Introduction to Mechanical Micro Machining
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Lecture - 43
Components of machine tool (Contd.)

Good morning everybody and welcome again to our course on introduction to mechanical micro machining, in the last class we have started discussion on spindle. And we have seen that there are two different type of spindles one is the belt driven spindle, and another is the integral motor type spindle and we discussed about the what are the advantages and disadvantages of belt drive spindle.

And we observed that it is very difficult to get a very, very high rpm because it is a one type of mechanical movement transfer from motor to the other spindle by belt or gear drive and we have seen that here are different type of slippage happens or there is a high tension. So, that you may get a different type of radial loading and that is not good for high speed spindle. So, there are some options like a integral motor spindle where we can mount the motor itself into the spindle. So, you do not require any type of belt drive or any other motion transmission element. So, let us continue our discussion on integral motor drive spindles.

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So this was the last slide where we have seen some of the disadvantages of the belt driven spindle.

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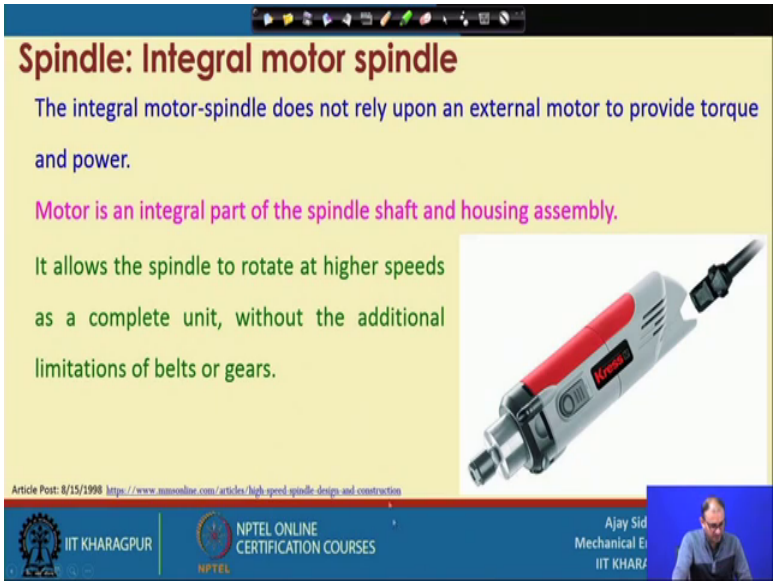

So, now, coming to the spindle with the integral motor so, these are the some of the spindles where spindle motor and whatever things you require for movement the spindle shaft everything is integrated in a single body. So, you do not required any belt drive or any other mechanism by which you can transfer the motion. So, integral motor spindle does not rely upon the external motor to provide the torque and power. So, you just required one power sig socket here, so that motor is inbuilt even if you are adding some encoder like a rotary encoder that is also inbuilt within the system. So, everything is very compact and you can easily mounted a small location in the machine tool.

So motor is an integral part of the spindle shaft and housing assembly. So, what is your problem here that you have to prepare a housing for this particular motor spindle, because if you have seen that belt drive spindle at that time what was that the belt the motor was located in different location.

So, your housing was not connected with the motor, but when you are using a integral motor spindle at that time you have to also think that you do not have any provision to change the motor or anything, that we have seen in some of the advantages of the belt drive spindle, but that advantages are not available for integral motor, because it is a single body and whatever specification is there you cannot actually change the

specification by changing any of the components because all components are designed with respect to the full body.

It allows the spindle to rotate at high speed as a complete unit without the additional limitation of belt and gear. So, that is the one of the advantages which is we are extracting out of this integral motor. So, that our re requirement of a very, very high speed is fulfilled by the integral motor.

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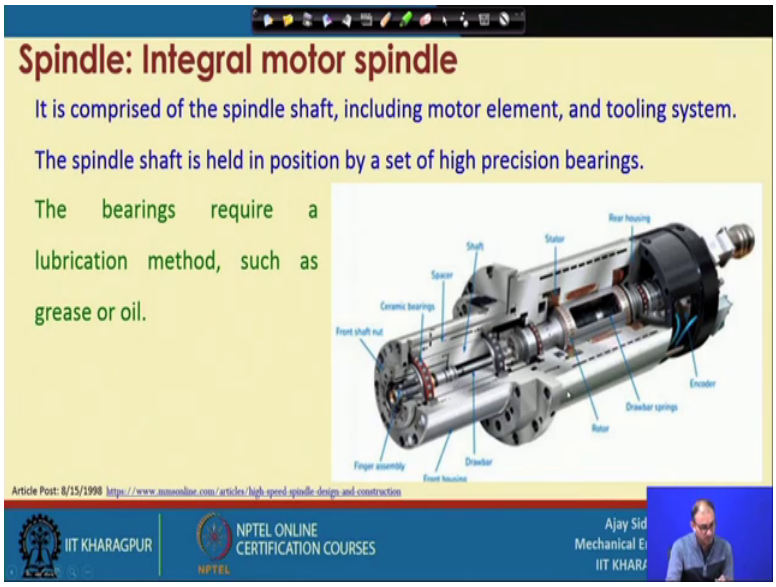

