the tool and workpiece this structural loop may get deform and you may get a different different type of deformation and errors during machining operation. And we have seen that the different parameters which also affect the structural loop configuration and how yours machine will behave during a machining operation.

So, let us continue this topic and let us understand; what are the different type of error and sources? So, that we can understand and we can find out some of the solution to rebut this particular. So, error or we can minimise this errors. So, let us continue this.

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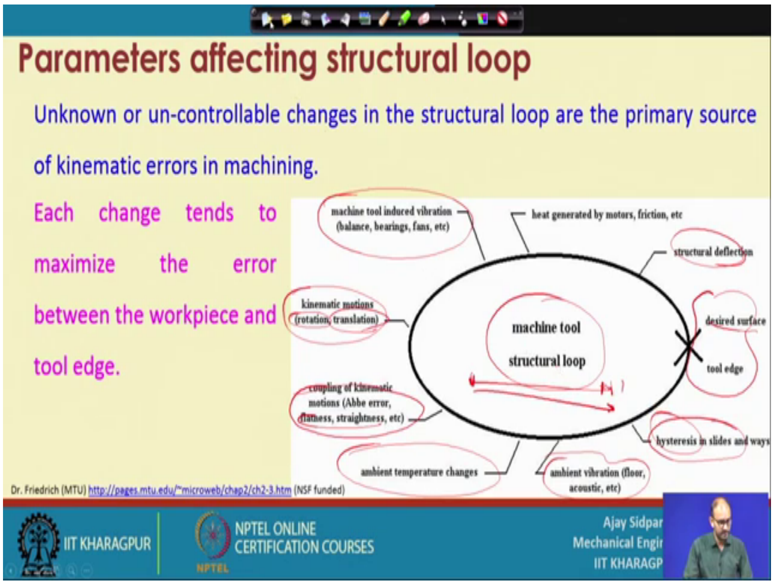

So, in the last class we have seen that. So, these are the different type of and we have seen that these are the issues which will be covered during the machining operation.

Vibrations are one of the things, then heat generation is one thing, then we have seen the structural deformation and these are the two locations which are keeping this particular loop in a close thing. Hysteresis in the slide and reverse way because if your moving in one direction and you are reaching this location; if you give the same distance travelled to the original location you will not reach that location it may be somewhere shorter than that it like that and then you are end up with this type of hysteresis.

Ambient vibration, floor acoustic vibration which will come through the other machine or some other equipment to our micro machining centre ambient temperature also play important; because if your room temperature where the machine is installed if that temperatures variable it will affect the machining performance. Then these are the errors which we are going to discuss now, flatness error, straightness error and some other things.

Kinematic motion we generally believed that your tool is rotating only along the z axis, but that is not true because there are some problems in the rotation axis also. Translation we believe that our x and y both are perpendicular to each other and there is no any other motion than the translation, but that is also not correct in many cases that we will see. Machine tool induced vibration also play important role. So, these are the prob different different parameters which will affect the structural loop of the machine tool.

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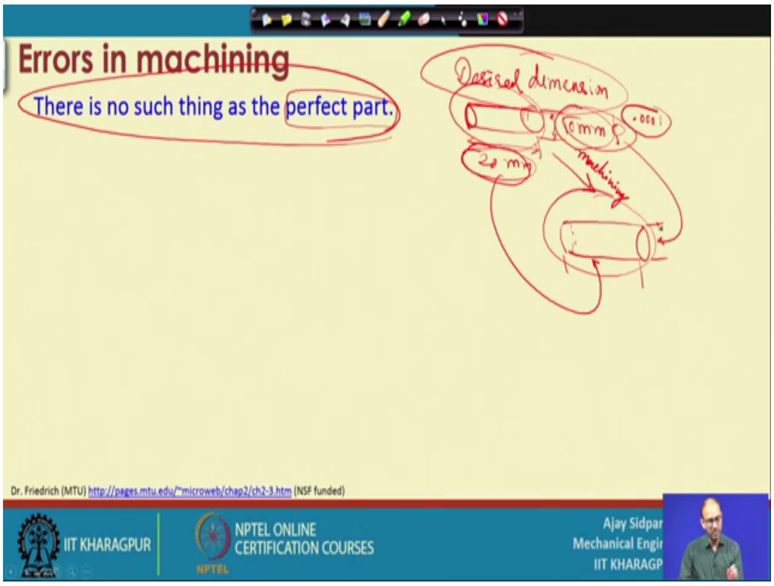

