Tribology

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Lecture No. # 29

Rolling Element Bearings (Contd.)

Welcome to 29 th lecture of video course on Tribology. The topic of present lecture is Rolling Element Bearings. In previous lecture also we discussed about the rolling element bearings, so we are continuing with those discussions.

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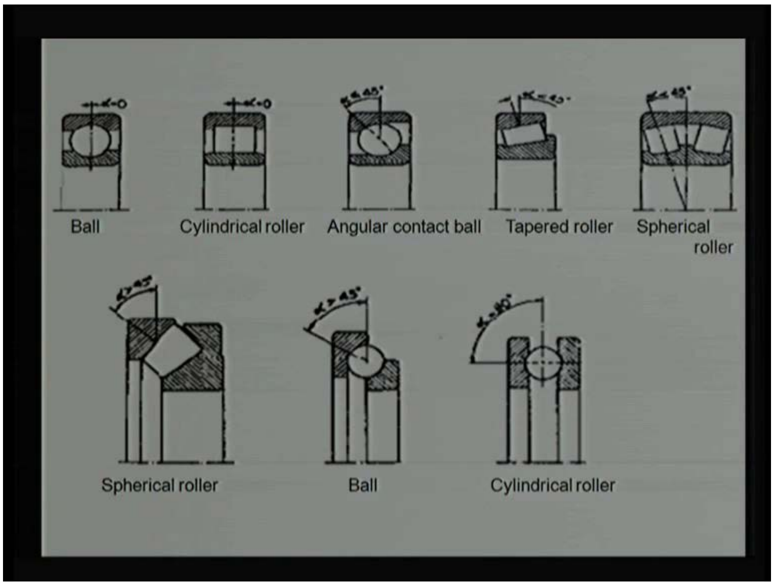

In previous lecture, we showed this slide and so that couple of bearings are exclusively used for the radial load, the first configuration, second configuration where alpha is equal to 0, this kind of bearings are meant for the radial load to support the radial load. Is the alpha angle is increasing to 45 degree, this kind of configuration can be used to support radial load as well as thrust load, axial load; when alpha turnout to be 90 degree meaning for this kind of bearing is to support axial load, thrust load that is the main focus.

So, it depends on the load arrangement, various configuration of the bearings can be used whether it is a ball bearing or roller bearing or taper roller bearing; it will be decided based on load, applied load which need to be supported by these bearing.

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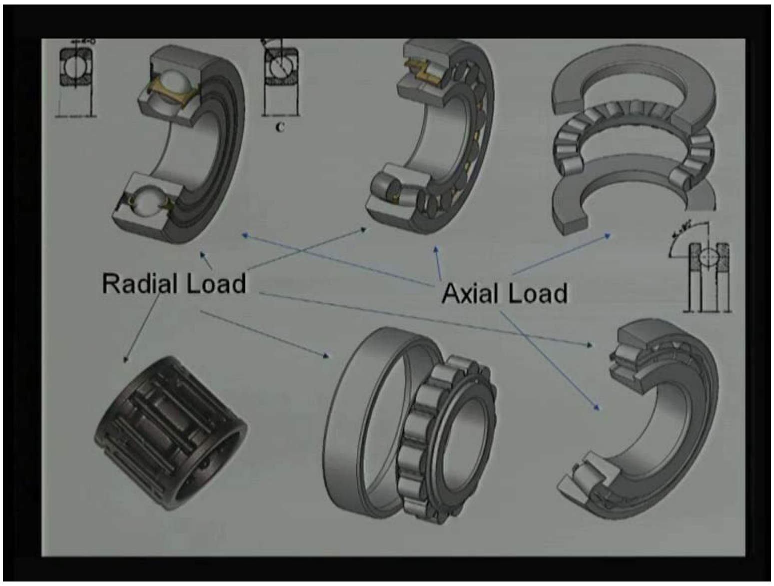

A better configuration or we say better presentation of those bearing is given in the present slide, there three dimensional models are given, so this is ball bearing with a some sought of curvature, some partition there is no complete race, there is a some sought of fragmentation of the race. And this looks like a this kind of configuration, were alpha is a 45 degree, this kind of bearings can be used for the axial as well as the radial load, that is why I say that radial load is pointed over here, axial load is also pointed over here.

Now, when we see this kind of a roller bearing, roller have a some curvature, this one these are rollers are not a straight not only this, there is a some sought of the groove arrangement in the rays or ring, were these kind, these roller can be placed. Again this kind of a bearing can be used for supporting, majorly radial load, but to some extent axial load, so that arrow which of the length of the arrow is showing a small axial load and more radial load.

Similarly, in this case the more axial load and small radial load, while in this case we are able to show that this bearing is meant only for thrust load, this is a thrust roller bearing. Rollers are arranged in cage to separate to keep some space between the rollers, so there should be not be much sliding among the rollers. And load will be transferred from one ring to other ring, but motion will not be transferred, one ring is rotating other is a stationary, the motion is not getting transferred, but load is getting transferred. And this is shown in this configuration, this is an alpha is equal to 90 degree, alpha 90 means, it is meant for axial load to support thrust load.

Now, this bearing is shown as a needle roller bearing, you can see the needles or length of these roller is much larger that diameter of these rollers. Again these needle roller bearings, needle rollers are placed in cage, to avoid the colliding or rubbing of one roller against another roller. And these bearings are meant to support radial load, these bearings are not capable to support axial load.

Similarly, this roller bearing you can see the length to diameter ratio is much lesser than this bearing, this kind of configuration is used to support radial load, there is the outer ring, and there is a cage, rollers and inner ring. Now, this bearing is showed with a radial load to support radial load as well as axial load. And there is some sought of a tapered group roller are inclined at axis, so it can be sustained or this kind of bearing can sustain some axial load.

