**Tribology**
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**Module No. # 04**

**Lecture No. # 17**

**Liquid Lubricants**

Welcome to 17th lecture of video course on tribology today's topic is a liquid lubricants. In previous lecture we understood solid and semi solid lubricants the merits and demerits. Today, we are going to discuss most popularly classification of lubricant or class of the lubricant which is a liquid lubricant.

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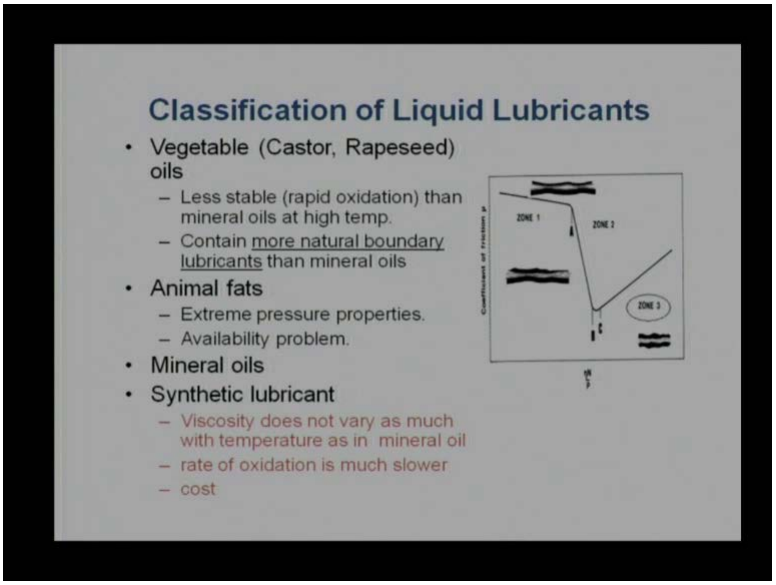


Liquid lubricant are classified based on the origin that with your extracted from vegetables, animals, crude oil, (( )) based on their origin, we classify as vegetable oil typically. Examples are castor and rapeseed animal oil is a may be fish oil, olive oil, mineral oil is the most popular and most economic category of this liquid lubricant finally, come the synthetic lubricant.

We assume that synthetic lubricants are last source of lubricant. If we do not have any other option we will (( )) synthetic lubricants every class has it is own merits. And

demerits talking about the vegetable oil it appears to the this will be economy very less costlier. But, it does not happen to be processing takes time as well as money.

So, they are not as economic as mineral oils in addition to that they are less stable thermal as well as oxidation. They detoriate with increase in temperature and they get oxidized when they heat oxidized they viscosity will increase.

And if they thermally degrade than they will be some deposit left with that degradation a would vegetable oil have a own good quality. Thus contended more contained natural boundary lubricants, they are good additives for high load applications coming to the animal fats. One of the major drawback about animal fat is availability with stringent norms, government rules. It is very difficult to find out lubricants from animals unless available in one way another form intentionally we cannot do things.

Very positive point about animal fats is extreme pressure additives or extreme pressure qualities they can sustain very high pressure. That is why they can be use as e p additives mineral oil is most popular most commonly used about liberal. And abundant and from cost point of view this will be cost and availability point of view.

Will always vote for the mineral oil coming to the synthetic oil see we can design any property in law. And utilize for the commercial purposes only problem is a cost more and more process is involved more and more design involved more and more cost, otherwise any lubricant can be synthesized. Also the lubricant can be synthesized for any applications major advantage of which is in the liquid is viscosity, viscosity degradation is very very low.

Viscosity index is generally higher than viscosity index on mineral oils few synthetic lubricant of slightly costlier compare to mineral oil, which can be utilized a common application otherwise (( )) synthetic lubricant are costlier even two to three four times compare to mineral oil that is why we have restricted application, when they are used, when we do not have any alternative.

One point I missed in a this slide is stribeck curve can you see, that we already studied this stribeck curve. We say that x axis, there is a sum of a number viscosity of lubricant sliding his feet divide by average pressure while coming to the x axis coming to y axis. It

is a coefficient of friction, we say as some of number increases (( )) of friction decreases to certain level and after that again it increases.

If I think about that all this lubricants I can place vegetable oil and animal fats. Somewhere in this region or we say that animal fat can be placed in zone one coming to vegetable oil, it can be placed in mixed lubrication oil, mineral oil. Somewhere here in zone three and some part of zone two.

So, based on the condition based on operating condition we can choose our lubricant or we can mix lubricant is a mineral oil can be mixed with animal fats. Mineral oil can be mixed with vegetable oils or synthetic lubricants also can be mixed with other lubricants based on our application, we can choose proper lubricant based on stribeck curve.

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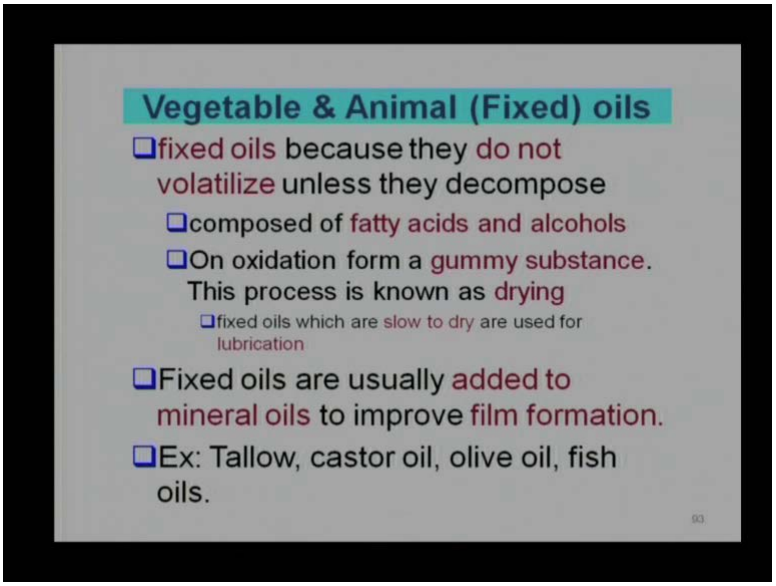


One slide on vegetable oil and animal oil such as a big subject processing, how to get, how to do hydrolysis and how to remove carbohydrates the prices contents. And use only content which are desirable, but trick was a complete process, we are not describing that we are not discussing that just discussing a few important points. Sometime this vegetable oil and animal oils are known as a fixed oil resenting they do not vaporize during the operating conditions they degrade they decompose.

