

Surface Engineering of Nanomaterials
Dr. Kaushik Pal
Department of Mechanical and Industrial Engineering
Indian Institute of Technology, Roorkee

Lecture - 04
Lubrication

Hello. Today we are going to start the chapter on Lubrications. As we have seen in the last two chapters that we have discussed about the frictions and wear. So now, we are going to introduce the lubrications which can reduce the friction in between the mating surface by which your total loss like in terms of wear can decrease.

Before going to start first we have to know that what is the lubrications. Lubrications is something which is any kind of material which can lubricate in between the mating surface. Either that surface can directly come into the contact or maybe there is a lubrications which will act in between the two mating surface.

So, lubrication is the process or technique implied to reduce friction between surfaces in proximately and moving relating to each other by interposing a substance called a lubricant. That means, lubrications is the terminology by which it is decreasing the wear and the material is called the lubricant which is doing the lubrication process.

(Refer Slide Time: 01:34)

Lubrication:

- ❖ Lubrication is the process or technique employed to reduce friction between surfaces in proximity and moving relative to each other, by interposing a substance called a lubricant in between them.
- ❖ This is mainly intended to minimise the wear of one or both of the surfaces.
- ❖ When lubrication breaks down, components can rub destructively against each other, causing heat, local welding, destructive damage and failure.

Adequate lubrication allows

- Low friction and heat generation
- Reduced wear of parts
- Reduced energy consumption

The slide also features a small image of a mechanical component, possibly a piston and crankshaft, and a footer with logos and text.

This is mainly intended to minimize the wear of one or both of the surfaces. When lubrications break down so the parts will directly come into the contact, so they will collide each other they will rub each other due to that the heat generation will be there or maybe they can heat each other due to that the material loss can occur. So, there are several types of problems if the lubrication system will fail inside any equipment or machines.

Adequate lubrications allow; smooth continuous operations of equipment, reduce rate of wear and prevents excessive stress and bearings. So, sometimes it can absorb the heat sometimes it can lubricate the material so that there will be some sliding motion smooth sliding motions in between them. So, there are numerous applications or may be advantages we can say it by which we can reduce the friction.

(Refer Slide Time: 02:39)



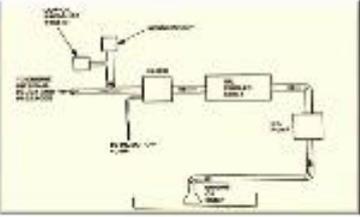
So, what are the objectives of lubrications? The lubrications objectives are: number one is called wear and tear of the surfaces, maintenance cost, heat from the bearing, unsmooth relative motions, expansion of metal due to frictional heat, power loss. That means, if we do not use the lubrications we can see these type of problem or maybe we cannot rectify all these problems inside the systems or maybe inside the metals or maybe the materials.

(Refer Slide Time: 03:15)

Lubrication System operation:

A lubrication system is the setup that delivers control amount of lubricant to multiple locations on a machine while the machine is operating

- Oil pump pulls oil from the oil sump
- Pump pushes oil through the oil filter and cooler coils.
- Oil filter removes very small particles
- Filtered oil flows to engine internal parts and other moving parts



WILSON COLLEGE OF ENGINEERING & TECHNOLOGY

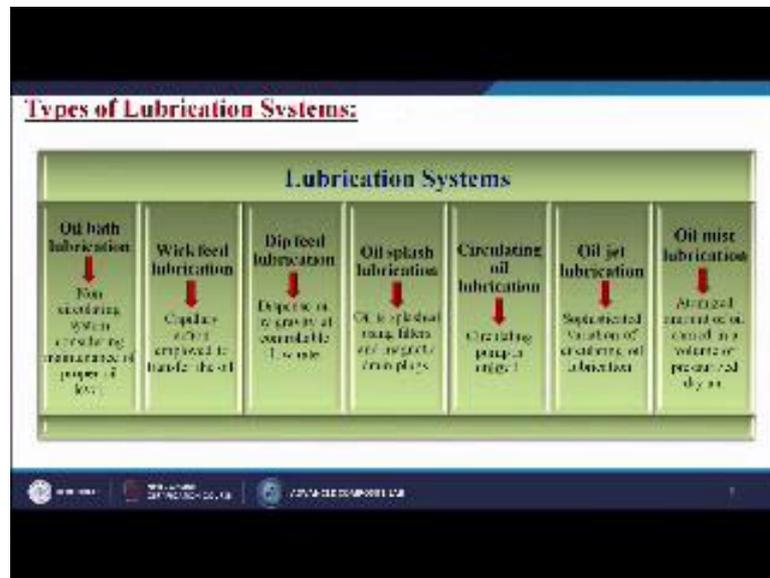
This is the simple example of the lubrication systems which is acting on any machines. So, from the right hand side figure we can understand that this is one kind of lubrication systems generally we are using it for the heavy machines or may be the ragged machines. But if, for the small machines generally we are having some kind of lubricating or lubrication related some kind of can or may be small gun by which directly we can put the oil or may be grease to some mating parts or may be to the bearings or maybe to the pistons.

