Introduction to Mechanical Micro Machining
Prof. Ajay M Sidpara
Department of Mechanical Engineering
Indian Institute of Technology, Kharagpur

Lecture – 45
Components of Machine Tool (Contd.)

Good morning everybody. So, we are discussing about the preloading of the ball bearing and we have seen that; there are different methods of preloading and we have also seen that without preloading your ball will create a lot of noise and we are end other problem and your bearing will fail at the later stage. So, preloading is one of the important parameters of the ball bearing for a application in the micro machining center or the high precision bearing systems.

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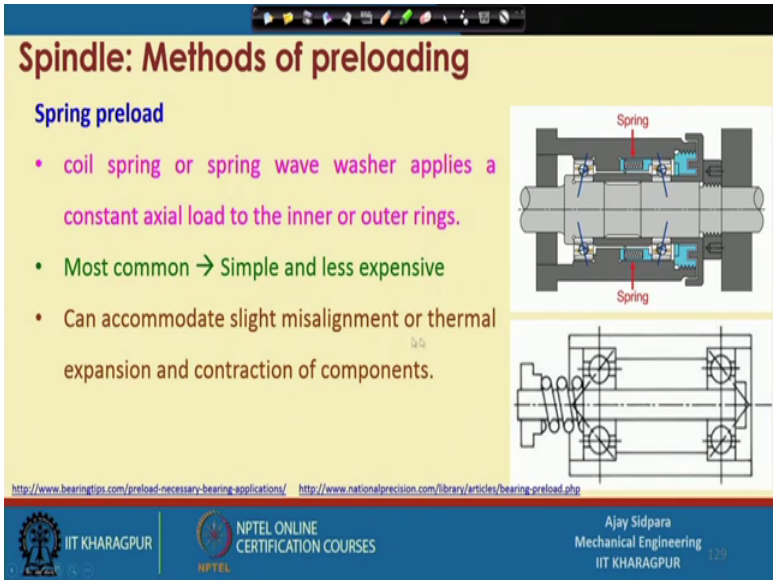

So, we have seen in the last class a there is one of the method is the spa spring preload by which you are applying a preload by means of a spring and we have seen also that it will accommodate slide misalignment, because of the thermal growth of the component mostly it is a shaft. So, in these particular case moving here and there we will not make much difference within a certain particular part.

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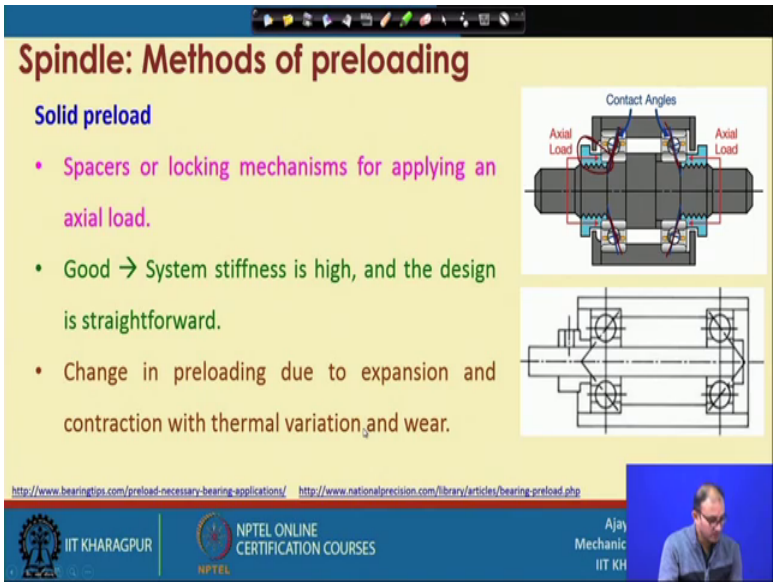

And then let us discuss this is the second is the solid preload. Now, what is the solid preload; that instead of a spring what we are using here, that we are using one type of not here. So, this particular note will actually fix this particular inner race or outer race depending on our application and so, that you can actually get the angle or the maximize the contact angle between the races and the ball.

So, what is that; that you can actually give a motion eh by means of a spacer or the locking mechanism for applying an a axial load. So, this is called a spacer or a locking mechanism, because it is a thread. So, actually you can rotate it and it will push the inner race or outer race to the different direction.

Why it is a good, because it is a high stiffness and design is straight forward, because when you are adding a spring at that time you have to actually spring also you have to preload little bit, otherwise by changing the stiffness of the spring you may get a different type of preloading at the later stage, but here it is a solid thing. So, it is very very good in terms of stiffness; because now it will not allow even a slight movement here and there that was possible depending on the stiffness of the spring, but that is not happening here in this case.

And design is straight forward, because here is what you have to create you have to create one thread on the shaft only that is enough to get this thing done, but if you want to do the same thing for the spring loaded at that time what you have to create a cavity

also then take the dimension of those part, because everything is internal part here that is not the thing. So, that is a advantage of this particular part, but problem is that whatever the advantage of the spring loaded, that is the problem here because change in the preloading due to expansion and contraction with thermal variation thermal with a thermal variation and the wear.

Now, what is happening that; if the same thing happens here there is the thermal growth of the components, but in the spring will that case spring will take care of those thing, but here nothing is there which is flexible like a spring. So, in that case it will not create it will not be able to compensate as a minor changes in the dimension then your system will create a problem, because if there is a expansion or contraction with the thermal and wear at that time your system will be in a more tight situation; that means, either preload preload will increase or preload will decrease. So, that is the situation of this part.