So, now what are the errors in machining? Because we know that there is no such thing as a perfect part. What is the perfect part; that means, suppose you want a a diameter something like a 10 millimetre is the diameter and length is a 20 millimetre. So, if this is your design or desired dimension. If you are getting the same thing whatever here this is getting. So, let us machine it and you are getting the same thing.

So, this is the same thing here and whatever is the dimension this is also same thing; then we can consider this is the perfect machining, but generally it will not happen because whatever way we are desiring in the solid that 3D modelling software or different type of cad software's that parts you can easily get; that means, you can easily do a drawing with a perfect dimension, but when you actually do machining at the time there are lot of issues which will play important role and because of that you will not get exactly 10 millimetre diameter and 20 millimetre in the length. It maybe something from deviated from 0, 0, 0, 1 or something, but still there will be some of the deviation in the dimension

So, we will mostly not get the perfect part; that means whatever you are designing and what you are getting there will be always some difference. So, what to do in this case?

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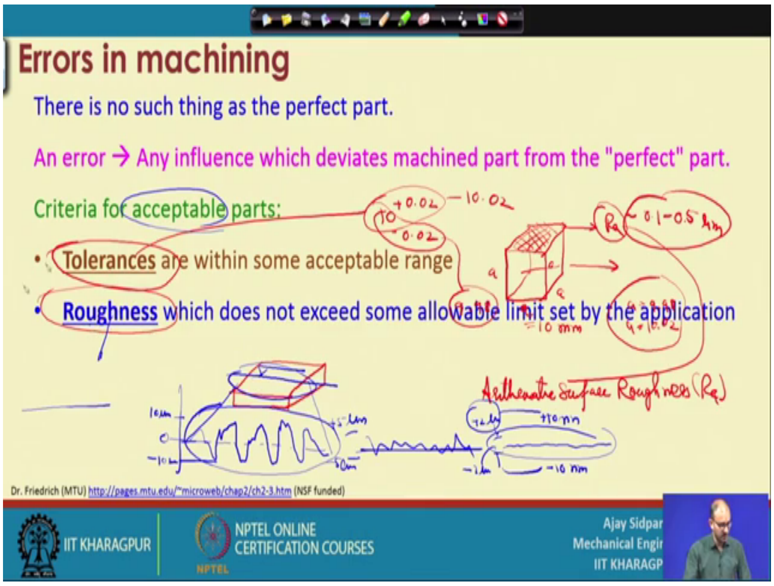

So, whatever is the difference that we consider as a error. So, what is an error? Error is any influence between which deviates machine part from the perfect part. That we have seen that suppose you want that diameter 10 micro or 10 millimetre diameter and you are getting 9.99 or 10.01 ; that means, there is some deviation and that deviation is considered as a error , but generally we accept this type of error. So, what are the level or what are the criteria for acceptance of this particular error? Because we know that it is difficult to remove this error ultimately you have to accept with a one particular variation.

So, let us see that what are the things? So, if you are making a part with reference to tolerances, then if your part is within the tolerance limit then you accept that part so; that means, suppose we have a cube with a dimension a, a and a in all the side this called the a and now that considered a is a 10 millimetre. And what you are making here? Suppose it has a dimension a equal to 9.98 or a equal to 10.02. If this is the thing which is acceptable in this particular application where ever this part is going to fit or going to assemble then it is a acceptable.

So, what we do this tolerance. So, tolerance what we write that 10 plus 0.02 minus 0.02 so; that means, if the part is with a 10.02 it is acceptable if the part is 9.98 then also it is acceptable. So, this is in terms of the tolerance if you are putting a acceptable or non acceptable limit mean with reference to the tolerance. Another thing is the roughness; suppose if your part is within the tolerance limit, but then you have some functional surface on the top surface.