Spindle, so what are the different components. So, this is one of the general view of the integral motor spindle. So, it comprise of the spindle shaft, so now, this is the spindle shaft whatever we are looking at this part. So, this is the spindle shaft and that will continue till you are getting the motor elec; that means, electrical power supply including motor elements and tooling system. So, here we are attaching tooling here at this location, and the spindle shaft is held in position by a set of high precision bearings.

Now, it is up to us that upto how many bearings we want to use because number of bearings will increase the stiffness of that if you are putting instead of a single bearing you can put more than one bearing also. So, that you get a more stiffness in terms of the radial loading and the axial loading, but minimum requirement is that you have to put bearings at the front part as well as the rear part, because the bear a whatever shaft you are talking right now it will undergo in a two different type of loading one is the radial loading and another is the thrush loading that is in along the axis of the shaft.

So, you have to choose the precision bearing because we will see in the next few slides that there are different type of bearings available ceramic bearing is the one of the latest things which mostly people are using in the high speed bearings, but other then ceramic bearing we have angular contact bearing cylindrical roller bearing are also available, so those things are there.

Then this is the frot front end of this part drawbar is used to actually remove and add a couple they or cutting tool here at this location, because drawbar has a one type of flanging mechanism by that flanging mechanism when it is moving out ward at that time it will open the joe of this particular assembly, whatever you are using here and when it is drawing back at that time it will actually grip whatever things you are adding here mostly it is a cutting tool.

Rotor is available here then drawbar spin spring is available, because once you retract it at that time spring will again come back into its original shape encoder is used because you want to also measure a what is the rpm at which this particular spindle is rotating. So, this is the rear housing stator and motor everything is in built in this is because we are considering as a integral motor spindle. So, this are the different, different type of components of integral motor spindle.

So bearing require lubrication methods such as grease and oil, so many times what happen it is a permanent lubrication. So, if you put bear a grease at that time you do not required a frequent use of the lubrication, but for this particular type of system where you are using a angular contact ball bearing or cylindrical roller bearing at that time you have to apply oil.

So, for applying oil what you have to do that you have to provide some spacing here or some type of ah, what we can say that some type of passage through which you can actually put the oil continuously or the intermittently. So, there is different mechanism we will see those some of those things in the one of the animation by which you can understand that which way we can provide the lubrication. Other then lubrication cooling is also required because even though we are using ball bearing and the roller bearing there is still physical contact either it is a point contact or it is a line contact.

So, at the end you need a cooling also, so it is more sometime it is a air cooling. So, you it will provide one type of air supply throughout the components other is the water

cooling. So, there are pro you can provide a different type of opening here slots and something where the water will pass through it. And then it will cool the most of the components, so this is the integral motor spindle now coming to the housing.

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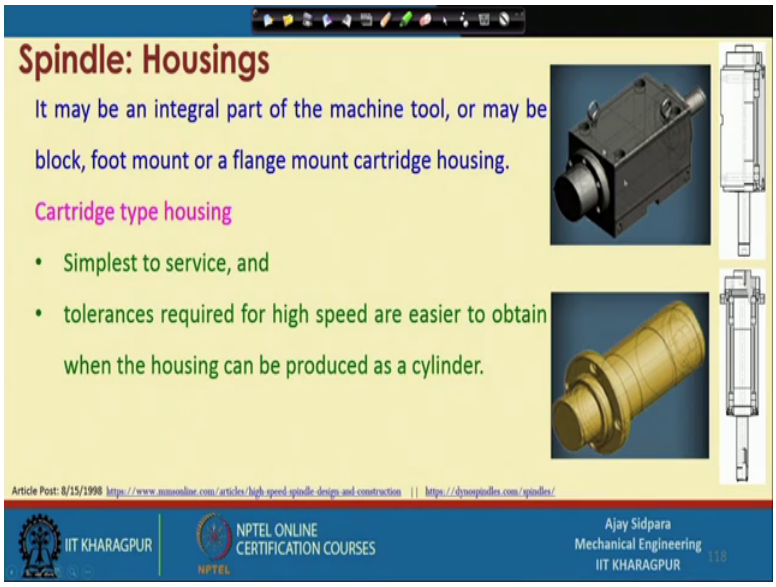

So, what is the housing the housing is the things where you are putting this integral motor spindle into it. So, it may be integral part of the machine tool or may be a block foot mounted or flange mounted cartridge housing. So, now, this is what we are talking is a housing, so this is actually the one of the block mounted.

