Introduction to Mechanical Micro Machining

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Lecture – 42
Components of machine tool (Contd.)

Good morning everybody and let us continue our discussion on the different component of the machine tool, in the last class we have discussed about the encoder and we have found that there are different type of encoders, but we have seen that if you want to move or if you want to measure a linear motion it is better to go with the linear encoder as compared with the rotary encoder, because linear encoder directly measures the assure position.

While rotary encoder it actually converts your calculation based on the pitch of the lead screw. So, if there are some thermal effect that is expansion of the shaft or bake clays or the wear then it will not account these types of error and that error will be actually reflected on to the machine components, you are not actually cutting as per the desired value, but you are getting some dimensional problem. So, we have seen the linear encoders are good for the linear motion measurements and rotary encoders we can measure the rotational motion.

So, now this lecture was we are talking about the spindle because we have seen that we have to get the high velocity, and we should know that what is the rpm limit what are the rundraw run out of the and system and what are the different spindle options available. So, that we can mount or we can use those spindle for the micro machining application, so let us continue our discussion on the spindle correct.

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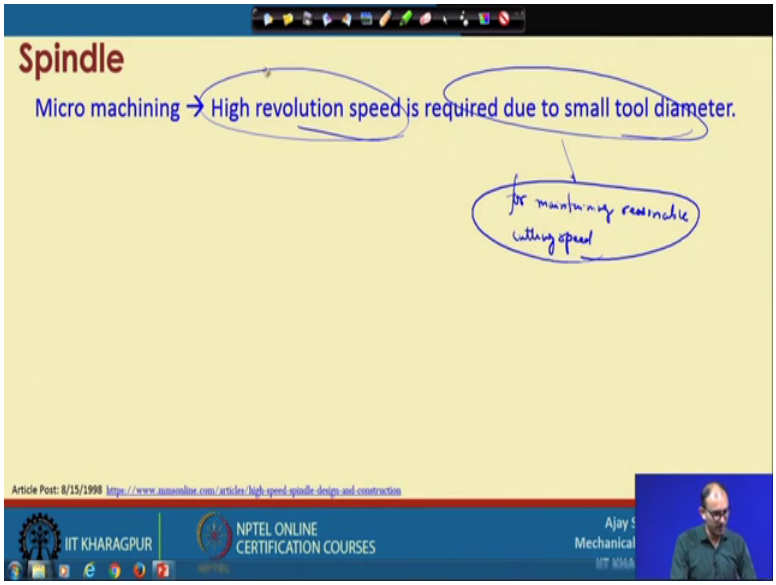

So, in micro machining spindle is very, very important high revolution speed is required to due to the small size of the diameter, that we have seen that we have to maintain the cutting speed correct. So, for maintaining the cutting speed is very important , so this is for maintaining reasonable cutting speed.

So, that you can get the amount reasonable amount of material removal (Refer Time: 02:11) because if you do not work with the high speed then what is going to happen just you we have to take very, very long time then we have to use very, very low speed rate because moving with a high, high speed rate then you have to go with a high resolution high revolution speed. So, that is the reason that we need a very, very high speed.

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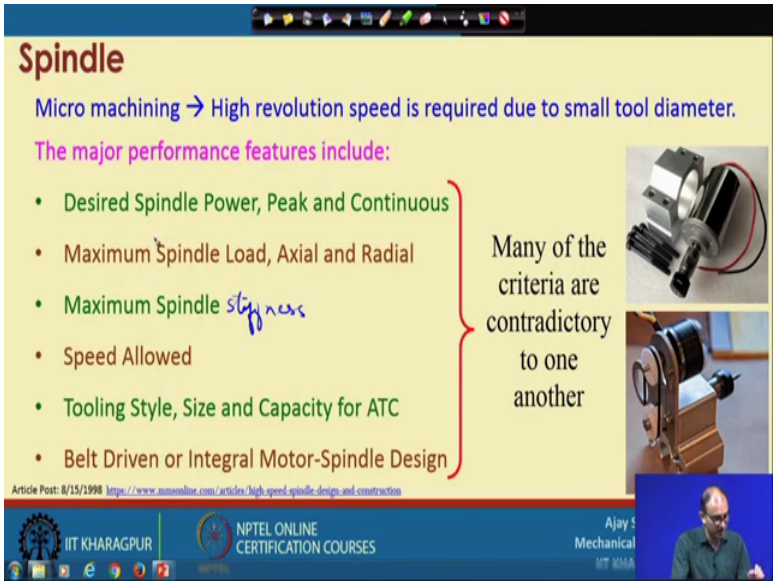

Yeah, so what are the measure performance features available or required for spindle is first is the desired spindle power the what is the power of the spindle, because that will decide that how much day for that you can get the how much force it will actually sustain during the machining peak power and the continuous. So, that is that continuous and when you have machining with a 40000 rpm or something how long you can continue with these things because there are limit on that also.