But here, what you are getting? You are getting a stiffness correct. So, now, it is up to you that which method is more suitable for particular application where you are putting particular bearing in the spindle. So, depending on that you have to select either a spring preload or the solid preload.

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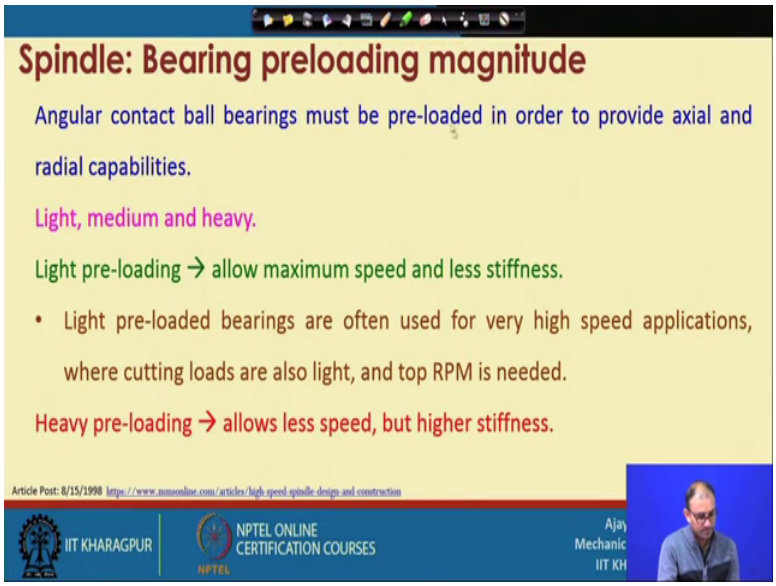

So, what is the magnitude of preloading is important here. So, angular contact bearing must be preloaded in order to provide the axial and radial capability that we have seen. So, now, there are three (Refer Time: 04:01); that means, light preload, medium preload,

and heavy preload. So, we have seen also that light preload; that means you are not giving more preloading heavy preloading and a excessive preloading is there.

So, if you are talking about light preload, then it allows the maximal speed and the less stiffness here, because now you are not pushing the ball too much into the races. So, at that time you have a less contact there. So, less contact you can go with a high speed because high speed you are getting, because you are not getting a contact or no contact; that means, less amount of heat generation and the less friction right that is, but stiffness is less because it is now not firmly grip with the inner race and outer race. So, you have to compromise with the stiffness. So, that is not good thing, but here you can go with the high speed. So, that is the advantage; correct.

So, light preloading bearings are often used in a very la high speed application where cutting loads are also very light and top rpm is needed. Now when you are talking about the machining of the plastic or the some type of polymer material; at that time we know that we are not actually going to get a very very high amount of forces; that means, your stiffness is not a issue that liver less stiffness; that means, it does not mean that there is no stiffness there is a stiffness, but it is not enough to get a sustain the forces by the metal cutting, but if your application is some type of we have seen lot of applications micro fudix where polymers are being machined by a micro machining center.

So, at that time what is our ob objective here? what we are talking about that our a forces or cutting forces are very very light in that case; because we are cutting a polymer material or some other material similar to plastic and then rpm is very very high because we have to maintain the productivity also, because if you go with a high rpm you can give go high speed rate and when you are giving a high speed rate within a short time you can cut a very very long cutting the machining part. So, that is advantage of this part and that is the thing for live preloading.

When you are talking about heavy preloading; it allows less speed because now your ball is actually firmly grip with the inner race or outer race if you go with a high rpm and this thing. Then again we know that there is a high heat generation and friction and wear and that will create a problem at the later stage, but you will get a high stiffness correct. So, now, you have to sacrifice the speed to a certain limit there is you cannot rotate more than 30000 or 40000 kind of thing, but you can get the stiffness if your application is

within that part where you want to cut some metallic component and your stiffness is very important there, because you do not want to damage the system.

If you are not getting a speed, then it mostly actually create a problem with a tool only, but if you actually go with a certain metal cutting with a light preload, then it will damage the system, because you do not have sti enough stiffness in the machine tool. So, it is better to go with this particular part, but there is a limitation of the speed also. So, in medium is in between these two that you have to play around to find the optimum setting for the particular application right.

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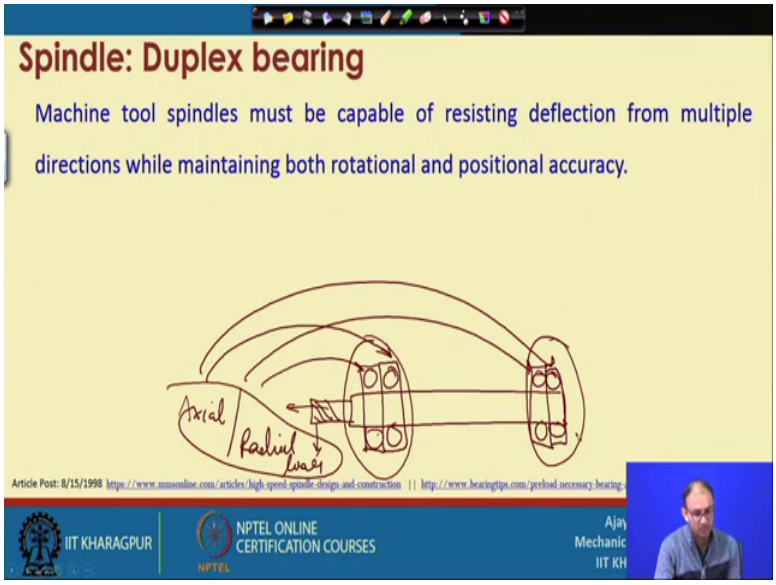

