Tribology

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Module No. # 06

Lecture No. # 27

Applications of Tribology

Welcome to 27th lecture of video course on Tribology, today's topic is Applications of Tribology or we can say this is the second part of the course; we have understood, we have learnt the various fundamentals related to friction, way of lubrication, some basic theories require to design any type of pair. So, it is now time to apply those theories those fundamentals for real applications, and that is why this module name as it is applications of tribology and present lecture name is also application or tribology. In this module we will be having around 8 to 10 lectures exploring various applications, and how to utilize fundamental or fundamentals, which we have learnt in earlier lectures.

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You see that most common elements, most common components, which are used in number of machines, machines which have relative motion, any rotary motion, any

sliding motion, take an example of car, which is an automobile, aircraft, turbines, any compressor all these require tribo elements, they require some sort of sliding motion, some sort of rotational motion. And that is why we require, application of tribologies to design those components, which are utilized for relative motion under load.

Common elements are the bearings, gears, cams, brakes and seals, what we say, bearing means to bear the load, this element needs to bear the load and provide some sort of isolation, isolation between rotating part and stationary part, isolation between sliding part and stationary part, so they are meant to support the load and provide isolation. Take an example of gears, gears are also supposed to bear the load, cams are also supposed to bear the load, brakes yeah they are supposed to bear the load, seals also they have some sort of sliding, some sort of relative motion.

So, in fact, all these components can be categorized as the bearings, then question comes while we are writing five different categories, bearings is separate category, gears are separate category, cams in separate category, brakes and seals in separate category, what is the logic, what is the reason behind that? You say this category of classification is from functional point of view, not from fundamental point of view, it is more like functional point of view. In case gears the main aim is to transmit the torque or transmit the motion; particularly they have been used as the amplification factors to enhance the torque to carry much more load.

So, they are supposed to increase the torque from 1 unit to the 40 unit and if we require much larger than that, then we can use the multi stage gears. Coming to cams, the functionality is basically to convert rotary motion in reciprocating motion, the function is different, and then gives that the function is different than the bearings even though fundamental knowledge required designing these kinds of cams may be same.

Coming to the brakes, these components are required to stop the motion, we do not have a motion or they are supposed to restrict the motion, sometimes we use the category clutches and brakes well as you have seen in clutches, we want motion to be transmitted. In brakes we need to stop the motion fundamentals are same, the design procedure remain same, so we will be discussing the brakes and may be to some extent we can describe about the clutches.

Next category is the seals, the functionality again change, we want to stop the leakage of the liquid or gases many times there are harmful gases and we cannot allowed to release those gases into the environment, so we require seals. There are very harmful liquids, which cannot be allowed to leak, so we require seals. Many times the leakage of the lubricant which we use in the contaminant environment, as well as product take an example of textile, if we use a lubricant and textile thesis get a contaminated with liquid lubricant; that fabric will not be useful, so we want to restrict that, we want to restrict the leakage of the lubricant.

So, function is stop or minimize the leakage that is why, we require product c, to stop the motion we require brakes, transmit the motion from rotary to trans reciprocating motion or oscillatory motions, then we require cams, transmit the motion with high torque in (()) torque, we require gears to support the load we require bearings.

And of course, as I mentioned here that, there is a there is a possibility of rolling and sliding in almost all the components there are some sliding, some rolling; we know very well rolling causes the lesser friction, and causes the lesser rare compared to the sliding. That is why, as far as possible we should move to the rolling or we should (()) for the rolling action, but if it is not permitted or functionality is not allowing it, then we can think about the sliding.

And whenever this kind of classification comes, and we think about the bearings, what comes to in a mind, some rolling bearing elements bearings which is most popular, most commonly used readily available in a market, that is why I say, when I talk about bearing or when we think about that bearing, bearing appears in a mind, bearing have some sort of risk or ring it is an inner ring; some rolling elements, while we are saying the rolling elements, because they have their own axis of the rotation.

And there is some sort of outer ring, if inner ring rotates there is a possibility that outer ring remains stationary; so they are providing some sort of isolation, rotary motion from this point is not getting transmitted to the outer portion, which is required in many times in number of mechanisms. We need to think about this kind of bearing, design of this kind of bearing or selection of this kind of bearing.

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When you think about the sliding motion, this kind of bearing appears or this can be machines other bearings also, what we are able to see there is some sort of conformation there is a again sort of a ring, but in a thesis and this kind of a pads, what we call is a thrust pads, may be the radial pads. And they show different performance, if they are able to develop some sort of convergence they will be able to develop the pressure and if there is the development of pressure this component can sustain the load at some relative motion, you see the two lines of bearings.