But, they do not vaporize they volatize volatility is negligible that is why is known as a fixed volume or fixed oils. And as I was mentioned earlier, they are made of the fatty

acids and alcohols are congested of alcohols and fatty acids, fatty acid work has a boundary additives.

What is the problem with their oxidation they make a gummy substance which will stick to surface reduce clearance. And the clearance is reduced operating condition will change the operating condition will change they bring much more difficult situation. So, as I if I refer to the stribeck curve again say a laser and laser clearance and more and more load will applied on that and it will turn out to be instable system or in stable condition.

Now, this last line of a the slide says a fixed oil, which are slow to drive are used for lubrication or in other words fixed oil vegetable or animal oils, which are slow to oxidize would be preferable lubricant compare to rapidly oxidized vegetable oils rapidly oxidized animal oil.

To reduce oxidization need to be processed properly to avoid the more complications we can use fixed oils in mineral oils, some of the example of the fixed oil are that given over here castor oil olive oil. We have heard number of times fish oil, they are good lubricant additives they are have a good lubricity stick to the surface. So, they can be utilized as additive in mineral oil for lubrication purpose for tribological purposes.

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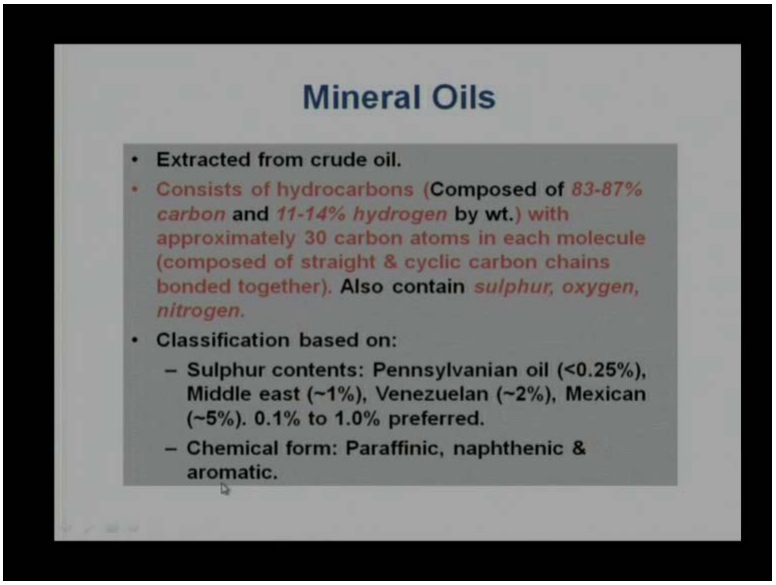

Coming to the mineral oil they are generally extracted we are process from the crude oil. And major constitute is a carbon and hydrogen all is the based, that is why we call as a hydrocarbon best lubricating oils and see that carbon percentage is 83 to 87 percent and hydrogen 11 to 14 percent this is by weight.

To get a proper lubrication often they are made with a long carbon chain 30 plus generally recommended for a mineral oils in addition to carbon and hydrogen. They often contains sulphur oxygen nitrogen, this carbon chain carbon and hydrogen, when they make bond they can make form in a straight line.

They can be in branched form on a cyclic form the property will change the carbon structure is straight chain, behavior will be one kind of the branched carbon chain. Then behavior will change even a cyclic one then behavior will quite change and based on the carbon structure also, they are classified.

Say the sometime mineral oils are classified based on sulphur content with more in stringent (( )) we require lubricating oil with low percentage of sulphur is harmful substance it pollute environment. As far low sulphur will be recommended are better any where depends on origin of mineral oil from, where it the extracting. They can be classified based on sulphur content pennsylvanian oil, which has a low sulphur percent will be recommended compare to middle east compare to Mexican.

We say tips of a content is lesser than point one percent are suggest by (( )) range it can be point 1 to 1 percent beyond. That we need to have a some sort of defining process to extract the (( )) mineral oils based on mechanical structure based on the branch form or straight form or cyclic form.

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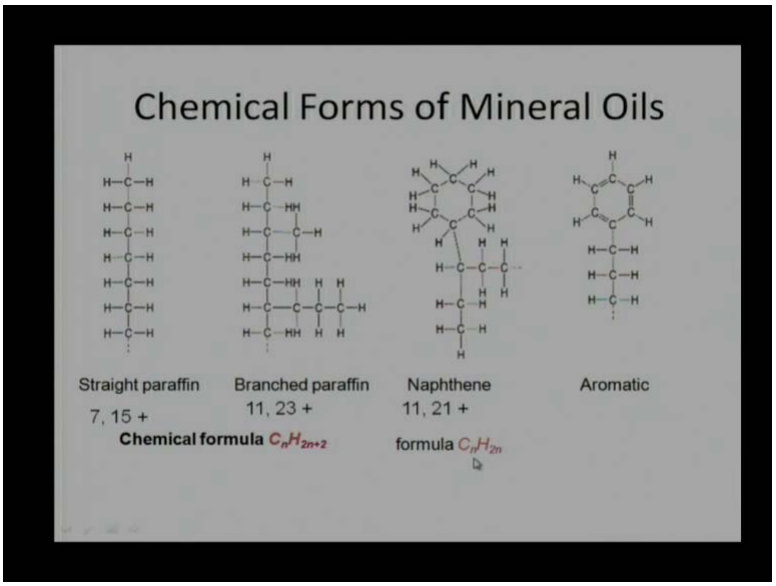


We divide mineral oils and paraffinic oil and naphthenic oil and aromatic oils one slight is given in the chemical formation you say the chemical forms or mineral oil. You see the simple is straight chain carbon, hydrogen carbon, hydrogen is complete structure. We will be more staple in this case here we have a second figure with branched carbon and carbon is making a branched they do not have a same axis, but a lateral axis is also be neutralized.

One important point is that the chemical formula for first figure is a C n H 2 n plus 2 hydrogen number of hydrogens are two times compare to carbon percentage. Carbon molecules plus 2 while the formula is changed C n H 2 n that structure also changes and this kind of thing will be call as an naphthenic oils or naphthalene.

While first case it is straight paraffinic oil the branch paraffinic oil I can verify very well that, what are the structure in a first chain or first figure, we find that they are seven carbon molecules of 7 carbons atoms in this case. But, H is the fifteen times I can count this is a 1 2 3 4 5 6 7 and H will be 15 times. But one there is a one vacancy over here there can be carbon hydrogen it continuous finally, one will be at.

