Tribology

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Lecture No. # 31

Selection of Rolling Element Bearing

Welcome to thirty first lecture of video course on Tribology. Today's topic or today's lectures topic is selection of rolling element bearings. We have discussed in previous lecture about rolling element bearings, some description was given about rolling element bearings, but selection is important. We need to select proper bearing for proper application or for our application.

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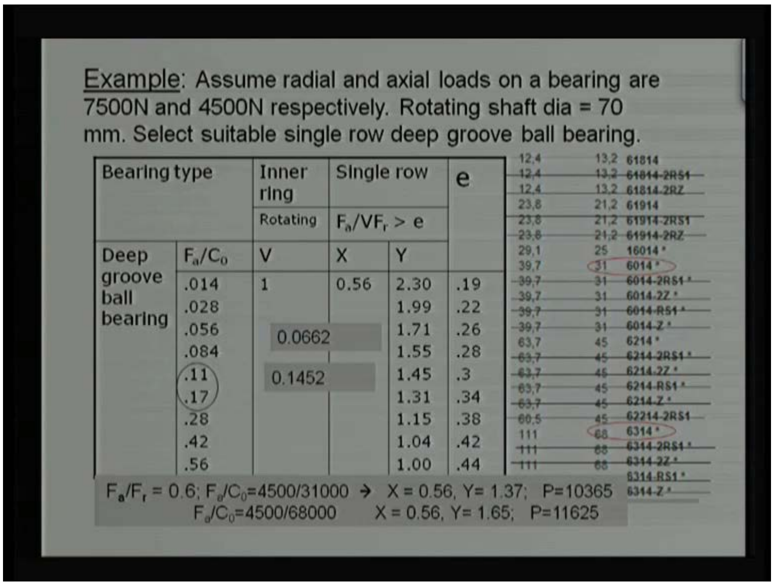

So, we are going to discuss that selection criterias in present lecture. Few points, which we already discussed, will be repeated for proper guidance. We started one example in previous lecture, and I am just repeating the same slide over here to say that assume there is a some radial load and axial load on a bearing, bearing load is coming perpendicular to the axis as well as along the axis, the magnitude of that load is also defined to say 7.5 kilo Newton is along the radial direction or perpendicular axis and 4.5 kilo Newton is along the axis. Shaft diameter is given and you are seeing the shaft is rotating; that means, inner ring is going to rotate. What we need to do select a suitable single row deep groove ball bearing.

Now, in this case we are not going to select the bearing among the diameter of the bearing only from deep groove ball bearing. One category of bearing that is a deep groove ball bearing more like we are going to choose different dimension or we are going to select from the different dimensions what will be the proper bearing for our application.

So, in this case the shaft diameters given to the bearing board diameter is defined in this case and gets, based on the bearing both diameter if we select the bearing that is a 1 4 series that is we know to find out the board diameter we need to multiply last two digit with the 5 number or number 5 that is a 14 into 5 is a17.

Similarly, 1 4 into 570, 1 4 into 570 all the bearings have a board diameter of 70 mm. We are going to choose bearing among these bearings. Now in this question particularly we do not have any shielding requirement or sealing requirement that is why we have removed the option 2 r s 1, 2 r s z, 2 r s 1, 2 r s z. all these options will removed remaining options are 6 1 8 1 4, 6 1 9 1 4, 1 6 0 1 4.

We described previously these are the special type of the bearings, generally manufacture by one particularly company and then if it is already mass produced technical develop(( )) or manufacturing process have been developed, then we, the particular company will open it to the open market to the other people also.

Similarly, bearings are also there the 6 0 1 from 6 3 1 4 and we need to select one of the this bearing. To select bearing we require rating particularly based on axial load to the static load carrying capacity that is F a is axial load, C 0 is a static load carrying capacity and a static load carrying capacity is defined over here, 13.2 25 31 same thing in this case 45 45 68.

And as a inner ring is rotating it says the shaft is rotating; that means, inner ring is going to rotate. Inner ring is rotating that rotation factor will be equal to 1. Coming to the single row side there is questions raising we need to select a single row deep groove ball bearing.

So, we need to find out what is a this ratio F a by F r. In our case this ratio F a is a 4.5 divide by 7.5 and we need to compare with this parameter. This e parameter generally defined on a geometry of the bearing, if this ratio F a by F r is greater than e then we will choose x parameter and y parameter and try to find out equivalent load.

In previous lecture we did that similar thing we say the F a by F r is a 0.6 in a most of the cases is a more than what is given as a F e parameter; that means, we have to select a parameter x and y from this, then we require F a by C 0 as individual bearing we have particular or typical value of C 0. Naturally, if I am choosing suppose a I want to find out bearing from this category I will just take up the two examples 6 0 1 4, 6 3 1 4.

Now, we need to choose a bearing or we need to find out which bearing is going to perform better even though we have other options also just for example, we picked up only 2 bearing for time bearing the 6 0 1 4, 6 3 1 4 and C 0 is defined. First case it is a 31 kilo Newton and the second case is a 68 kilo Newton that is why it is given over here the 4.5 kilo Newton divided by 31 kilo Newton, 4.5 kilo Newton divided by 68 kilo Newton and when we find this ratio this ratio is not coming it is not exactly matching any of this value. So, we need to do some interpolation. This is what in the first case the this value is turning out to be 0.145 which is not equal to 0.11 it is not equal to 0.17 that is why we required a some sort of interpolation between these 2 to find out exact value of this.

Based on that interpolation we can also compare with the e value Interpol find the, to correct e value from the interpolation and based on that we can compare and we can say what will be the parameter x and what will be the y. We know x is not changing at all. So, interpolation does not mean much to this, x will be exactly 0.56 while y will be different it will be somewhere value between 1.45 to 1.31. Up in correct manner we say that value will range or will be greater than 1.31, but lesser than 1.45.

And what we find from our catalog, this value is a y value is a 1.37. Similarly, we can find out this ratio F a by C 0 that is a 4.5 divided by 68 that is coming out to be 0.0662 again we are not able to get exact value this exact value over here we have value the 0.056 and 0.084 we need to do interpolation to get this value and with that interpolation we will be able to find out the correct value of y, which will be ranging between or will be greater than 1.55 while lesser than1.71.

And what we get after interpolation that is a y is equal to 1.65. Now using this parameter 0.56 and 1.37 I can find out equivalent load. How to find out equivalent load ? This x needs to be multiplied with a radial load; that means, the 7.5 kilo Newton into 0.56 plus 4.5 kilo Newton of axial load into y that is a 1.37, this summation will be equivalent load which is turning out to be 1 0 3 6 5.

Same thing for second bearing which is a 6 3 1 4. We have x is equal to 0.56 same multiply with a 7500 Newton, second will be a 1.65 into 4500 Newton. So, it will be summation the 0.56 into 7500 plus 1.65 into 4500 Newton or summation turn out to be 11625.

In previous lecture, I mentioned if I want to select based on the applied load bearing, the first bearing will be a proper choice because in this case equivalent load is lesser than second bearing. First case is a 1 0 3 6 5 which is a lesser than 1 1 6 2 5, but this is not all.