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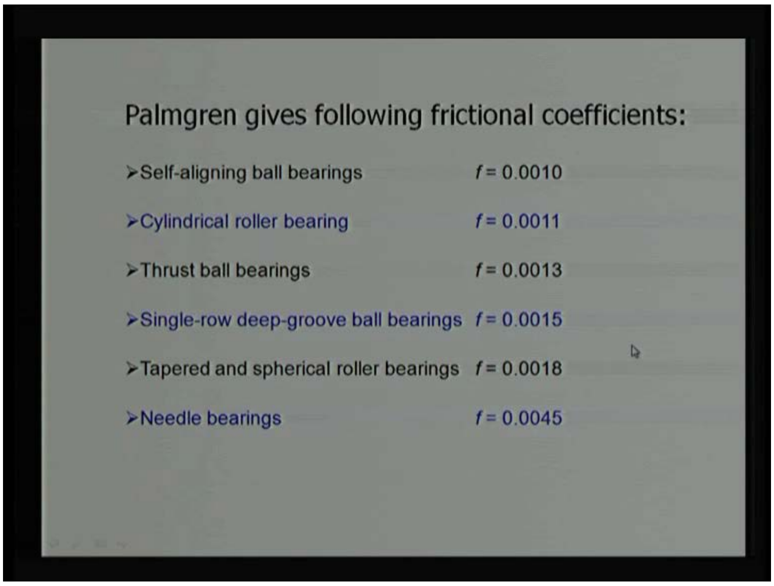

This slide shows a comparative study among the coefficient of frictions, you can say the coefficient of coefficient of friction f, for self aligning ball bearing is given as a 0.001, coefficient of friction for needle roller bearing is given as a 0.0045, for other bearings also description of friction is given. But, we know very well the coefficient of friction is a system property, it cannot be just a bearing property, without lubricant coefficient of friction will increase; with the too much lubricant again coefficient of friction will increase. And lubricant with a different viscosity of with a different boundary additive may show different results.

So, we say that coefficient of friction, as such is the system property with the lubricant plays a role kind of configuration or arrangement of roller bearing will play role in addition, how these bearings are mounting will be playing important role. But, this is a comparative study, we are assuming good lubricant in used and bearings are properly mounted in the other situation, this is relate to ranking of bearing from coefficient of friction point of view.

So, one question comes or we say that, one point or one discussion point comes should, I choose self aligning ball bearing for the every case, in previous slide we say that depending on the load we had to choose a configuration. And if we have configuration or we have option, then we may choose one of the sphere ring or we say that, for all the kind of load or we say in our application all kind of bearings can be utilized, then coefficient of friction comes.

But, we know radial roller bearing and thrust bearing cannot be kept in a same basket. So, depending which is the application, what is the application, where load is a radial or thrust we have to select the good kind of the bearing first, and then if we have a choice, when we can then we can think about the coefficient of friction.

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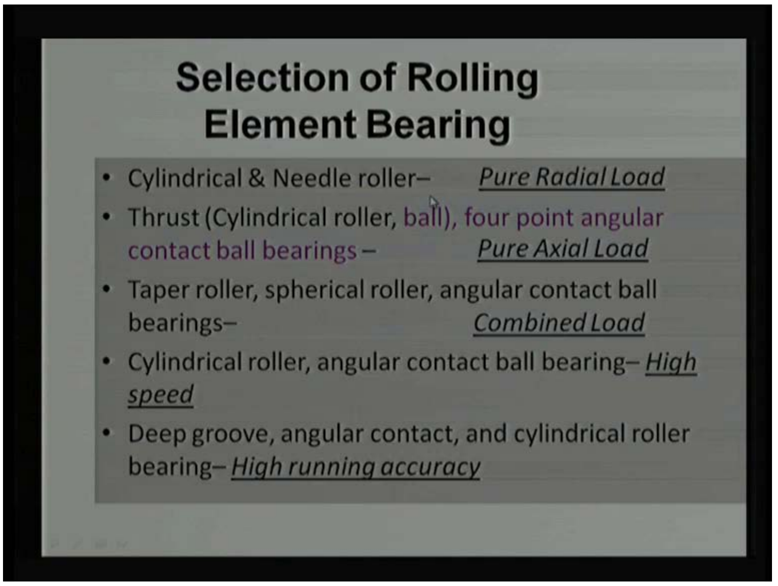

To think about selection of bearing from load point of view, say pure radial load, pure axial load, a combination of axial and radial load, we have a options available say for pure radial load, I can think about a needle roller bearing, I can think about a cylindrical roller bearing, many times we are able to think about the ball bearings also. But, if I compare from load point of view, from radial load point of view cylindrical roller bearing and needle roller bearing will be preferable choice compared to ball bearings.

Coming to the pure axial load, will be thinking either the ball bearing or roller bearing but, of thrust type, it is a thrust cylindrical roller bearing, thrust ball bearing, there is another configuration of ball bearing, what we call as a four point angular contact ball bearing. Why we are using the word four, because we know the in case of the ball bearing we will be having two point of contacts, but if you want to increase a load carrying capacity in axial direction, then we need to increase a contact points. And optimum contact points in that situation are four, that is why we say the four point angular contact ball bearing.

Coming to combined load, we have a number of options, but preferable options are tapered roller bearing, spherical roller bearing or angular contact ball bearings; we saw preferable choices, how the deep groove ball bearing was also can be used for the combined load. But, in that situation axial load friction is much lesser than radial load however, other than the load option, if we have requirement for the high speed application or we say that we require extremely high running accuracy, then we have a different option, it is a deep groove ball bearing. Generally have more confined rollers, they will show better support or they will provide better support to the spindle or shaft that is why, they can be named with a high running accuracy or closely confined roller bearings can be used for that purpose. Coming to the high speed application, where we require lesser contact in that situation we can recommend, cylindrical roller bearing with liquor lubricant or angular contact bearing with liquor lubricant.

On other configuration can be used with the greases, when we think about high speed application we need to think from liquor lubricant point of view. And bearing need to have high load carrying capacity, where scissor has a lesser tendency, so based on the requirement whether it is a radial load, thrust load, combined load, high accuracy, high speed application, we can choose one of the this kind of bearing; and if we have options, we can choose from coefficient of friction point of view.