So, there is the peak one is suppose is the 40000, then it is a peak only, but you cannot continue for a longer period of time for a 40000 rpm continuous are within you can continue with that. So, that is the different first is the maximum speed spindle load axial and the radial. So, when you do machining when you are doing a drilling machine drilling operation then what will happen mostly you are actually encounter axial loading only, but when you are doing a machining with a milling machine or the slot cutting or something, at that time you will encounter axial as well as radial load also maximum spindle size the speed allowed.

So, how much is the speed here because everything depends on the what are the things available with the load and the power setting and other things, then tooling type that which type of tooling it is possible to fit with this particular spindle, because bigger the part particle spindle size and you can put the this is very, very bigger size of cutting tool,

but our things are different here then again it will decide the capacity of automatic tool changer that what is the capacity of automatic tool changer in the size of those things.

So, this are the different performance feature which we have to consider before you finalize the spindle for a particular machine belt driven or integrated motor spindle. So, there are two different type you consider these things this is a integrated motor spindle because here motor is directly inside, it and then you are extracting the motion rotation motion directly from there.

So, it is integrated motor part, if you see this thing motor is separated, but it is actually belt driven your tool is attached with this particular part there are bearings available for making these things straight and housing is also there and these motor rotation because of this belt drive you are getting the motion from the belt, belt driven and then you are getting extracting that motion to the cutting tool.

So, these are the two different type both are used for the high speed, but there are some limitation with the belt driven. So, mostly for the 10 of 1000 of 40000, 50000 rpm mostly people go with the integrated motor spindle. So, many of this criteria are contradictory to one each other because now if you want to give a very, very high load and all this thing then what you have to do you have to actually go with the you have to sacrifice the size of the cutting tool because both the things cannot be match with other maximum spindle stiffness is also important here probably this is the stiffness.

So, if you want a very high stiffness then you have to sacrifice with the size of the tooling size and then you cannot use a very, very big tool for that particular application. So, there is are many different criteria's are available, so you have to finalize the which you have to reach to a one particular optimum level. So, that you can get the maximum the required features without much sacrifice of the other things what are the design constraints here.

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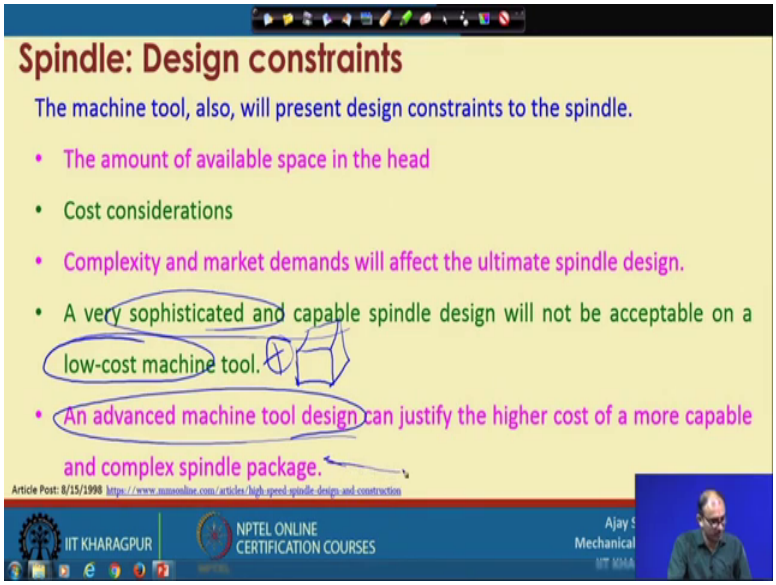

The machine tool also will present a design constraints to the spindle because you know that each and every machine spindle cannot be fitted to each and every machine tool because machine tool has its design constraints. So, first thing is the amount of available space in the head because when you design a machine tool at that time suppose you are adding one spindle here, but later on you found that the spindle rpm is not enough. So, you want to replace this spindle.

So, now what is the problem that whatever space available you have to play within that area only. So, another spindle if the size is a different and the other fitting arrangements are not available then it is not fitting at that particular machine tool, cost consideration is another thing because the many time the changing the spindle or the adding on repla side spindle that is many times people are also using the auxiliary spindle beside the original spindle of the machine tool.