We need to find out how to choose a proper bearing based on other criteria’s also in this case it is the only the load or we say equivalent load and equivalent load states that this is a better bearing because equivalent load is a lesser and we know very well that lesser load will be preferable for the bearing life.

So, the question comes for to estimate the bearing life or if the life is given or estimated life is a comes in the question then how to proceed further for that purpose this is the next slide says that consider the shaft rotational speed.

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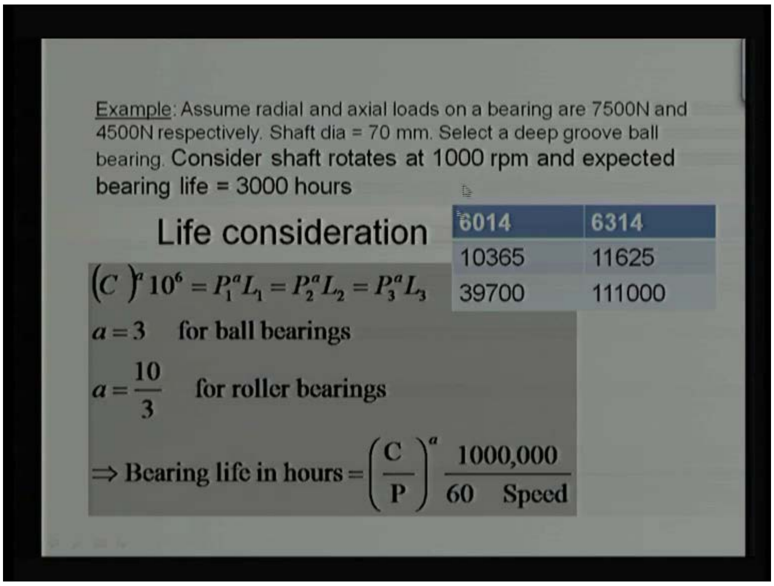

Generally bearing life is given in rotations it is the dynamic load, it is a fatigue load. So, how many rotation that bearing can survive. Naturally we require rotation per minute reading. As well as how much life is expected, in this case this question has been added with a 1000 RPM as a rotating speed of the shaft and the expected bearing life is a 3000 hours. We require bearing to survive without any pit on the surface for 3000 hours or minimum of 3000 hours, with a 90 percent reliability. Of course, if the reliability increases naturally we know whether we have to count a parameter e 1 which was discussed in previous to previous lecture that need to be accounted.

So, when we add these things, these parameters we need to consider the life equation which was a derived in previous lectures and that is equivalent to this equation we say the this c is a dynamic load carrying capacity; that means, bearing can survive for 10 is to 6 cycles for this kind of the load. And ‘a’ decides, is decided based on whether the geometry is a ball geometry or the roller geometry for ball bearing is equal to 3, while for roller bearing ‘a’ is equal to 10 by 3; that means, 3.33 that is a slightly more than ball bearing because we know roller bearing can sustain slightly more load compared to the ball bearing.

Same relation for other loads, we know the p 1 is a lesser than C , L 1 will be greater than 10 is to 6. Similarly, for other cases p 2, L 2, p 3, L 3. We can utilize this relation.

Now, using previous slides we can find out what is equivalent to p. We can substitute the value of p and L 1 is already given to us, what is the expected life. If we convert in the rotation, to convert in a rotation we have using this relation. What is that ? It says that we are counting this speed, we know this is 1000 rotation per minute. If I multiply with a 60 then in that case it will be 60000 rotation per hour and we require bearing life in hour, that is why this equation has come. Bearing life in hours because we require 3000 hours, can be rearranged in such a way the C by p power to a.

That means here we are more important about the ratio of the C by p, it is not only the value of p, but what is the value of that bearing or what is the value of C for that bearing is important. This ratio is important for us for both the bearing speed will remain same because same we have to mount on the same shaft the shaft is speed is given that is defined for us.

So, we need to select a bearing, there is C by p ratio in this case. Of course, other cases also will come when we consider the friction or we say that we require low friction by high load carrying capacity, naturally bearing choice will be different than what we are doing it, just now we are concentrating on the load and we are concentrating on the bearing life.

If bearing life is 3000 hours are expected naturally C by p is going to be a dominating parameter in this case. So, for 2 bearings what we given in, we picked up when in previous slide that is 6 0 1 4 and 6 3 1 4 we know very well 6 3 is a high bearing load carrying capacity series. It will be dimension will be more than 6 0 1 4 naturally if there is space constraint, say the consideration come and there is a restriction or constraint in on the space then we have to also choose accordingly.

Then we say that we do not have a more space available diametric space they have to keep in within this envelope dimensions. Naturally, we have to choose that bearing or from that angle of bearing, however in this question nothing is been defined, we are free to choose bearing there is no restriction on dimensions.

Now, for 6 0 1 4 the equivalent load equivalent radial load turn out to be 1 0 3 6 5; however, for a 6 3 1 4 bearing it was a 1 1 6 2 5 and based on this criteria equivalent criteria we say that this bearing is a better option compared to this bearing.

Now, we are counting C because we are interested in ratio of C by p. C for 6 0 1 4 is a 39700 Newton. It is more like a 3 times or may be 3.8 times of this while coming to this side dynamic load carrying capacity that is C is equal to 1 1 1 0 0 0 or say 111 kilo Newton which is almost a 3 times of this.

So, here slight increase in the p, but here the major increase or more increase in the C; that means, we are going to get a better value of C by p for this kind of bearing. Naturally this bearing is going to survive for much longer time compared to this bearing because if this ratio is a higher then there is a power series also, it is a cubic series naturally if this ratio is a more than 1 ‘a’ will always be in favor of the situation for us.

So, if I substitute all these value. If I substitute C over here, p over here, speed is already defined as a 1000 RPM we will be able to find out the relation or we will be able to find out whether this bearing can survive for 3000 hours or not or this bearing can survive 3000 hours or not.

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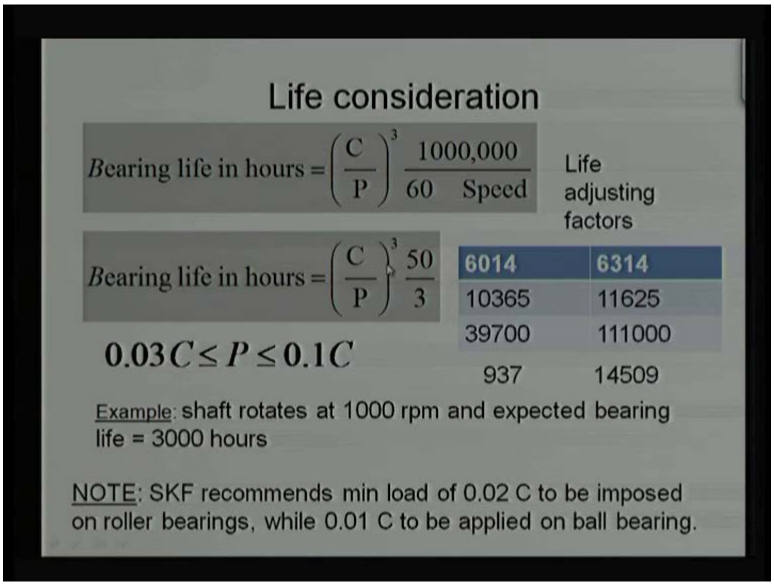

If we do that what we are going to get 937 hours for the first kind of bearing there is a 6014 bearing, 937 hours which is lesser than 3000 hours; that means, this bearing cannot be selected for our application, there defining is for the 3000 hours; however, if the bearing life estimated bearing life are 600 hours, 700 hours, 800 hours, 900 hours this bearing is a better option, because it have a lesser envelope dimensions and naturally it will be lesser costlier compared to this.