But from this particular figure you can understand that this generally we are using for the ragged machines. Here, we are having some kind of engine oil sump, so where we are storing our lubrications oil, then through pump we are taking out that oil and then there is certain kind of strainer by which the oil is passing. So, if there is any dirt or maybe particles or maybe any kind of wear debris are present that can be strain out from the oil itself. Then the fresh oil again we are applying certain kind of pump by which it can generate certain kind of pressure so that it can reach to all the corners of the bearings or maybe the machines where there is relative motions in between the parts.

So, oil pump pulls oil from the oil sump, pump pushes oil through the oil filter and cooler coils. Oil filter removes very small particles, because that oil continuously we are reusing, we are not putting the new oil frequently. So, whatever the oil it is coming through from some device or may be equipment may be it can carry some kind of wear

debris or may be particles that can be stored into the oil sump itself. So, while again we are suctioning that oil again it is going through some strainer so that will take out that part particle or may be debris and fresh oil can directly go to the mating surface.

(Refer Slide Time: 05:35)



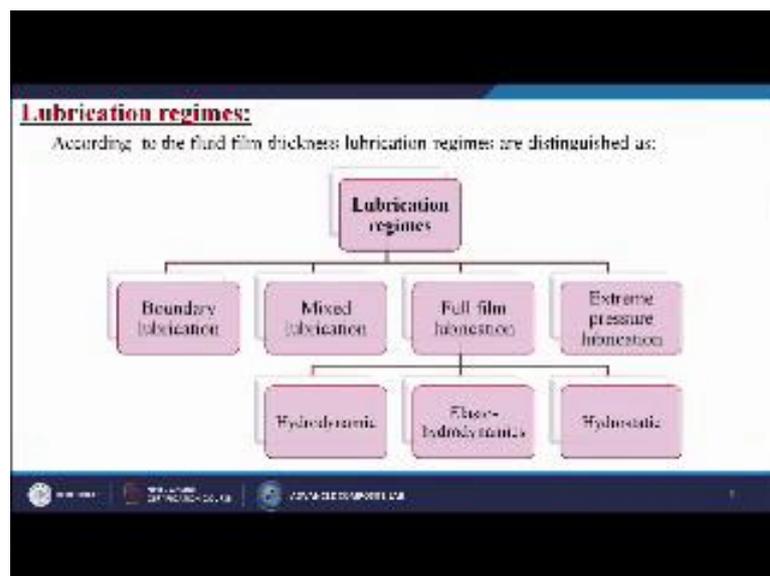
Next slide will see; what is the type of lubrications systems? So, from this particular slide we can understand that there are several types of lubrication systems. That means how we can lubricate different machines by different processes. First one is called the oil bath lubrications; this is the common lubricating systems generally we are adopting in our daily life. It is a non circulating system considering maintenance of proper oil level. So, simply we can see that the lubrications may be the volume or may be quantity is going down so then we can pour some kind of lubrications into it, so that there will not be any pump or pressure by normal means you are lubricating the machines.

Second is called the wick feed lubrications. Here, generally we are using certain kind of cottons or maybe some kind of threads by which your lubrication oil is sucking from the sump or may be the container and directly it is going to the machines or maybe the bearings or pistons. Third one is called the dip feed lubrication; dispense oil by gravity at controllable flow rate. In this particular case the lubrication sum is into the top and by the gravitational force automatically the lubrication oil is coming down and directly it is feeding to the gears or maybe the bearings.

Next is called the oil splash lubrications. Here, the oil is splashed, so here we are creating little bit of maybe back worms or maybe little bit of pressure so that the oil is coming through the pipes then it is totally splitting in a high form and it is cohering the whole mating surface or maybe the in between the interfacing surface it is entering. Next is called the circulating oil lubrications. From this particular you can understand that here we are using certain kind of pump, so that the pump is talking out the lubricant from the sump itself then it is directly throwing into the mating parts then again it is collecting that lubrications or may be the oil and then again it is depositing that into the sump. So, it is in circulatory motions or maybe it is a circulating process.

Next one is called the oil jet lubrications; where you are using certain kind of pressures so that the oil is passing through in a very high velocity. The advantage of this that: if there are any complex shapes or maybe any complex places where that lubricant cannot reach so that we are giving certain kind of pressure, so that that oil can reach each and every corner. And the last one is called the oil mist lubrications. Mist is nothing but the small droplet. So, with oil we are injecting high air or may be high pressure so that like a spray the oil is floating on to the surface, it is not the continuous oil is coming its like a droplet the oil is coming on to the surface in between the mating parts and it is doing the lubricating or maybe it is using for the best lubrications.