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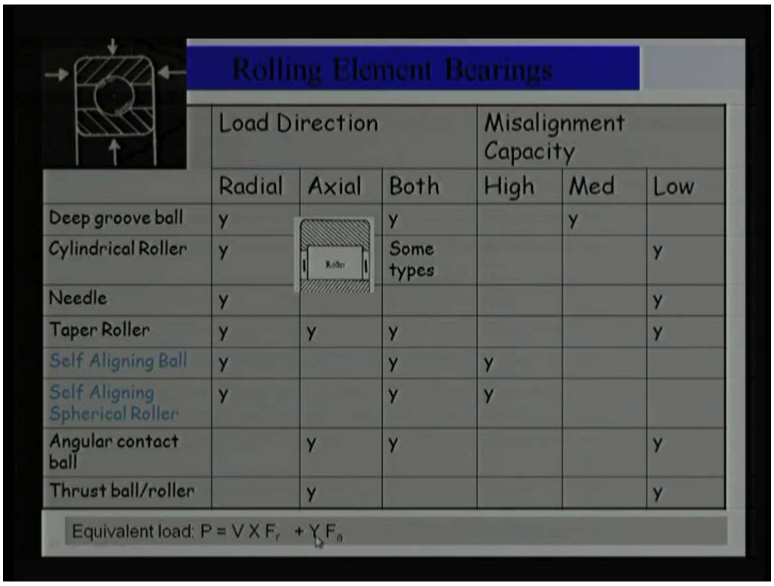

Now, this is another slide shown as a for the comparative study, whether we are adding one more parameter that is a misalignment capabilities, say deep groove ball bearings, they have a medium misalignment capability. However, roller bearing, needle roller bearing, taper roller bearing they have very low capability to sustain misalignment. So, if there is a misalignment and we have a choice, we prefer self aligning ball bearing or self aligning spherical roller bearing, from misalignment capabilities point of view. A factor load carrying capacity will be lesser, but the misalignment point of view they are preferable, we know if there is a misalignment. And if I am going to choose a cylindrical roller bearing, whatever the load carrying capacity is given that will not be sufficient, because load will be concentrated on one or two points and will generate very high coefficient of friction there, and this kind of bearing will fail.

So, slightly lesser load carrying capacity, but more adjustable bearing or more adoptable bearing can perform much better way similarly, we have options for other bearing. Say now, if I think from the combination point of view, deep groove ball bearing is able to sustain, major radial load and to some extent axial load, cylindrical roller bearing only few configurations can be used for the axial load also. There major thing of this cylindrical roller bearings, majorly are used for a radial load but, some configuration like this configuration can be used for slightly axial load.

Coming to needle roller bearing they should not be used for axial load, unless they is a axial needle roller bearing or thrust needle roller bearing. Angular contact bearing and thrust ball bearings, they are mainly used for the axial load; no one should be used for that purpose. So, this kind of a comparison gives some option to us how to select the bearing, some time we need to think, if there is a application of radial load and axial load how to treat that, how to find which load is really required for our application.

To deal with this situation, we can deal with or we can say that there is a equivalent load concept, we need to find what is equivalent load, how to define equivalent load the P it is a V into X into F r plus Y into F a, what is the meaning of this term, what is a V, what is X, what is F r, what is Y, what is F a, it has been defined in this slide.

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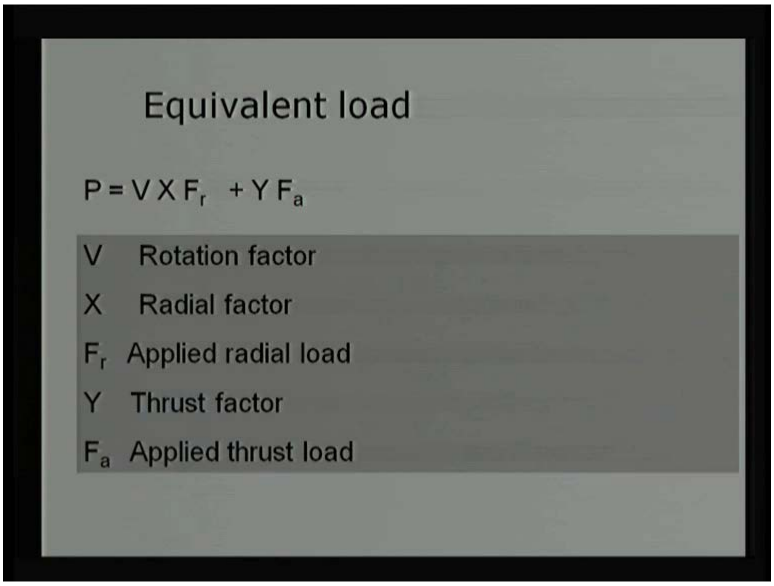

So, V is a rotation factor, with the inner ring is rotating or outer ring is rotating, if there is a rotation of outer ring, V factor will increase or we say that, impose low is going to be increase, if we are allowing outer ring to rotate and inner ring to be stationary. Coming to the X factor is a radial factor is a fraction, which need to be multiplied with a radial load F r is a radial load similarly, Y is a thrust factor need to be multiplied with a thrust load.

So, once we know F a, once we know F r we know whether the inner ring is rotating or outer ring is rotating. We can choose some bearings and for those bearings, we can find what is a value of X and Y, from the catalog, is your X and Y bearings are values will be given in a catalog from different manufacturer.

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Bearing type		Inner ring		Single row		Double row				e
		Rotating	Stationary	$F_a/VF_r > e$		$F_a/VF_r \le e$		$F_a/VF_r > e$		
Deep groove ball bearing	F_a/C_0	V	V	X	Y	X	Y	X	Y	
	.014	1	1.2	0.56	2.30	1	0	0.56	2.30	.19
	.028				1.99				1.99	.22
	.056				1.71				1.71	.26
	.084				1.55				1.55	.28
	.11				1.45				1.45	.3
	.17				1.31				1.31	.34
	.28				1.15				1.15	.38
	.42				1.04				1.04	.42
	.56				1.00				1.00	.44
Angular contact ball bearing	20	1	1.2	.43	1.0	1	1.09	.70	1.63	.57
	25			.41	.87		.92	.67	1.44	.68
	30			.39	.76		.78	.63	1.24	.80
	35			.37	.66		.66	.60	1.07	.95
	40			.35	.57		.55	.57	.93	1.14
Self aligning ball bearing		1	1	.4	.4 $\cot\alpha$	1	.42 $\cot\alpha$	.65	.65 $\cot\alpha$	1.5 $\tan\alpha$

For example, if I think about the deep groove ball bearing, factors are given off course, for single row, for double row this factors are slightly different, and these factors are decided based on the one parameter that is the e of in coated in catalog. And we need to compare this e with this ration, what we say, what is axial force and what is static load carrying capacity of the bearing, C 0 will be available in catalog, F is generally given in question.

So, we need to find out the fraction for that kind of bearing, and inner ring if it is rotating this V will be 1, if a outer ring is rotating and inner ring is stationary, this factor will be 1.2 based on this, we can find out what is the F divided by V divided by F r and based on this factor, we find whether the this ratio is more than e or lesser than e, is this factor is a more than e than only we need to choose this factor X and Y. Otherwise, it will be always 1 and 0, if this fraction is a lesser than e or we say that, we have selected this bearing or this kind of bearing and we have a value of e as a 0.19.