So, cost consideration also there whether you want to replace the spindle or you want add additional spindle there, complexity and market demand will affect the ultimate spindle design complexity; that means, when you are mounting a additional spindle what are the things you have to change in the machine tool that were whether it is favorable or not market demand; that means, when you are adding one additional spindle what is the purpose of that thing that is how much is the job work you are getting what is the cost to

the demand ratio; that means, if the demand is very, very high it is better to spend some money to get this thing done very easily.

So, those are the complexity and market demand kind of thing a very sophisticated and capable spindle design will not be acceptable on a low cost machine tool that is very, very important because suppose you have spindle rotating at a 50000 rpm, but your machine tool does not have that much stiffness right, because when you are rotating you also demand something from the machine tool that we have seen in the different component, that your base should be from the polymer granite.

And then you have a different, different type of ex, ex most and for that air bearing is also available if it is a linear motion then it is a linear drives available if the sophisticated components are available in a machine tool then it is better that you spend some money into the sophisticated and capable spindle design, but suppose your machine is a routinely used CNC machine and you want to go with a very, very high air bearing kind of thing and extremely high, lacks of rpm then your machine tools actually not suitable for those type of spindle.

So, first you have to find out that whether your machine is capable in terms of stiffness damping of vibration then what are the axis orthogonality; that means, xyz axis should be exactly perpendicular to each other that we have seen in the geometric error and everything. So, machine also demands something where the spindle has also some application. So, better first see the what is the level of the accuracy of the machine tool and then you decide the what is the which type of the sophisticated spindle you can use for the machine tool , right an advanced machine tool design can justify the higher cost of a more capable and complex spindle package.

So, here what we have to do that the first you have to find that, what is the machine tool design that if stiffness vibration damping capacity. And the access orthogonality everything is very, very fine tune then you can justify that whatever part you are machining from that it will have a high quality part.

Because here if in this particular case if you are adding your machine tool that you are putting your sophisticated spindle in the low cost machine tool your cutting one component here and then finally, you found that the sides dimensions are not exactly as

per the required drawing then there is a no issue of way of doing any satisfactory work out of it then; that means, you have to find a advanced machine tool also and then only you can find the suitable spindle design for that.

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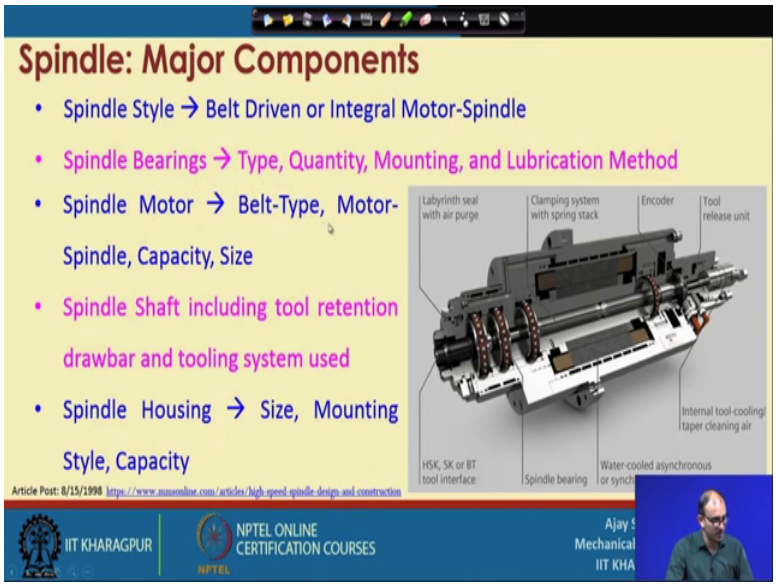

So what are the major compound of these things. So, this is one of the diagram means very, very generic diagram of the spindle of the motion. So, first is the spindle style that is the belt driven or the integrated motor type of things. So, here it is a many different types of things are given here, so it is a encoder because we have seen that rotary encoders are used for measurement of those thing rotational speed tool release unit. So, this is the tool our tool is attached these particular location.

So, interfaces hsk sk or bt or iso kind of thing and when you are pushing this part this particular joe will be open little bit and then you can remove the part and once you are detracting it then again joe will be clamp or it will grief that particular tool. So, you can get those thing done very easily then other then that you have a bearing set of bearings which are used to rotate these things and make it to the central line here then you to apply some cooling mechanism here, either it is a air cool or the water cool that because here also you will get a hitting of those thing which is very, very completely envelope in between this two.

So, those things are very important to design this part and you have to also find some ceiling here because you are working with a coolant and cheap and every many dust particles it should not actually enter inside it, so have to provide some type of ceiling. So, that nothing no for an element will enter into the spindle system, so spindle bearings are there, there are type quantity mounting lubrication method, so those things are making at different changes of the parts.