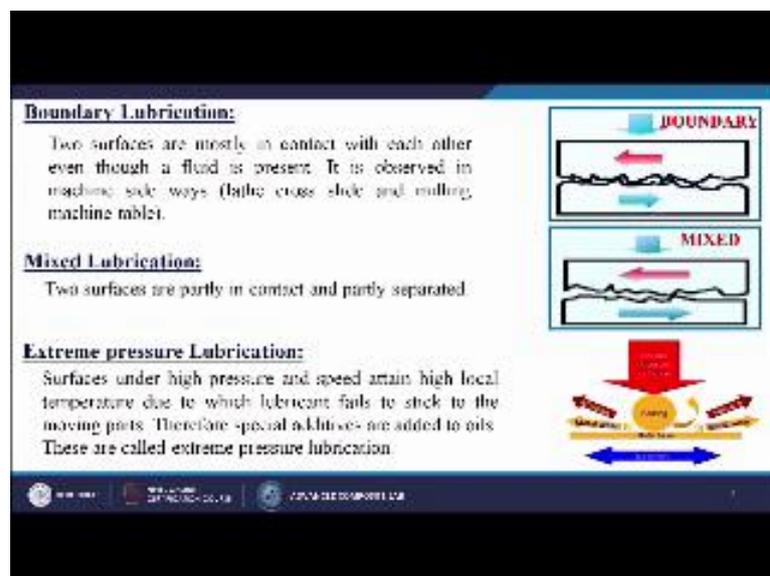
(Refer Slide Time: 08:54)



Then next one is called the lubrication regimes. From these we can understand that there are several types of lubrications generally we are adopting. Based on that how we are going to lubricate the materials. First one is called the boundary lubrications, then mixed lubrications, full film lubrications and extreme pressure lubrications. Then full film lubrications are also divided into three parts: one is called the hydrodynamic lubrications, elasto-hydrodynamics lubrications and the hydrostatic lubrications.

So, next slide we will discuss all these. So, first one is called the Boundary Lubrications, it is the common type of lubrication system generally we are adopting in our daily life, maybe the part may not directly contact in between them they are contacting through the lubricating oil.

(Refer Slide Time: 09:53)



So, two surfaces are mostly in contact with each other even though a fluid is present. It is observed in machine sideways lathe cross slide milling machine table. So, either may be there is a film in between them or may be the parts are directly contact, but still your lubricating film thickness is very very less in between them.

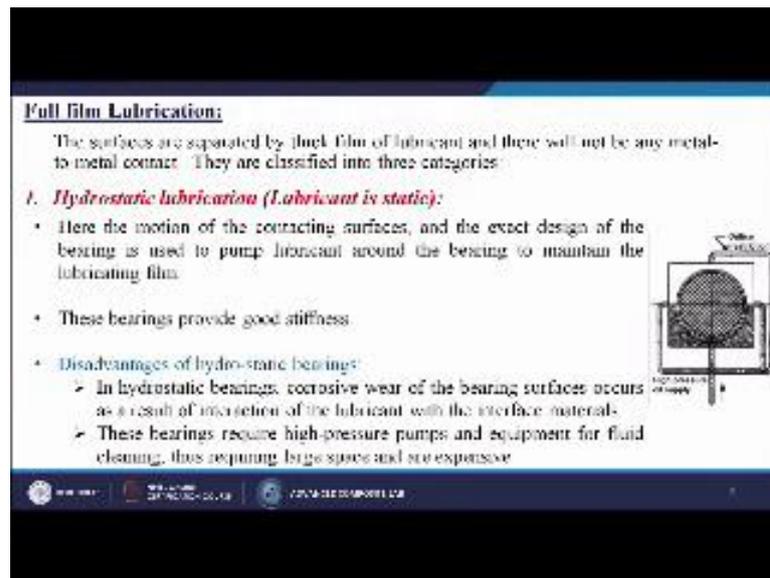
Second one is called the Mixed Lubrications. In the mixed lubrications systems we can see that the part maximum cases it is not contacting each other there is certain kind of lubrication films are present. From this particular figure you can understand that two bodies are moving into the opposite directions and in between the lubrication is acting. Next is called the Extreme pressure Lubrications. So, surface under high pressure and

speed attain high local temperature due to which lubricant fails to stick to the moving parts. Therefore, special additives are added to oils these are called extreme pressure lubrication.

So, from that particular figure you can understand that bearing is acting on to the metal base. So, when it is rolling, due to its normal load the bearing is giving a pressure on to the surface. Due to which maybe the lubrications in between the bearing surface and your metal base maybe can go out. So, we are using certain kind of additives which can stick the lubricant with the bearing itself as well as with the metal base itself.