If this fraction axial load is a lesser than 19 percent and off course, the inner ring is rotating than we say that this bearing can sustain the load, axial load without accounting or without calculating a factor load. Similarly, there is a column or there is a row for the angular contact ball bearing, where the contact angle alpha is going to decide what will be the factor, if the contact angle is 20 degree, we can see this of a single row, this factor is 0.43 and 1.0.

As this contact angle is increasing X value is decreasing of fraction of radial load is decreasing, and this is also decreasing, when we talk about the double row, in this case it is comparing with e (Refer Slide Time: 18:30). Similarly, for the self aligning ball bearing however, in this case alpha lining, but this is already have adjustment. So, it does not affect, their inner ring rotation or outer ring rotation, V is 1 always, 1 for self aligning ball bearing.

So, based on this kind of chart, based on the bearing or selected bearing, we can find out what will be factual load on bearing, if there is a combination of load applied on the bearing, in this no combination, if there exclusively axial thrust force is applied, we do not have to use, we do not have to calculate P equivalent using F r and F a that will be straight forward. Similarly, if there is a exclusively radial load then I do not have to or we do not have to calculate, a factual load using that equation, a factual load is given as such in a problem.

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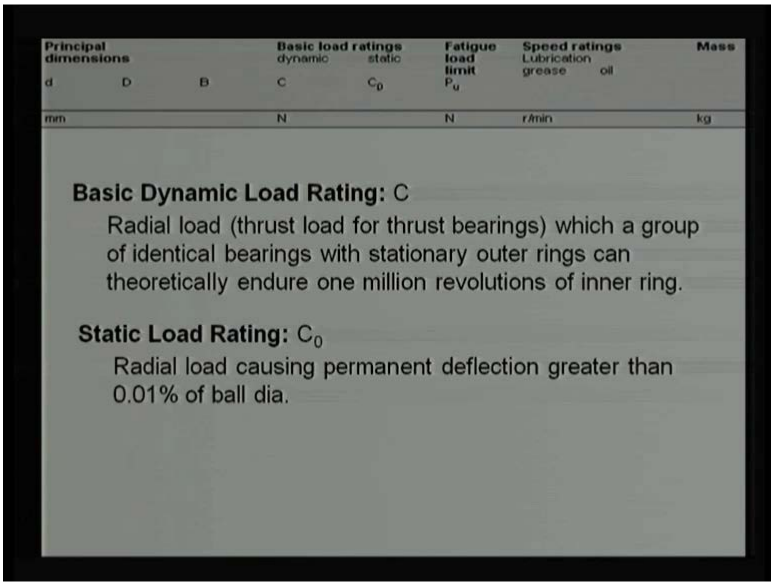

Now, we use the word or we use the parameter C 0, in the previous slide that is known as static load carrying capacity. When we see the catalog, catalog will be given in this term, there will be D dimension of the diameter of what we known as the board diameter, outer diameter, length or bearing that is a B. C is a dynamic load carrying capacity, C 0 is a static load carrying capacity, than we have another column that is shown as a fatigue load limit, then we have a column for with the lubrication is a grease lubricated or is a oil lubricated, based on this speed will be decided, as I say that it maximum is speed of operation can be decided based on this. And often speed of operation, in case of the oil will be higher than the grease, so on the time is to define what is C 0, and what is a C, which is generally coated, listed in catalog but, we say the static load carrying capacity that is a C 0 is related to how much force is been applied.

And that force is able to generate 0.01 percent of ball diameter deflection, say that when we apply a load on any structure or any element, on any material that material is going to deflect, may be at the (()) or a nanometer level or in a micro meter level, depend on a stiffness of the element and depend on apply load. And C 0 says this is a load when applied on the ball bearing or the roller bearing, the deflection will be equivalent to 0.01 percent of rolling element diameter, if it is a roller it will be roller diameter, if it is a ball is a ball diameter.

Another one the ball diameter is a 5 mm, than what we have to do 0.01 divided by 100 into 5 mm, that will be deflection or it will be 5 into 5 is to minus 4 mm or we say the 500 micron will be the deflection fast this much load. And we should never exceed a static load more than C 0, coming to the dynamic load we know every rolling bearing or every rolling element bearing will be subjected to fatigue loading, that is decided what will be the life of bearing, say it is a radial load, if it is a thrust bearing then it will be thrust load.

Apply to a group of identical bearings; because these bearings are thruster in group, it is not individual bearing with stationary outer ring that means, V is always one for this situation. And with this kind of a load bearing is able to show 10 is to 6 rotation of inner ring or bearing is able to show 10 is to 6 cycles for the apply load equivalent to C in Newton, when inner ring is rotating and outer ring is a stationary. So, these ratings are these capacities, load capacities are defined in catalog, how to utilize this, what is the benefit of using this kind of a parameters.

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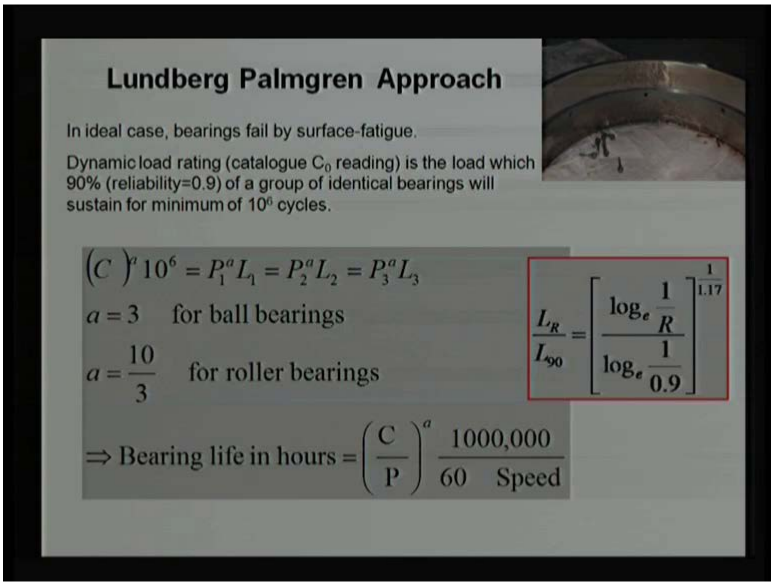

We say that, when we have values of c available we can find out what will be the life of bearing or we say fatigue life of the bearing, what will be the survivability of that kind of bearing. And that equation is famous with the author name the Lundberg and Palmgren we have showed a in earlier slide Palmgren comparative chart for coefficient of friction that guy is more famous for bearing life equation, it was very famous equation.