So, now considered the; these surface is going in contact with the some other component. So, now, surface roughness play important role. So, now, what you have to do that? You have to provide one another acceptable or non acceptable limit. So, that that your roughness should be within these to this range so, now, this is the component now you can say. So, this is the roughness R, R a that is mostly given by the R a that is means there is arithmetic surface roughness arithmetic surface roughness that is called R a. So, here also we they are tell that if R a is less than considered that it is approximately 0.1 micron to 0.5 micron then it is acceptable. So, what is this R a? That supposed this is the one particular surface.

Now, consider this is one surface. Now what we have done here whatever this top part is there right now we have given a completely flat surface, but if you said microscopically and if you come down this particular part any to do a stretching of this particular part by some stylers then what you will see that this will be this is the main line and then you will get some type of this type of profile. So, this is called the surface roughness. So, this will be in this will be 0 and here it will be 10 micron or whatever way it is moving; that means, you are magnitude is moving up and down or amplitude that will be considered as a scale or the range on which this particular roughness is variable, but this is one of the way because you will never get this particular profile is a straight line correct because it is a stochastic nature you always get some roughness; only thing this scale will reduce suppose you polish this particular component and then this will be reduced you may get something likes and this variation will be plus or minus 5 micron you further polish it then you will gets very very small variation and this will be may be plus or minus 2 micron.

And this may go to the nanometre also few nanometre of 10s nanometre in the plus side and 10s of nanometre into the negative side, but you always gets some variation here. So, there is nothing like a straight line in the roughness.

So, only things which will tell us whether it is acceptable part or not acceptable part we have to finalise that which particular roughness is or which is which is allowable for a particular application. So, we decide a criteria for acceptable in terms of roughness by giving or mentioning a value of the roughness.

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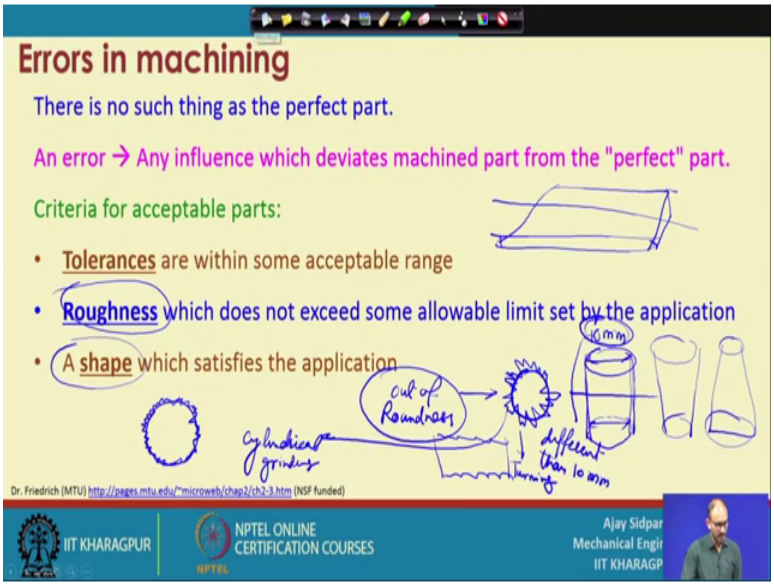

Then the shape which satisfies the application; now shapes are also important because here it is a tolerance it is the, what is the deviation in the dimension. Roughness is what is the surface characteristic which will come into contact with the another surface shape is the work pieces.

Now, suppose let us consider a cylindrical component or it is a circular right suppose this is the and let us consider a cylindrical component correct and if you cut down from the centre this is the cut section. Now generally what we believe that when you are telling the diameter is 10 mm; we assume that 10 mm is throughout the length, but sometimes what happened that at the starting point it is 10 millimetre at the bottom portion it may be something different than 10 mm different than 10 mm maybe on the plus side or minus side also. So, there is a problem with the shape.

So, it may you may come across this type of taper shape in this direction or it may be taper in this direction. Other than that that now in roughness we have seen that we are measuring the roughness on a flat surface correct we are measuring in, but you can measure roughness on this also because there is always a variation on the surface also when you do turning operation you always end up with the some type of this type of marks this is the tool marks and when you do measurement of the roughness you will get the roughness profile on to the part of a cylindrical surface also. So, this is the roughness profile, but here we tell this thing is a out of roundness right.