So, here what is the thing that your spindle is actually completely packed inside it and this is the whole block or you can say housing of that. So, it will actually retain the spindle at a one particular location or it will not allow any type of movement. So, if you want to fix this particular thing then what you can do that you can actually change this particular spin Integral spindle without changing this part.

Sometimes it is a integral part of the machine tool, so if you know that which particular spindle you want to use then a what you can do that you can put this thing in a integral part. So, you do not require any type of additional assembly here and when is you reduce the assembly at that time we know that wherever there is a assembly or wherever number of many parts are there chances are high that it will be loosen at the later stage. So, it is better to make a monolithic structure, so that you can reduce the number of joints and at

the end it will increase the stiffness of the machine tool also. So, it is sometimes it is like that or sometimes you put the block or flange mounted cartridge housing type of thing.

And this is the another thing, so that is called cartridge type housing, so this is cartridge. So, here a things is that this is a block type and this is the cylindrical cartridge type. So, there are some advantages associated with this particular cartridge type housing. So, there is a simple two service, so here because here what is going to happen that you first thing you have to prepare a block and then you have to create a dimension as per the size of this particular spindle, but here what happen the both the things are cylindrical part.

So, it is easy to actually make the cylinder compared to box because you have to turn only and whatever dimensions on the tolerance issue are require need for this particular thing everything will be achieved in a much greater way as well as much easiest way.

So, tolerance is required for high speeds are easier to obtain when housing can be produced as a cylinder. So, in the cylinder you can actually create a very, very fine surfaces and whatever things you want to require want, want this one for this particular housing you can easily get this thing done in the cartridge type housing. So, there are some advantages associated with these things.

So, mostly people go with the cartridge type housing compared to this particular part, but here you what is that it is mostly for the heavy duty operations, but it is not considered for the micro machining operation. Now coming to the bearing because we have seen in the one or two sides before the bearings are playing very important role compared to other components, because wherever you want to transfer motion from one body to another body without much friction then bearing is very, very important that it may not make any problems during the transmission or the power losses.

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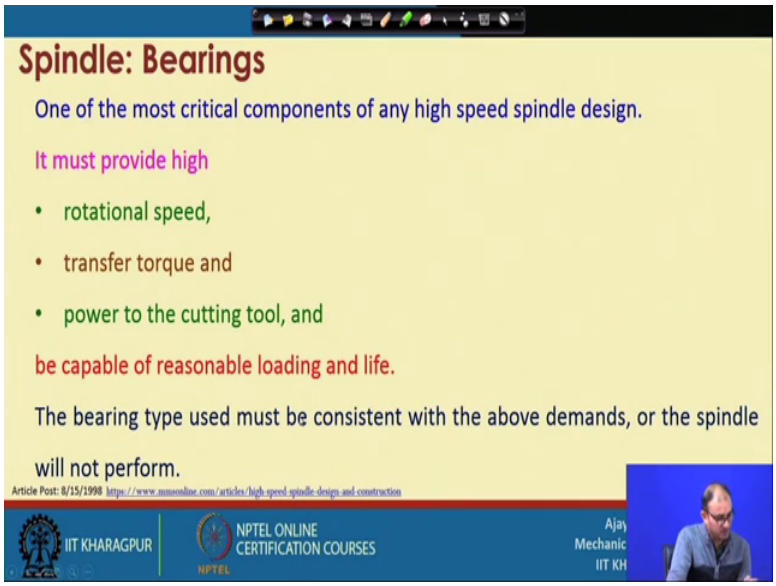

So, one of the most critical component of any high speed spindle design, so what are the things we need from the bearing. So, it should provide a very high rotational speed because that is we required because our diameter of the tool is very, very small and we have to maintain the productivity. And transfer the torque because torque is also important when you are drilling in a vay, very, very high depth and if you do not have sufficient torque then your particular motor will be jammed, and you are not able to rotate the spindle at a reasonable speed.