So, now what is the duplex bearing? So, now, we know there is a machine tool must be capable of resisting deflection from multiple direction with maintain while maintaining both rotational and positional accuracy right. So, we are talking about both the things axial loading and the radial loading in both the cases. So, what is going to happen here that, now consider that we have a shaft here and this is the one bearing located at the rear side and this is at the front side and our cutting tool is located here at this location correct.

Now, you are doing machining with this part; now you have a one set of bearing at the front and another set of bearing. At the later stage when you do cutting with these particular part you are doing a mis going down also in the material and then you are cutting by this. So, you are cutting some slot cutting slot machining at that time, what is

happening that; when you have only two bearings here at that time the load whatever you are getting here the maximum load you will get at this location, because front loaded bearing is mostly more loaded, because of the location near to this part, but you will get loading here also and all the load whether it is axial load or radial load that will be said by the two bearings only correct instead of two bearing let us add one more set here.

Now, what is going to happen this all the load will be said by another one more set of the bearing. So, per bearing amount of load is less correct. So, more you add the bearing more there will be the distribution of the forces or the reduction of the preload per unit of the ball bearing so that is very important here. So, that is why we have to mount more than one bearing so that your load will be distributed among the more number of bearings. So, that is called the duplex bearing correct.

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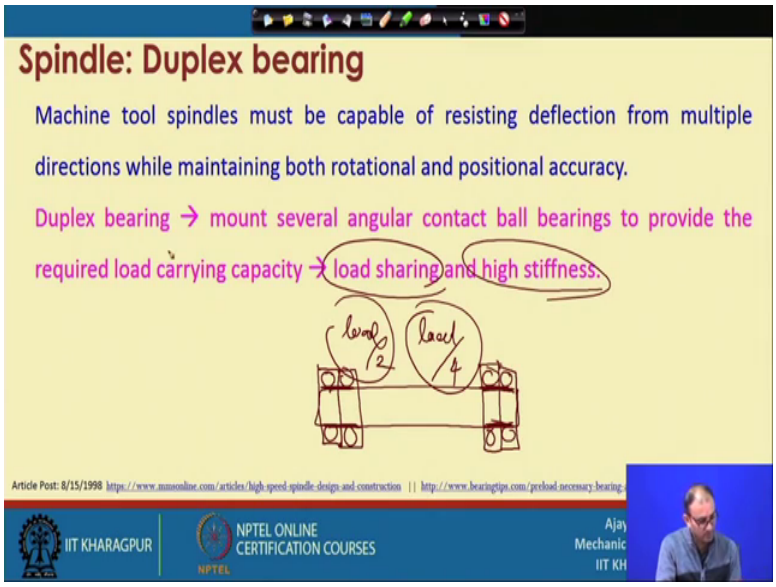

So, what is the duplex bearing the mount several angular contact bearings to provide the required load carrying capacity it is load sharing and the high stiffness. Because now we know that our shaft is connecting at the two different locations correct; and so, this is the one thing this is the second thing. Now, high stiffness is important, because now it is a fix at two locations only then stiffness is less, but if you add one more here than it is grip at the two locations here at this location and this location right.

So, your shaft is firmly grip between the two bearings. So, now, you will get high stiffness also load is also sharing, because earlier the load was divided by 2 only now it is

a load is divided by 4. So, now, per unit load will be less in this particular case. So, that is very good advantage compared to the single load bearing right.

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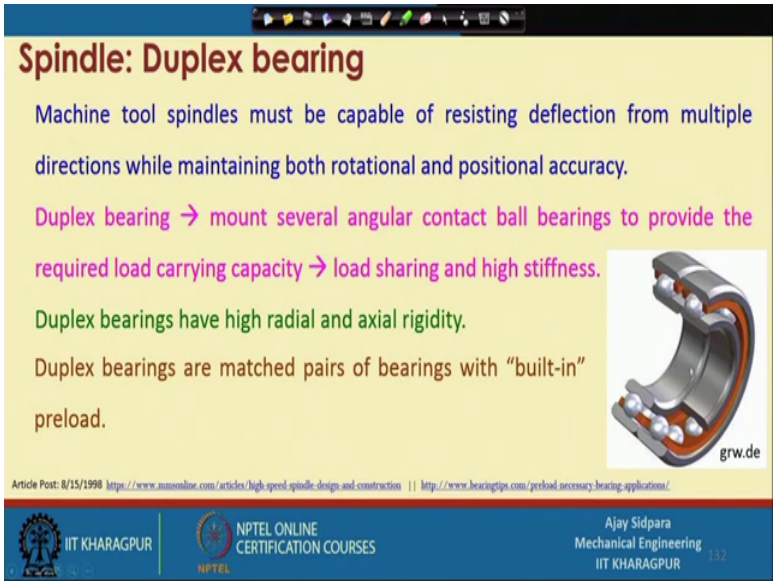

So, this is the thing that instead of a single bearing you can use the duplex bearing duplex bearing does not mean that you are using two separate bearings.