So, this formula will be satisfied 7 carbon hydrogen is 15 and finally, one will come 15 plus 1 as a 16 is a two times of seven plus 2. This formula is satisfied similarly coming to the branched one, we have 11 carbon over here and H number of H are 23 plus 1, where is again vacancy over here. There is a one more left either it can contain carbon and

hydrogen if it is not containing carbon it will be hydrogen then we will be getting 23 plus 124 ; that means, 20 11 into 2 is 20 2 plus 2 is 24.

So, this both the structures are satisfying paraffinic structure coming to the naphthalene or naphthenic structure, we are able to see they are some complexity coming in this. And because of this structure here both temperature deduces a solidification temperature is slightly higher, they will solidify comparatively some temperature which is higher than paraffinic plus.

I am just reversing, they have a lowest solidification temperature, they will solidify at a lesser temperature compare to the paraffinic oil. So, for low temperature application nothings had good. But, they will not be having that structural or thermal capabilities to sustain high temperature as a paraffinic oil. So, both have merits and demerits.

Coming to the aromatic, but we find are the unsaturated these bonds are unsaturated can react easily with other agents other chemical forms. So, aromatic are least preferred compare to the paraffinic and naphthalene. And in this case also we count number of carbon particles or carbon contents compare and compare with H, we will find this is 11 number of carbon, while H are 21 plus 1. There is a one vacancy here it can be occupied by H or carbon for continuation if it is a H. Then it will be 22 that is why 11 into 2 is 22 that formula is satisfied.

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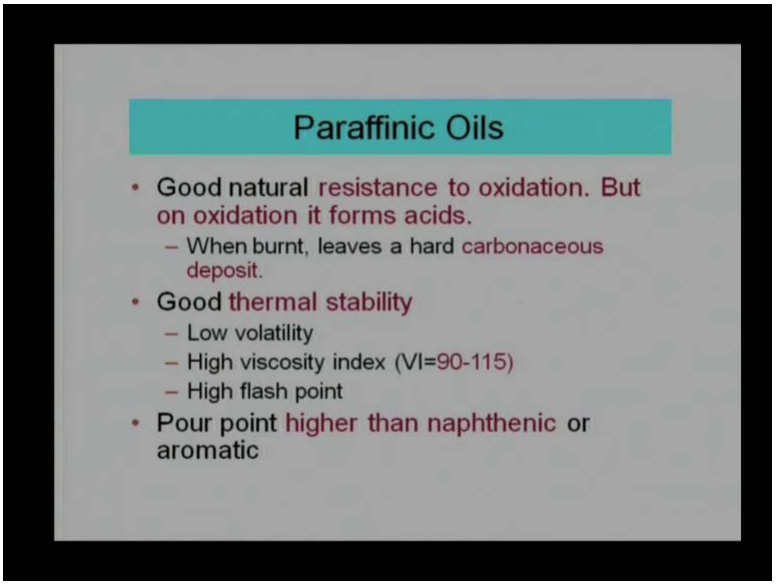

Some merits and demerits and demerits of paraffinic are you say that paraffinic all have a good resistance to oxidation, they are more stable against oxygen. But, when they oxidized they are no useful, they can corrode the environment or corrode the component. Which are in contact in any shell they are not very (( )) stable, when the abundant they make very hard deposits which can abstract the surface.

So, the lubricants are use to reduce a friction and where. But, if we slight choose lubricant which is not thermally stable burnt at high temperature. The temperature may be 150 degree, 170 degree, 190 degree. Then they will make a deposits and presence of deposits are clearance will deduce in addition, there is a possibility of this hard deposits to act as a absorption we are more and more.

So, we select the lubricant for good reason to reduce friction to reduce (( )). But, because of the lack of understanding if you slight a lubricant, which is not able to sustain that high temperature which is operating temperature. Than they will form deposit on the surface and it is a often case in engine it find that oils are making are making deposits on the surface. And it required additives to wash away this deposits coming to second point you say that they have a thermal stability volatility is a level, they are not as fast grating with temperature.

So, viscosity index is high is 92 1 1 5 (( )) is a subjective and few mineral oil have lesser than few paraffinic have lesser than 90 (( )), we are leaving those exceptions and in addition we have a high plus temperature.

Here it says the power point is higher than naphthenic the power point, where the flow are the start freezing. And high temperature come between naphthenic, which was mentioned in last line also, that means, for cold applications paraffinic oil will not be as good as naphthenic oils for low temperature applications.

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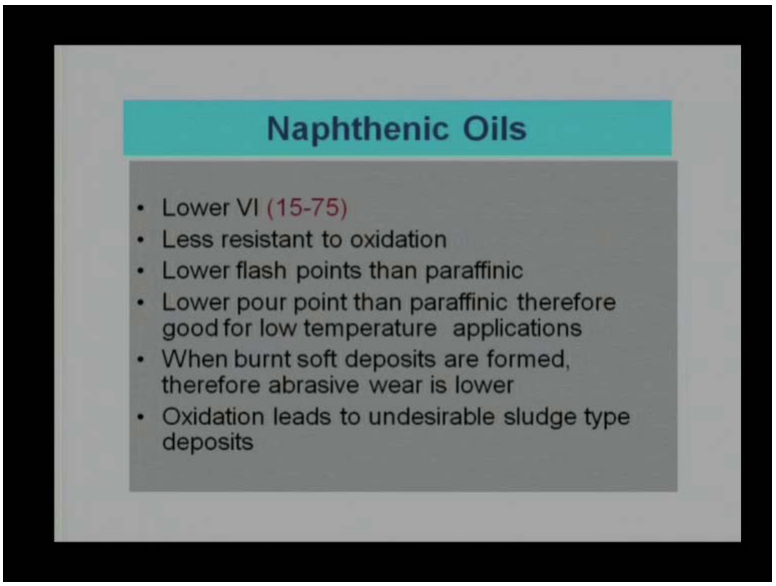


Coming to the naphthenic oils, we say they have relatively low V r I viscosity index if I am very sure about the operating temperature. If I not operating temperature is not going to change significantly. Then I can choose naphthenic oils particularly at lower temperature applications, I went it says that they have a good lower power point, compare to the paraffinic oils are good for the low temperature applications in addition naphthenic oil one positive point. They do not make deposit as hard as paraffinic oil when they burnt when naphthenic oils have burnt, they mix soft deposits compare to paraffinic oil.