And power to cut the cutting tool because when you are talking high power means you are mostly talking about the high torque only low power motor has low torque, but it has a high rotational speed. So, those are the things and be capable of reasonable loading and the complete life, because if you change any of this parameter what is going to happen that your life will be in sacrifice will be sacrifice because you are not maintaining something within the specified limit of the allowable part.

so here you have to also consider what is loading because, if you are spindle is designed for soft material; that means, it is a high rpm and you can go with a very small amount of depth of cut or small amount of cutting parts. At that times you can actually use this things very easily, but if you increase the depth of cut beyond a certain limit what is going to happen that your tool will actually experience more amount of loading let it be thrust loading or the a radial loading. So, in that case it will exceed the allowable limit of

the particular specific bearing and then there is a failure of bearing or some type of other problems will occur.

So, bearing type must be used must be consistent with the above demands or the spindle will not perform. So, that is what we have discussed that whatever we want to get out of this particular spindle, then we have to think about that what are the different type of bearings which we will fulfill this requirement with a reasonable amount of allowances because we know that we cannot fulfill all the this some of them are very contradictory to each other. So, you have to reach to a one compromise position where you are not losing many things, but you are also gaining something which is required for your application, so what are the selection criteria.

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So, what is our requirement first then we have to select that which one is the bearing we can use and then you have to see that what is the design impact in (Refer Time: 13:05). So, if you see if you are looking for a high speed, then what you have to go, with a you have to go with a small angular contact bearing. And if you are going with this thing what are the design impact that you can your shaft will be small and the power will be very, very low, because when you are going with a high speed what is going to happen if the shaft is very, very large then there is a inner size effect.

So, you have to rotate a very, very heavy object via very large high speed and at that time it will create at that time of acceleration and deceleration. And low power is required

because if the small shaft is small you do not require very high power and similar for the high speed, so this is one of the thing.

Now, if you are recommend high stiff; that means, stiffness; that means, when it is going with going to operate under a some type of aggressive machining like a depth of cut is very, very high and material is very hard at that time you need a very high stiffness in that because you do not need do not required that yours bearing or the spindle will actually get a loosen or what we can say that will deform internally because of this external forces.

So, what we have to req need that here we require a large roller, so large roller will help you to actually take care of all the external loading and it will not actually deform itself, but if you use a large roller then again inertial effect will come and centrifugal force effect will come. So, that you cannot go with a low high speed, so your spindle design impact will be low speed and the large shaft, so it is exactly opposite to this particular part.

So, now you can see that stiffness and speed both the things cannot be match together so; obviously, we have to compromise with a one particular location where both the things can be reasonably good within the limit if you are talking about axial loading that is mostly in the drilling operation. So, when you do drilling we know that we are just push pushing the drill from top to bottom only we are not moving in the sides.

So, that it is called axial loading, so at that time we have to go with a high contact angle. So, that I will discuss in the few slide that what is the contact angle how it will impact the axial loading, at that time when you are talking about axial loading then the speed will be lower, because when you increase the speed at that time ball will try to escape in the radial direction, but you do not have the more loading more stiffness in the radial direction, so you have to go with the lower speed.

Now, it is over the if it is radial loading then lower contact angles are require and at that time you can go with the higher speed. So, this both the things, so you what is that, so this particular contact angle will decide that which one is higher whether it is a axial loading or it is radial loading.

So, if it is a if you put a something in between this two that is moderate contact angle, then you can get the advantages of both the things that is axial loading and the radial loading high accuracy; that means, what is the dimension of this particular that is means inner bore outer bore reties as well as the compute dimensions then this is one particular standard that is American bearing engineering committee. So, this particular nine and this are the symbols I will show you in the next slide and high preload is required, because if your pre loading is not very, very high what will happen that your ball will actually not firmly grip between the inner race and outer race.

And that is because of that reason you will not get the higher accuracy, but there are problems also associated with this be because if you are increasing the accuracy at a ab ABEC 9, it is they are very expensive because you have to spend more amount of time in refining the dimension and making it more and more compact or within a time tolerances, but you cannot go with the low high speed because if your pre loading is very, very high then you have to sacrifice the speed.

So, these are the problems now you can show that many of these things are actually not in the same trend if; that means, if you increase the one thing other thing you have to decrease. So, compromises must be made in order to arrive at the most efficient design possible.

So, you have to find it how you can extract the maximum benefit out of these particular things, and always see that, what is your requirement, which bearing you are selecting and what is going to happen with your design, if you are going with a high rpm then it is go with you have to go with a radial or a thing and you can again go with the other power that is the high speed this thing. So, we by this particular table you can find a finalize the, which type of bearing is more suitable for your application.