So, there are different bearings a lot of bearings available bold bearing available air bearing is also there, then how many bearings you are putting here if you are putting less bearing then stiffness is less if you are putting more bearing stiffness is high, but cost is also issue right lubrication is important that how you are lubricating it, it is a external lubrication or it is a inline; that means, it is a automatic lubrication or something more kind of things are there.

So, that will make the different motor; obviously, belt type motor spindle type of the capacity size is also important, spindle shaft including tool retention drawbar and the tooling system used. So, many times what happen that you put a some type of manual removal and the attachment of the cutting tool, but this drawbar mechanism will help you to automated or you can actually flunk this tool bar and you can get these things done very easily.

So, that is the manual with respect to automatic tool bar or the tool attachment system housing also important that which type of housing you are asing using for this all the thing here. So, that is the size mounting style capacity what is the total size of these things. So, this are the different types of components which are different for different type of spindle because, if you are looking with a high speed spindle then you have to go with the this particular thing that integrated motor spindle.

Then you have to also provide the lubrication of the bearing and everything because if when it is rotating at high speed then, lubrication is very, very important then other then that thing that you have to provide a very, very uniform or the very, very precise tool holding mechanism. So, that is mostly people go with hsk because it has a dual contact that you will discuss later but now other then that there are many issues with that, so these are the major components of a spindle.

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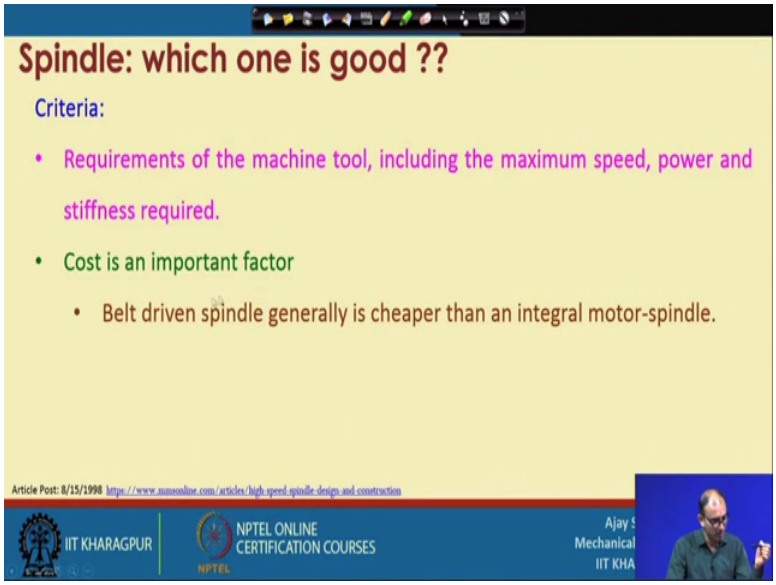

So, which one is good, so depending on the criteria you have to select that because we have lot of option available in terms of retting in terms of type. So, what are the criteria? So, requirement of the machine tool including maximum speed power and stiffness required right, because once you have to finalize that machine tool is in a capable to handle a sophisticated spindle then everything depends on which spindle you have to use. So, first thing is that include the what is the maximum speed you required correct if the speed is around 20000 or something 10000, 20000, you can go with the belt driven if it is very, very high it is better to go with the integrated motor type.

Power is also very important because power will tell you that how much is the how much aggressive machining you can do there and stiffness is; obviously, there because it should not a deflect under any type of load whatever machine load or the static load. Cost is a important factor because whatever sophistication you are adding here everything is a cost higher you go with the sophisticated or very very high power thing your cost will increase exponentially correct belt driven spindle generally cheaper than the integrated spindle that is; obviously, that thing are there now let us continue discussion about the belt driven spindle first then we will go with the integrated motor kind of thing.

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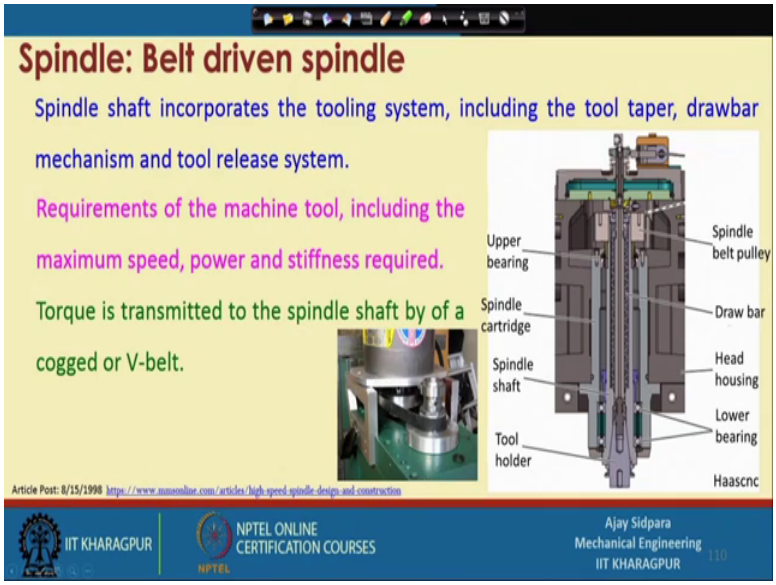