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So, we can think about the classification of the bearings, you see the bearing classification based on relative motion; bearing can be classified as the rolling contact bearings or sliding contact bearings, using the word sliding contact bearings, many questions comes (()), if there is a sliding, there is a contact, so there will be too much friction. So, we should say only sliding bearing, we should not say sliding contact bearing, because always our aim is to separate two surfaces or we say our aim is always the sliding non contact bearing; so that is why I have many time used the word sliding bearing without thinking about contact or non contact.

And we try to design a non contact and we know very well at the initial level there will be some contact, when we are in start we can think about separation one way another way, where there is a magnetic gravitation, there is a hydrostatic levitation or some other levitation, where these points will be discussed when we detail about this kind of bearings. While this is an introductory lecture, where the classification of the elements are coming we are not going to discuss much about that, but which the two diagrams, I have two pictures which I showed in previous slide and just repeating here, there is a rolling contact bearing and this is a rolling contact bearing, because there are rolling element they have their own axis as well as they rotate about the axis of shaft.

They have their own axis as well as axis of a shaft and their rule, when there is a rule they have continuous point, change in a point of contact, because the wear is much be lesser compared to sliding contact and most of the energy is being consumed in the rolling motion, which is advisable particularly for tribo pairs. Coming after this one is this, is this the sliding contact wherever, other thrust bearing pads this is the, these are the pads and when other component comes will be the contact with this kind of pads or with this kind of pads.

And the fluid film is developed then there will be non contact, so we can say this is the classification, this is the relative motion, in this case of relative motion is rotational motion, while in this case relative motion is a sliding motion.

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We can think about as a arrangement is shown here, we can think about classification of bearing based on the direction available, this is color radial bearing apply load is generally in radial direction perpendicular to the axis, if I assume that is a axis passing at the center of this inner ring, now the load which is perpendicular to that, that is going to develop a radial stress.

And that is why, we call this as a radial bearing and many times as general bearing as the radial motion, while in this case this can be called as the thrust bearing, because a load will be along the axis of rotation, so it can be called a thrust bearing. However, if this is configuration, this configuration is being used, then we will call this also as the radial bearing, because the load applied load this case it can be perpendicular to the axis.

So, if the load is perpendicular to this phase then it will be cover thrust bearing, load perpendicular to this phase it will be called as radial bearing, and there is a possibility of combination there is a thrust bearing, there thrust load as well as the radial load, the biaxial load. So, the x along the x perpendicular to the axis there is a load yeah the possibility, so we use some kind of bearing as are this bearing or it can be use for sustaining the both radial load as well as the thrust load.

But, some kind of especial classification is colored taper roller bearing that is shown over here. So, remove this top cover outer ring while we are able to see, there is a some sort of taper roller, some sort of inclination I mean I know there is an inclination there will be

two components on the loads. One will be along the axis other will be perpendicular to the axis, that means this kind of configuration or this kind of bearing assembly or this kind of assembly is able to sustain radial load as well as axial load and it can be called a conical bearing or can be called taper roller bearing and is a very useful, most of the precision machines they use taper roller bearings. To manufacture sophisticated slightly costlier compared to the cylindrical bearing, compared to the wall bearings, kind of perfection in the cone is important, we will be discussing when we discuss about the rolling bearing.

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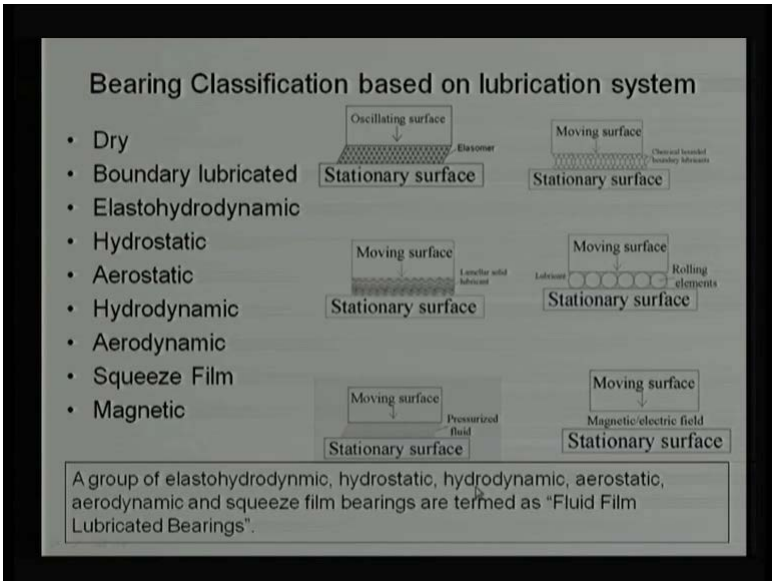

These are the possibility of a bearing classification (()) on lubrication mechanisms, we have understood what is a dry lubrication, what is a boundary lubrication, what is elastohydrodynamic lubrication, hydrostatic lubrication, aerostatic lubrication, hydrodynamic lubrication, aerodynamic lubrication, squeeze film lubrication of course, we have not discussed about the magnetic lubrication.