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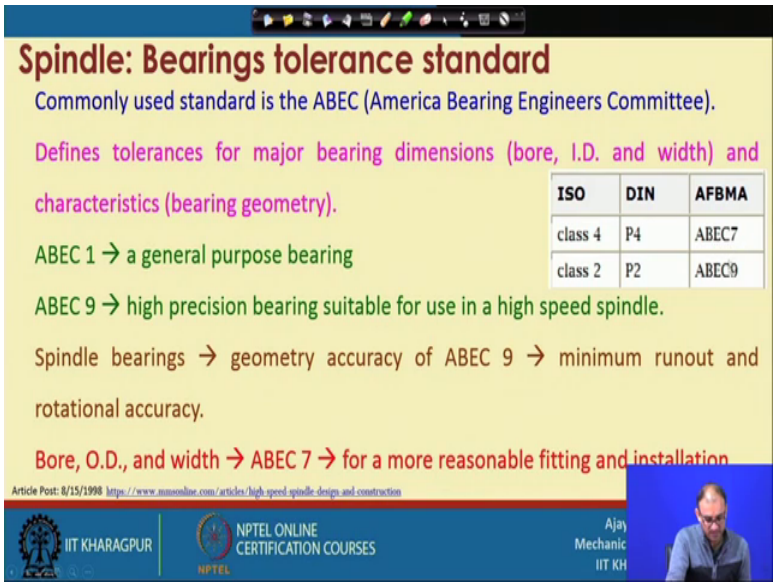

Now, this is the stolen stander, so this is commonly used standard is the ABEC America bearing engineering committee and it is also equivalent in ISO in din standard. So, what it defines that it defined tolerances for major bearing dimension that is bore inner diameter and the width and the characteristics that is the bearing geometry. So, what things are there the if you are telling talking about the ABEC 1, it is mostly general purpose bearing because here we are not making a very, very tight tolerances.

So, that it is very, very it because very, very specific, but if it is a general purpose then actually what you need you need a enter changeability, suppose you want to change the bearing you want to not a operating at a particular level then you can change it. So, if it is ABEC 1, then it is very, very easy to get some replacement without any problem if you go with ABEC 9 that is high precision bearing suitable for use in a high speed spindle.

So, what we are looking here that we know that our requirement is a very, very high precision requirement and we have to rotate it also a very high speed. So, in this particular case our target is ABEC 9, but you can say that this are be this as you go down in terms of number that is 1, 2, 3, 4, 5, 6, 7, 8, 9, your requirement cannot be general purpose then you have to focused on a one particular part only; that means, you do not have. So, much of inter changeability you have to go with the same bearing which you want to replace with the one.

So, how you can actually decide the which one is best for you then when you are actually making a spindle bearing geometric accuracy should be in the ABEC 9, because here what is our requirement because we need a very, very high precision we want to minimize the run out and rotational accuracy.

So, minimizing Rota run out is very important we have to maintain the rotational accuracy also, because we don't want that it should rotate in a some other then this cos a concentric rotation. So, this is for making of geometric of this bearing, but when you are talk out you are talking about the bore id and width at that time it is better to go with a little bit lower side not on to the higher side, because we have to fit this things in a particular one dimension because if you go with this also ABEC 9, what is going to happen that your dimensions are extremely tight in this case.

So, if dimensions are very, very stringent controlled then what is going to happen the whatever way you are putting; that means, when you are putting in a housing at that time housing should have been also machine at a this particular ABEC 9.

So, it actually increase the more amount of tightness in that; that means, you do not have, so much of flexibility in terms of fitting an installation. So, it is better to go with a accuracy of a ABEC 9, when you are talking about the spindle bearings and all those things, but other than that when you are talking about dimensional; that means, in geometric point of view at that time it is better to go with ABEC 7, which will allow you to become a more flexible in terms of fitting in the installation and this are the equivalent standard of this the class 4, class 2 are the ISO this is din standard p 4, p 2 and this is what we are discussing right now here it is ABEC 7 and ABEC 9.