But, it is a common use single unit in such a way that the preloading in everything is designed with in the bearings. So, that will see that how those things are there the duplex bearings have the high radial and the radial and the axial rigidity, that is; obvious because we are using two bearings in place of a single bearings here and duplex bearings are matched pair of bearing with a inbuilt preload right.

So, here what we are doing that we are adding the preload between; before we put this in application, because we know that for this particular bearing is going to use at which location. So, these are the specifically made bearings for the specific applications right.

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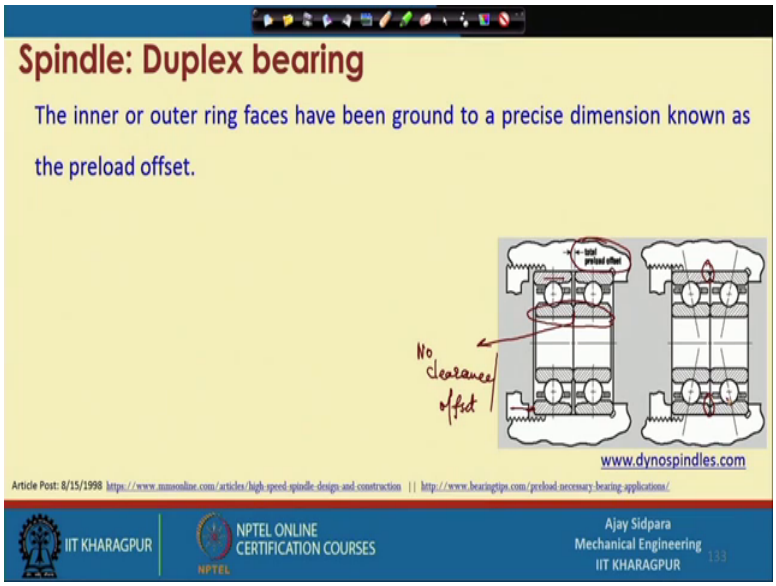

So, inner race outer race faces have the ground having ground precise dimension known as the preload offset. So, now, this is the duplex bearing.

Now, what is this thing; when you are fabricating or when you are manufacturing this particular bearing at that time itself you are giving this preload offset. So, whatever we are looking at here, now you can see that how inner race whatever you are looking here. So, there is no clearance in these right no clearance or offset correct. Now, if you see the same thing and the outer race that is a total preload offset one when offset is given there.

Now, we use the solid preloading here. So, now, when you are putting this not into this particular part then, what is going to happen, that it will push this outer race and then you continue then you will not get any type of clearance here now clearance is filled and other then that if you see this particular part the contact angle if you see this contact angle is 0 here right.

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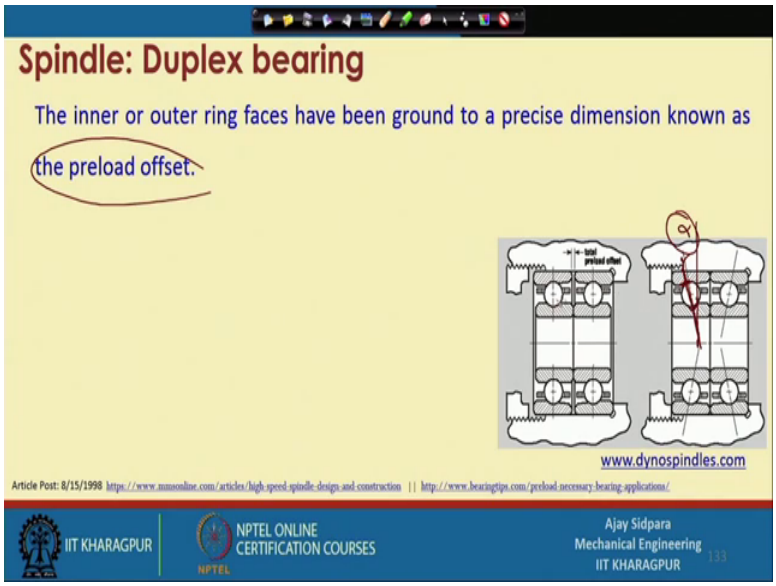

Because we know that the contact angle is measurement between these two axes. So, this is the contact angle alpha, but it is no contact angle, because it is mostly consider as a roller bearing only. So, here what is happening here that when you are pushing this thing then you will get a contact between these two parts, because you are pushing from here. So, you get a contact here and this contact and you will get one line passing through the contact between the inner race or outer race and the ball.

So, you will get a angle also. So, this is the way you can actually get the preload offset and when you push this the inner race or outer race depending upon, where you are putting this preloading and then you can get the things done.