So, now what your to do that if you are getting this type of part after turning operation those this is a turning; then what you do that you do cylindrical grinding operation. And now the same part and then you can actually reduce the variation in the out of roundness. So, now, you are more reaching close to the perfect circle whatever we want to measure this 10 millimetre of diameter. So, in that case you actually say yes or no with the part selection where if there is a deviation in the shape.

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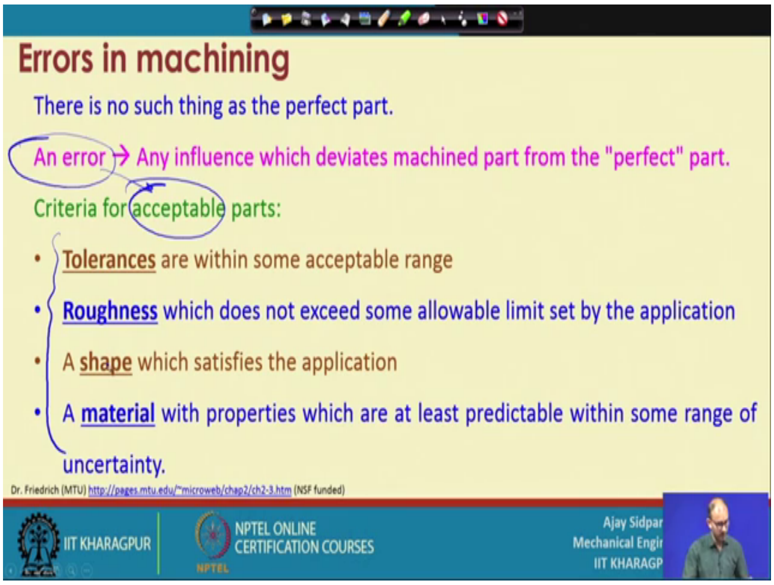

And material also play important because sometimes you want a particular of material property we by making a functional material then you have to understand the part is acceptable if it if the properties are least predictable within the some range of the uncertainty. So, if you think that the; what are property you have got from this particular fabrication material? If it is a predictable or whatever you want if it is within a sert some range of uncertainty then you can accept the part.

So, what we are understanding from this slide that; you cannot avoid error first thing then if you cannot avoid the error then what we have to do we have to put one particular range if your component is falling between that particular range then you accept that particular component if it is not falling in this particular range or selection criteria; then what you have to do? You have to reject the component right.

So, another thing is a cost verses performance in the error correction. Now we know that we are end of with error, because anyhow you have to remove those errors here, but first we have to see that what things you have to do to correct this error and how much cost and time you have to spend for reducing or the correcting those errors?

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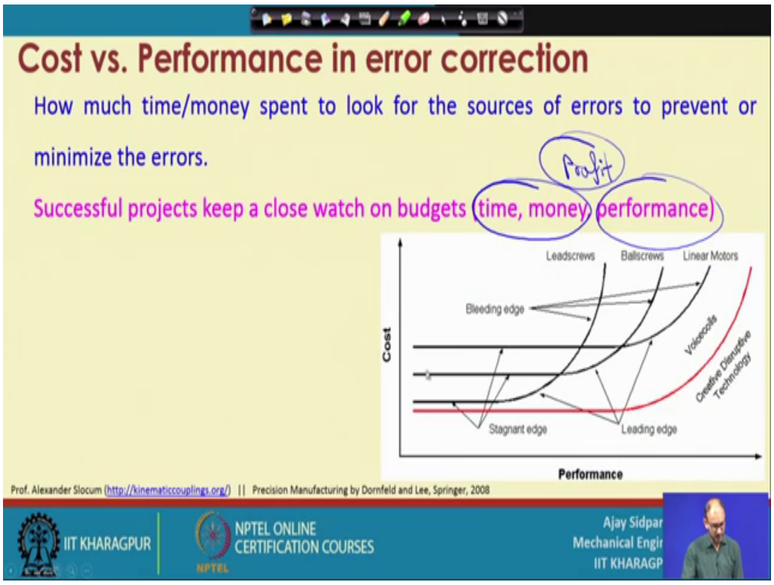

So, what is important? How much time or money spent to look for the source of the error to prevent or to minimise? Now here you have to spend in two different way first thing that suppose there is error you have to find the source of that error. So, you have to spend some time and money for just looking at the source only.