Next one is called the Full Film Lubrications. From the name itself you can understand that these lubrication sys systems will act throughout the whole operation process and not only that, it will always cover all the mating parts.

(Refer Slide Time: 11:43)

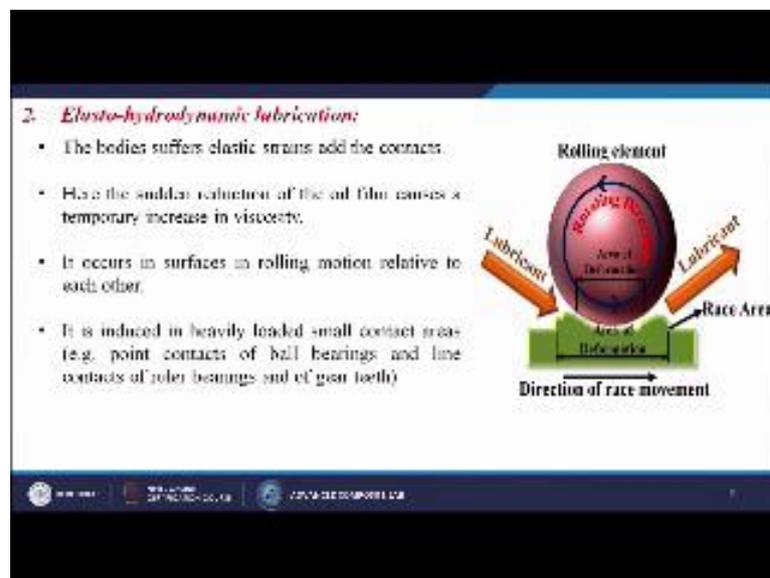


First one is called the hydrostatic lubrications or may be in another way we can say it called the lubrication is in static. That means, lubrications is not flowing or maybe not movable. So, here the motions of the contacting surface and the exact design of the bearing is used to pump lubricant around the bearing to maintain the lubricating film. So, from this particular figure you can understand that there is some housing and in which the piston is rotating and piston is having some bearings. From this particular figure you can understand from outside we are creating certain kind of channels or making certain kind of piping arrangement by which the constant the lubrication is coming and it is

going inside the system. So, here the lubrications actually is not into the moving contact, only it is into the touching contact in between the pistons and the housing.

So, there are some disadvantages also for this process, what are those. In hydrostatic bearings corrosive wear of the bearing surface occurs as a result of interaction of the lubricant with the interface materials. These bearings require high pressure pumps because we have to take that liquid then we have to throw it in high velocity, because there is a very narrow gap in between the bearings and the housings, so that oil should reach in between that space. So, you need a high pressure; and equipment for fluid cleaning thus requiring large space and its expensive too.

(Refer Slide Time: 13:30)



Next is called the Elasto-hydrodynamic Lubrications. From this particular figure you can understand that here the shaft is rotating on to some base materials and your lubrications is coming in one way and it is going into the other way. Means, when there is some rotating parts and we are lubricating from a one side due to the centrifugal force the lubrication will try to go out, outer surface. So, that is why it is called the elasto-hydrodynamic lubrications; the bodies suffers elastic strains add the contacts. Here the sudden reduction of the oil film causes a temporary increasing viscosity, because it is acting in these directions also it is rotating so the gap in between these two, in between the bearings or may be the pistons and in between the surface is very very narrow. So, sometimes the thickness of the lubricating film is getting reduced.

It occurs in surface in rolling motions relative to each other. It is induced in heavily loaded small contact areas; point contacts of ball bearings and the line contacts of roller bearings and of gear teeth.

And the last one is called the Hydro Dynamic Lubrications. From the hydro dynamic lubrications you can understand that here the lubrication itself into in motion. So, that is why it is called the lubricant is dynamic over here.

(Refer Slide Time: 14:51)

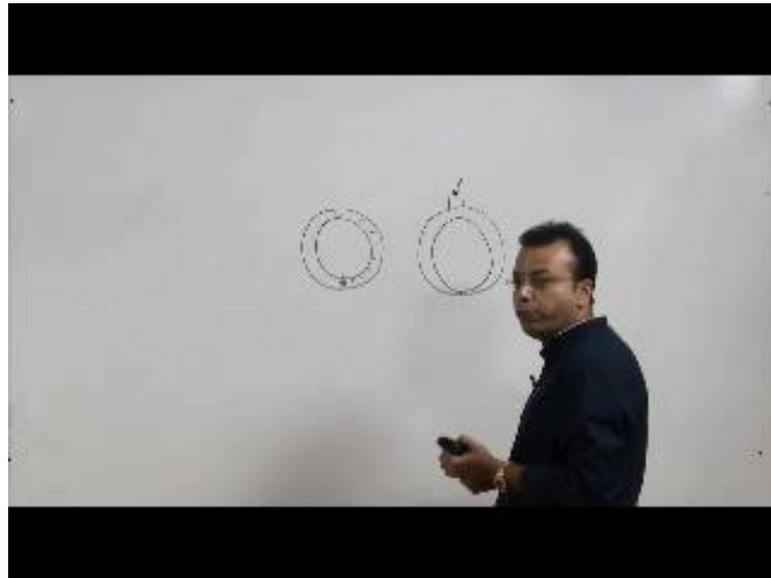
3. Hydrodynamic lubrication (Lubricant is dynamic):