So, what is these things that shaft spindle shaft incorporates the tooling system including tool taper drawbar mechanism and the tool release system. So, now, this is the one of the cross sectional view of a typical belt driven spindle now if you see here, so this is the upper pulley and this is the. So, your belt will be here at this location you will get the belt here correct. So, this is the upper bearing this is the lower bearing at this location this is total thing is housing this is the drawbar, so now, this is the tool holder part thing.

So, what is happening there when you are pushing these things down by means of air. So, at that time this particular thing will be actually expanding because now these you if you see this particular tool bar it has a different type of joes and and when it is moving down then it will expands. So, we can remove this tool bar down and when a when you actually dictate this particular thing then you have to mount one tool here and let it go inside it so, once it will go inside then again it will grief that particular tool, so that is called the drawbar.

Housing is there then the spindle shaft this is the old shaft whatever is available this will rotate along with this because of this belt drive and this is called spindle cartridge, all thing is there because you have to keep everything secured from outer elements. So, this are the different components of the belt drive spindle.

So, this is the sim actual photograph of that part because your motor is low located here it is attached with a pulley and this belt is there is a small pulley and your whole system; that means, this whole part is there this is that part and then the spindle and bearings everything is here beneath this particular surface, requirements of the machine tool including machine maximum speed power stiffness required.

So, this are the different parameters which you have to look into before selecting the belt drive spindle because, in within the belt driven spindle also there are many because we are changing the power rating also you how to also look into that that how many bearings are there what is the stiffness of that let it your let it be your rotating at a 20000 rpm or 10000 rpm, but still everything matters here because still you need a stiffness it does not means that your rotating it in a low rpm you do not require stiffness the stiffness is; obviously, required.

So, this are the different parameters which you have to think before selecting the particular belt driven spindle right. So, torque is transmitted to the spindle shaft via a cogged or the v belt because we have use some belt here and that should not sleep otherwise if there is a sleeping you will not able to get transmit the exact rotation from motor spindle to the tool spindle right.

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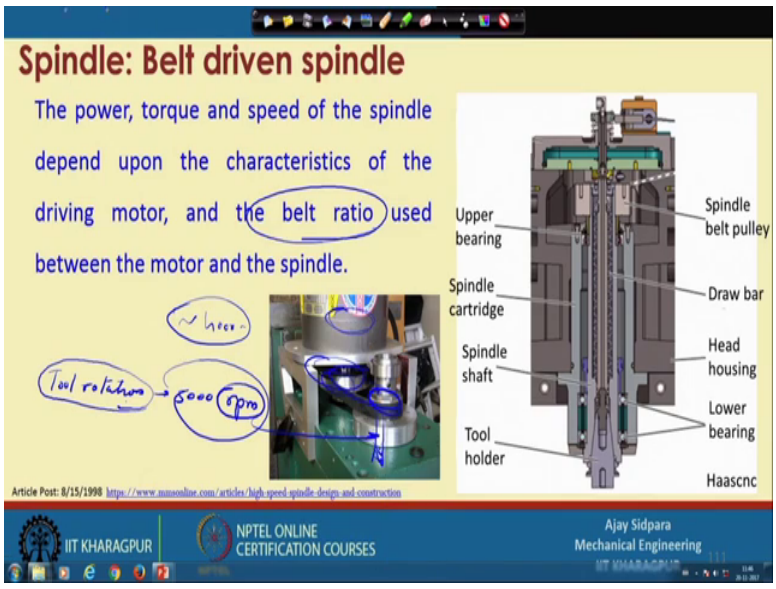

So, power torque and speed of the spindle depend upon the characteristics of the driven mo driving motor belt ratio used between the driven motor and the spindle, now you can see in this location here that this pulley is big and this pulley is small correct. So, now, when you are telling your tool that tool rotation, you are rotating at a 5000 rpm correct.

So, actually you need a 5000 rpm here at this location yeah, so your tool is located here. So, this thing is required here at this location correct. So, when you are rotating this one as a 5000 rpm this is a small pulley. So, your motor rpm will be different because it is using a bigger pulley here. So, consider these thing is a driver and this thing is a driven if a rotating if your rotating this one is a 5000, this will rotate at a lower rpm.