But, that can also come as a part of the lubrication mechanism, because we say the lubrication is lubricant is a substance to reduce the friction and wear, so in magnetic case there will be separation between the two components, two surfaces there will not be any where; so bearing based on the magnetic principles can also be classified in this category we can said a dry bearings, no lubricant or only solid lubricant.

Boundary lubricated some sort of additives, which have a stickiness either physical attachment or chemical attachment elastohydrodynamic lubrication, with this surfaces are going to deformed and with that kind of deformation the (()) of the series is going to increase, now that is configuration in travel fields, hydrostatic where we have to supply lubricant at higher pressure from external sources.

Coming to aerostatic instead of liquid, we are going to give some sort of gases especially used for high speed levitations what we are talking about is more like 50,000 RPM, we are talking about the sliding speed of the 50 meter per second, that is very high aerostatic. Coming to high coming to hydrodynamic lubrication, we are not going to supply from outside, but geometry is used in such a manner which can generate high pressure by containing liquid appropriately.

Instead of liquid, if we come to the gases on we start using the gases then it will be called aerodynamic bearing principle remains same except, we use the compressibility of gases, we know the liquid cannot be compressed beyond certain limit, the compressibility is very very limited while in gases the compressibility is not limited to that extent, that kind of compressibility can be utilized. Wherever, we utilized a clean bearings, no pollution, no contamination you can think about aerodynamic bearing only the problem is the control system, kind of surface surface which we require for aerodynamic bearing, so if all have cost permit, if all have pocket permit you should go aerodynamic bearing, if you pocket does not permit, we can think about other chip sources.

Coming this squeeze film bearing, most commonly it comes, because of the load application, because of the speed application, where there is a variable speed and variable load and this squeezing is actually will happen, so this can be the assumed as the byproduct, main action will be done by some other mechanism, and this can be, so this will be supporting, will be add one formation or additional load carrying capacity, because of the a squeeze film action.

Magnetic bearing known as the growing field, wherever more reliability is required we think about the magnetic bearing, no polishing, no contamination, and no maintenance you think about magnetic bearing. So, that is a growing fleet for time being the cost of the manufacturing is very very high, so cost really does not permit, pocket does not permit this kind of bearing. And many simple applications, we use this conventional

bearings or most extensively used bearing or where the technology is fully developed they can be produced in mass level and are the production cost is much cheaper, however every bearing has its own advantage and disadvantages, just to illustrate this kind of mechanism, we use a six sketches, you see there is a stationary surface, there is a oscillating surface. If this is the situation, because oscillation (()) 15 degree, 20 degree, 30 degree there is no computation it is only oscillation this moving surface is going to move this way, that way.

You mean, that way we can use elastro (()) bearing or elastro vessel lubricant, because we know that well in external can be stretched up to 50 percent and poison ratio is 1.5, so elastro can be used as the bearing material and it can be treated as the dry bearing there is no liquid lubricant, there is no gases lubricant its only the solid on a stretch ability of elastomeric is utilized to the full extent.

Talking about the second one is the boundary lubricated, we can able to show that there is some sort of polar ends at (()) surface, polar end attach the moving surface and there will be some sort of repulsion in their (()) and because of the repulsion they will not be intermingled, and there is no intermingling, and these are the soft easily bendable. The other lesser friction and boundary lubricated bearings can be utilized and in fact (()) when we talk about the hydrodynamic bearing we mix some sort of boundary additives, so that, initial situations can be sustained easily.

This is sketch is some sort of level of solid lubricants which is more like a molybdenum disulphide graphite with a labour layer structure can be separated out or stretched the way elastromers, you can say that they have a weak bond and there is a layer structure, so one layer can be stretched up to 20 percent, next layer on top of that 20 percent, 20 percent, 20 percent, 20 percent, so keep on adding.

And we are able to do develop lot of deformation without separation of layer itself, it is more like a modified form of elastomer and this layer keep the stretching and helping each other joining hands is the stretch and and enable to reduce friction and width however, depends on the application kind of what we say the rate of the speed variation, rate of the stretching or temperature, moisture many other parameters, they can show different performance. So, again now, this generally are not used as the main criteria as

they lubrication mechanisms, but can be added with (()) lubrication can be added with hydrodynamic lubrication it will be useful.

This shows some sort of rolling elements, there is a stationary surface, there is a moving surface and this is the load direction, surface is moving, partly in sliding there is no rotation, but because of this sliding, this sliding motion is getting rotational motion over here, if this balls are stationary, not stationary or fixed or hinged or some places and they are able to roll about on their own axis; this is more like conveyer belt, this this these are rollers are rotating about their own axis, so there is a rotational motion, easy rotational motion is not getting transmitted to the stationary service. So, isolation is done by rotational motion of these rolling elements, and this is the main function rolling about their axis that is why these kinds of bearings are known as the rolling element bearings.