So, (( )) will be lesser where tendency or they will have a lesser tendency compare to paraffinic oils wet. Because, of the deposits and in addition, when there is a oxidation they make a sludge formation clearance will reduce operating condition will change and that is undesirable.

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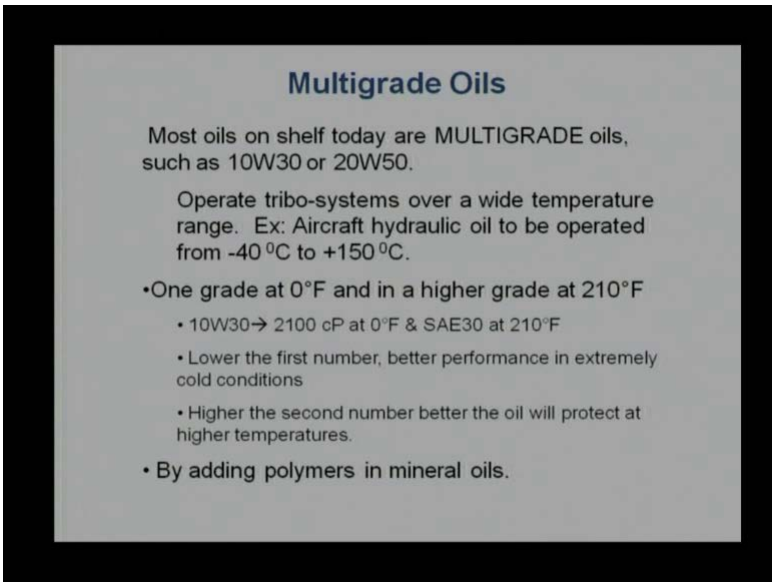


Continuing with mineral oils not very v I not very high viscosity index more tendency towards oxidation at moderate to high temperature, we use a multigrade oils main ingredient is a mineral oil. What we are trying to do?

We are doing some sort of hybridization may be one lubricating oil is good for low temperature application, other lubricating oil is good for high temperature application. You want to hybridize to come up with result lubricating oil is good for low temperature application. As well as high temperature application and interesting thing is that when we go in a market most of time available oils are multigrade oils.

Let us take an example, some sort of classification says that 10 w 30 w is stands for winter and that divides left hand side of that is referred to winter oil right hand side left hand side. This w refers to the hot temperature condition or another word this multi grade oil has a something like a S I then characteristics as well as S I 30 characteristics (( )).

When we are talking about second example we say that it has a 2 characteristics is all S I 20 and S I 15 characteristics. That is why the multigrade oil instead of one single grade it contains two grades, that is why it says that when tribo systems operate in a y temperature applications. We are born to use multigrade oils one typical example is given as a aircraft hydraulic oil, which operates from minus 40 degree centigrade to 150 degree centigrades is quite huge range.

And most of time mineral oils will not be very useful may you require synthetic oils for this compare applications. But is cause is a major consideration, then we can go ahead with some sort of multigrade oil.

And as I said that multigrade oil shows one grade at a 0 degree fahrenheit and higher grade at the 210 fahrenheit or 212 fahrenheit. This is as I mentioned initially the 10 w 30 the same example say the very viscosity at 0 degree fahrenheit and S I 30 characteristics as a 210 fahrenheit.

Whenever this kind of specification comes, we say that lower the first number better will be the results at a low temperature conditions instead of 10. If you use a five that will have a better characteristics at a low temperature conditions.

Similarly, add the second number add the left hand side number better will be the performance is higher temperature condition in other word. If I say 10 w 50 that 10 w 50 will have a better performance of the high temperature compare to 10 w 13 viscosity will be highest. So, this is the multigrade oil question comes what to make this should I bring that 2 oils S I 10 S I 30 50 percent of S I 1050 percent of S I 30 makes. It use it is that up work or we should use 30 percent of S I 10 70 percent of S I 15 in reality in practice, this kind approach does not work simple mixing will not work there are number of matrix.

But, one method which more most popular method is adding polymers adding additives in mineral oil.So, we add polymers in mineral oil two increase it is temperature range the question comes, how this mineral oil are polymers is going to work in mineral oil?

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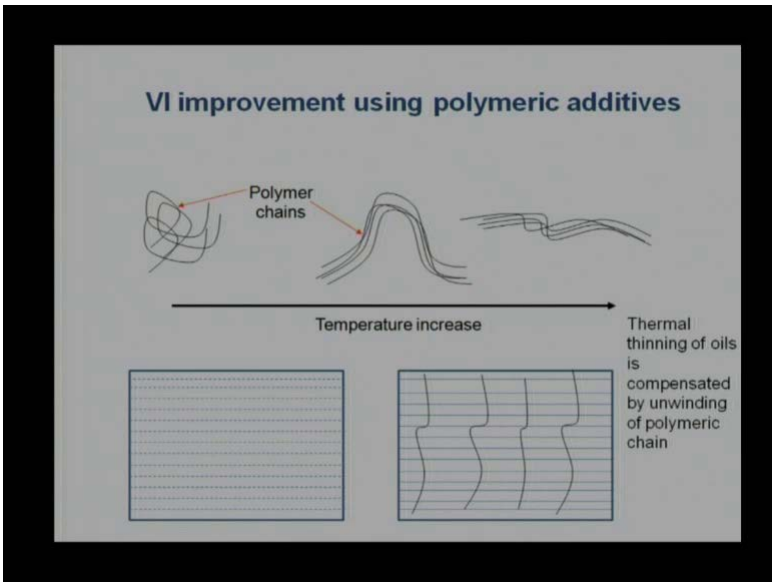


This schematic is given in the slide is a polymer when they are in chain form mix in mineral oil they have a coiled characteristics. They will be in coil form is roughly a coil form is a (( )) the polymers are in coiled form they do not occupy much space they remain in compressed form.

As temperature increases they change their form instead complete form they open up and with further increase in temperature they turn to fibers. And we how you learn in a semi solid this kind of fibers give more resistance to the flow they increase viscosity.

So, this a what how the polymers work at the low temperature they will not work or maybe they are added in mineral oil, they will increase slight viscosity because of this addition. But, will not affect to great extent as a temperature increases the viscosity of the oil will increase in other word. If I am using in a mineral oil mineral oil viscosity will decrease with the temperature, but it is been compensated with increase in viscosity because of this fibers.

So, one negative one positive it should give as a same results change in the temperature is not change in the viscosity to demonstrate that in a other field, we have one figure and assuming this is containing lubricating oil.