Then coming to the this bearing we have a much longer life as a 1 4 5 0 9 bearing. Naturally this is a much, we say the high speed coming over here or we say operating hours almost a 5 times compared to what we require we can go ahead with a some other bearing like a 6 2 1 4 bearing which will show lesser dimension as well as other lesser life which will be more than 3000 hours.

So, based on this example we can say that equivalent load as well as the operating hours should be considered when we go for the bearing selection that is important for us to choose a proper bearing. In this case what we have picked up the two bearing 1 is not able to sustain or survive for the life which we require, other bearing is showing much longer life compared to what we require.

Naturally an intermediate bearing or in between bearing which will be coming in the catalog should be selected or should be checked first and then selected bearing based on that. So, that is giving some idea how to choose a proper bearing for our application. In addition there are some statements which generally we quote or which we specify or some notes generally be specified and the thumb rule applied load equivalent radial load should be lesser than 10 percent of C, that is a recommendation it should be lesser than 0.1 times C .If the load is more than that bearing life will not be much.

So, thumb rule says p need to be lesser than 10 percent of C and here if you can see this is a 39700 and this is a 10365, ratio will be coming (( )) if something like that which is much larger than what we require. In this case applied load is very high from that point of view this bearing is not selected and cannot be selected. So, it is another way if we know what is a p and what is a C directly based on that ration we can say or this bearing will not give a good life. So, we should not select it we should not move to the towards the direction we should reject this bearing at the first instant), we do not have to do this kind of calculations itself.

Coming to other side you say the bearing need to sustain some load; however, there will be some sort of vibration because the we know the rolling elements will be having some separation from inner ring and outer ring there will be some clearance, if there is no load there will be lot of vibration lot of noise that is why there will be and there is a need of some load on that.

And ofcourse this there is a form rule that p need to be exactly like this because we have seen in a number of books and we find that every where this value is different. Thumb rule says that it should be greater than 3 percent of C it should not happen that you are applying very low load on a bearing and bearing is a making lot of noise in that because of noise and noise as well as a vibration there is a possibility of early failure of the bearing. So, it should be avoided.

However as I mentioned this is not a firm rule 0.03 because we have seen the SKF catalog, they recommend 0.02 C to be imposed for the roller bearing. The roller bearing minimum load need to be 2 percent of C. However slightly lesser is been applied for the ball bearing, here the ball bearing they recommend 1 percent of the C the load need to be more than 1 percent of C and for roller bearing it need to be more than 2 percent of the C. Of course, if they are too many parameters involved too much geometry involved in that doing a detail analysis will give the right value, but as a thumb rule or the starting purpose we can say p as far as possible from economic point of view need to be more than 3 percent of the C. We can stick to that rule.

There is another consideration or a you say that this bearing life an estimated without correction factors. What we say the life adjusting factors, we assume here bearing life for the ninety percent reliability. If we required other than ninety percent reliability that factor should come over here. Similarly, we are assuming there is a ideal lubrication whatever the lubrication wherever the lubrication is required, that is getting supplied or that is been fulfilled completely when there is a possibility of the starvation there is a possibility of excess of lubrication that has not been counted over here.

So, there will be a some factor counted over here. Another thing is that we are assuming the bearing material is perfect, there is no crack formation, there is no manufacturing related problems and then the kind of the material which we are using is perfect. If material is not perfect then that factor also should be accounted; however, the most of the industries they go out to the better material and the material parameter or material factor is generally equal to 1, we need to adjust this bearing lifefor the reliability as well as for lubrication parameter. For lubrication related aspect or lubrication parameter we will be discussing and we will start the lecture on the lubrication of rolling element bearing, for time being we are assuming this relation. We will be carrying this relation for a next calculations also.

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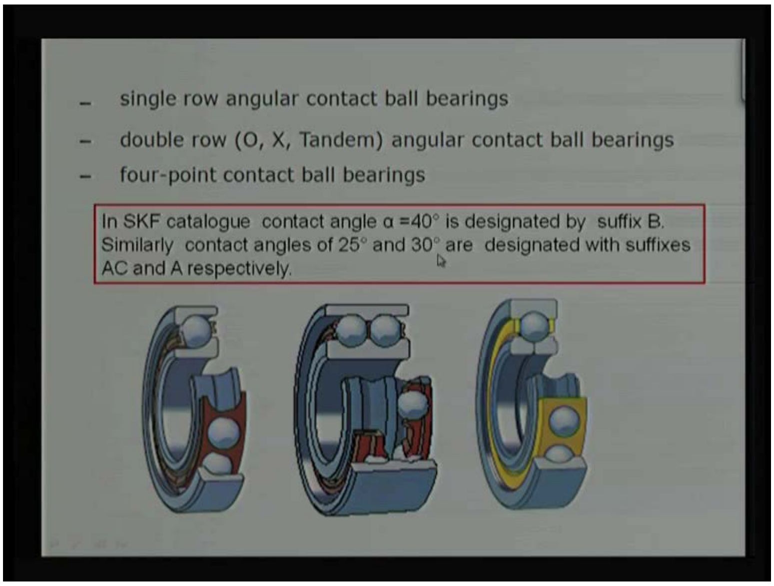

We discussed something about the deep groove ball bearing and that is, it gives a good position like accuracy and it is cheap one this is more like a low cost factor, readily available in the market. However there are some other bearings also with having a some contact angle and we are trying to show how other bearings are better than deep groove ball bearing when there is a axial load. These deep groove ball, these kind of the bearing which can sustain some axial load having some contact angle. Contact angle can be 20 degree, 30 degree, 40 degree, 50 degree depends on the which bearing you are going to select that is that is why this bearing are known as angular contact ball bearing. This is the first picture shows a this angular contact and if I draw a line perpendicular to the axis of this ring, we find that this is not merging with a load axis or the contact axis.

There will be some angle between this. This is a single row similarly we have a double row also, 2 row bearings with naturally we know very well load carrying capacity of the 2 rows will be higher than the single row with they have number of rolling elements and wherever load will be shared. Naturally load carrying capacity of this bearing will be higher or on higher side compared to this bearing.