What we say that, this is a bearing life follows power law, what is the meaning of this to say the C is generally capacity given in a catalog power a into 10 is to 6 cycle will be equivalent to any load applied on the bearing again power a into L 1 rotations; if P L is a lesser than C, naturally bearing life will be more than 10 is to 6 cycles. Off course, that depends on the, what is the value of a generally value of a is more than 1 its equal to 3 for ball bearing, and slightly more than 3 for roller bearing that, is a 10 by 3, that is 3.33.

In other words, for the same load, same capacity roller bearing will show slightly longer life compared to ball bearings. Now, if we define this the Lundeberg Palmgren equation, this kind of equation is valid for reliability equal to 0.9 or 90 percent survivability or some time they use L 10 life that means, failure probability is 10 percent. If I rearrange this equation, we can find bearing life in hours by this relation, it is a C is a dynamic load carrying capacity.

P is applied load if applied is a mixture or combination, then we should use P equivalent with radial load and thrust load is been combined, equal to in multiplied 10 is to 6 cycle divided by 60 to convert minute into speed, minute in hours and speed in rotation per minute. This is a simple way to define bearing life, that is why I say when we design, when we select bearing for any equipment you say bearing will survive for 2 years, 2 and half years, 3 years, 4 years, 5 years that will be based on this kind of equation with probability of success of 90 percent, and probability of failure as a 10 percent. If you want any other probability, then we need to modify this equation, and modification can be given by this relation.

What says that L for the some probability, it can be 99 percent, 95 percent, it can be 50 percent also, as function of log 1 by T that is a reliability value, it may be lesser than 1 and 0.99, 0.95, 0.9 or this is a 0.9 and this whole factor will be 1, 0.8, 0.7, 0.6 depend, what is aim of the design, when we have this equation we can find out the probability of success or life for that kind of probability.

And this is given for the as a fatigue life, we are not talking about the cracking, we are not talking about any other failure, exclusively pits formation, exclusively fatigue failure of ring. If there is a misalignment, the factor load will increase there is a possibility of the cracking of this bearings, in those situation this equation will not be valid, will not be very useful.

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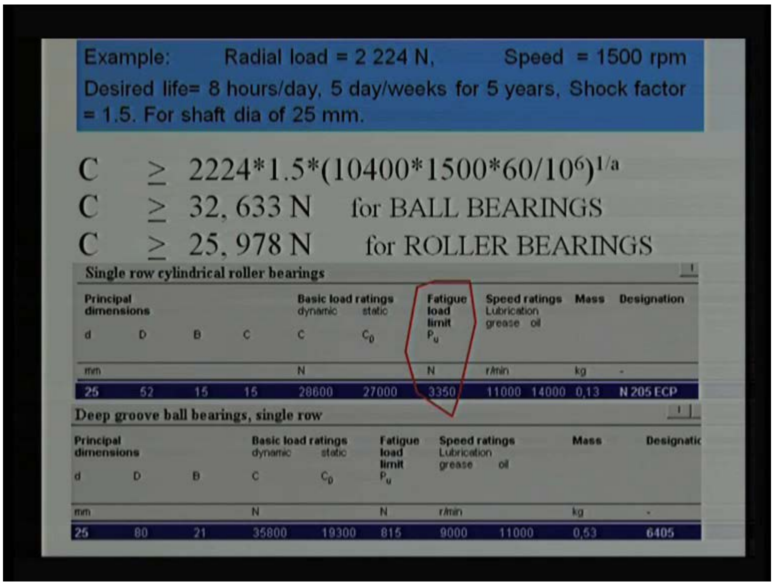

Now, let us take a one example, we say applied load on a bearing is radial load, and that value of the radial load is 2224 Newton, speed of operation or we say the rotational speed is given as a 1500 rpm, 1500 rotations per minute and what is the desirable life. So, we want to operate that machine for 8 hours in a day use well 5 days in a week again common practice, and we want that bearing in machine should survive for 5 years, there is a possibility of from shock loading some trans gen loading in between.

So, we need to tick slightly larger factor that the shock loading, because that is going to increase the fatigue failure that is going to cause some slightly more of fatigue value is equivalent to 1.5. And we need to select our bearing for sharp diameter or more than 25 mm, so we need to see catalog available to us, if we know what required dynamic load carrying capacity is.

So, what we will do we use a Palmgren equation, Lundeberg Palmgren equation, we know the radial load we do not have to calculate equivalent load, we need to calculate only the C, that will be 224 2224 into 1.5 as a shock factor, then desirable life, in hours than rpm into 60 divided by 10 is to 6 rotation. So, this has been converted in a factory rotations, we require this many rotations of bearing that is the 10400 into 1500 into 60, which is much larger than 10 is to 6.

And we know what is a applied load, here it will turn out to be 1 by a and a we know for the roller bearing is 10 by 3 and if ball bearing is 3, based on that if we calculate what we find, C for ball bearing is 32633 Newton is something like that 33 Newton, for ball bearing. As we know a is slightly move for roller bearing, even though for some same all other data, this factor will turn out to be slightly lesser; and that factor or we say static dynamic capacity for roller bearing is 25978 Newton or 26 clue Newton, which is surely lesser than 32.6 clue Newton.

Now, we have catalog for roller bearing, we have a catalog for ball bearing, see first is the single row cylindrical roller bearing, which is the easiest configuration; we are we are selecting bearing for shaft diameter of 25 mm done. So, that is over here, this bearing is for 25 mm shaft diameter, that is the board diameter is 25 mm outer diameter, for this kind of bearing which is able to dynamic capacity more than 25.978 clue Newton, that is available as 28.6 clue Newton.

And actually, the 28.6 clue Newton is more than this, so that means our bearings selection is justifiable is going to survive for the 5 years in ideal situation, without much misalignment, without improper mounting. Now, bearing links as a roller bearing, so the two-dimensions are given 15, 15 mm, inner ring 15 mm, outer ring 15 mm they are perfect combination, in addition we have fatigue limit, that is given as a 3350 Newton, which is a more than this radial load. That means, if the shock shock factor which we consider 1.5 is not necessary 1.5 may be lesser than that, then this kind of bearing is going to survive for forever, its not going to fail.