Now, if the temperature increases. So, these dots are decreasing in other with these dash are decreasing in with that indicates that viscosity is decreasing with increase in

temperature. So, this is increasing temperature sign viscosity is increasing or decreasing in this way. But, as we know there is a other constitute there is additive in this which will also open up and with a temperature increases viscosity may be some in this form you can say there is a mineral oil thinned out.

And this kind of fibers they come in between to give more and more resistance to the flow of liquid and to resistance to flow of liquid is known as viscosity. That means, this kind of polymers are acting as viscosity resistance or resistance to decrease in viscosity.

So, I can say thermal thinning of a oil is been compensated by unwinding of polymer chain and this are the multigrade oils. And reality they are not mixed they are not two separate oils. But, they behave like the sure performance like two great oils like multigrade oils now different kind of polymers can be used, which can show three or three grade oil, four grade oil five grade oil. But, we will be trying to show the performance or the extremes lowest temperature and highest temperature and based on that we can get a good results.

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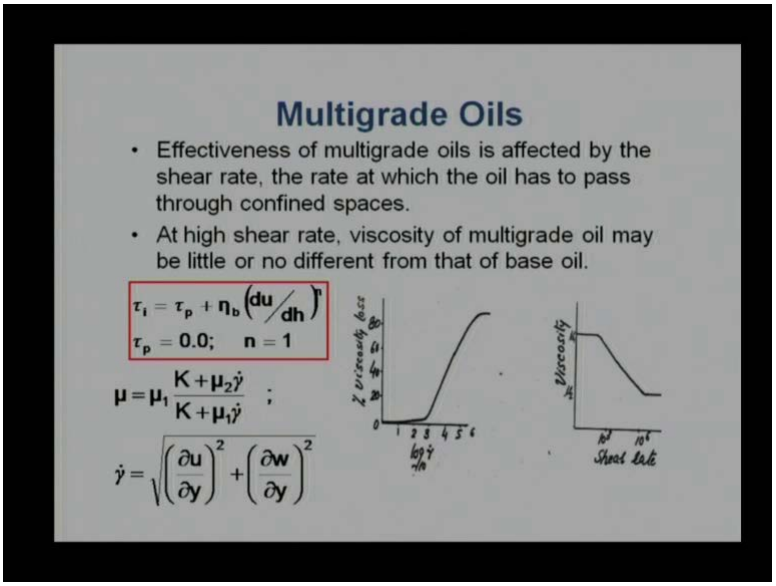


Again every advantage is not without any cast or every positive comes for some negative points. That is why we are discussing over here mulitgrade oil have some draw backs first thing is, that they do not work as newtonian characteristics. It will show shear dependence with increase in shear rate viscosity of that oil will decrease. It will show a shear thinning behavior, that is why I said that effectiveness of multigrade oils is affected

by the shear rate, the shear rate had which the oil has to pass through confined space nano, space convergence, space oil are pushed formed at the space. And they will shear they will reduce viscosity.

So, that at high shear rate viscosity of multigrade oil may be little on not different from the base oil. This research shown in this diagram say that when shear rate is low viscosity is high actual multigrade oil is working over here. But, as a shear rate is increasing the a sudden change in behavior and try to (( )) viscosity, which of the multigrade oil a viscosity of the fixed oil or mineral oil in which the polymers are mixed.

This loss in viscosity with increase in shear rate is governed by power law that is why it is given on the (( )) say. That if increase in shear rate initially loss of viscosity is not significant, but finite it is not a straight line as shown here. Their will be some loss, but there (( )) sudden transition once the transition is over it again reaches to the viscosity of mineral oil from with the multi grade oil for soften or main constitute of the multi grade oil mathematically.

This can be expressed the way we have treated this as a semi solid lubricant, see shear a strength interface shear strength of a due to the multi grade oil can be again given by tau I as initially, some shear as strength is required to flow it may be zero also and viscosity plus this is going to change here. And will be where multi grade oil it may be 0.8 0.85 0.9 depends on the kind of polymers mixed with that.

Sometime we use this lubricant or this lubricant relation he say that there is a shear stability constant k, shear rate is given it can be one dimensional it can be two dimensional. What we have considered previous examples mostly, we assume what relative velocity or sliding velocity is only in one direction, that was x direction that is why the velocity was express in by u.

However, for general application when velocity is a mu and x direction, as well as a z direction then shear rate in y direction can be expressed by first term. And then shear rate in second or z direction can be expressed for second term is this shear rate can be substituted, whatever the value we know if operating conditions are known to us. We can substitute here is viscosity had a high shear rate it is more like assen diagram for the fatigue loading.

Initially mu change then suddenly change and after that reaching to one new formation the constant value. If the mineral oil is not depended much on shear rate it works as a neutron fluid or we can say in other word also this mineral oil is a mixed with a polymer additives can show two kind of neutron fluid high viscosity, neutron fluid initially. If the low shear rate and low viscosity neutron fluid other rate and in between transition can be.

Transition behavior can be obtained by using this relation if the viscosity or with the shear rate is a lesser than this limit. Then it will be high viscosity neutron liquid and if shear rate is more than this limit. That will be high viscosity, low viscosity neutron fluid in between the shear rate, whatever the in this is the example, we are saying the 10 is to 3 is to 10 is to 6. But, not necessary for every oil will be 10 is to 3 into 10 is to 6. It can be different.

Now, if I use a high shear rate in this case, then relation will be how was turning out to be equal to the viscosity mu 2. Because, mu 1 mu 1 will be cancelled out and if the low shear rate, then it will be the mu 1 we can substitute. And we can find it depends whether this parameter is very high or low you assume the shear stability parameter is zero. That means, this multigrade oil is working with a viscosity equal into mu 2.

Now, if k value is very very high, then this multigrade oil will remain for the longer duration for much higher shear rate. The another word this shear stability parameter had the higher value better will be result. Even if I use a multigrade oil 10 w 40 in one case (( )) turn out to be 20000 in other case for the semi specification k 1 k turn out to be 50000.