And interesting think is that, this is the most commonly used bearings and there are more than 20,000 type of rolling element bearing, weighing from few mile grams to tons, these are stationary surface catch in this case is that we are saying the pressurizing of the liquid either by hydrodynamic action, aerodynamic action or by outside agencies from compressors, from palms, so there is a pressurization of the fluid and that pressure is able to keep two surfaces separate.

Able to generate some sort of isolation between moving surface and a stationary surfaces and the last one, we say that we have talked about the magnetic separation, well there is a possibility of electric separation also, we can generate field in such a manner there is a repulsion motion between two surfaces or we say magnetic repulsion between two surfaces or if we have a good control system, we can make this kind of configuration with attraction mode also, overall configuration can be used that way. Generally the group of elastohydrodynamic, hydrostatic, hydrodynamic, aerostatic, aerodynamic and squeeze film bearings, there is a clear cut liquid film between two surfaces, this gambit of bearings or this group of bearings can be termed as fluid film lubricated bearings.

And they have very common mechanism, common equation which we have done in our previous module, developing Reynolds's equation using elastic equation, using thermal equation, a combination of those equations are going to be helpful are able to give us designed guidelines for this kind of bearings, we will be exploring this in detail.

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Let us start, the application of tribology or whatever the various applications, so the bearings which we have discussed in the previous three, four slides number is gears the second number, we say that gears are more like a wheels having teeth and the tooth wheel and these teeth are required for the positive motion, we can use a two simple discs in fiction contact, what will be the advantage, if there is a one disc rotation or rotation of one disc that rotation can be transmitted to the other. And based on their diameter ratio we can decrease their speed, assuming the same energy is being transmitted, if the decrease in the speed naturally torque will increase or we know from the frictional point of view and confirmative point of view that this kind of friction disc there will be not in a contact, there will be more slip it lesser rolling action.

And that can generate more heat, more problems that is why, we say teeth are required for positive placement, so that there is continuous motion you should not happen one is rotating at 3,000 RPM, other sometime rotate at 200 RPM, sometime 400 RPM, sometime 600 RPM, 800 RPM or continuous variation then what will what is the loss, we are not going to get any definite motion, and whole functionality will be 0, useless component and that is why this kind of positive drive is important. But, this positive drive comes, because of the trip profile, you can see there is a variation in the dimension starting from some root dimension is reaching to the maximum dimension, and if the rotation is given with a variable dimensions, naturally speed ratio will change.

That is why we need a definite profile, definite profile of that trip and that trip profile is of often known as invalid profile, it is possible to use invalid profile for the cost and speed ratio, speed is not going to change, obviously the speed ratio is not going to change. Can you see the kind of profile it has some sort of convex trip, some sort of flirting, and this convex trip in common of contact with other trip pair is going to generate, very high pressure, high velocity formation when we talking about high that means still it is in the micron level, but need to be concrete, elastic deformation will have a fact on the load carrying capacity, and the kind of lubricant we use there will be some sort of thickening of those lubricants.

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Now, let us draw the different kind of configurations gears are classified you can see that there is a (()) a straight trip whatever the motion transmitted from a one or say smaller gear will be known as pinion to the gear, the axis are parallel; it is a parallel transmission however, there is a possibility of some sort of 90 degree bend, 60 degree bend or angle of inclination may be changing from 30, 45, 60 degree, then we need to change the profile then we use bevel gears, this is the bevel gears.

There is some sort of helical shape also, you see often we use the helical gear for the smooth motion, what we know as contact ratio, effective contact ratio then helical profile is more than two, what is the meaning of that, see when you see this per gears, there is a contact between the one trip pair, because the second trip comes in contact naturally they

need to be disengagement of first trip pair and there is no disengagement then there will be motion and this kind of variation changes the stiffness of the gear.

And that induce some sort of additional vibration to avoid that, that kind of impact loading, that kind of vibration we use helical profile, so this is a smoothing engagement, smooth disengagement. Contact ratio is high, what is the contact ratio is that when we say two, contact ratio more than two, effectively two pair of teeth are in contact; sometime we require a high torque ratio shall we use, we use a warm gear, the torque ratio can be you mean up to 40 to 1.

So, depends on kind of the profile which we use kind of applications which we use we can classify this gears are pro gears, helical gear, bevel gear, warm gear or hair bend gear when gearing of the helical gears, but whatever the gear, their value of phenomena (()) to some extent it is factor of a tooth and greater extent is a surface for teeth.

Mostly happens, because of the variable rolling to sliding ratio, even though I said this need to be rolling motion, but leg of the lubricant, change of the profile, change of the clearance, some sort of misalignment introduced more and more sliding, and it has been observed. Sliding to the rolling ratio many times happened to be 9 percent, this should show good performance, good efficiency, may be say 98 percent efficiency then sliding should be lesser than 2 percent, but the change in condition, change in clearance, environment is change in different performance.