- When an external pressure is applied to the lubricant in the bearing, to maintain the fluid lubricant film where it would otherwise be squeezed out.
- This lubrication is referred to as ideal lubricated contact condition because the lubricating films are quite thicker than height of irregularities on the bearing surface, and solid contacts do not occur.

At Rest Starts to Rotate At 1000 RPM

So, when an external pressure is applied to the lubricant in the bearings to maintain the fluid lubricant film where it would otherwise be squeezed out. So, we are having some pistons and in between that we are having the piston outer ring and we are having the piston inner ring the lubrications is acting in between that.

(Refer Slide Time: 15:22)

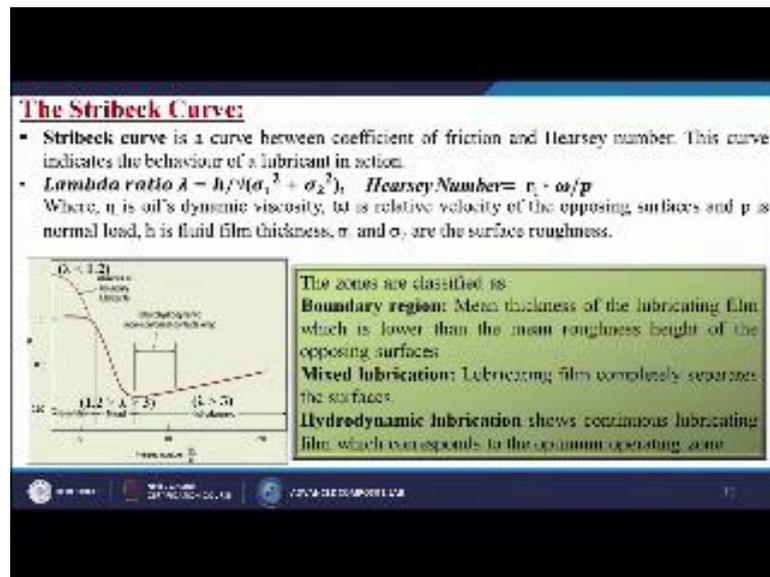


So, when the piston is moving inside it then what is happening actually; the inner valve is like this and the inner valve of the piston is like this and the inner valve of this piston hole is looking like this. So, the lubricants is acting in these regions, but sometimes while rotating this is due to its maybe weight or maybe the gravitational force sometimes it is coming down. So, sometimes it is becoming like these also; so the thickness of the lubrication film is getting reduced. But, again it is rotating so due to that that lubrications also inside the system is also continuously rotating. So, that is why it is called the lubricant in dynamic motions.

And you are having some port over her. So, if the volume of that lubrication is going down or may be the quantity is going down so that again you can pour the new lubrication or maybe new lubricating oil inside the system. So, it is the confined manner by which your lubrications is also rotating with the moving force of that particular piston.

So in this slide will see; what is the stribeck curve. Actually, stribeck curve will define that whether our lubricant is lying on to some mixed conditions or may be some hydro dynamic conditions or maybe into the boundary conditions.

(Refer Slide Time: 17:00)



So here, from this particular graph we can understand that y axis is denoting the coefficient of friction in between two mating parts and x axis is giving the Harsey number which is nothing but the eta into omega divided by p. Here, eta is called the oil dynamic viscosity (Refer Time: 17:13) is called the normal load which is acting on to the meta surface, and your p is the total load acting on this surface, and omega is the relative viscosity or maybe the relative velocity of the opposing surfaces acting in between the two mating parts.

So, from this particular case we can understand that Harsey number is like a number, it is a may be which will define that whether your material will lie into different conditions. So if we draw this curve, from that particular curve we can calculate the lambda ratio. So, lambda ratio is h; h is called what is the height or may be the depth in between the two surfaces or may be the fluid thickness in between the surfaces or may be the height means how much it is touched gap in between the two mating surface that will give you the lubrication thickness. Then, sigma 1 and sigma 2 are the surface roughness of these two mating parts, so sigma 1 and sigma 2 are acting each other. So, from these particular equations we can calculate that; what is the lambda value? The lambda value if it is less than 1.2 then your lubrications will lie in between the boundary conditions. If the lambda value will lie in between 1.2 to 3 then you lubrication will lie on the mixed conditions. And your lambda value will be more than 3 then it will come into the hydro dynamic positions.