So, in that situation we say that 50000 value of k equal to 50000 will be preferable option preferable multigrade oil compare to 20000 value of k. So, based on this shear a stability parameter we can choose multigrade oil how was the specification both the oils will be 10 w 40 will not be able to distinguish much from one component to other component, that distinguish can come using he shear stability parameter

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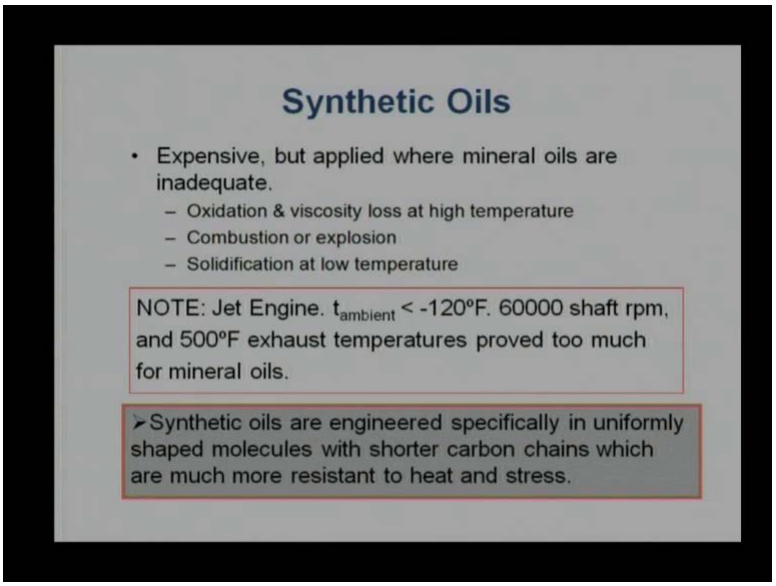


Now, final one comes on a liquid lubricant is synthetic oil is that major thing is expensive. Because, the steam designed for major companies who have a very high production overall cost may come down. Because, of the design cost will be only one time after that one fabrication or synthesis cost. But, for the new applications this will turn out to be very very costly fair.

And it say that because of the cost this oils should be use whenever mineral oil are inadequate either they have this mu tendency of oxidation. And it is more tendency of viscosity loss there is more tendency of explosion, there is more tendency of solidification in those situation. Synthetic oil should be utilized how was the mineral oils are very cost effective those oil should be utilized with on either pure form or with some mineral some sort of additives to give extra properties.

Typical situation where the synthetic oil are used is a given as jet engine the temperature, we can see the minus 120 Fahrenheit operating speed very very high. The 60000 plus and exhaust temperature of that engine is more than 500 fahranheit in this situation. Mineral oil with all kind of additives may not give very good results may not give desirable results to us.

And that is why say synthetic oils are engineered is an being as they are engineered they will be uniformly shaped molecules that is why will be having much more (( )) than mineral oils and they are generally made with a low carbon chain. So, that if they have

more heat and stress stability they have much more strength. However, they (( )) property will go down with low chain that means, a good for high speed application. If there is more possibility of hydrodynamic action for high temperature separation is not a problem. But, the high temperature is problem based on requirement is in (( )) can be selected.

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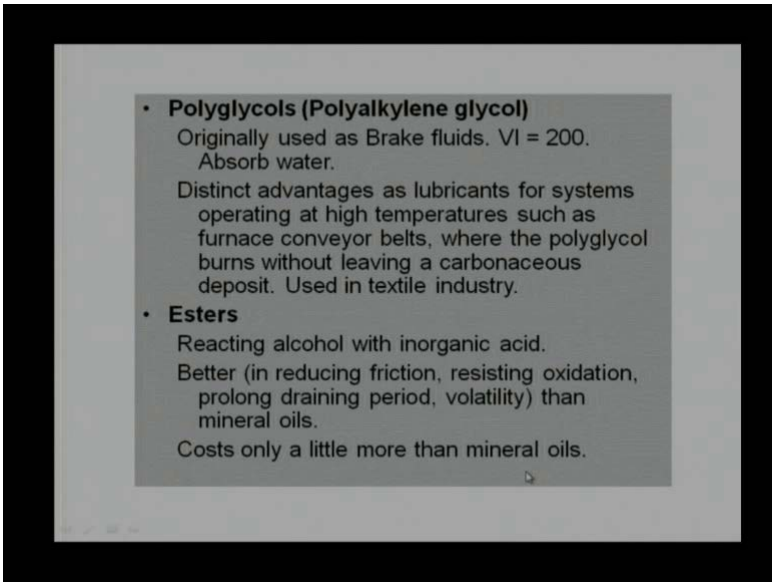


There are few synthetic oils, which we are describing here how was there is a complete subject on. So, synthetic oils poor on chemistry side mineral chemical engineering inside you first common category is a polyglycols, v I is almost 200. And they have been utilized in brake as a brake fluids we try to utilize this kind of polyglycol in our magnetic bearing (( )). Where desire was low temp low lubrication requirement and film thickness was maintain by the magnitude repletion.

If we would have use high viscosity oil they would have been much more shear sharing of that oil much more heat generation. But, we use brake fluids which have low viscosity and what we have use viscosity equal to the 2 s (( )) 100 degree centigrade, we run that set for the 6000 R P M for the almost 3 to 4 hours. And we found non (( )) signal degree temperature wise reason being magnetic limitation was there and even though, there was a problem created for the high dynamic action.

But there was a clear separation between two surfaces. So, for high speed applications this kind of oils can be utilized, we have a low viscosity which is always a desirable for

high speed applications. And another thing is that they have a good cooling capabilities. So, which are desirable in addition if they have a high temperature application, if they start burning they do not leave any debris they do not leave any deposits. So, they are clean liquids therefore, (()) you do not show they were those these kind of lubricants were there in the dominant (()). So, they can be utilized for the textile industries if the cleanliness is the prime required.

A kind of low lost lubricants synthetic lubricant are the Easters can be made by alcohol in an in organic acids they are much cheaper than other synthetic lubricants. But, they show a good performance they show the lesser the friction lesser resister lesser oxidation is more resistance for the oxidation.

And because of that good resistance flow oxidation, they are draining time they are draining period is large or we say that, they do not require a sequent replacement draining period, during draining duration is large it do not vaporize easily as the mineral oils as I mentioned. And they are less costly compared to number of other synthetic oil that is why they are popular I can say that they have a cause more than mineral oil. But, not to significantly.

