Tribology

Module4: Lubrication & Lubrication

Q.1. Abrasion causes interlocking and damaging between surfaces, then why is it less significant than adhesive in the reduction of friction?

Ans: Continuous abrasion process causes rounding of asperities and reduces the magnitude of friction. On the other hand adhesion causes formation and rupture of cold junctions, which does not guarantee the reduction of friction. In other word, with improving manufacturing processes controlling adhesive friction is more important compared to abrasive friciton.

Q.2. If lubricant reacts with corrosive product of combustion won't its own composition change which might lead to loosing of its lubrication properties?

Ans: Corrosion inhibitors are used as additives in lubricating oils. The main purpose of these additives is to prevent the reaction of chemicals with the Tribo-surfaces; they do not play much role to lubricate the surface. However with continuous usage depletion of corrosion inhibitors occur and lubricant needs to be replaced after certain km (mile) usage.

Q.3. Will boundary lubrication fail in the case of similar materials surfaces in contact?

Ans: No. Boundary lubrication works well with similar materials. Boundary additives form a thin layer between similar materials and maintain separation between those materials.

Q.4. Are the products of boundary lubricants formed at high temperature corrosive?

Ans: Yes. Chemisorption mechanism (high temperature boundary lubrication) corrodes the contacting surfaces to mild level to make low shear strength interface layer.

Q.5. If we have a boundary layer on one surface and now a second surface which has higher adhesion properties compare to the first one is passes over it; will the boundary layer get transferred to the second surface.

Ans: If attached boundary layer is formed due to the Physisorption, then that layer can be destabilized by supplying more energy than the bound energy between first surface and polar additives. If the supplied energy is lesser than the bound energy between polar additives and second surface, then the boundary layer will get transferred to the second surface.

Q.6. In the presence of boundary additive and mechanical contact interface of similar metals, will the boundary layer get equally divided on the surface of similar metals?

Ans: Local surface defects and surface roughness may affect the equal division.

Q.7. Amount of lubricant vs. wear and friction, how do we decide which will be the guiding parameter in selection of type of lubrication?

Ans: In most of the cases, the effect of lubricant is greater in reducing wear of contacting surfaces, therefore amount of lubricant vs. wear get priority compared to amount of lubricant vs. friction.

Q.8. For a solid lubricant what is the ideal shape and size? Solid lubrication should cause three body abrasions, then why are they used?

Ans: Solid lubricants can be used as:

- loose particles carried by liquid or semi-liquid (i.e. grease) at the interface; or
- Coating on the surface.

In both the cases nano-size particles are preferred. To reduce abrasion often spherical shape is preferred.

Q.9. If adhesion wear is becoming zero, then is metal-metal contact with lubrication is preferred or advisable to use?

Ans: If there is no possibility of adhesive junction formation, then lubrication is not required.

Q.10. Why corrosion does not come to zero, when the surface is covered with lubricants?

Ans: Often lubricants contain moisture and acid, which cause the corrosion of metal surface.

Q.11. In Bingham fluids if initial shear stress is a negative value, what does that would mean?

Ans: There is no possibility of negative shear stress. Negative signs are used to define the direction. In the words there is no possibility of negative shear stress in Bingham fluids.

Q.12. Economy vs. environment (like in case of engine), how do we decide?

<u>Ans</u>: Polluting environment with cheap technology is going to cost to society. Therefore better environment is main concern. Let us take example of sulphur contents of lubricant provide lubricity and reduce the wear rate, but we minimize its usage to prevent the environment pollution. In other words we born additional cost to filter sulphur from lubricant and mix other additives to reduce the wear rate. This is done to reduce the environment pollution.

Q.13. If we rub two carpets on each other than there will be more friction due to entangling, so why do we use boundary lubrication where there can be entangling? Also longer the chain more the entangling then why we use them? If attachment and detachment is a continuous process then there should be lumps of entangled molecules this should increase the friction, comment.

<u>Ans</u>: In boundary lubrication, polar head has affinity towards the metal surface, while non-polar tails repel other non-polar tails. Due to this repulsion force, entangling does not happen. As entangling does not happen, lump of entangled molecules does not form.

Q.14. Can boundary lubrication be used in an application where we have to apply electric field or magnetic field?

<u>Ans</u>: Boundary lubrication can be used to support part load even in the presence of electric and magnetic fields.

Q.15. Why low shear strength at interface surface?

<u>Ans</u>: Low interface shear strength causes lesser friction resistance; therefore to reduce the friction losses low shear strength at interface is required.

Q.16. In chemisorption we use active agents like Cl, S, P etc., what will happen if the contacting surface contain moistures? If it has damaging effect how can we reduce it?