So the zones are classified as; boundary region, mean thickness of the lubricating film which is lower than the mean roughness height of the opposing surfaces. Mixed lubrications lubricating film is completely separate the surfaces. And hydrodynamic lubrications show continuous lubricating film which corresponds to the optimum operating zone. From that particular case we can understand that whether there is certain gap in between the two mating surface or not, whether the lubricating or may be the film or may be the lubrication oil is touching the two surface or not and the most vital thing is that whether the two contact is directly coming into the contact or maybe there is some gap or maybe there is some partial contact in between them.

Next one is called the Lubricant. So, till now we are talking about the lubrication systems, so by which we are doing the lubrications systems or maybe the lubricating the machines that is known as the Lubricant. So, lubricant may be in the solid form or may be in the liquid form also it can be possible. And nowadays we are using the lubricant in the gaseous forms too.

(Refer Slide Time: 20:13)



So, it is a substance introduced to reduce friction between surfaces in mutual contact which ultimately reduces the heat generated when the surface moves. So there are several components of the lubricant, generally we are using the base oil. Mineral by products of crude oil refining base oils are polymerized or synthesized further and called the synthetic. There are two types of things; either directly whatever we are getting from

the nature we are using it for the lubricating purpose that is called the Natural Lubricant. Or may be some lubricant which we are doing or may be preparing in our labs then we are adding some additives or may be some kind of fillers that is known as the Synthetic Lubricating Oil.

(Refer Slide Time: 20:53)

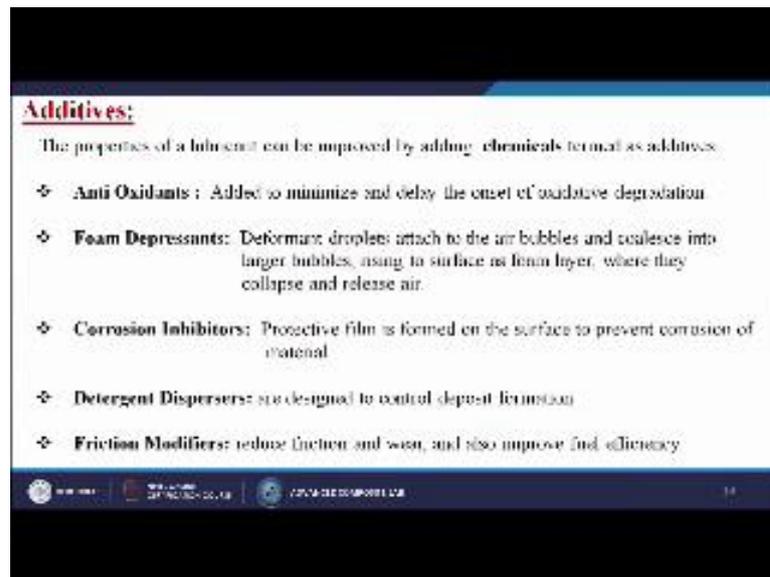
Base oil:
American petroleum institute categorized base oil into five groups:

Base Oil Category	Sulphur (%)	Saturates (%)	Viscosity Index
Group I (solvent refined)	>0.03	<90	80 to 120
Group II (hydro treated)	<0.03	>90	80 to 120
Group III (hydro cracked)	<0.03	>90	>120
Group IV	PAO Synthetic Lubricants		
Group V	All other base oils not included in Groups I, II, III or IV		

So, what are the base oils? So, American petroleum institute categorized the base oils into five groups; these all are called the Standards. First one is called the group one that is solvent refined; its sulphur percentage is greater than 0.03 percent, Saturation is less than 90 percent; viscosity index is 80 to 120. Then group two is called the hydro treated; where the sulphur content is less than 0.03, saturations is more than 90 percent, viscosity index is 80 to 120. Group three is called the hydro cracked; sulphur percentage is 0.03 percent, saturations is more than 90 percent, viscosity index is more than 120. Group four PAO Synthetic Lubricants. Group five all other base oils not included in groups 1 2 3 or 4.

From that particular standard we can see that what is the viscosity of that particular lubricant, what is the chemical properties of that particular lubricant; because lubricant we are using certain kinds of lubricant that does not means that it will not harm your body maybe some lubricant can react with the mating parts too or may be can do some kind of chemical reactions in between the mating parts, that also we have to take care.