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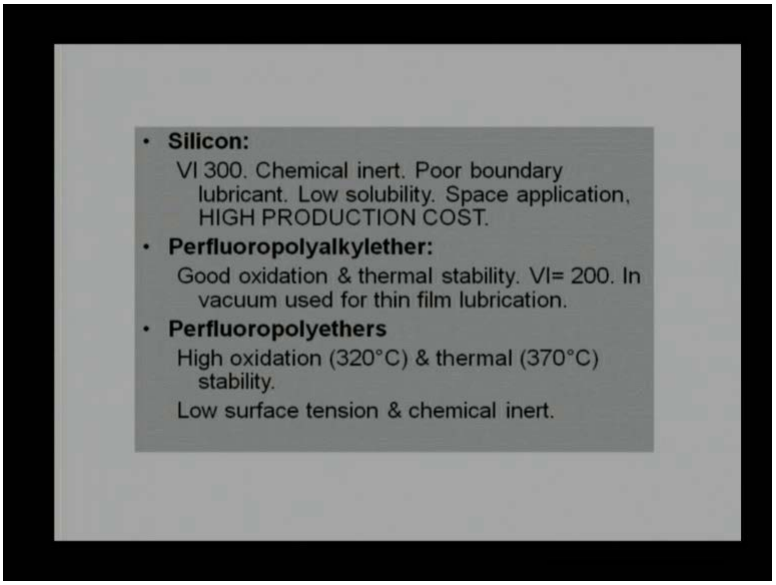


This is marginal even silicon oil very very costly liquid very good high wear much more resistance temperature thinly viscosity does not decrease that much in addition they chemical inert.

So, wherever there is a tedious or there is a composing environment they are high temperature applications and reactive environment, we can choose silicon oils. But, they have a low boundary additives or we say of boundary performance is low there oiliness level is negligible. They done strict to the surface they can be use as a lubricant see if there is a hydrodynamic action.

They should be used if cost permits most often, they are used this kind of lubricants are used for this space applications keep in a mind silicon oils or always required with good design, good understanding of the system. If we do not have very good design assume the lubricating oil is going to deal with all the situation that will not work particularly with a silicon oils.

There are two similar kind perfluropolyethers their v I is high they have very good a thermal. And oxidation stabilities even can be use in vacuum application can see perfluropolyethers the temperature limit is 320 degree centigrade same as silicon oil their also chemical inert in their chemical inert. They will not react with environment easily. So, we have good lubricant high temperature lubricants and cheaper than silicon oils.

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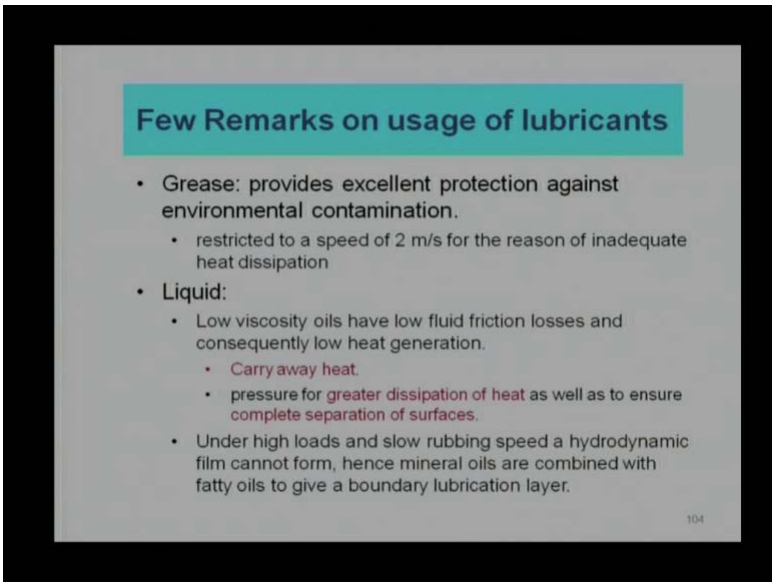


So, this kind of lubricant be selected as per our wish, as per our application with the cost is permitting us there few remarks. When we choose a use lubricants first remark is in the grease good point is that it attach to the surface it covers the surface.

So, gives a good production against the environmental contamination. But, they restricted to the speed application. Higher speed application they will be very high thinning of the grease or we say that there will be belding of the grease. That is why the speed limit many times is capter the two meter per second accept the few rolling (( )) or rolling element bearings if the speed limit is slightly larger because of the rolling action. But, in sliding condition major reason given for this is inadequate heat dissipation their thermal conductivity is negligible. They cant dissipate the they conduct heat properly they cant convert heat properly.

So, this kind of grease is will not be having mode of heat transfer coming to liquid side you say that prefer low viscosity oils major reason. There will be lesser sharing if the neutron fluid, we can say shear stress in purposely to viscosity lesser the viscosity, lesser will be shear resistance. Lesser the shear resistance clear solved the friction force lesser the friction force lesser will be the heat generation.

So, low viscosity oil should be prefer compare to high viscosity oil provided minimum film thickness is maintain. Now, this low viscosity oil are also prefer from the cooling point of view, that is why they can carry the heat in addition they are prefer from the heat pressure point of view, if we as trying to levitate once surface over other surface or keeping the separation.

Between the surfaces sometime we force speed the lubricant and pressurize the lubricant between the two surfaces in that those situation again. There low viscosity lubricant will be prefer because, high viscosity will give more resistance to pumping and more resistance should be pumping means there will be more power consumption.

So, cost of power loss will be increasing we say power loss will increase the cost will increase. However, if this low viscosity oils they are not able to give good performance because, of the high load condition or slow rubbing speed, when the hydrodynamic reaction is not made. Then we can use additives or we can add additives in this case is a mineral oils are can be combined with boundary additives or we say can be attach or mixed with e p additives together desirable results to us.

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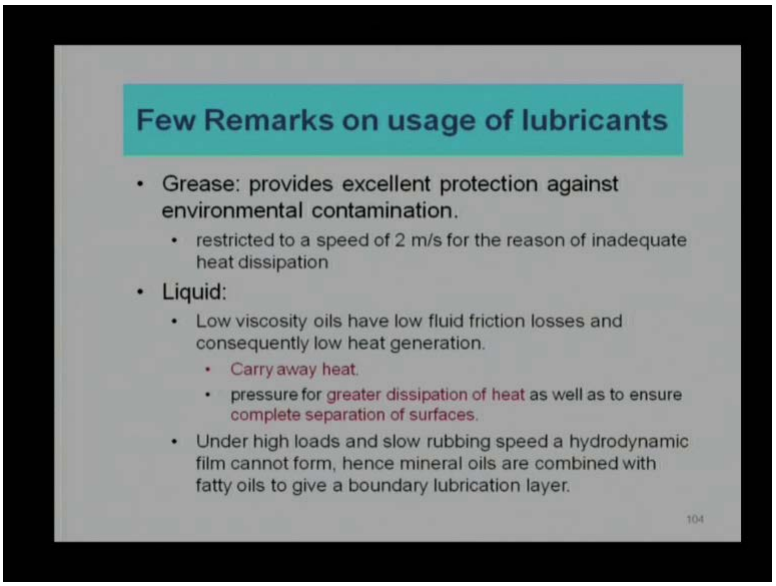


Final one after liquid lubricant comes a gas lubrication, we have only one slide because gas is not intent lubricant unless it is pressurized.