So, when you are telling that tool rotation is a 5000 you are giving command to this things, but actually this command goes to the motor correct. So, motor may rotate at a 4000 rpm or something then only you will get 5000 rpm here right. So, here belt is very important here what you are telling to the machine tool and what machine tool is sending into this motor that is directly depend on what is the ratio of the belt right and then between the spindle and the spindle as. So, this is the one thing this is the another thing that whatever it is coming out of it.

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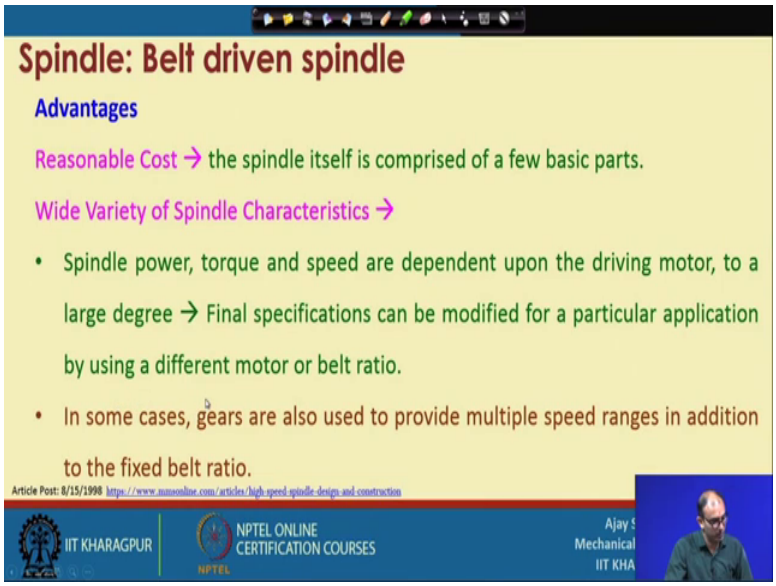

Let see what are the advantage because cost is reasonable that is obvious because spindle itself as a compre is comprised of a very few basic parts, wide variety of spindle

characteristics available because that a spindle power torque spindle speed at depended on the driving motor to a large degree. So, you have a large variety of the driving motor, so that is not a issue final specifications can be modified for a particular application by using a different motor of the belt ratio.

So, that is very big advantage here because now, if you see you are using a one particular tool that is your using a 5 millimeter tool or something and you want to go with a one millimeter tool. So, you have to; obviously, increase the speed right. So, what is going to happen now if that particular motor which you have attach this particular machine it does not have that much speed, suppose you want to rotate a 20000 rpm, but you rating is right now 10000 only.

So, here you have freedom that you change this particular motor only correct or you change the belt ratio right. So, without changing anything if you just change the belt ratio you can get the speed, but suppose your motor eh your that is not provision; that means, you are notable to change the belt ratio that you are not able to change the size of the pool is there then there is another option that you change the motor because ultimately nothing is going to change near the spindle and the tooling mechanism, because that is independent what you need here you need a belt around that particular mechanism and then motor will take care of rest of the things.

So, that is very, very big advantages that without spending more money you are actually getting a wide range of the characteristics of the spindle correct. In some cases gears are also use to provide multiple speed ranges in addition to the fixed belt ratio, but mostly people do not go with the gears because when you are talking about tens of thousands of rpm mostly it is better to wave out the gears because gear has a very large contact area and the vo noise and the other things are alignment is also problem in that case, but when you are talking about a low rpm speed at that time you can actually go with the multiple range of the gear to increase the speed range or you can rivulet the speed to a lower level or the higher level.

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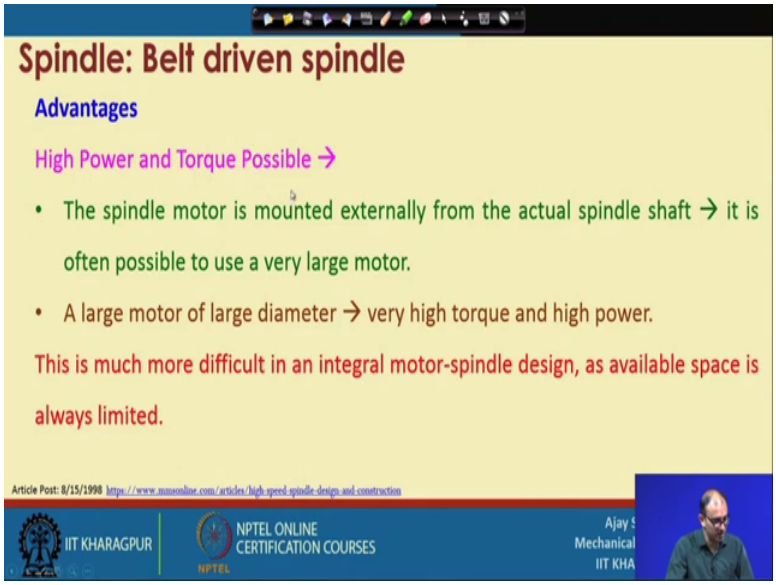