There is another option available, we say the instead of going for the this kind of bearing we want what we want we want more contact. Particularly in a for axial direction why not we go ahead with a 4 contact , 4 point contact bearings which can sustain some axial force as well as a radial force and also it is advisable from the size point of view. We do not have as high size as a these kind of bearings.

So, we can think about 4 contact ball bearing or 4 point contact ball bearing, double row angular contact bearing, single row contact bearing depends what is a requirement. If the load requirement says that we do not have an axial force naturally we will not choose any of this bearings because they are going to show a high coefficient of friction. From friction point of view this bearings are less advisable or lesser advisable compared to deep groove ball bearing compared to roller bearings.

Now, there is a some sort of a specification if we see some catalog and in this case we am referring a SKF catalog that for contact angle they do not write a contact angle to 40 degree, they do not write a 25 degree, they do not write 30 degree. What they give they give us a some sort of suffix at the end of the bearing series and then for 40 degree they give suffix equal to B, So, if we find any time bearing with a B specification in a suffix we say contact angle is a 40 degree, similarly if the contact angle is the lesser that is a 25 degree then it will be known as AC series or say a suffix will be with AC and if contact angle is 30 the suffix will be A.

So, if we are scanning through the catalogs, we can say what will be the contact angle because for our calculation purpose we require a contact angle. So, that we can figure out with what will be a contact life of the bearing.

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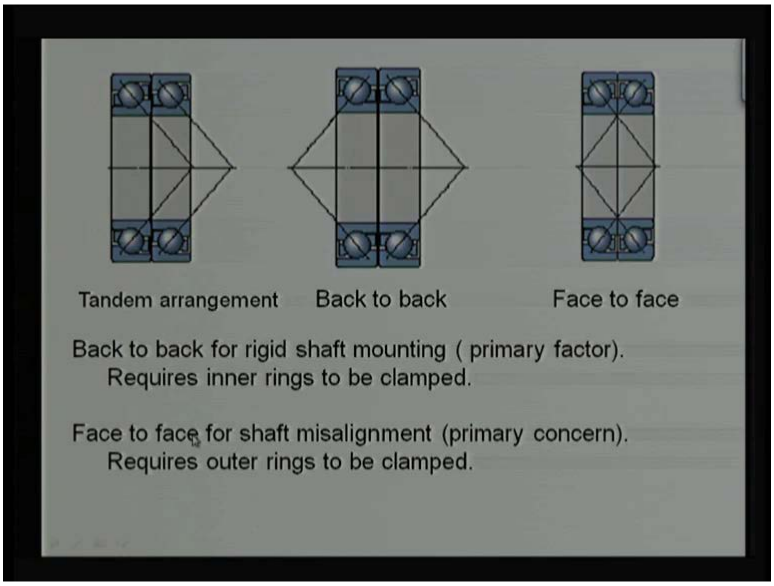

Just I discussed in a previous slide about double row contact bearing or we say the angular contact bearing and double row contact bearing, that is the this is the 3 arrangement have been shown here this is a tandem. We say that bearing is supporting or we say enhancing the load carrying capacity in one direction in this case.

Now, they are in a same arrangement. There is a other possibility of back to back arrangement or face to face arrangement or some time it is known as o bearing and this is known as x bearing. If you see the previous slide this is what we are saying that double row o bearing, x bearing, tandem bearing.

And this all three bearing are shown in this slide, say there is a tandem arrangement, there is a back to back arrangement, there is a face to face arrangement every configuration have has its own advantages. What we say that back to back bearing is going to provide. Back to back bearing is going to provide more and more rigidity more and more attachment or fixation of that bearing.

And that is why they the primary factor is that we require rigid mounting. We do not want the shaft if it is deflected or displaced in any way, then we should go ahead with back to back bearing. While in this situation particularly inner ring need to be clamped, but the outer ring is rotating naturally from the load point of view this is not very highly recommend from positional of view this is can be recommended.

Coming to the face to face bearing in this case what we are going to get a some sort of a flexibility in outer ring; that means, we can allow some sort of misalignment in this kind of bearing there is a possibility of slight misalignment what will happen in this case thee roller or this ball will get shifted to one side it will be losing load carrying capacity for that, but it can sustain some misalignment because of the this kind of the groove.

And in this case outer ring will be clamped. So, that this will be preferable choice for a general purposes and if we require specially positional accuracy then we can go ahead with this kind of bearing arrangement. This is a giving introduction or we say some sort of a description about when the two bearings are arranged are in a tandem arrangement; that means, we are supporting the load in one direction or in the back to back arrangement or the face to face arrangement.

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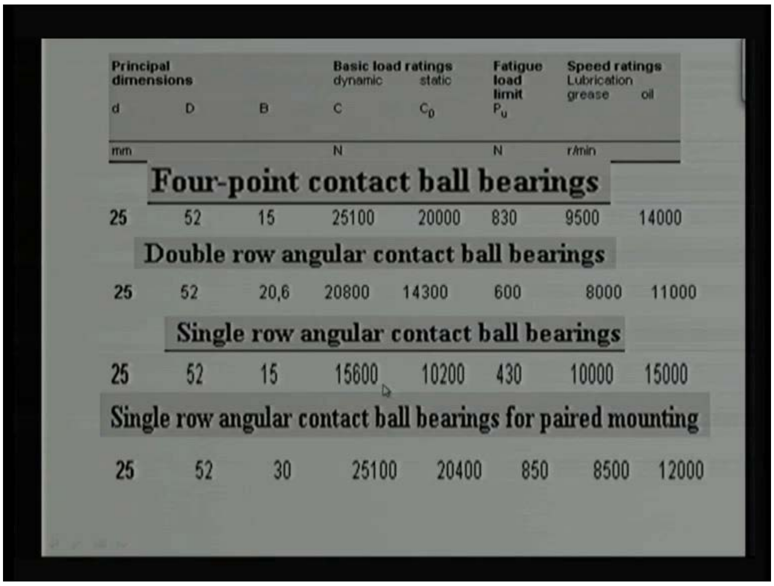

If I compare all these bearing what we say the 4 point contact ball bearing, double row angular contact bearing, single row angular contact bearing and single row angular contact bearing for the paired mounting for the tandem mounting whatever we show that pervious slide the paired mounting and tandem mounting. And for same diameter of the shaft we say assuming that these bearing is going to get mounted on 25 mm diameter, all the bearings are 0 5 C that is why I have shown here d 25, 25, 25, 25.

Now, outer dimension that is a envelop outer dimension of we say that final dimension of a outer ring is also same is 52, 52, 52, 52 mm. Coming to the length side say 4 point contact bearing is a 15 mm. Coming to the double row it is 20.6 mm. Single row angular contact bearing which will be naturally lesser than this dimension that is the 15 mm.

Coming to the paired one tandem bearing arrangement that has a 30 mm so, that means from dimensional point of view from axial length point of view naturally this bearing should be recommended and this bearing should be recommended, but not this bearing, not this bearing, but this is only the space consideration. We are concentrating on the space coming to the dynamic load capacity or c, In this case particularly the dynamic load is a capacity is the 25 kilo Newton while here it is a just 21 kilo Newton.