So, that when we are talking the gas it can be anything, it can be environmentally available air it can be nitrogen, it can be helium. We know the helium have good leviting capacity major or main important point of the air is a temperature range temperature range may start minus 200 degree centigrade to 2000 degree centigrade. And major thing is this no vaporization that is advantage is to us.

They will not have cavitation when we discuss application on the liquid lubricant will discuss about the cavitation also there is no problem related to solidification unless the temperature is very very very low.

And there is only composition also. So, is aware from all those problems related viscosity it as a very very low viscosity will not give much problem relatively clean. They do not require seal unless we pressurizing we are sending we are passing air or helium or nitrogen as some pressure of course, if the environment the issue curve related then seals will be requirement.

But, not from a operating point of view, but they sun drawbacks we say this kind of lubrication is a effective, when the low requirement is not very high applied load is very very low, we do not require any damping or there is no vibration related problem.

And even ultra thin film thickness is sufficient to separate to surfaces. That means, we required very good surfaces of the tribo surfaces, now this is imposing major design problem if surface is need to be very very smooth. And by way if they come in a contact they will be very high adhesion. So, gas lubrication required extreme optimization with all calculation of uneven days or we say that all situation in all the situation you should be working. How was it will be turn out to be instable situation slight change in the load.

It may (( )) or surface may (( )) together or one against, one against each other and there will be high adhesion between surfaces that will be problematic. That is why we say that it is lesser forgiving of the errors in estimating the load, the load estimation is not proper than there will be problem. These bearings are highly optimized once, we have a throw understanding of complete system load is speed temperature variation in the load vibration in is speed than only, we should be able to utilized air bearing.

Talk about reometer, where we want to find out the actual measuring talk or whatever the talk in accumate, we want to measure that or talk resistance given by fluid, we required extremely good bearings in those situation this at bearings can be replaced a very sensitive towards. The operating condition that is why once we know we have throw understanding of systems.

Then only we should utilized this sometime we to tolerate this kind of transit conditions, we mix solid lubricant of course, mixing solid lubricant does not mean that you have to mix in gas. What we apply a coatings solid lubricant coating on the surface 15 to 20 micron coating, that will extra smooth surface even the two surface are coming in a (( )) coming in contact. They will not wear away easily because, of the solid lubricant which because of the junction formation will be low interface low shear strength or junction.

That will be good option may be mixed solid lubricant with air lubricant or apply solid lubricant on the surface and then operate on air related operation either air static aerodynamic conditions.

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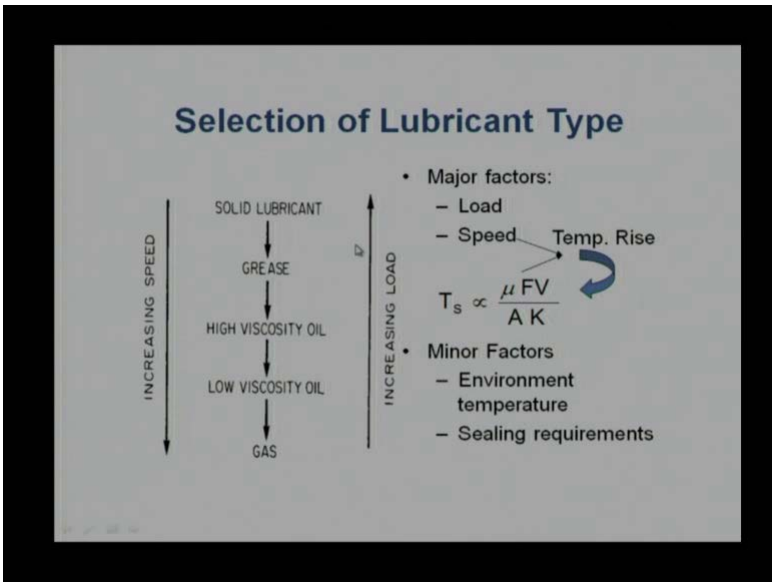


Now, there is overall selection criteria for choosing the lubricant, we say that there are the slide has one arrow which indicating the increase in speed, just opposite sigh there is one arrow which is increasing the load that means, increase load and speed. They are contradictory, they hire a speed will give different trials on higher load will give different trials and they are always in contradiction.

See, this meaning at there is a very high load and load lowest speed application, we should choose a solid lubricants after that number of grease comes, we say that moderate loads and moderate speed similarly high viscosity oil. And moderate load moderate speed low viscosity oil low load lowest speed.

Coming to the gas which is the extra load, very very lower load, very very high speed based on this, we can choose lubricant whether we half for the solid lubricant grease semisolid high viscosity oil low viscosity oil or gas. That is why we say that whenever the selection comes at two major criterias will be the load as well as speed.

And both the criterias pointing towards the temperature rise (( )) in a lowest speed will give high friction, speed high heat generation, high temperature rise same thing. That they are by high speed again the temperature rise will be larger.

And this can be given operating temperature can be given this relation coefficient, higher coefficient of friction is high temperature high temperature means, we should go for the

low viscosity oil or the gas high force again high temperature. Then the situation we need to tolerate there, we need to tolerate combine to lubricants high velocity again we have high operating temperature.

So, we choose a lubricant accordingly the two factors in addition to this mu half and v are given as area, larger area lesser will be the operating temperature. Because, there will be more dissipation area, will be available heat will be dissipated easily in addition to that last parameter comes that is a k. That is a conductivity the meeting surface have a good surface have a good thermal conductivity.

Than operating temperature will be low any other (( )), we can see if the operating temperature will be slow. And we can choose low viscosity oil of the gas if high temperature which is going to reduce a viscosity to oil again in that situation we choose a high viscosity.

So, it is a slightly complex more note we should choose semi solid and solids. But, there is going to increase the temperature increase in temperature. If it is a deducing this there is a viscosity of the lubricant. Then we should choose some sort of additives and this in indicates that study of the additives along with kind of lubricant is essential. So, that will be our next lecture on relating to the additives will discuss about the lubricant additives. Thanks for your attention.