So, this are the advantages of using the belt spindle high power and torque possibility because spindle motor is mounted externally from the actual spindle shaft. So, it is often possible to use a very large motor right. So, you do not have problem with the high power and the torque possibility, because changing motor is not a problem you are not going to change the spindle or a tooling mechanism which is integrated to the machine tool, a large motor of a large diameter very high torque and high power can be used in this particular case, this is much more difficult integral motor spindle design as available space is very limited. Because when you design your machine tool with a condition that you are going to use the integral motor spindle design at that time you do not create more of space of that and everything is integrated in that.

So, if you want to change the power and the torque and what you to do that you do not have flexibility of doing that there. So, either you make a specific or the customize spindle design. So, that everything is matching with the dimension of all the available space or you have to add one of auxiliary spindle just beside the main spindle. So, that you can get the motion or the a required things to be done with the requirement.

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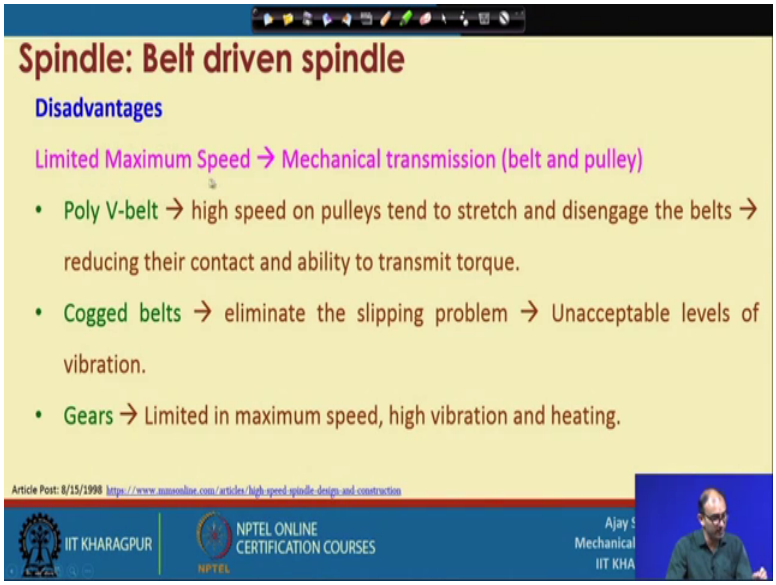

What are the disadvantage this is limited by the speed because it is a mechanical transmission belt and the pulley type of thing? So, if you increase the speed beyond a certain limit what is going to happen there is a slippage between the belt and the pulley and you are not able to transmit the full power of the spindle from one location to another location, pulley v belt type if you are using this belt type high speed on the pulley tend to stretch and disengage the belts.

So, that is the big problem with the v belt type of the reducing their contact and ability to transmit the torque. So, that is going to happen then your contact main thing is that torque transmission, whatever you are actually getting from the main motor it should be transmitted to the tooling management, but that is not happening in this particular case if you go with the very, very high speed.

If you cogged a belt in this case the eliminate the slipping problem. So, the slipping problem will not be there, but you may get a unacceptable level of the vibration. So, in this case, so both the cases are very, very problematic of you go with a maximum speed. So, your speed is limited because of this si type of problems gears; obviously, if we will not get the maximum speed because it is vibrating heating many problems are there. So, maximum speed is limited by.

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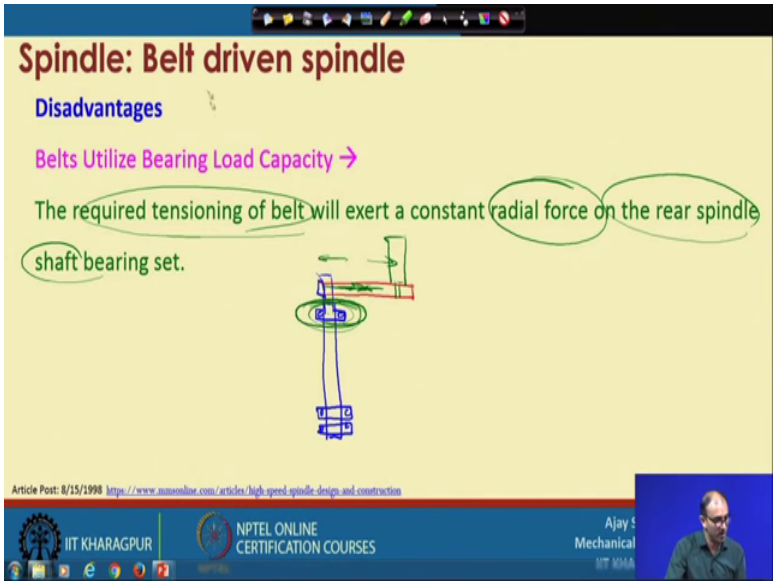