Coming to this side it is a 15.6 kilo Newton we say lesser than 16 kilo Newton which is a least in this bearing configuration. In a single row angular contact bearing occupy the same space the 4 point contact ball bearing, same outer dimension, same board dimension, but load carrying capacity is inferior compared to this 25.1 kilo Newton, here the 15.6 kilo Newton naturally this bearing cannot be recommended in compared to the 4 point contact bearing if we are not considering the friction losess. Naturally if we consider friction is also having highest important than in this situation this bearing cannot be recommended, this bearing can be recommended based on the load, this can bearing can be recommended based on the life estimation say life will be higher in this case.

Coming to the static load capacity, static load capacity also almost two times compared to this (( )) it will not be much plastic deformation compared to this or we say that plastic deformation in this case will be lesser than this case; however, coming to the 430 with the fatigue load limit. Lets choose also the fatigue load limit for the four contact, 4 point contact bearing is higher compared to this. Only the problem is the running the speed that is 9500 running the speed for the 4 contact bell bearing reason being it is a higher friction and will generate a high heat if you rotate at a higher speed.

But in this case it is 10000, in case of the presence of r is 14000, in presence of r single row angular contact bearing showing 15000. So, if I compare 4 point contact ball bearings with a single row angular contact bearing other than friction this bearing or 4 point contact bearing is showing a better performance. So, we should select this kind of bearing; however, other parameters the cost or the parameters is also like availability in a market bearing is not available in market or very costly and do not want to invest this much and that much money then we need to think about at a different way, but from load point of view from my estimation point of view 4 point contact ball bearing is preferable compared to single row.

Coming to the double row here we are able to see in this case the length is increasing by roughly 25 percent to 30 percent. In this case the same thing is happening in load carrying capacity and we gain much advantage from the double row angular contact bearing, slight increase what we say some increment and load carrying capacity similar increment is happening in the length side. So, this is a double row angular contact bearing is not giving that much profit as much as expected.

Coming to the paired bearing, paired bearing, we say that we are giving too much length the two bearing are been combined together and for pairing cases there is a some decrease in decrement in load carrying capacity. Instead of 15600 now it is, it is not two times in two into 15600 slightly lesser than that was 25.1 kilo Newton which was lesser and was almost same as what we are getting in a 4 point ball bearing.

Now, if I compare 4 point contact ball bearing with a single row angular contact bearings for the paired arrangement with a tandem arrangement, what we are going to loose, length is almost half, load carrying capacity is almost same. Either dynamic capacity or static load carrying capacity, fatigue load is also same. So, note we are not going to much if we are choosing the paired bearings. Here this bearing will be better option compared to this bearing.

So, what I am trying to complete from this slide is that we need to see all kind of bearings we need to find what is a exact requirement for us and ensure for our requirement we will be finding a number of bearing and later we will add the friction aspect, we want to add cost aspect, we want to add availability aspect based on that we can make a final selection, but if those selections or those criteria's are not dominating criteria's or cost is not a major factor then we can choose a best bearing load based on the life estimation.

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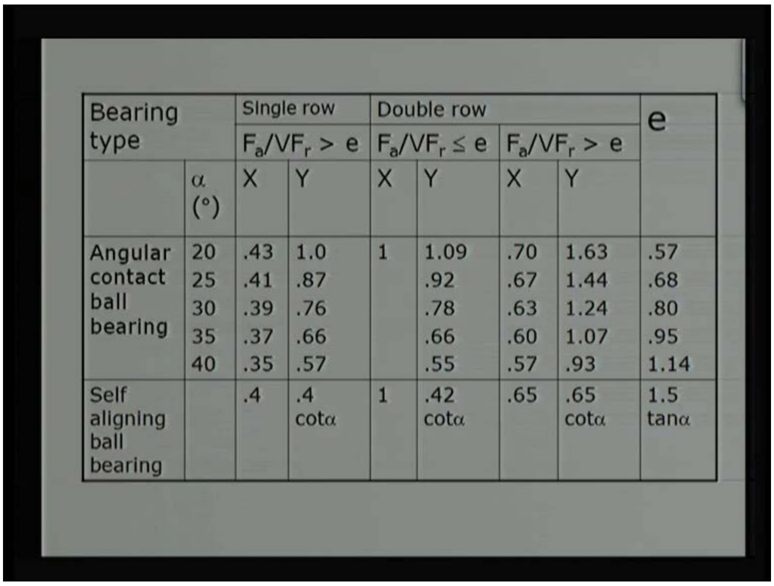

Bearing type		Single row		Double row				e
		$F_a/VF_r > e$		$F_a/VF_r \le e$		$F_a/VF_r > e$		
	α (°)	X	Y	X	Y	X	Y	
Angular contact ball bearing	20 25 30 35 40	.43 .41 .39 .37 .35	1.0 .87 .76 .66 .57	1	1.09 .92 .78 .66 .55	.70 .67 .63 .60 .57	1.63 1.44 1.24 1.07 .93	.57 .68 .80 .95 1.14
Self aligning ball bearing		.4	.4 cotα	1	.42 cotα	.65	.65 cotα	1.5 tanα

Now, this slide shows a how to choose an angular contact ball bearing, but it was just repetition of previous one lecture slide. So, that for different contact angles x and y factor will be different for single row as well as for double row. When we are talking about the double row both the factors are accounted this ratio is a greater than e or lesser equal to e; that means, the four cases we need to consider x y factor.

However when that is a lesser than e, x is equal to 1 that need not to be considered you can say directly F r plus y into F a that can be used whenever there is a this ratio is lesser than e or equal to e. So, based on that we can find out the equivalent load we can choose a proper bearing. And am going to show that deep groove ball bearing angular contact ball bearing comparison, you can see that deep groove ball bearing is generally a typical choice of a designers may not be a good choice when we think about a signs, when we think about a proper Tribological knowledge for that purpose I am considering this example.

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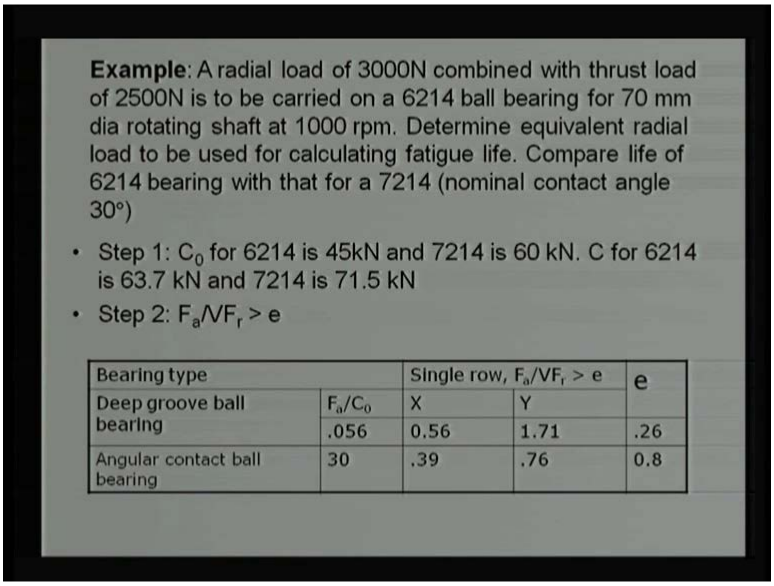

What is this example you say that lets consider a bearing is subjected to 3000 Newton radial load with thrust load equal to 2500 Newton you can say the ratio 2.5 divided by 3 it is a very high ratio more than point 8 is to be carried by the 1 deep groove ball bearing 6 2 1 4 series bearing, for either the already shown over here is last 2 digit is fourteen 1 4 if we multiply with the 5 naturally we are going to get a 70 mm. It is for 70 mm shaft rotating which is rotating at a 1000 RPM.