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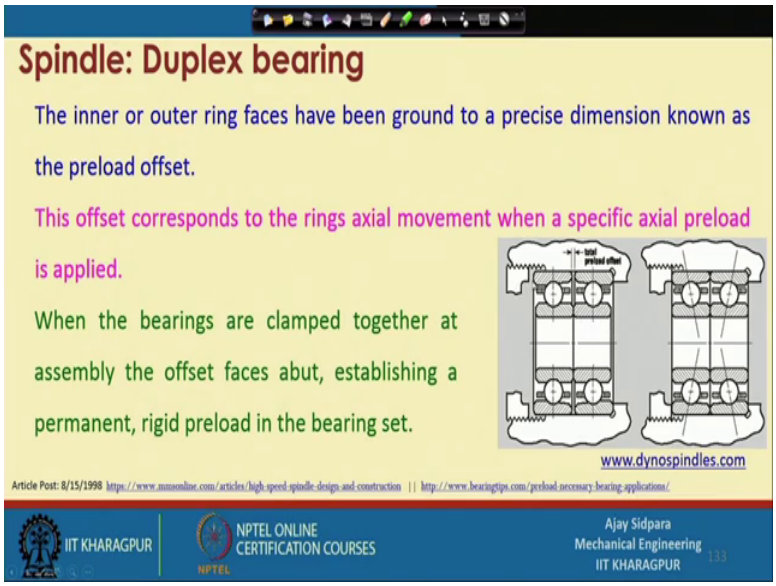

So, this is the duplex bearing correct this offset corresponds to the rings a axial movement when a specific axial preload is applied.

So, when you are putting this axial preload at that time this offset will be matched or it will be completed and you can get the firm contact between the bearings. So, when the bearings are clamped together at assembly the offset face is abut and establish the permanent rigid preload in the bearing set. So, this is the permanent; now when you remove this particular part at that time it may loosen little bit here and there depending on the; what is the total stiffness of this particular bearing and then this particular thing will create a very very high permanent preload for a certain applications. So, now, you are not worried about the; system where you are getting the rear radial load or the axial load during the operation.

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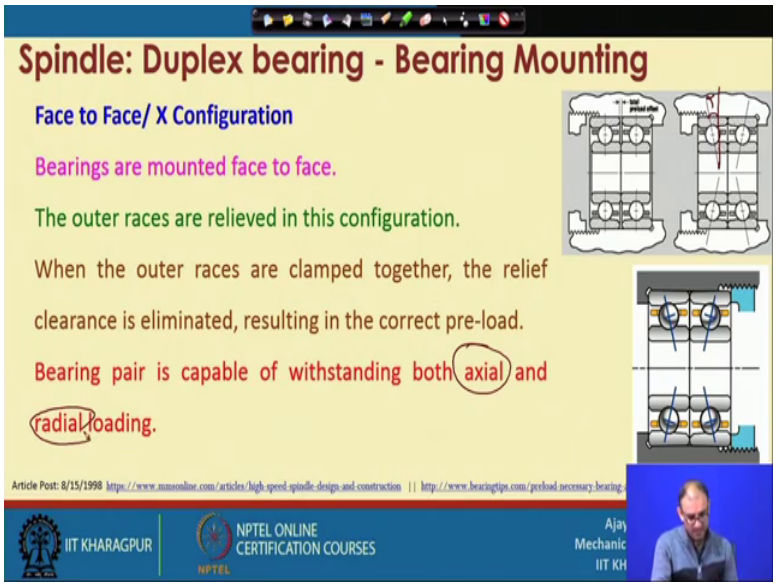

So, what are the different types of mountings are there do this is one particular thing is called face to face or x configuration. Now, if you see this particular graph the same thing is here, now if you see this part that when you are pushing you are pushing your outer race into this direction. Now, if you see this particular contact angle this contact angle is 0; and this all axis are matching with a this vertical line.

So, when you are moving in this particular direction, how outer race at that time your contact between the inner race outer race and ball is following this line. So, now, if you follow this actually this configuration is called the ex. Now, if you see this all axis are moving in this part. So, that is why it is a called the X configuration or face to face configuration.

So, what is this thing let us see right. So, bearing mounted are bearing are mounted face to face. So, this is what we are looking at this time the outer faces are relieved in the; this configuration or relieved means; that means, we are actually pushing or we are working with the outer race only where we are providing axial loading for the direction in this part.

So, this is again the same direction in the color graph, when the outer races are clamped together the relief clearances is eliminated resulting in the correct preloading correct. So, here it is right now it was not preloaded you consider that there is a some radial plays available. So, when you are pushing at that part here at that time you are getting the

motion you are getting the; you are pushing this your contact will occur here and when your ball will move it will appoint here also. So, this are the contact. So, when you are in this cas. So, this is moving in this. So, it will move in the opposite direction.

So, you will get the direction or the radial dire preloading in this particular way right. So, bearing pair is capable of withstanding both axial and the radial loading. So, now, it everything depends on this particular angle which, what is this angle; which is created here. So, we know that higher is the angle mostly we go with the axial loading and the lower is the angle, and then you are actually more focusing on the radial loading correct.