So, once you identify that source, location, then what is the next thing that you have to either prevent that particular error or if it is very difficult to prevent what you can do actually you can minimise that thing, but still this is the first thing then again you have to spend money for either preventing that particular error or you have to minimise that error. So, how much money and time you can spend that again depends are how what is the importance of that particular component or that particular machine.

So, there is always a break even between the time in money spent to correct that error or to identify that error and then what is the benefit you are getting by correction of this error? So, that particular break even you should know otherwise you are always wasting more amount of time and money just finding or just preventing the error which may not be important in a different different components right.

So, what is the successful project? So, successful project keeps a close watch on the budget because you have to understand that how much gain in the performance by spending how much time and money? Because these two things are very important; you cannot always just think about spending time and money, but you have to also extract at least more number of performance or more number of components by spending time and money, because ultimately everything is connected with the profit. If you are not looking at the profit, then you are always in the particular problem that you are not utilising the machine and the resources perfectly right.

So, this is one of the examples; now here say that this is the one example which is given in terms of the three components. The one is the lead screw on this ball screw linear motor in there is one there is a voice coil motor and the graph is with respect to performance versus cost. Now see whenever you are utilising a one particular technology; now consider lead screw is very very old age in comparison with the other three technologies. So, let us start with the lead screw. So, now, if you see the lead screw lead screw has one particular stagnant edge.

So, this is called stagnant edge. What is this stagnant edge? That you are getting improvement in the performance without costing anything because this is mostly that once you put a initial cost that this is a new machine you have spent the money in that and then you are getting a constant or consistent performance for a longer time and then after sometime what happened that if you want to incorporate some type of intelligence in the machine that suppose you want to incorporate some sensors or some type of other equipments or other equipments which you can install in the system.

So, that you can get some extra advantage in terms of the machining of different components or identifying different errors or you can actually monitor the process control then what happens that after that this particular line increases.

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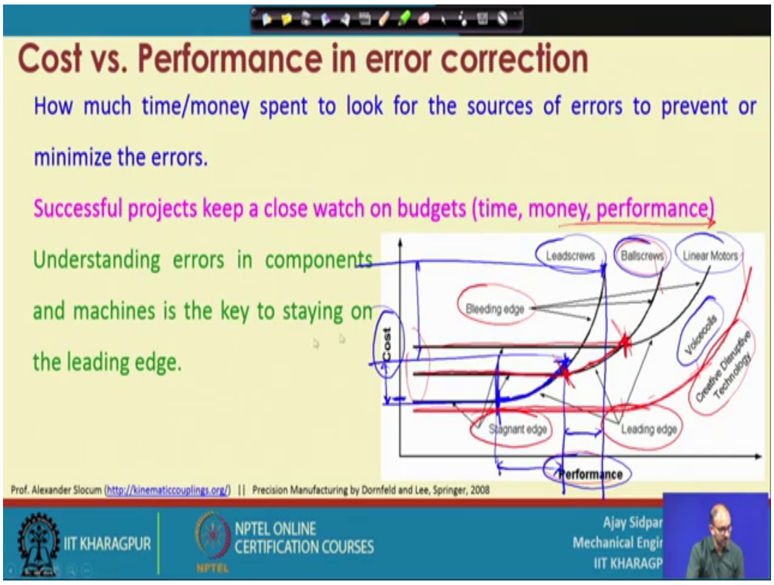

Now, you are not getting performance free of cost. Now cost also increases with increasing those types of sensors and some type of other accessories which you are installing in to the machine. So, it has also one of the limitations; now you have to find out the; what is the slope of this particular curve? Now if you see starting from this thing and you are ending at this location now consider. So, you are increasing cost is this much; and same way if you are looking at this location your increasing performance is this much.