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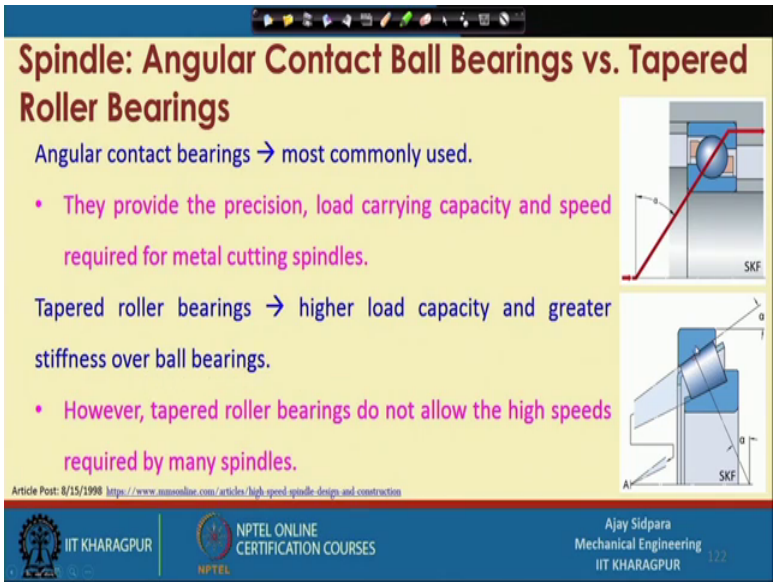

Now, these are the two different types of bearings which are routinely used for the high speed spindle that is angular contact ball bearing and the tapered roller bearing. So, what is this angular contact ball bearing. So, this is the commonly used ball bearing and it is most commonly used for the different, different applications they provide precision load carrying capacity and speed required for the metal cutting spindles, because why it called the angular contact bearing because these particular contacts is at some angle.

So, that particular alpha angle is the contact angle, so we have seen that high contact angle and low contact angle. So, this is that particular angle at which you are putting that much where is the contact bearing we have between the ball and the race is that particular line will tell you this angle we will see in the next slide that what is more detail about this then.

The tapered roller bearing now we know that it is a roller bearing, so it is a shape is a roll type not the ball type and it is a taper. So, there is a taper in between this, so, so what is the advantage here the you will get the high load capacity and the greatest stiffness over the ball bearing why it is, so because here what is going to happen that your contact is at the very, very small area, but if you see this particular thing then your contact area is very, very large here.

So, bearing will actually take more load and that is the reason that it has a higher load caring capacity and stiffness is also very, very high because your size of this particular

thing is very, very large. So, you per unit force will be very, very less in this case, so your stiffness is very high compared to the ball bearing.

Right; however, tapered roller bearings do not allow the high speed required by many spindle, because here also know the when you have high contact area; that means, there is a high fiction in wear also then that he here it is a mostly a very small area of contact, but here it is a more area contact.

So, it may create a problem at the later stage when you operate this particular bearing beyond a certain speed. So, at that time it will not allow you to operate as compared to the ball bearing. So, many times your speed is limited by the area also, but if you are looking with a high load capacity and high stiffness you can select this particular bearing right.

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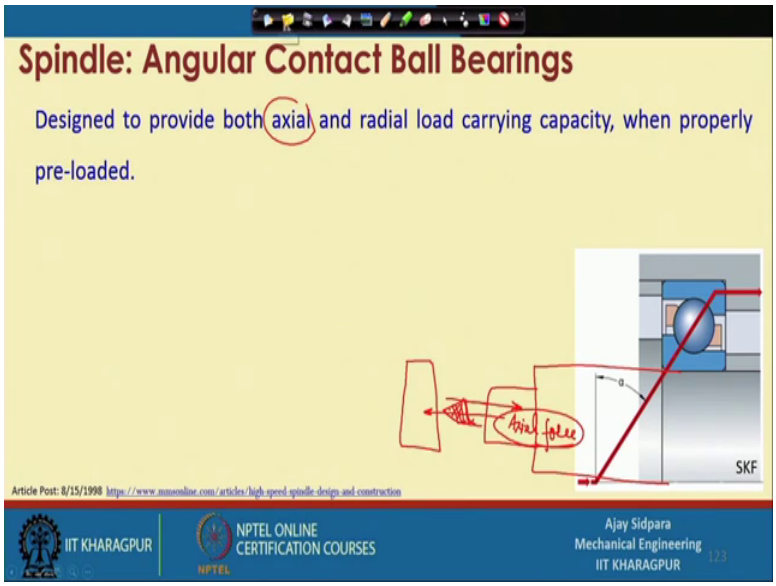

So, this is the angular contact ball bearing, so here it is designed to both axial and the radial load carrying capacity when properly reloaded. So, this is the preloading I will talk about this thing is in one or two slide later. So, where do you need this ball both the things because when you are talking about axial loading what we are talking about that this is consider it is a shaft right and bearing is located here.