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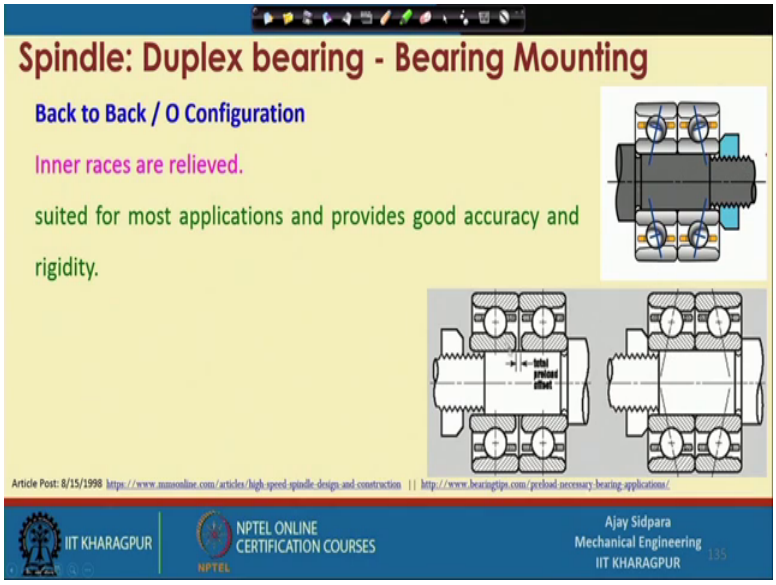

Another one is the back to back or O configuration, now here what we are doing that; instead of pushing the outer race. Now, we are pushing the inner race correct. So, now, whatever the way we have given the same preloading option, but now it is on the inner race, now this preloading offset is a, but there is no offset here in this location correct.

So, now what we are doing now we are actually threading the shaft and then this particular thing will actually push this material, when you are pushing this part in this direction, what is happening that this will push this shaft? So, this particular inner race will move in this direction, when it is moving in this direction you have a support from this also in this location correct. So, at that location actually push this inner race is in this direction. So, you will get a contact at four different location on the two bearings right.

So, when it is pushing here this is moving in this direction right. So, this will move in this direction. So, this when it is moving in this direction just a minute so, it will create a contact here and this ball will move in this way and it will create a contact here and we know that this slide is completely blocked here. So, when you pushing here it will push this particular inner race in this direction.

So, it will create a contact here. So, because of this contact the ball is also moving in this direction and it will create contact here that. So, in that way you will get the two double contact in earlier case it was a contacting point was from the top side. So, it was moving in this direction or was creating contact here and here. So, contact line was like this correct, but here it is in the other direction. So, now, you have contact here and here and here. So, that time it will create a O shape. So, it is called the O configuration or the back to back slide.

So, what is the difference that in earlier case we were relieving the outer race, but here we are relieving the inner race suitable for most application provides good accuracy and the rigidity in this particular case. So, that is advantage of using this particular back to back or the O configuration another one is called the tandem or the dt configuration.

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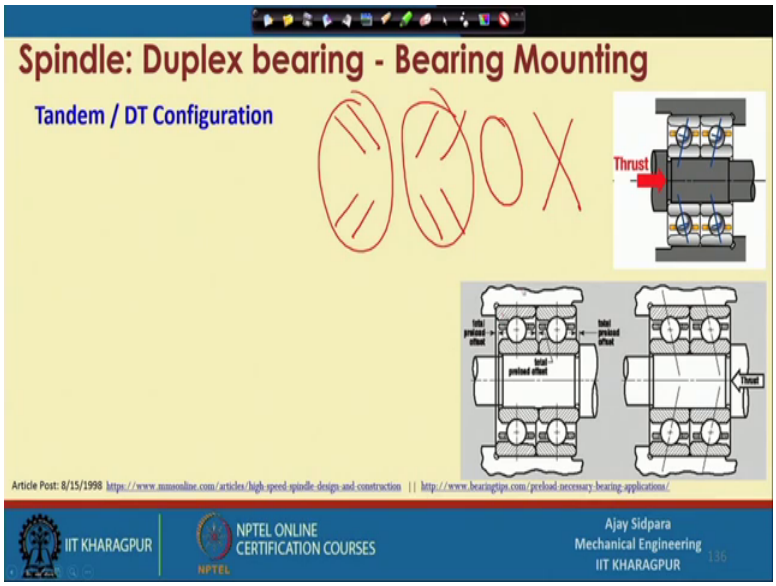

So, in earlier case we have seen that there were two different ways that one was the this way crossway and another one was the circular way O type of things, but here what is

happening that we are getting both the things. So, either it is like these or these or it is a this or this. So, this both the things are called the tandem.

So, now if you see this part; so this is that bearing now here the total preload is given at this direction this location and this location also.

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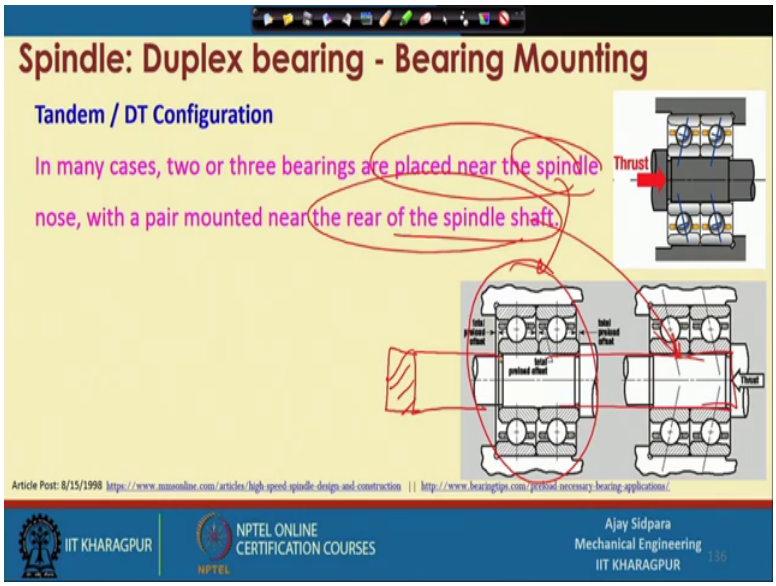

Both the location we are giving preload right. So, this is the preload. So, here is one is there and this is another preload is given, now you to provide a thrust force here in this direction correct. So, when you provide a thrust force, what is going to happen; these particular bearing will try to contact here and here, that is we know that which direction we are pushing it down and then this whole thing will move see this both thing move in this direction correct.