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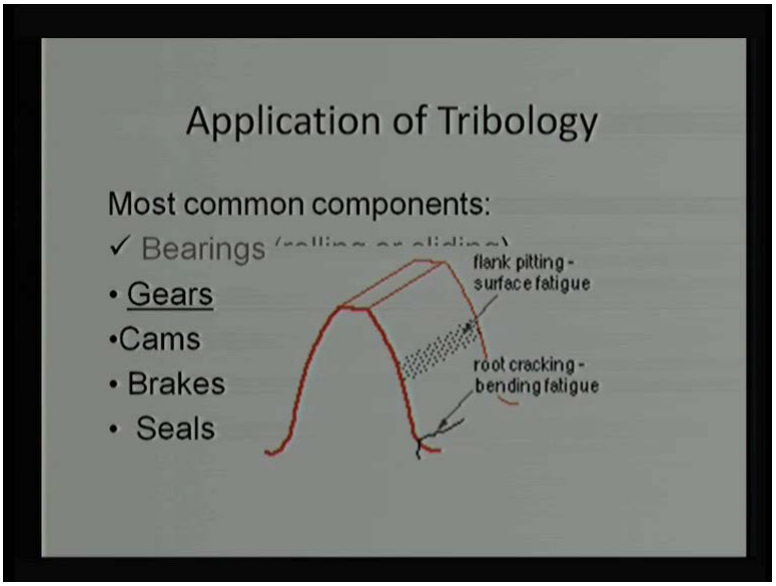

As I mentioned, whatever the helical profile or bevel profile or axis of rotation is different or angle of a rotation or angle of a load is different (()) may happen like this, the structure or the root surface or may be some sort of fatigue, client fatigue what we name as surface fatigue, we have a study of the surface fatigue. There is a possibility and again there is symmetry, there is a same knowledge can be utilized for the different gear pairs, we will be exploring these options. You have already learnt some sort of cracking, you have already learnt something about the surface fatigue, and we will be utilizing the kind of knowledge to predict the life of the gear pair to design the gear pair.

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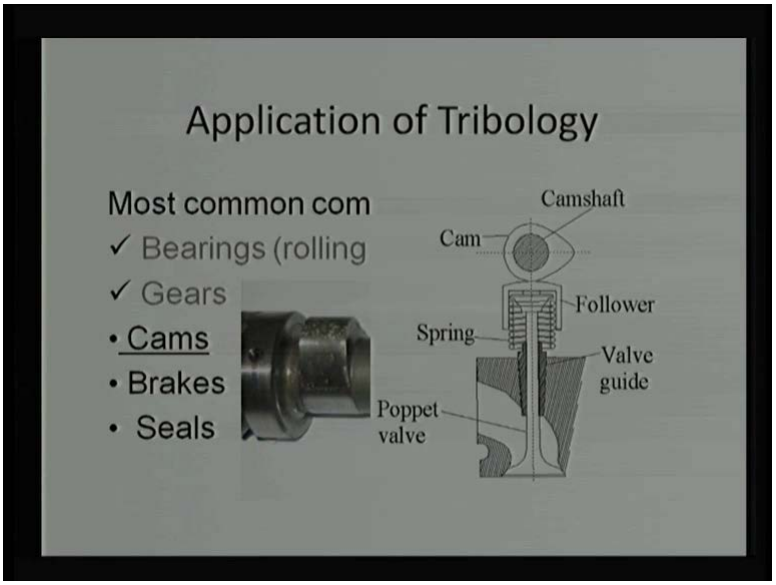

Third category comes under the cams that is some sort of strange shape, this is the perfect slightly damaged much more damaged, this kind of profile is a cam profile, you can see it is generally on the shaft, and shaft generally means the rotation. Because of this profile the rotational motion will be changed to the reciprocating motion, there is something like this, the cam has a rotational motion follower which is coming in the contact will be subjected to sometime very high speed rotation or pushing more harder pushing, sometime lesser pushing, and if this is the surface which comes in a cam, naturally no motion will be transmitted.

But, when this kind of portion comes there will be continuously increase or displacement of the this cam or when disc motion comes there will be retraction or the closure of the wall right, so kind of a cam profile which we use it will be transmitting the different kind

of motions, we use a centric cam then it will be much different kind of motion which is getting transmitted, we use this kind of a conical shape cam, then the motion will be different.

Because, depends on the functionality, depends on the when we use a cam profile, but with different cam profile we need to keep in a mind what is the pressure angle as far as my knowledge is concerned, as far as our designers knowledge is concerned, we should transmit maximum force to the desired direction, if lesser force is getting transmitted to desired direction then that is a failure, that is going to cause more and more system failure.