This the dis e disadvantages what are the furthermore, so belt utilize bearing load capacity because it required tensioning of the belt will exert a constraints radial force on the rear spindle shaft bearing set. Now, what does it mean that because now if you see that earlier design we had a shaft correct. So, we had a bearing here, and we had a bearing here also correct and then we had a suppose this is a belt and this is the motor correct, so motor is providing.

So, now, first thing is we have to make sure that no loosening of this particular belt. So, before doing that we have to actually stretch this belt correctly right. So, this is the stretching of this thing it is continuously loading. So, when it is in loading what is going to happen the radial load on to the real spindle shaft bearing. So, this is the real spindle shaft bearing, so, when you are tightening in this direction what is going to happen this particular bearings will get the radial loading of this particular part.

So, when you are getting required tensioning, tensioning; that means, you have to make sure that there is no any type of loosening between this term. So, every time you have to manage this means you are putting this particular motor in this direction. So, your tightening the belt, so when you are doing this, this particular bearing will exert a radial constraints radial force. So, if you continue with these things then what is going to happen damage of this bearing is likely to happen in the near futures. So, that is the problem of the belt driven spindle.

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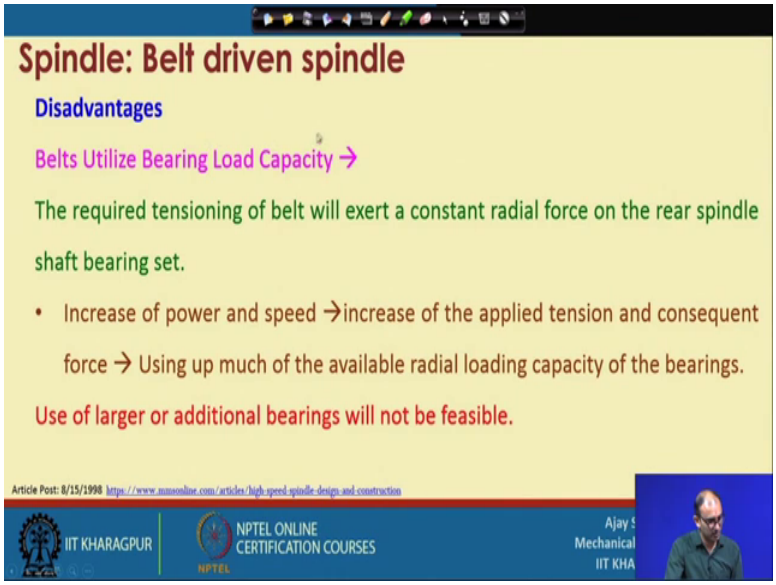

Right increase of power and speed it will increase the applied tension and see consequently forces of when, it is in this radial force is if you continue with the higher power and higher speed it will further increase this tension because this tensioning is; obviously, you have to maintain because if you want to go with higher power speed you have to further increase the tension if you increase the tension what is going to happen that your radial force is further increase in this case so, using up much of the available radial loading capacity of the bearing, because bearings are actually designed with the radial force and the trust force.

So, if you are maintaining this particular loading capacity then there are no problem, but if you are tightening continuously to extract more power and speed what is going to happen then most of the radial boll load bearing capacity it will be completely consumed in these particular tensioning only, then further if you continue motion then what is going to happen there is likely to become a failure in the bearing or it will not behave as a routine object.

So, use of larger or the additional bearing will not be feasible because if you want to avoid this thing either you change the bearing or add additional bearing is there, but you know that within that system you do not have that much space for doing changes. So, this is the disadvantages one of the disadvantages of the belt driven spindle, now coming

to the integral spindle let me do this thing that this thing we will discuss in the next lecture because still now what you have discuss that is related to belt driven.

So, we understood from this that it is very routinely used things when you are talking about the belt driven spindle, you will find in most of the machine even CNC machines are also used by the belt driven spindle we have some machines which has a belt driven spindle, but it has a speed limitation that is maximum you can go with the 7000 or 8000 only and as well as there are alignment problems and many things are there. So, with a high speed it is better to go with the integrated motor spindle, so these things will discuss in the next class.

Thank you very much.