In the other word, any time applied load is lesser than fatigue limit than that kind of bearing can survive forever; if situations are situations remain ideal, there is no starvation, lubricant is proper, temperature is not going to increase suddenly from external environment, and then this kind of bearing is going to survive for ever. Now, in addition to this, there is two more value given, what is what is the values say speed rating, we can operate this bearing up to 11000 rpm, operating a speed in our case is a only 1500 rpm that means, this kind of a bearing can be (()) lubricated easily.

However, if some how we choose a bearing and that this speed is a lesser than what we require, then we need to go ahead with the liquid lubrication, while in this case the eleven thousand is much higher value compared to what we desire, than in those situation we can think about grease lubricated bearing. And there is a some number here given that this kind of bearing has a some designation, while say that N 205 ECP, what is the meaning of this designation, we will be discussing latter.

Now, we think about the ball bearing, this is from the roller bearing point of view; we have other option to the ball bearing. Now for ball bearing what we require, dynamic load carrying capacity as a 32.6 clue Newton, so we selected bearing which can survive or which can show this dynamic capacity more than this. And that is this kind of bearing which shows a 35800 Newton, which is more than that, however the dimension 25 mm is a board diameter which need to be the same as the shaft diameter.

Outer diameter of this bearing is 80 mm, which is much larger than 52 mm for the roller bearing that means, if there is a diametrical space restriction, I should choose cylindrical roller bearing compared to this deep groove ball bearing. Coming to the axial with side, length of the bearing in a roller case is a 15 mm, again which is a shorter that this 21 mm bearing length, that means we are going to get wind situation for the cylindrical roller bearing, if apply lid is load is exclusively axial load, we are getting lesser length, we are getting a lesser dimension or outer diameter.

In addition there was a fatigue limit, which is a more than what is applied load, well in case of the ball bearing, apply fatigue limit is a 1850 Newton, which is a much lesser is almost a 1 z compares to apply load that means, this bearing is surely going to subject to fatigue loading is going to be fatigue failure or there will be fatigue failure of this kind of bearing.

That means, if I go a head with some knowledge, I can choose a proper bearing otherwise is I do not go higher with the is, I now had to choose a one bearing easiest method is the choose directly ball bearing; assuming there will be a point contact coefficient of friction will be lesser for the deep groove ball bearing, I will pick up the ball bearing.

And when I do good analysis, I will find my choice is wrong or I have selected a bad bearing is a bad from outer dimension, is bad from length point of view, is a bad from fatigue point of view, and is bad also from operating speed point of view here, operating a speed was a 11000 permitted while, here we have only 9000. In addition with consideration, weight of this bearing is only 130 grams, while weight of this bearing is a 530 grams, from weight point of view this bearing is bad, from the speed point of view this bearing is bad.

From fatigue point of view this bearing is bad, from line point of view, from outer dimension point of view this deep groove ball bearing which is a general choice of an engineer is a bad choice (Refer Slide Time: 37:57). We should choose bearing after doing some analysis, some understanding is essential for bearing selection.

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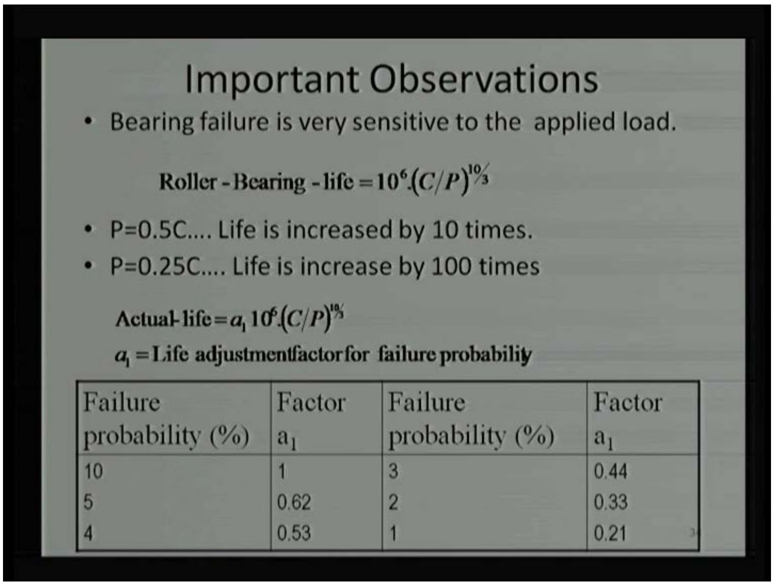

Now, what are the important observations which we got from this previous slide, you say that bearing failure is very sensitive to the applied load, why do we say that see, you have a bearing life calculation like this, where the C by P is a ratio, and power for the roller bearing is 10 by 3. Now, if I say instead of P equivalent to C, if I use p just of 50 percent of C reduce a load by 50 percent, am going to get 10 times benefit in the bearing life.

So, applied load is always going to show very high sensitivity towards the bearing life, now if applied load is further reduced to 50 percent of this 0.5 C, the bearing life is going to increase by another 10 times that means, if instead of P we apply a load equivalent to 25.25 P or we say initially if you apply P is equal to C. And latter second case, if we apply P is equal to 0.25 C, we are going to gain 100 times more life that means, bearing failure is very sensitive to the applied load particularly for fatigue failure.

Another thing, this bearing life is for the 90 percent reliability, if you want any other reliability then we need to add one factor, what we say this as a life adjustment factor, and that factor will change with kind of the reliability we need. We need a 90 percent reliability this factor is equal to 1, now we need a reliability of 95 percent or we say failure of probability of 5 percent then this factor is reduces to 62 percent only.

Now, if we increase reliability by 1, say we 1 reliability instead of 95 percent to 96 percent and we are able to see the factor is further reduced, this factor is a 0.53 almost half of that. So, instead of 90 percent reliability, if you think about the 96 percent reliability, we are going to lose almost 50 percent of the life, and we want 99 percent reliability, in that case only we are going to show or we are going to see the 21 percent of the bearing life. That means, again the reliability is very sensitive parameter as reliability changes, we are going to see different life of the bearing or we say that we bearing need to be replaced after that much.

If we have calculated bearing life with this equation, and we say that we need bearing life or we need very high reliability 99 percent of reliability, we need to multiply with the that bearing life calculated by this equation with 0.21, and it will be we need to replace this bearing after this much number of cycles.