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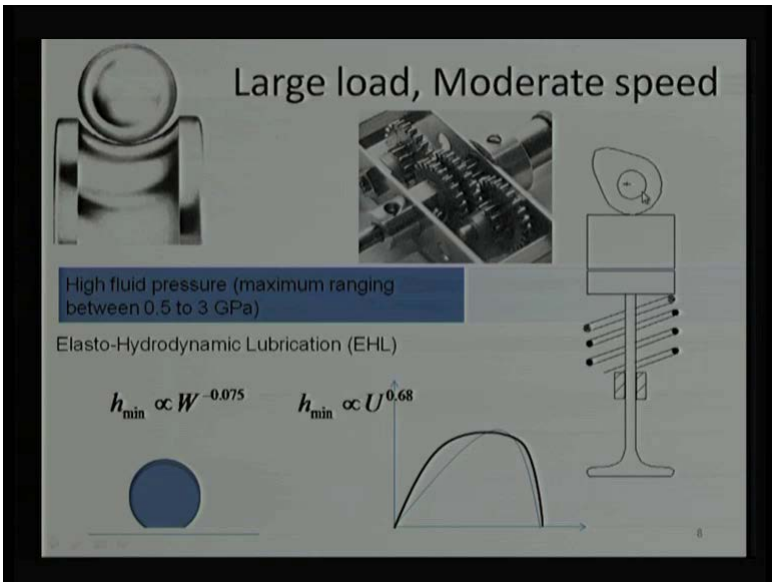

Now, what is the common in rolling element bearing, gears and cam following mechanism, that is a large load and moderate speed of course, it is a subjective term moderate speed can be a very well, we talk about the nano level, we talk about the micro level, we talk about macro level these remain always the subjective.

I can say 1 meter per second is a moderate speed, I can say 10 meters per second is a moderate speed, 100 meters per second is a moderate speed, so these are the terms which we generally use loosely, which is nothing like an firm guideline no it has to be more than 1 meter per second and lesser than 5 meter per second and something like that.

It depends on the scale on which we are working, but larger load if we talk about the larger load, we should talk about the contact pressure, contact pressure in this kind of bearings or in this kind of the tribo surfaces or the rolling element bearing (()) or cam follower this is even in gigapascal that is why, we say they have a high pressure and this pressure is been exerted by the fluid.

And such a high pressure the fluid will get solidified, the viscosity will increase tremendously and that is a common in all elements rolling element, gears and cam following mechanism, this kind of mechanism or this kind of high contact pressure, high fluid film pressure is common and that is a life line for this kind of components; that is the main strength of this component and we analyze this high contact pressure, high fluid pressure using elastohydrodynamic lubrication.

And more appropriately, we can say hard elastohydrodynamic lubrication surfaces is are not soft, the surfaces are generally very hard, we are talking about the hardness of 60 HRC, they are not very soft surfaces, hard surface and (()) pressure too deflective services; interesting thing is the minimum film thickness, functionality with the load and functionality with the velocity, what we are talking is the relative velocity.

You can see, the functionality with the load, as a load increases film thickness will decrease that is known, what kind of exponent which comes over here, this is negligible what we are trying to convey you keep on increasing load beyond uncertain limit film thickness is not going to change that is strange.

And taking the velocity, velocity sensitivity is very high this factor is 0.68, 0.7 if increase in the velocity is going to increase the film thickness and decrease in the velocity is going to decrease the film thickness right, this is a reason that we need to design properly, with proper justification on the speed. We know the load is not going to changing, the load is not that sensitive or effect is that load is negligible form thickness; effect of velocity is very high.

If I compare with hydrodynamic lubrication we are able to see, in hydrodynamic lubrication film thickness is power in this case particularly velocity is 0.5 while here, the power has increased from 0.5 to 0.68 of course, this is not 100 percent correct, but few as the geometry changes realization will also change, but always greater than 0.5.

While in case of fluids and hydrodynamic lubrication as the load increases, film thickness decreases and that effect is almost 1, the power is 1 while in this case power is much lower in sensitive, increase a (()) load carrying, increase in applied load is not going to change from thickness, it can be justified with some sort of diagram, you say that this diagram was shown in our previous lecture, so you assume this is the pressure axis, this is x l direction or tangential direction. No, if I increase the load what is going to happen, there is a more deformation whatever the here, the pressure was reaching a little max value, think of the further load, the flattening of this curves; maximum pressure biology remains the same, but there is a more and more area coming in this curve, load carrying capacity is increasing.

But, the flattening, maintaining same high pressure and when we talk about the film thickness point of view, you say let us say there is one straight profile, and straight line profile other one is spherical profile or the cylindrical profile. Initial shape or initial film thickness is this much you say h min, no what will happen, if I apply more loads, if I apply more load then this, if there is the flattening of the surface, fractioning is happening and film thickness is still the same is going to sustain much more load, but film thickness is not going to change, that is a beauty of elastohydrodynamic lubrication mechanism.