So, in this case particularly the inner is rotating naturally v will be equal to 1, determine equivalent radial load to be used for calculating fatigue life or for estimating the fatigue life we can find out our first we need to find out equivalent radial load as equal to p.

Compare life of this 6 2 1 4 bearing with that of 7 2 1 4 bearing that is a angular contact bearing and the here the contact angle is a 30 degree; that means, whatever we choose from catalog we need to choose for the 30 degree contact angle.

If we scan through the catalog we find out C o a static load carrying capacity 6 to 1 4 is a bearing which we are defining over here is 45 kilo Newton and for the 7 2 1 4 this bear static capacity is slightly on higher side that is 60 kilo Newton.

Now, we say that is almost a 25 percent plus or more than 25 percent high side compared to the C 0 for the 6 2 1 4 bearing coming to dynamic capacity that is the value of C for the 6 2 1 4 is 63.7 kilo Newton and for the 7 2 1 4 this bearing load carrying capacity is 71.5 kilo Newton. So, from this load comparison clearly indicated naturally 7 2 1 4 bearing is going to be better bearing compared to this bearing, just by scanning catalog we can find the 7 2 1 4 bearing is going to show true performance compared to 6 2 1 4 bearing.

Now, we need to find out what are additional advantages. This conclusion is based on the C value 7 2 1 4 bearing C 71.5 kilo Newton which is a greater than 63.7 kilo Newton as a load carrying capacity or dynamic load carrying capacity of this bearing is higher naturally 7 2 1 4 bearing should perform better. Now, we need to find out second option that is say what will be the equivalent load because as we earlier mentioned, bearing life will always be depending on the C by p ratio we are showing here C is higher side, what is the value of p we need to find out that. And to find out that equivalent load, we require x parameter and we require y parameter. To find out x parameter y parameter we need to find out what is F by r. F by r in this case is a 2.5 divided by 3 which is need to be greater than e, if it is a lesser than e then we need not consider equivalent load or we say F r will be equivalent load.

Now, we have considered two bearings the deep groove ball bearing and angular contact bearing and static capacity as well as axial load will be defined. So, we can find out this ratio in this case F by C 0 is a 0.056 for angular contact 30 degree angle we know and based on that we can find out those parameters x and y. So, for x parameter for deep groove ball bearing is a 0.56; that means, we have to consider 56 percent of radial load F r, while y parameter is F panel t. Panel t is coming 71 percent, if we are not just adding F a, we are panelizing the F a with a 1.71 and that means, enhancing x F a and then adding to the radial load. We are not being the single combination and in this case this e is equal to 0.26 naturally or F a y F r is greater than this that we will have to choose x and y parameter to find out what is equivalent load for 6 2 1 4 bearing, coming to the angular contact ball bearing is 7 2 1 4 bearing we need to choose 0.39 into F r plus 0.76 into F a.

If we do the this kind of the study its clear this parameter is a lesser here. We know F r is same for the both the bearing, apply load remains same for the both the bearing, but x parameter in this case is a less naturally. We are going to get a first component of equivalent load lesser in this bearing. Coming to the second component if the 0.76 again lesser than fifty percent of this. Naturally equivalent load which is a required for us is will be lesser for the angular contact bearing in that case we are getting win-win situation. First thing is C is on a higher side and p is on lower side, naturally C by p ratio will be much larger for angular contact bearing for 7 2 1 4 bearing.

Naturally life estimated or estimated life for the bearing for angular contact bearing will be much larger compared to deep groove ball bearing. So, this analysis is also indicates we are going to right direction whereas if we replace 6 2 1 4 or say 7 2 1 4 with the 6 2 1 4 will replace the deep groove ball bearing with angular contact bearing will be better option for us.

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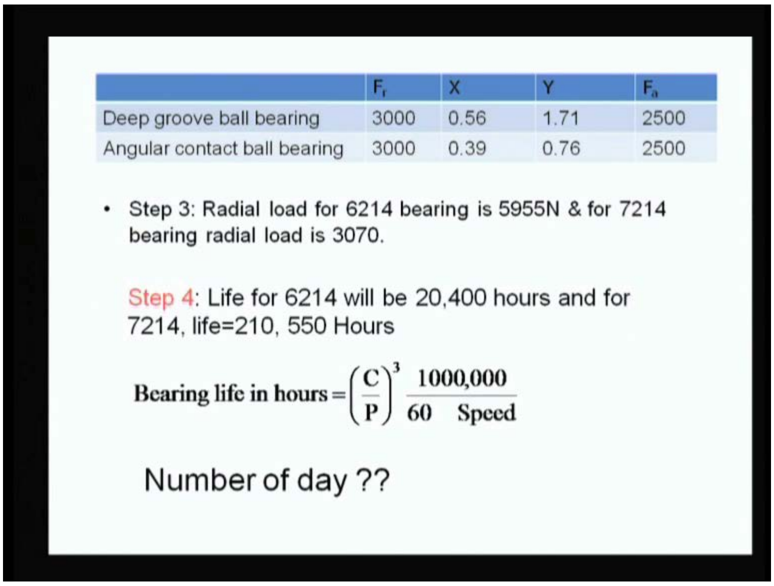

So, now what whatever I mentioned in previous slide is same thing over here F r is a 3000 for the both the bearings. x is a 0.56 for the deep groove ball bearing for angular contact bearing is 0.39. So, we are multiplied 3000 into 0.39 then naturally this sum is this multiplication will be lesser than point multiply 0.56 into 3000. So, because of this parameter is lesser than this when we add, we have to multiply add with this 1.71 into 2500, while in the second case it will be 0.76 into 2500. Again this product is a lesser naturally summation will be lesser.

And when we find that this for radial load equivalent on radial load for 6 2 1 4 bearing is a 5955 Newton, well for 7 2 1 4 bearing this load is a 3070, its almost half of the bearing. naturally we are going to see or we are going to estimate bearing life much higher or longer or much higher compared to 6 2 1 4 bearing to do that kind of calculation we know about the speed of the equation that is the 1000 RPM.