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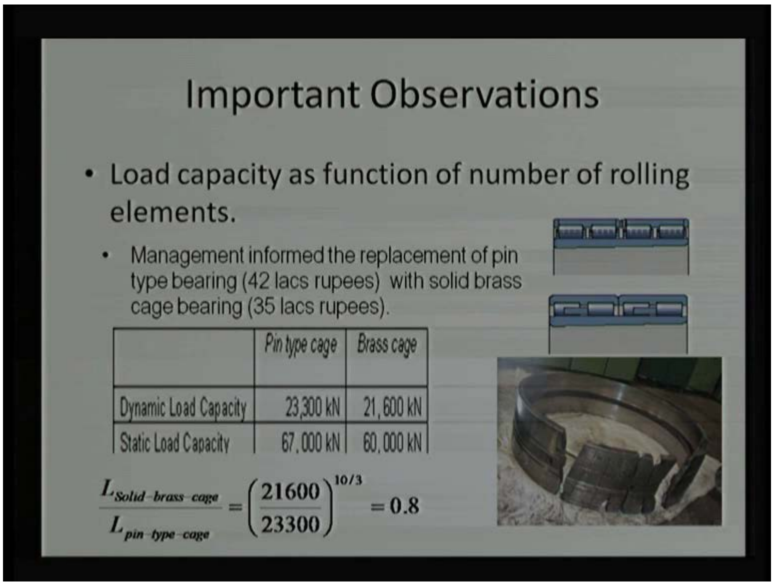

Go to the second observation, second observation was that load capacity, was shown in a previous lecture, load capacity depends on the number of rolling element. If in a one configuration same invalid dimension, number of rolling elements are increasing than you will know there will be increase in a coefficient of friction by load carrying capacity is going to increase. That was also realized in actual case, when we were dealing with a case study, were options were pin type cage and solid brass cage.

So, this is a cage were the pin type cage, this is a solid brass cage and am referring the case study of a previous lecture, when we mentioned when outer ring failed badly in almost no time 105 hours, and 300 operating hours. So, in this situation when we analyzing we found management took some decision, to replace existing pin type bearing with solid brass cage bearing. When we see or when we examine this kind of configuration, one obvious question comes, if there is a pin that is going to occupy lesser space, if there is a solid brass cage naturally, that is going to occupy more space, so how this kind of configuration was made.

In this situation, when we were using our company was using this kind of bearing there were 38 rollers per row, so 38 into 38 into 38 into 38 or we say 38 plus 38 plus 38 plus 38, while they shift it from pin type bearing to the solid case bearing number of rollers reduced, from 38 it reduced to the 34, means there was a 4 number of rollers lesser or we say almost 10 percent load carrying capacity must be reduced or that kind of bearing.

And we know load capacity is a very sensitive parameter and to affect the bearing life, that is why we ask them to provide the data, and then when we got the data something like this, so if dynamic load capacity for pin type cage bearing was 23.3 mega Newton. While for the brass cage, this capacity was 25 21.6 mega Newton, I will show you that clearly shows, this bearing are lesser number of rolling elements.

Off course, another kind of some other configuration was a solid cage also to some extent is affecting load carrying capacity, but major thing is number of rollers, here from 38, it has been reduced to 34 as a number of rollers are reduced naturally, load capacity will come down. And that is from 23.3 mega Newton load capacity was reduced to 21.6 mega Newton, when we pointed to company they say that, they took this decision from financial point of view bearing with the solid brass case, was a lesser in a cost roughly 35 lacks rupees.

While bearing with the pin type that time cost was around 42 lack rupees, it is something like a more than a 15 percent change in a cost, and they wanted to save the money and that is why they changed the bearing type. And interesting thing, they were also lying that solid brass cage is going to show always a lesser life, this kind of bearing was showing around 5 years life or we say 40000 hours of the life.

While this kind of the cage bearing was suppose to show slightly lesser life, and how much lesser, that can be calculated using the our equation, we say life for solid brass cage divided by life of pin type cage, can be given as a ratio of the dynamic capacity, that is to solid brass cage it will be for the same load, for same value of P. We can use this equation for same value of P, it will be 21.6 divided by 23.3 power of 10 or we say 3.33, and this ratio will turn out to be 0.8, that means solid brass cage bearing was suppose to show only 80 percent of pin type bearing life. If it was defined that the life of pin type cage bearing was 40000 hours, for solid brass case in this kind of bearing was suppose to show only 32000 of operating hours, so we point it out that, because of the change in the bearing life will change.

And if the life is changing naturally, the bearing will fail slightly earlier compared to what was supposed to be life of the bearing, and they agree also, but when they know very clearly that 40000 to 32000 is not a major decrease bearing; which was suppose to show 5 years life, it will show 4 years life, and they were ready to adjust this kind of behavior.

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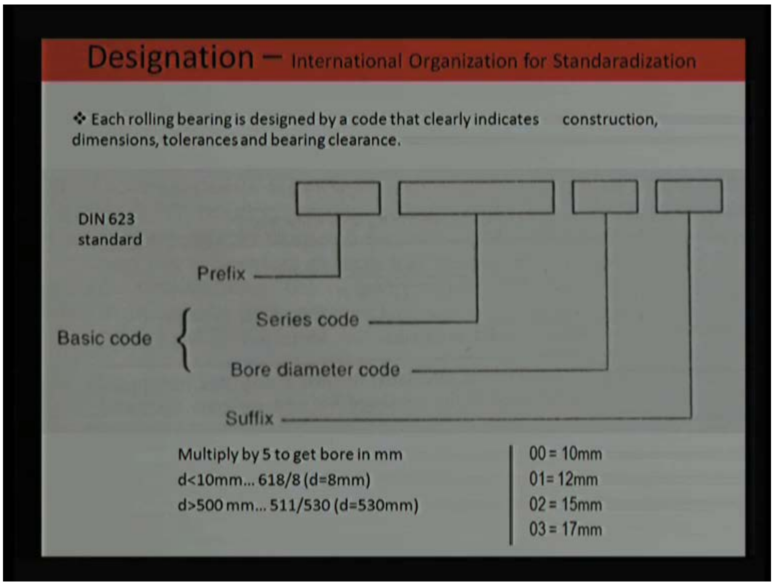

Now, in previous slide we mentioned about the some sought of a specification, when we referred the catalog we found there was some a specification was given for the bearing is something like an N and for the ball bearing it was a something like a 6405, some bearing number was given for the bearing. Now, if I we can refer back and see that catalog yeah here the designation for the ball bearing is given as a 6405 similarly, for roller bearing some specification is given as a N 205 ECP.