That is what we say that these elements are optimally designed, they show all performance which are desired of course, if there is a mistake in calculation, then they show the worst behavior, these are optimized surfaces, optimized components any where wrong we are going to pay a amount for that.

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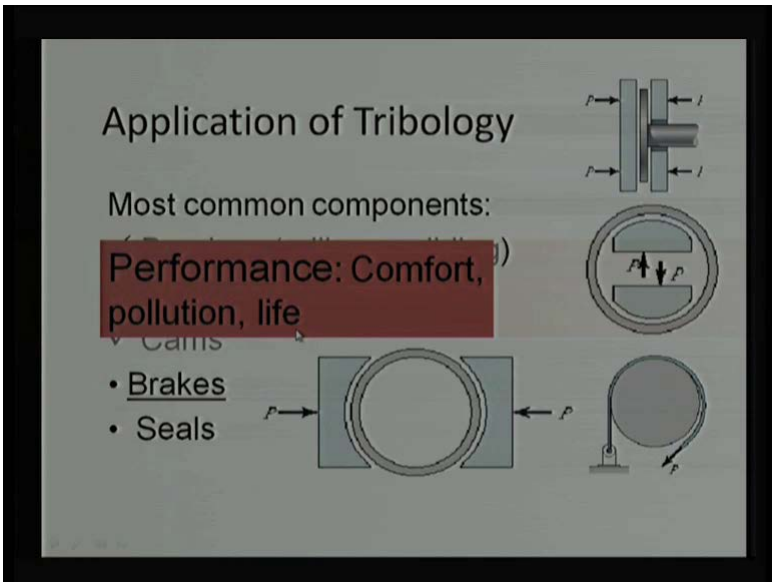

So, bearings are over, gears are over, introduction of gears, introduction of cams is over, now we are talking about the brakes, what we think about the brakes is typical application of this; that is one disc here obviously one pad one pad here, one wheel, one wheel here, and there will be disc or if there is a wheel, there is a some sort of pad is coming in contact to stop it, because the disc pad bearing, pad that can be anything will be lesser larger depend on what is required.

The other kind of bearings also, these are the block bearings was disc bearing, block bearing what do we say, internal expanding shoes, external contacting shoes, what is the purpose to stop this rotating ring, in this case pressure is applied, so that they come in contact, apply more friction, if there is a more friction there will be resistance and this thing will stop.

Same thing in this case, external contractions of the shoe come in the contact stop this rotating effect, block its, block its motion; that is why, we can say this bearings are going to be very sensitive, this kind of bearing can be very sensitive, we are going to generate very high friction.

You can see that there is no friction initially, there is no contact it is there is almost negligible friction expect the air friction, air draft, but when this kind of surface come in contact the coarse friction is going to be very very high, say 0.03 to 0.45 (()) friction is going to be high that is why there will be heat generation. And if there is heat generation,

material property will change, now that depends, sensitivity at the material was crib behavior, the brakes are applied continuously, there will be possibility of significant change in the property.

The brakes are applied only for fraction of seconds, then there is possibility of no change in material properties, so we require for our understanding we require our study of this kind of systems; there is one kind of the brake what we call as the band brake of course, every brake system has its own utility own application so depends on the requirement we can design the brakes.

We required performance, now performance can be in terms of stopping distance, how fast you want to reduce the energy of rotating element to 0, it can be comfort also it should not be any (()); it can be related to the pollution, there should not be much pollution or it must be zero pollution. Because, we are going to increase the cut short friction and that increase in the friction is a possibility of the very high rubbing with heat, and that rubbing is going to generate more and more rear particles change in dimension.

And this way of particle they get mixed in the environment and is going to cause pollution, how should we avoid it; in sometimes we say that there is a more were, then there is a live production in that. We want a desirable life in your pollution maximum comfort and high performance, you want to stop that wheel you should get the stop in no time that kind of performance.

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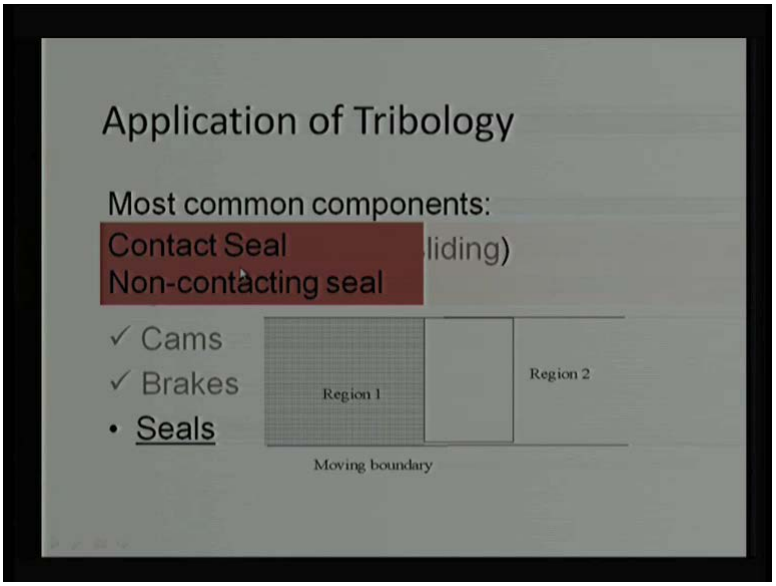