So, when you are getting a force here now you consider your tool is located here, this is a tool and now consider it is a drill let us consider it is a drill right. And this is your work

piece and when you are pushing this, things inside what is going to happen you will get one force that is called thrust force and, so this is the axial force correct. So, this is called axial force now consider that this is mostly for the drilling operation.

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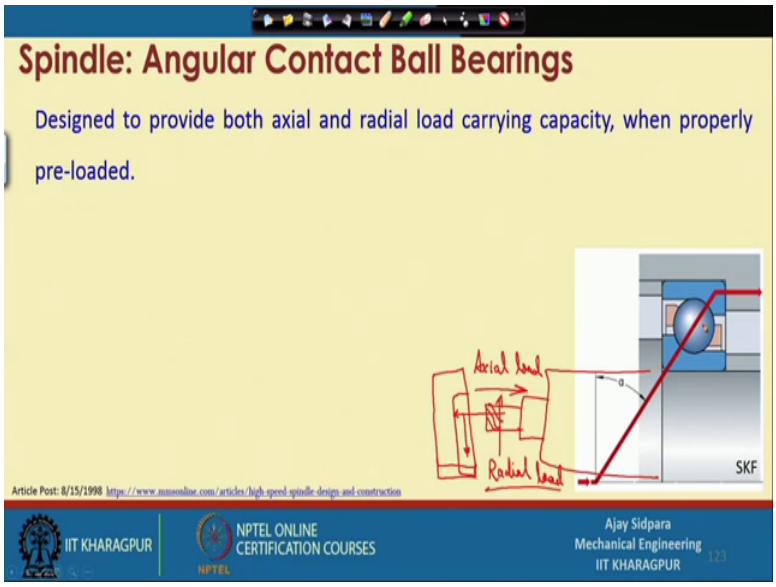

Now, again consider that you have a shaft, but instead of drilling you have a milling cutter right and this is your joe correct. So, now, you want to create one pocket here this is the pocket which you want to cut out of it. So, first what thing you are doing that you are flanging these things up to the depth. So, when you are flanging at that time it will create axial loading, correct and after flanging and then what you are giving you are giving a motion in these particular direction. So, when you are moving at that time at that time your tool will experience one radial load correct. So, at that time it will provide both the thing how it will provide we will see if soon yeah.

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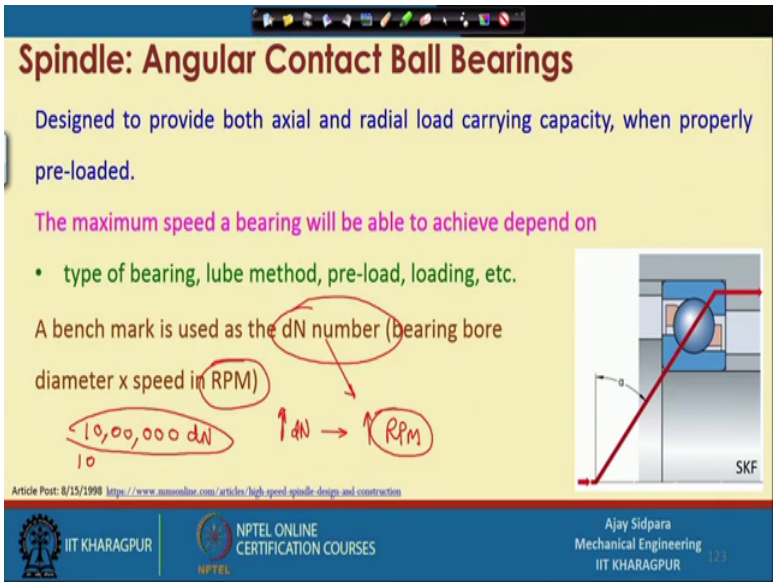

So, maximum speed a bearing will be able to achieve that depends on many parameters that is first is the type of bearings. So, which type of bearing you are using lubrication method because if you are going with a very, very high speed what is going to happen that it will actually heat up this lubrication also and when you are heating up at that time viscosity changes whatever lubrication method you are using it is a oil base or some may be different type of other grease or other kinds then it is a problem, preloading is important how tight you are holding it how loosely you are holding the bold in between these two and which types of loadings are there.

So, if it is a both the loads it is a radial and axial load then you have to actually fined the which way you can actually control the speed. So, that it will rotate within a permeable limit of the bearing. A bench mark is used by the dN number, so mostly we are we talk about dN number dN number goes up to the 10 of lakh also 10 lakh, 20 lakhs also available.