(Refer Slide Time: 22:12)



Then comes the next is called Additives. Additives are nothing but the certain kind of fillers. Till now we are using certain kind of virgin oil, but that is also have some limitations. Then we are using or may be adding certain kind of additives or fillers so that it can go with the oil to that particular zone maybe it can absorb more heat than the lubricant oil or may be it can cool the system very easily. So, what are those additives? First one is called the Anti Oxidants: added to minimize and delay the onset of oxidative degradations. So, we are adding some kind of anti oxidant materials into the oil itself. Next is called the Foam Depressants: deformant droplets attach to the air bubbles and coalesce into larger bubbles rising to surface as a foam layer, where they collapse and release air. So, they can create a bubble which can held air at that particular point then they will collapse and they will release the air so that the material will cool down very easily.

Next one is called the Corrosion Inhibitors: from that particular name you can understand that we are using certain kind of materials which can resist the corrosions in between the mating parts. Detergent Disperse are designed to control the deposit formations. Next one is called the Friction Modifiers: reduce friction and wear and also improve the fuel efficiency, so that we can use that fuel for longer time.

Next is called the types of lubricants. So, from this I already said that we are using the lubricant maybe in normal life we are using into the solid form, but maximum cases we

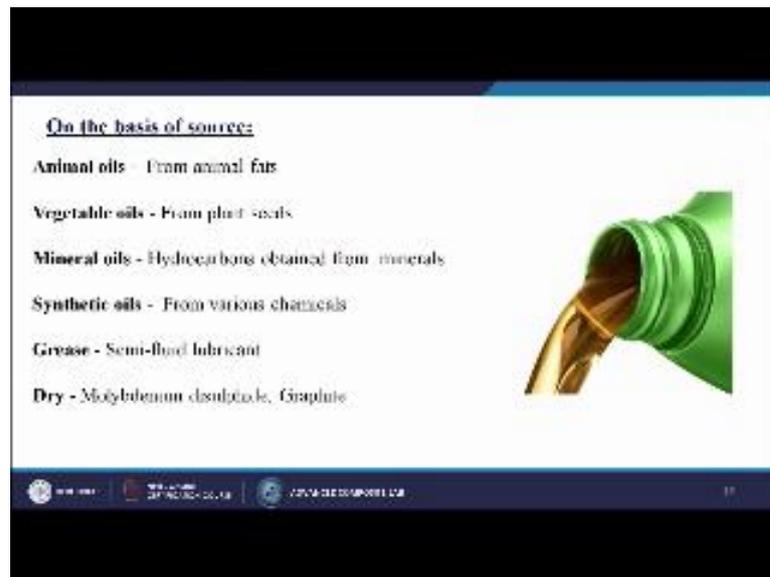
are using into the liquid form, but nowadays we are using the lubricant in gaseous form too. So, liquid typical lubricants are liquid fluids mineral, oil or may be the synthetic oil. So, from this particular oil we are having some very famous companies like Castrol or maybe some kind of Mitsubishi oil, so they can use or may be the Veedol which are making very good lubrications oil by which we can lubricating our engines, our pistons, our cylinders, everything.

(Refer Slide Time: 24:33)



Next some kind of solid materials like graphite or Molybdenum Disulfide which can act at the time of pressure maybe they can lubricate the systems easily, but they are in solid form. Next is called the semi solid, it is called the greases generally in our automobile parts we are using this kind of systems and gases atomized two stroke oil. So, nowadays we are using for racing bikes or may be some kind of parts which is highly movable so that time we can use some kind of atomized gases over there for acting as a lubricant.

(Refer Slide Time: 25:09)



On the basis of source: so first one is called the Animal oils. So, from animal fats we are getting that kind of lubricating oil directly. Vegetable oil, so from the vegetable from our natures or some maximum cases these vegetable oils biodegradable too so that cannot do any kind of environmental hazard. Mineral oils, hydro carbons obtained from some minerals. Synthetic oils, as I already told these we are preparing into our laboratory by doing any kind of reactions over there. Grease, semi fluid lubricant it is also a one kind of synthetic materials. And dry, molybdenum disulphide or maybe the graphite dry means. These all are the solid lubricants.

Now, next one is called the impurities and contaminants in the lubricants. So, when we are using that lubricant, when it is going into some bearings or may be the gears or may be the mating parts that mating parts is constantly rubbing each other. So, due to that frictions both the material is losing, then some lose materials or maybe the debris that is coming and that is mixing with the lubricant itself.

(Refer Slide Time: 26:20)

Impurities and Contaminants in Lubricants:

Contaminants and impurities in lubricants degrade the life and performance of machine.

Types of Contaminants

- Solid Particles:**
Include wear debris which damage mechanical components.
- Liquid Particles:**
Include fuel and water which hinder proper operation of lubricant and its additives.
- Gaseous Contaminants:**
Include combustion products which corrode component surface and breakdown oil.