The last element in this case is the seal, what is seal, we see generally, if I assume there are two regions, region one and region two; this is the sealing element attached to the one surface and there is a possibility of small gaps in the surface. Of course, if there is a gap we will call this as a non contacting seal, however there is contact that will be contacting seal in our case, we will be discussing more about the contacting seal.

Which is also known as a mechanical seal, there is a mechanical contact between the surfaces, so we will be discussing more about the contact seals of course, there are number of non contacting seals available based on full film, based on the turbulence, based on the restriction base, like generating some feature on the bear or on sea surface. But, we will be concentrating more on the contact seals, we will be discussing more on the contact seals, now this is the general introductory part of the different applications which we are going to discuss.

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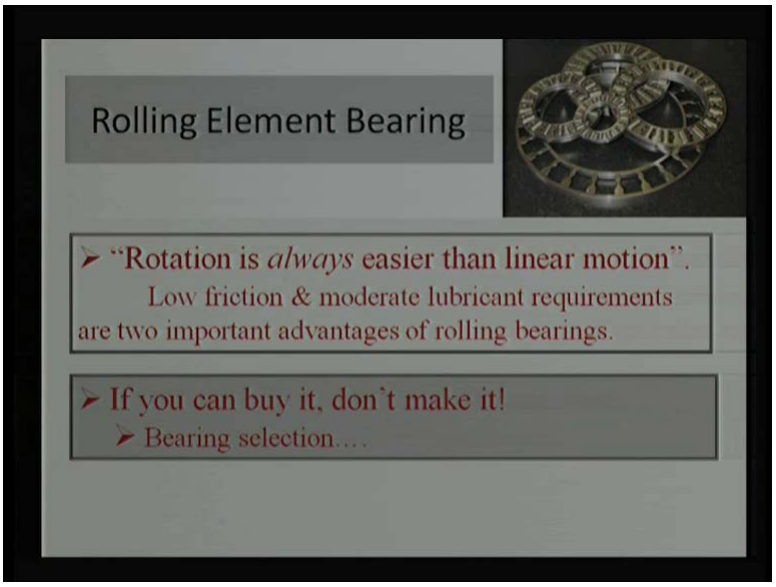

And first element which we are going to discuss, these are the rolling element bearing as they mentioned there are more than 20,000 rolling element bearing available in the market, we can see there is there are number of elements in rolling element bearing. And this diagram is permanently shown as cages, retainers undesirable from a tribology point of view, because these retainers are going to introduce some sort of sliding in the rolling motion, obviously between the rolling elements.

So, its undesirable, so problem is that if you do not use this kind of retainer there is more friction all rolling element will be in contact and they will not be able to rotate easily there will be more sliding. So, that should be some sort of justification, we require retainers, we do not require retainers some sort of material selection is important in this case.

And this is one famous thing is the rotation is always easier than linear motion, that is why we require rolling element bearings an these are available extensively in the market and much cheaper cost; that is why we say, if you can buy it do not make it.

And interesting thing is that if I start making a rolling element in house or give to some when a designer ask him to make rolling element bearing for us, cost of that fabrication will be almost 10 times to the market cost or the cost in which bearing I available in the market, this is the reason; why we say that we generally go ahead with the selection of rolling element bearing, generally we do not design rolling element bearing, we pick up from the market, because these kind of bearings are available in the market in abundant rigidly available and almost nook and corner we can find out the rolling element bearings.

Applications are extensive, they are not found much machines which do not use a rolling element bearing, there is very very common element, so we will be describing about that, but when we see, we are going to select in the question comes do I really require some fundamentals for selection truly no, catalog some sort of thumb rules are sufficient, but problem comes, if this rolling element fails and we do not have any clue why those bearings failed.

The bearing cost is cheaper and we are able to immediately replace the bearing with the other bearing then there is no problem, but the bearing cost is very high or their failure is going to cost the system are plant very high cost. Than we require good thorough analysis, we require a thorough understanding, even though we are going to pick up from the market, we require a good knowledge for selection as well as application of how to arrange it in proper order.

We will not be thinking about some hypothetical questions, I will say any bearing can be utilized, we have knowledge we will be having better knowledge about or we say the we have basic knowledge, we having better understanding of the bearing selection. We will

be discussing this in our next lecture, so the next lecture will be on rolling element bearings, thank you.