So, what is a; that means that is actually d is the diameter ball diameter of the bearing and n is the RPM of this part. So, if you are talking higher the dN number higher is the rpm right, so this is the thing. So so it is higher the dN number higher is the RPM, when you are going with the higher RPM, we know that we have to use a very small shaft because shaft dimension also play important role. So, when you are talking about lakhs of a consider the 10 lakh dN number.

So, at that time mostly this measure part is the RPM here. So, if you are talking about 1 lakh RPM and then what you can think about that it is a 10 millimeter is the diameter. So, 10 millimeter diameter and the 1 lakh RPM; that means, you can go with a 10 lakh dN number. So, in that way you can actually define this time. So, this is defined with mostly we talk about the dN number what is that dN number higher is the dN number more you are thinking about the higher speed of the spindle.

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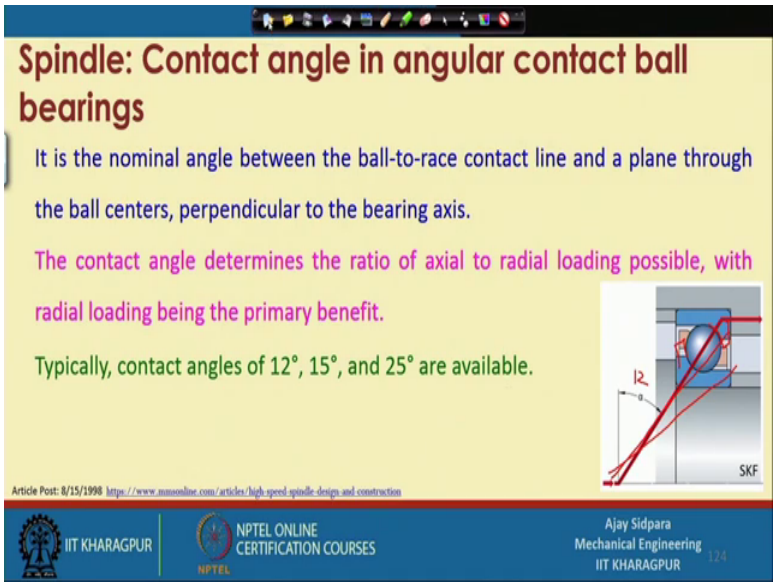

So, what is the contact angle here, so it is a nominal angle between the ball to race contact, so where is the ball to race contact, so this is the ball to race contact correct. So, this is the ball to race contact line, so where ever this contact is there you have to draw one line in a. So, this is the line passing through the ball to race and a plan through the ball center.

So, this is ball center perpendicular to the bearing axis. So, so this is the ba ball this is the ball center passing through the, that plan and this is the axis ob bearing axis this is the perpendicular line to both the things correct. So, nominal angle between the ball to race contact line and a plane through the ball center. So, this is the plane through the ball center, so it is crossing here at this location and perpendicular to the bearing axis. So, this is the bearing axis perpendicular to the bearing axis.

So, these particular angle is called alpha right, so contact angle determines the ratio of the axial to the radial loading possible with the radial loading being the primary benefit

here, because here what is going to happen when you increase the RPM, what is going to happen and we are talking when it is under operation right you are doing mining operation or a drilling operation, when you do those things at that time your bore will actually experience many things one is the radial loading and another one is the axial loading.

So, now, you have to decide at that at which particular angle you can actually get the benefit of both the things that is axial loading and the radial loading. So, based on that you have to select the contact angle the, which contact angle is better for a particular application. So, what are the typical contact typical contact angle are the 12 degree, 15 degree and 25 degree.

So, what do you mean by that 12 degree suppose you consider this one is the 12 degree then when you are talking about 15 degree; that means, it is increasing this part increasing this part; that means, your contact area if you increase, then your line of a thing that will actually pass through this way then you more you can go by this way then at that time you can go with this particular part, but you are actually then compromising with one of this thing you are either increasing the axial loading or the increasing radial loading both the things cannot be increasing or decrease together we have to this because both the things actually invest to each other the both things are not goes simultaneously.

So, you have to first see that which particular application we are using this it a primary or a drilling operation better to go with a axial loading because you are not worried about the radial loading there right. So, now this are the different, different ways we can think about those parts. So, now, this particular application will tell you that how we can select this particular bearing. So, let me continue this topic in the next class we will see that what are the different types of the contact angle will create a problem for the different type of loading.

Thank you very much.