So, by look was it understood that your performance range is more compared to the cost. So, you can continue, but now consider from this particular point to this particular point. Now you look at this particular graph. So, this is the addition of the performance, but if you see this is the cost you have spent for getting that performance. So, this is not the way you have to spend the time and money to get the very very little increment in the performance.

So, that is what is happening in this particular case. So, if you continue in this case. So, this is the; this is the another technology. So, this is a ball screw now what happened if you use a ball screw, then your machine will perform little bit longer time with a stagnant edge this is up to this one and then the same thing will occurred that you want to increase that sophistication of that machine intelligence of that machine. Then you have to spend money again you have to think you have to which location you are getting a stagnant edge or this is for the leading edge and.

So, leading edge is the something; where this is the most preferable thing that mostly we do not want to give more any cost, but you are getting performance, but at at the end because of the edging of the machine and controller you have to spend something there. So, it is better you stay always in the leading edge because leading edge will give you a more performance compared to the cost. As soon as you are moving into this bleeding; edge bleeding edge means this one where you are spending more money and you are getting a less performance.

So, this is way to the bolt screw if you continue with the linear motor, because here the sophistication in terms of the motion controller it is increasing in this direction. So, these are the linear motors. So, that is more even important things we are getting a micron on the nano level of resolution mean moving, but if you see cost is also increasing continuously. So, this is more costly, but you can get the more amount of performance without any cost. So, the within the stagnant edge is very very long. In this case and this is that creative our disruptive technology those are called voice coils.

So, if you are getting something with a low cost, but if you are moving in this case which is has a very long leading edge and this very very small bleeding edge, then you can actually consider these are the very creative or the disruptive technology which can increase the performance of the machine without actually compromising between the performance and spending the very very spending the less amount cost. So, that is the advantage of going through this part.

So, what is that the understanding error in the components and machines is the key to staying on the leading edge? So, our objective is to stay within the leading edges. So, wherever this a leading edge leading edge starts as soon as you are getting a cost increase and then you can think about a one point where you can actually normalize the things.

So, now you can see this particular thing is the leading edge of the lead screw, because here the performance is high compared to the cost you are spending in this particular case same thing the leading edge available for the other three other two equipments also, but if you go with a.

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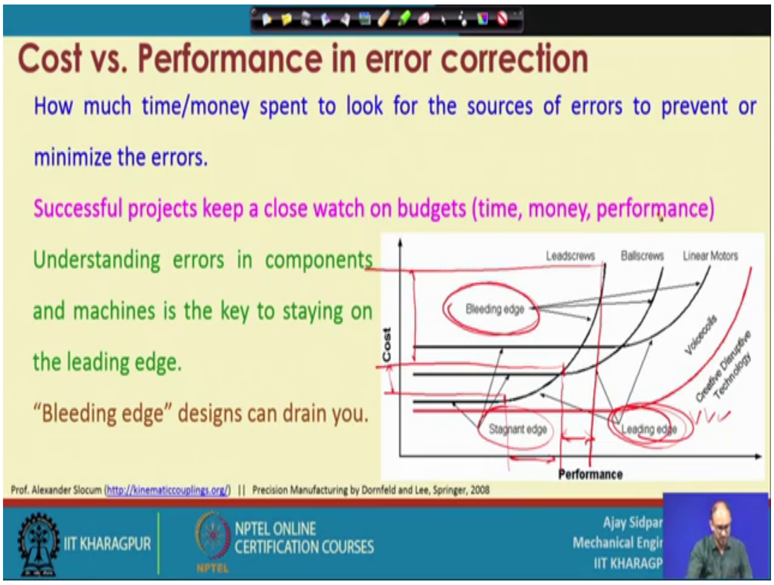

Last one the bleeding edge designs can drain you drain you; that means, you have to spend more amount of cost and time and you will get a very very small amount of performance increase. So, this is what is that thing? So, this is the thing. So, now, you can see. So, this is very very small amount of increase in the performance, but whatever you are spending you are spendable more amount of cost here.

So, our objective is to stay within this particular leading edge that is very important, if you are getting this thing that is standard machine, but if you want to increase the capability of that machine you have to always staying the leading edge and you have to avoid this particular bleeding edge. So, that you can get more performance compared to the spending of more money.