We already calculated C or we figure out C from the catalog. C has been estimated or calculated, we can find out bearing life in hours and that is for the deep groove ball bearing is a 7192 hours not very low life, but as high as a second bearing that shows a 1,24,420 hours. So, when compared 7 verses 124 cost will not be that much higher, availability will not be that much problematic. If we for this kind of load carrying capacity or for the axial load on higher is ratio F a by F r is almost a 0.8 plus than we should choose angular contact bearing compared to deep groove ball bearing.

As I mentioned earlier deep groove ball bearing is easily available and often designer choose a deep groove ball bearing, but slight more consideration, slight calculation indicates no that is not that right choice. Right choice will be angular contact ball bearing which is a better option or the much better option compared to the deep groove ball bearing right. Of course at it is a simple thing that if we want to find number of days we need to find out how many operating hours in a day is a 8 hours, 10 hours, 12 hours, 16 hours based on that we can find out how many days this kind of bearing is going to survive and generally for machines we calculate a bearing life in number of days not in number of hours.

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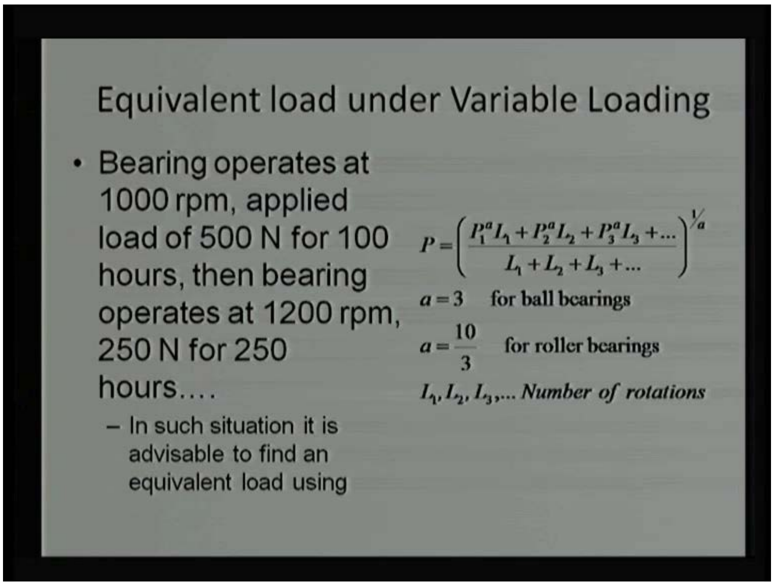

Now, there is another we say we have calculated equivalent load, equivalent radial load for a static load carrying capacity or we say that when the apply load is a static it is not going to fluctuate in magnitude as well as in direction. Apply load is always pointing in 1 direction adding cost and magnitude, either radial load and axial load whatever we have considered combination and based on the combination or we say using those parameter the x y parameter from catalog we calculate what will be the equivalent load carrying capacity. There is a possibility route magnitude changes we say that bearing may be operating at the load p 1, p 2, p 3, p 4 for different hours. That is why we it is given here bearing operates at a 1000 RPM for apply load equal to 500 Newton. This 500 Newton is been applied for 100 hours at this for 100 hours applied load to 500 Newton and operating speed was 1000 rotation.

Then some change in the system, some difference in the operational requirement. See then in that case bearing operates at 1200 RPM, slightly higher RPM compared to this, but lesser load to under 15 Newton and operating hours are more that the instead of 100 hours, now the operating hours to 250 hours. In this situation you have to estimate bearing life, that is the big question. Here we do not know what will be the equivalent load to find out the equivalent load we use this equation. You see we know what should be the final life 10 is to 6 cycle or operating hours based on whatever we require, may be we say that for L 1 number of rotation bearing is subjected to p 1 load. For L 2 number of rotation bearing is subjected to load p 2. For L 3 number of rotation bearing is subjected to load p 3 and so on.

So, what will be the bearing life? Estimated bearing life will be required L 1 plus L 2 plus L 3 plus L 4 plus L 5 whatever number final number comes repetition of that also. So, based on that we can find out what will be p equivalent and this is been derived same equation, we are able to estimate equivalent load based on this relation.

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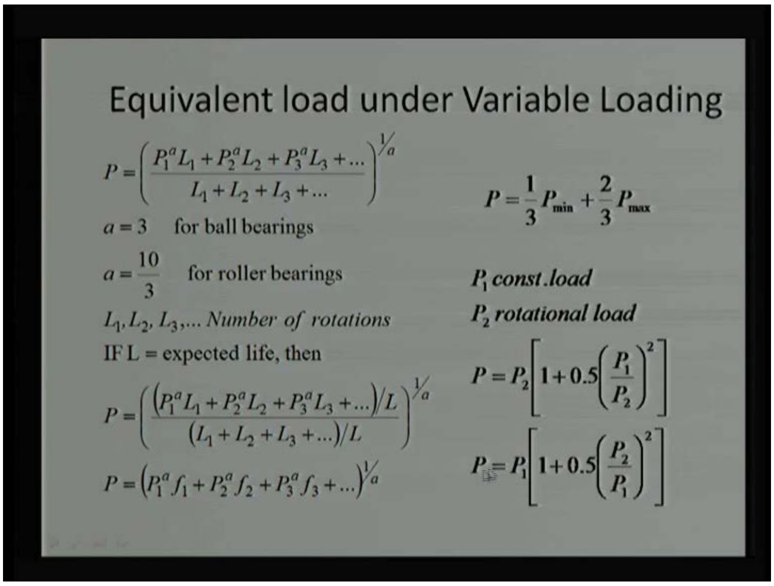

This is what we do simplify this relation what we can do, we can say let us say assume L is expected life. Would l is expected life they can divided numerator as well as denominator with the L; that means, here the summation will be L 1 plus L 2 plus L 3 plus L 4 plus L 5 and all and this is overall life. So, this ratio will turn out to be 1 because all a summation of L or L’s will be equal to L and that L divided by L will turn out to be 1, but here what we are going to gain L 1 divided by L let me see the fraction of the life, 10 percent of the life will subject to load p 1 20 percent life is subjected to load p2.

So, that fraction is important for us, that is why I say L 1 divided by L is F 1, L 2 divided by L is F 2, L 3 divided by L is F 3 and now if we know F 1, if we know F 2, if we know F 3 and the loads corresponding load on for those number of rotations then can find out what will be equivalent load. Once I know the equivalent load we can find out the operating life, here is the total number of cycles and then we can find out the bearing life in number of hours, number of days, number of rotations whichever is required.

But here again we are assuming the life bearing is subjected to load for the sometime it is repeating, it is not continuously changing for L 1 rotation the bearing is subjected to load p 1 and more like a static load, but magnitude is changing after certain rotation. There is other possibility load is changing on magnitude from p max to p minimum in the average rotation, say maximum load and minimum load.

In that case we do not use a summation and p min plus p max divided by 2 because we know higher load is much more harmful compared to lower load that is why we go ahead with this kind of ratio say 33 percent of the p min and 66.6 percent of a p max. Again we are not directly going for the maximum load, we know the bearing is the fatigue is subjected to fatigue, lower load is always half. So, we want to count that that, that is why we say the equivalent load for dynamic cases. Dynamic cases in the sense the load is continuously changing, is changing between the p max and p min in 1 rotation then we should count equivalent load this 1 this relation.