So, this particular inner race that inner race will shift to this location and this inner race will shift to this location right. So, both the things are moving and then you are what you are getting that you are getting in tandem. So, now, on contact angles are in same direction in both the cases. So, that is why it is called the tandem configuration correct.

In many cases 2 or 3 bearings are placed near the spindle noise that is on the front side of the spindle. Now consider this is the spindle location. So, then you are putting 2 or more than 2 also with pair mounted near the rear spindle shaft. So, now consider this is the spi cutting tool. So, this is called the this particular thing is called the spindle nose near the

spindle nose, whatever it is showing here and then you extent this particular shaft and you reach to this location this is called the rear spindle of the rear spindle shaft. So, this is at the other end correct.

So, because we have to provide the set of bearing on both the side front side as well as the rear side also correct it can handle.

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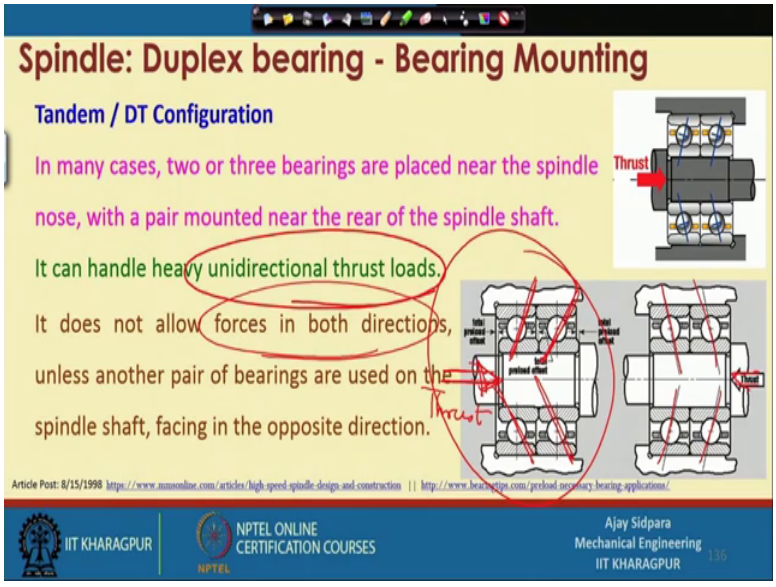

Heavy unidirectional thrust loads, now this is one of the problems of this particular loading. Let us complete this also it does not allow forces in both the direction unless other pair is of the bearings are used on the spindle shaft facing the opposite direction.

Now, what does it mean now you consider this thing that we are providing thrush force from here to peel up this particular gap correct. So, thrust force is continuously from this direction only correct. So, now, you consider that is my it is called the unidirectional thrust load, why it is unidirectional thrust load; now consider that your spindle is mounted here and now it is a drilling operation. So, you are doing drilling operation here then it will create a force in this direction.

So, if it is in force it is in this direction what is going to happen; that again you are getting the problem here; that means, your preloading whatever force you are getting thrush load here whatever thrush load you are putting here, if your machining force is more the this particular thrush load, then what is going to happen you are again going to

come into this location; that means, whatever this preloading is there that preloading will be sacrificed because of this excess loading in the opposite direction of this. So, that is why that your whole loading should be from this part only.

So, whatever you are want to do that things; that means, you have to provide full loading from this direction, that is the only thing that is the thrust load, but if you want to do in oppo this way that is if you are getting this forces from both the direction; that means, that you have to get these things done in the other way; that means, the other facing bearing should have opposite direction.

So, this is the one bad bearing suppose you consider this is one side of bearing then other side of bearing, whatever you are talking that those bearing should have this configuration that is from the other side. So, now, you consider for getting these particular part, what is your doing that you are doing forces from this direction, that is the thrust force right. So, this is the one set of bearings that is on the one side that is because of the thrust force in this direction.

But, if you are getting the forces from the both the direction, then whatever is the rear side or front side other bearing it should have thrush force from this direction. So, whatever this tandem that should be this thing should be opposite to each other, if this angle is in this direction then the other angle in the opposite direction that is on face to face side or it is on the opposite side, then it will take care of both the side of loading without any problem.

So, if you are loading from the one direction. So, then it is better to go with the unit directional thrush load, that is mostly we talk about the drilling operation, because after drilling once drilling of completed then when you are removing from drill bid from the machine surface it will not encounter more forces here, because here already metal is removed, but when you are doing a cutting of a this different type of other material when you are doing milling operation and other things at that time you may get the radial forces also and radial force we will create a problem a for the later operation.

So, that is the things which we can we have to consider when you want to use the tandem design for a bearing application right.