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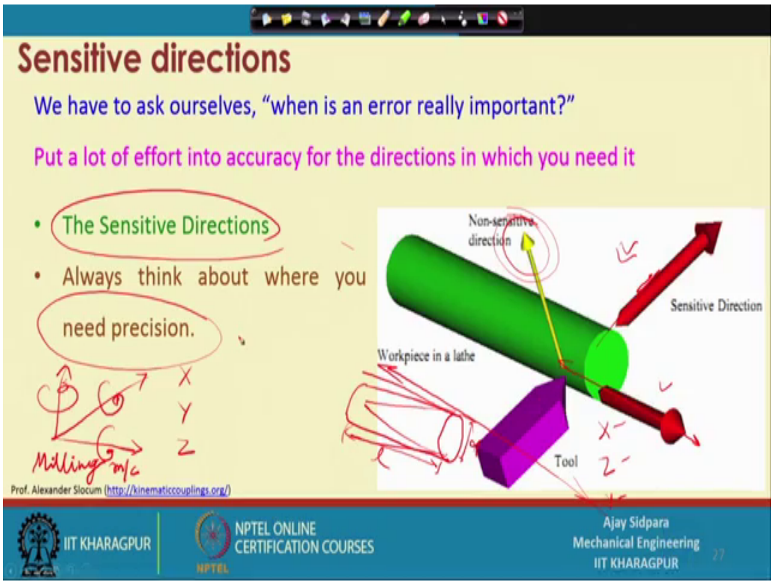

Now, sensitive directions now this is also important; because we have seen that we have to reduce this errors and we have to again look into the monetary aspect that time and cost also very important that how much you are spending and how much your gaining out of it, but before you go to that particular aspect first you have to find that; what are the errors and whether that error is really important to remove or not because many times; what happened that some errors or according into the process, but it may not be very very critical when you are getting a part out of it.

So, first you have to find out the; what are those errors and how important is that error if you remove those things. So, put a lot of effort into accuracy of for the direction in which you need it. So, now, consider this is that turning operation now what we are getting out of turning operation that we will get a have one particular component. So, this is the component what we are getting out of it or a how we specified this component we specify this component in terms of the diameter and the length correct.

So, now these are the two direction which are sensitive; because if this particular direction if your component or a machine is not most stiff. What have will happen that you will get a you will not get a circular dimension and if your sensitive direction is not is no in your machine is not stiff in this direction that mean when your tool is moving in this direction your tools should be always in a straight line, then what you are getting that you are getting a taper turning in this direction or it may get this direction right. So, these are the two sensitive directions, but this is insensitive direction because we know that our lathe or the machines are the x and z axis it does not have the y axis because you all the component mostly you are getting as the axisymmetric component. So, this is a non sensitive direction

So, you have to find out first that there which errors you are getting in that particular machine or any type of other operation; and what is the importance of that error? Whether you really need to remove those errors or if that error represents it will not make any problem in there. So, you have to understand that thing first. So, these are the sensitive direction in non sensitive direction even if something occurs; this non sensitive direction you can ignore also because you can instead of spending a time and money for this non sensitive direction error it is better you spend little more money in the sensitive direction. So, that you can get a near perfect component and always think about where you need a precision

So, now you have a two options here this is the first one and this is the second one: now if you have limitation in terms of time and money then again you have to actually do a one type of optimisation study. So, that you can find out the in which particular direction you have to spend money and then you can get the precision out of this particular component. So, in this way you can actually play this is only example of a lathe machine in terms of the milling machine there are different different axis; because now if you are talking about in milling machine then you are coming x was the another axis x y and z axis and we know that all this three axis are perpendicular to each other and a because of this reason you may end up with more error compared to the lathe machine.

So, this is the milling machine machine configuration. So, more and more axis you added then there is a chance of more and more amount of error in a different different direction we know that if there is a direction that is; that means, rotational around this all this three axis that also create a more complex system that is five degree freedom axis and the six degree of freedom axis of the different different machine. So, find out the first sensitive direction and then find out how much precision is required. So, by that way you can actually reduce the total cost and time spent for making your system intelligent.

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

Thank you very much.