However there is another possibility, a combination. You say p 1 is a constant load the way we consider in the previous slides, but p 2 is a rotational load at every degree that load is a changing its direction. So, this is a not magnitude is changing, but the direction is changing that is why we have divided p 1 constant load always directed to 1 direction while p 2 is continuously changing.

So, in that situation we use this relation. This relation shows say the p 2 1 plus 0.5 in bracket p 1 by p 2 square of the that similarly in the second the p is equal to p 1 one plus 0.5 p 2 by p 1 square of that. Question comes when should I use this relation when then should I use this relation? This is for the only this situation when p is a constant load, p 2 is a rotational load. Again these are the (( )) equation there is no complete science behind that it has been based on the experience.

Now, wherever the dominating factors comes if the p 2, if the p 2 is much larger than p 1 then we should use this relation. If p 1 is much larger than p 2 then we should choose this relation what is a overall thing or some time people can think what will happen if p 1 is equal to p 2, if p 1 is equal to p 2 we can choose any of this relation both the relations because we are going to convert to the same solution same results you can see p 1 is a p 2 and this will be 1 one plus 0.5.

Now, here the p 1 and p 2 is the same relation. So, whenever p 1 p 2 I can choose any of the relation p 2 is greater than p 1 I will choose this relation, when p 1 is greater than p 2 I will choose this relation. So, depends on what is the magnitude of p 1 and p 2 and compare it and based on that we can find out what will be the equivalent to radial load carrying capacity or equivalent load capacity required from the system.

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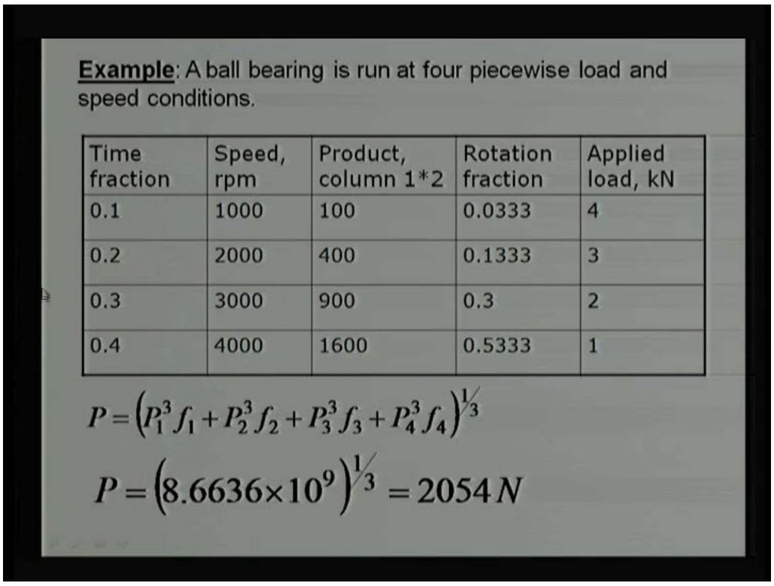

Example: A ball bearing is run at four piecewise load and speed conditions.

Time fraction	Speed, rpm	Product, column 1*2	Rotation fraction	Applied load, kN
0.1	1000	100	0.0333	4
0.2	2000	400	0.1333	3
0.3	3000	900	0.3	2
0.4	4000	1600	0.5333	1

$$P = \left(P_1^3 f_1 + P_2^3 f_2 + P_3^3 f_3 + P_4^3 f_4\right)^{1/3}$$

$$P = \left(8.6636 \times 10^9\right)^{1/3} = 2054\,N$$

Now, once we know p we can estimate bearing life. Let us have an example; see in this case we have seen 1 ball bearing is running at a 4 piece wise load. What is a piece wise load? We say that in first case it is subjected to load or the 4 kilo Newton for certain rotation may be say when is the operating at the 1000 RPM and for the overall time, we say the for 10 percent of the total time is running at the 4 kilo Newton. For that 20 percent of total time, it is running at 2000 RPM, but lesser load that is a 3 kilo Newton; for 30 percent of the total time this bearing is running at 3000 RPM and applied load 2 kilo Newton, for 40 percent of total friction of time or time is running at a 4000 RPM and applied load is 1 kilo Newton.

Here we required f 1, f 2, f 3, f 4 and nothing is been given. So, what we need to do we need to find out first the rotation. How many rotations at this load? Naturally 0.1 time into 1000, we are calculating based on that we find that this product is giving 100, here again the 0.2 into this rotation or this RPM is been the 400. What we are saying that number of rotation have increasing or we do not need final number of rotations for time being when we are trying to find out the equivalent load final number of rotation we required when we trying to find out overall life.

In this case we are just calculating fraction and we say that ratio here the 1 into 2, it is the time which we assume in the minutes or it is a dimensional as such, but if I assume from that point of view that is the 0.1 into 100 we say total time. I can assume here which is a can be neglected later; that means, this is not giving absolute value in the rotation, but it is giving in that proportion.

So, the this product is giving value proportion to rotation multiplied will be the t here and this 100 is one, 400, 900 and 1600 we sum up and normalize it what we will get a fraction, that fraction F 1 for the first case is a 0.033 was much lesser; that means, this bearing is not operating at a much longer time for much longer number of rotation or 4 kilo Newton. That means, happening only for the some time when we say some rotation or some rotation. Coming to the second rotation is a 0.133 for 3 kilo Newton the fraction is a 0.3 on a higher side for the 2 kilo Newton. A major junk a major number of rotations are happening at the 1 kilo Newton.

Now, if we use this relation in this equivalent load what we get p 1 q that is a 4 kilo Newton is here in the highly penalty on that, but this friction is lesser, since 1 that second thing is a 3 kilo Newton over here. So, we need to substitute p 2 is equal to 3 kilo Newton and F 2 is 0.133, for third case what we are saying that this 2 kilo Newton, p 3 is equal to 2 kilo Newton and F 3 is equal to point 3 here in this case the p 4 is equal to 1 kilo Newton, F 4 is equal to 0.533. Naturally we need to represent this kilo Newton and Newton we have to say p 1 is 4000, p 2 is a 3000, p 3 is a 2000. p 4 is a 1000 and this fraction will be multiplied with that when we take a cubic route of this what we get is equivalent load is 2054 Newton or this equivalent load is a roughly 2 kilo Newton.

And this can be shown over here the major junk of time is happening in 1 and 2 and in some time between the 3. So, this is a average is coming somewhere here, it is not in between. It is not 2.5 because the fraction of the time which is spent on the 4 kilo Newton and a 3 kilo Newton is much lesser than this fraction. So, this is an equivalent load carrying capacity. They can utilize this to find out what will be the overall life of the bearing based on this. We will continue on the selection of the bearing in our next lecture. Thank you for your attention.