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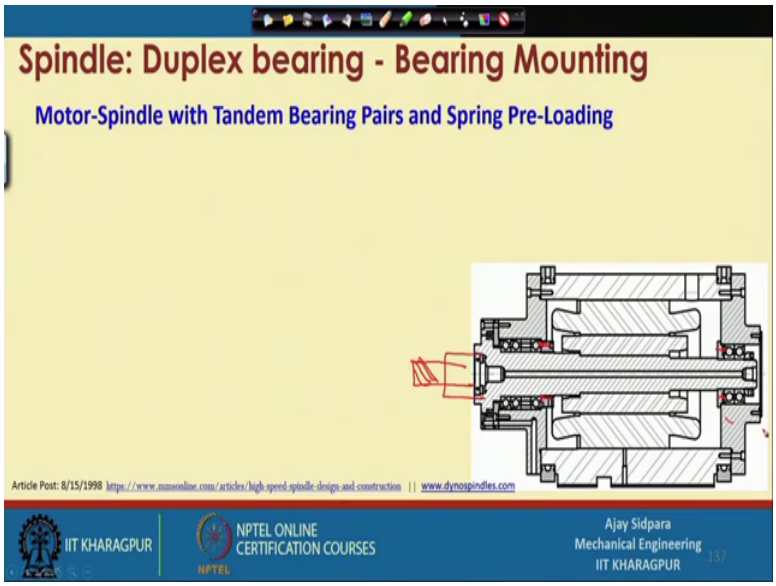

So now, let us consider how you are mounting this particular bearing in a motor spindle. So, this is the motor spindle will tandem bearing pairs and a spring preloading. So, this is the complete cross section of a spindle where we have mounted the bearings also it is in tandem bearing pair and there is a spring which is used for preloading of that. Now this particular thing you consider that our spindle is located tool is located this side and this is the tool holder and this is the part and this is the on the rear side of the thing. So, we are mounting a one pair of tandem bearing here one additional bearing here and one pair of tandem bearing at this particular end of the shaft.

So, that is what is there in. So, spring we are using suppose you consider this is spring which we are using for a; preloading of that and here also we are using spring for preloading at this location right.

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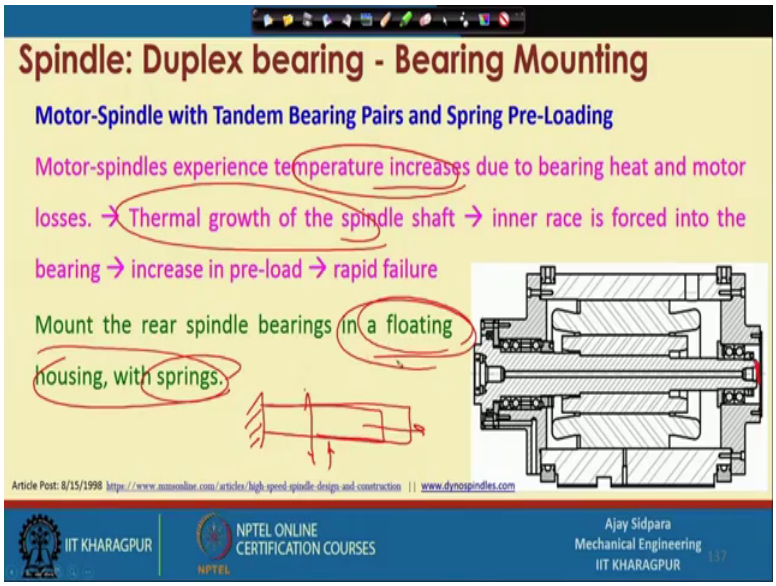

So, what is happening here that; when motor spindle experience temperature rise due to bearing heat or motor loses at that time there is a thermal growth of the spindle shaft because now, this is the things which is rotating at a extremely high rpm and when there is a heating in a motor loses there is a thermal growth of the shaft.

So, what is going to happen; because of that inner race is forced into the bearing, because now whenever there is a thermal growth the inner race we will try to force into the bearing part. So, this are the inner race whatever we are looking at this location that will try to move in the bearing side and when there is a that you will actually increase the preload, because now contact will be further increase or aggressive and there is a rapid failure of the bearing.

So, what is happening in this particular case that once this part is done then what you have to do that you have to do create one type of floating housing? So, mount the rear spindle bearing in a floating housing with a spring right. So, now, how does it will happ help in this our case that when there is a thermal growth of the shaft what is going to happen if everything is fixed.

Now you consider that this is the shaft fixed from both the sides and now you heat the shaft, now after heating the shaft what is going to happen that it will expand. So, what is going to become, now both the things are fixed; that means, it will bend some like this in this way or it will bend in this way correct. So, bending will happen and once the

bending will happen your system will completely fail, because it is not able to accommodate this additional movement of the shaft.

Now, consider the same thing here now what you are doing that you are fixing only one and let it the other end open and then you heat it. So, now, what is going to happen that it will it is no problem in that, because still you can maintain it is not increasing in terms of the diameter, but it will increase the length wise. So, it is why we are putting the floating house rear spindle. So, here what we are giving here we are providing some space here. So, that whenever there is a expansion or the growth of the spindle shaft and, because of this particular spring small amount of expansion we will not create any problem at the later stage.

So, whatever thermal growth is there temperature increase, because of the different-different regions yours full spindle system will not create any problem at the later stage or during the operation. So, that will be taken care by this floating house.

So, let us discuss these particular floating house things in the next class and let me stop it here.

Thank you very much.