So, types of contaminants. First one is called the solid particles include wear debris which damage the mechanical components. Liquid particles include fuel and water which hinder proper operation of lubricant and its additives. And the gaseous contaminants include combustion products which corrode component surface and breakdown oil. So that is why each and every lubrications or maybe lubricating oil maybe or lubrication systems has some service life. So, after certain time when the properties of that particular lubricant will go down we have to change that lubricating oil so that it can work properly.

(Refer Slide Time: 27:10)

Characteristics of good lubricant:

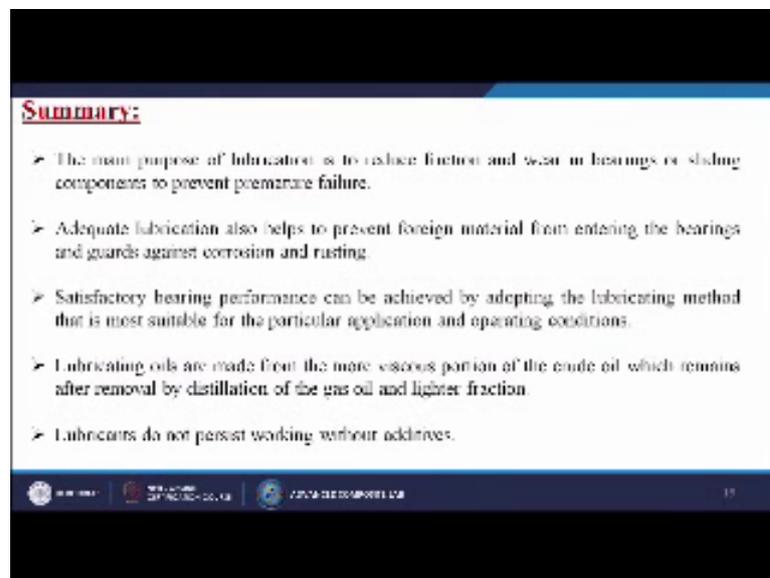
- High viscosity index
- Flash point should be higher than operating temperature of machine.
- High oiliness.
- Cloud point should be lower than operating temperature of machine.
- Volatility of lubricating oil should be low.
- Carbon deposited during usage should be low.
- High aniline point.
- Higher resistance towards oxidation and corrosion.
- Deposit least amount of carbon during use.
- Have good detergent quality.



Next is called the characteristics of the good lubricant. What properties should have that lubricant so that we can use it? First one is called the high viscosity index. So, with temperature also it should not be in the liquid form or may be the liquidity nature of that lubricant should be very very less, so that it will create always a film in between the mating surface it will not go out. Flash point should be higher than the operating temperature. Its flash point means, its burning temperature or may be melting temperature should be higher than the temperature whatever it is generating due to the friction in between the mating parts otherwise it will itself burnt or may be the melt.

Cloud point should be lower than the operating temperature of machines, due to the temperature it should not be agglomerate if it will be agglomerate then it will be very difficult, the lubricant will not pass through all the surface. Volatility of lubricant oil should be low. Carbon deposited during usage should be low. High aniline point, higher resistance towards oxidation and corrosions; deposit least amount of carbon using have good detergent quality. So, these all are the properties a good lubricant should have.

(Refer Slide Time: 28:44)



Summary:

- The main purpose of lubrication is to reduce friction and wear in bearings or sliding components to prevent premature failure.
- Adequate lubrication also helps to prevent foreign material from entering the bearings and guards against corrosion and rusting.
- Satisfactory bearing performance can be achieved by adopting the lubricating method that is most suitable for the particular application and operating conditions.
- Lubricating oils are made from the more viscous portion of the crude oil which remains after removal by distillation of the gas oil and lighter fraction.
- Lubricants do not persist working without additives.

Then in summary we can say that; the main purpose of lubrications is just to reduce the wear or may be the friction in between the mating parts so that the parts or maybe the surface or maybe any kind of engine or machine life can be increased. Adequate lubrication also helps to prevent foreign material from entering the bearings and guards against corrosion and rusting. Yes of course, because it will create a film in between so

that the bearing or piston it will not directly come into the contact to the environment, or maybe it will make a coating so that some other particles or maybe impurities not come directly contact to the mating surface.

Satisfactory bearing performance can be achieved by adopting the lubricating method, that is most suitable for the particular applications and operating conditions. Lubricating oils are made from the more viscous portions of the crude oil which remains after removal by distillation of the gas oil and lighter fractions. Lubricants do not persist working without additives.

Nowadays we are using certain kind of lubrications not certain kind of maximum cases we are using certain kind of nanoparticles over there nanofillers over there just to enhance the properties of that particular lubricants. And, a lubricant can work for several machines for several applications.

Thank you.