So, what is the meaning of that that is a called a normal creature of bearing, when we see the catalog this bearings are generally normal creature with some numbers. And we need to understand what is the meaning of that number, so we should not go ahead with a bad choice, and that designation, that specification is standardize by standards we say DIN 623 standard. What is the meaning of this number we say there is a different different option available, there will be prefix, there will be suffix, there will be serious code and there will be diameter code.

When we saw 64, 05 64, 05 for the ball bearing that means, series code was 64 both diameter code was 05, and there was no prefix there was no suffix was no prefix there was no suffix in this situation. But, for the roller bearing, there was suffix as well as prefix, suffix was ECP, we will be discussing those things. So, first see in this situation this series has been given as a board diameter code, we say that whatever the code board diameter code given in this, other 2 numbers need to be multiplied by 5 to give the board diameter.

For ball bearing what was the 64 in this and 05, in this 05 into 5 that is going to give what will be the diameter of both diameter of the bearing that is our 05 into 5, will be 25 mm and that is why we say that kind of bearing was selected for the shaft. However, there are some exceptions, some time we get a code here 00, (()) is that 00 cannot be multiplied with a 5, and we say if you multiply with a 5 the value will be 00.

And we know very well, there will not be any diameter board diameter something like a 00, which will not be able to mount on any shaft. So, some exception say when value of this bore code diameter code is 00, that meaning is 10 mm when this value is a 01 again it is not 5 mm diameter. If I multiply 01 into 5, it will be 5 mm but, actual diameter of the bearing will be 12 mm, 02 actual diameter of the bearing will be 15 mm, zero 03 it is the 17 mm.

And after that there is no problem 04 will be multiplied with a 5 to find out a board diameter, 05 will be multiplied with a 5 to find out the board diameter, 06 will be multiplied with the 5 to get a board diameter, 10 will be multiplied with a 5 to get the board diameter, even in the 99 will be multiplied with the 5 to get board diameter. So, the question comes its only two series, when we come to the 100 plus, then again there will be some variation, we say whenever there is a 100 number where the diameter is reaching to the 500 mm, in that case we need to write directly what is the diameter. Whether the 530 diameter, 511 diameter whatever, we need to write actual diameter in that situation we do not have to multiply with it. Similarly, if diameter of the bearing is a lesser than 10 mm, then again in that situation we need to specify diameter directly, so there is a bearing number 511, bearing number 618 (()), there is a bearing board diameter and the 530 there is a bearing diameter. So, this is a way one way to define a bearings, and when we talk about the series naturally, it is going to be different kind of series, may be series number 4, series number 5, series number 6 that is with a different dimension on the bearing.

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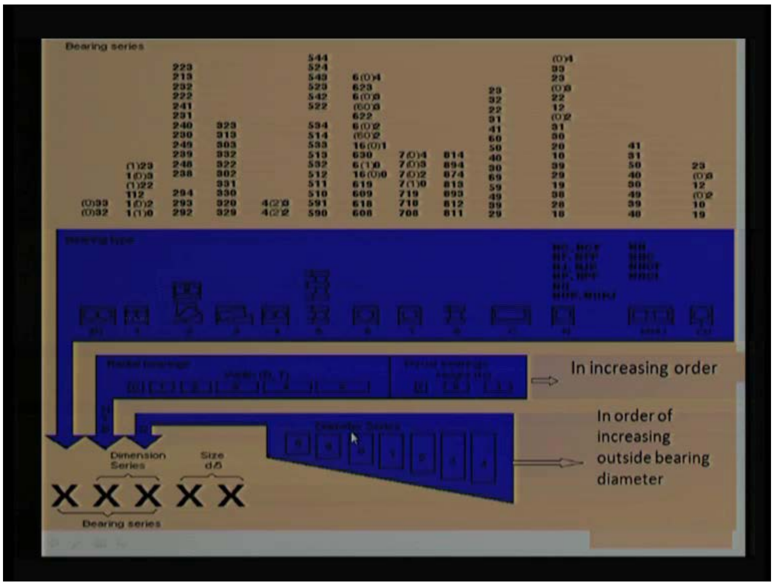

We will continue this topic, you can see this bearing dimensions are given, when we talk about the bearing type there are specified with a 0 number, 1 number, 2 number, 3 number, 4 number, 5 number, then we have a some sought of a width series, we have a height series, we have a diameter series.

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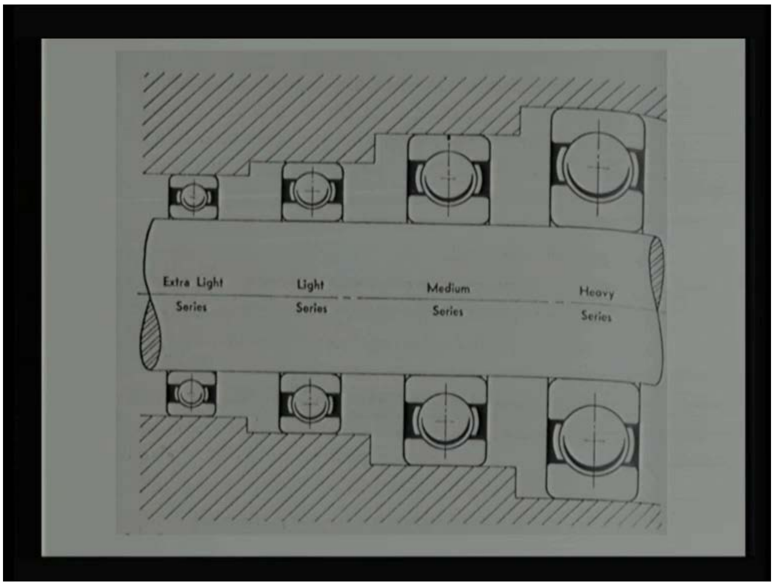

What is the meaning of that is this you say, for the same board diameter, if am assuming the 05 series for the same board diameter outer diameter may be different, in this case this is a smallest outer diameter, we can say this bearing can be used for a extra light series, then light series medium series and highway series. So, we are able to see four different diameters for the same kind of the board diameter.

So, we have a number of bearings available for the same board diameter, for the same shaft which we require for larger load carrying capacity, naturally load carrying capacity of this kind of bearing will be much larger, than this kind of the bearing. We will continue with this in our next lecture, thanks for your attention.