<u>Ans</u>: Often chemisorptions and chemical reactions are differentiated based on their interaction with the surface. In chemisorptions, electron interchange between the chemisorbed species and solid surface occurs and adsorbed species are covalently bonded to the solid surface. Therefore from this type of classification, chemisorption does not cause any damage to the surface. The chemisorbed layer is limited to monolayer; therefore in the presence of moisture on the surface, chemisorption does not occur. However, if chemisorption is treated as chemical reaction (ionic bond) between chemisorbed species and solid surface, a new chemical species (i.e. corrosive layer, oxide layer) is generated, which slowly damages the surface.

Such damage (which is generally much lesser than the damage caused in the absence of such layer) can be reduced by reducing the volume percentage of active chemicals (i.e. Cl, S, P).

Q.17. If chemisorption is a process of chemical action between additives and solid surface, then how do we decide the dimensions of a component, since whenever chemisorption is taking place it reacts with a certain thickness of component and as it gets removes of more part of component is required? How many times a surface can get chemisorbed?

Ans: The thickness of chemical layer formed on the solid surface increases with increase in applied load and operating temperature, but limited by increased wear rate. Therefore the formation and rupture of chemical layer is a continuous process, which is either hindered by depletion, below certain percentage, of chemical additives (mixed in lubricating oil) or increase in operating clearance, beyond permissible limit, between contacting surfaces. In other words, the replacement of machine components or lubricating oil is a function of operating load, materials, operating relative velocity, and operating environment (i.e. temperature, presence of other chemicals).

Q.18. If elastodynamic region is best, then why don't we just use Elasto dynamic lubrication only?

Ans: A designer must aim for Elasto hydrodynamic lubrication regime. However, there is very short span of EHL regime compare to hydrodynamic and mixed lubrication, therefore exact knowledge of operating conditions (which is often very difficult) is a must for EHL design.

Q.19. In which applications are gas lubricants used?

Ans: Gas lubrication is recommended for high temperature, high speed and light load conditions. Typical applications are gyroscopes for inertial navigation, scientific instruments (i.e. rheometer), drilling machines, etc.

Q.20. What is the maximum weight that a lubricant support (not getting squeezed out)? Can we put lubricant in between 1 ton-100ton weights?

Ans: In static condition, we cannot put any load on the lubricant. Lubricant will squeezed out under load. However, under dynamic condition we can load the lubricant. The magnitude of lubricant will depend on the frequency, viscosity of the lubricant and boundary conditions.

Q.21. Why friction increases with speed?

<u>Ans</u>: Friction resistance depends on interface shear stress. If interface shear stress increases (like in hydrodynamic lubrication) with speed, friction will increase with speed.

Q.22. Why pressure is the maximum in the middle or shifted a little from middle rather than at the end in case of tilted bearing?

<u>Ans</u>: At the end of tilted bearing (narrow exit), pressure will be atmospheric (zero gauge pressure), therefore to conserve the mass flow pressure needs to be higher well before exit location. The location of maximum pressure will be between middle and exit locations, depending on the angle of inclination, load, speed and viscosity.

Q.23. Can pure sand with consistent composition be used as a lubricant?

<u>Ans</u>: Hardness of pure sand is generally higher compared to surfaces to be lubricated. The usage of sand as lubricant may cause the damage of the surfaces, which is highly undesirable. Therefore pure sand cannot be used as lubricant.

Q.24. In which applications melted metals are used as lubricant, liquid metals must be having high viscosity then why are they used as lubricant?

<u>Ans</u>: In some applications we prefer to use working fluids as lubricants. These are often referred as close loop lubricants. For example mercury, potassium, rubidium which are used as working fluids as these metals are vaporized in heat source (i.e. nuclear, solar boiler), the hot vapors are then expanded to drive a turbine which drives a generator; the exhaust vapor is condensed in a heat exchanger and pumped back in heat source. A small portion of these working fluids, after leaving the pump, is diverted to the bearings as lubricant.

Q.25. Do we use boundary lubricants in pistons? If yes, it is known at 200^0C they fatty acids decompose and lose their effectiveness, then why are they used?

<u>Ans:</u> Yes we use boundary lubricants to lubricate the piston surface. There are two types of boundary lubrication mechanisms: **Physisorption & Chemisorption**. Physically absorbed boundary additive (such as fatty acids) detach/decompose/melt at high temperature (~200^0C), therefore chemisorption mechanism (requires extreme pressure additives) is used for piston lubrication.

Q.26. How and why graphite is used at 500-600^{0}C, when at 100^{0}C it is not able to maintain low friction?

<u>Ans:</u> Graphite provides low friction between100^{0}C to 600^{0}C. The limit on 600^{0}C comes due the oxidation tendency of graphite at temperature greater than 600^{0}C. The limit on 100^{0}C comes due to loss of its lubricating properties below this temperature. The main reason of this loss in lubricating properties is due to lubricating properties of graphite in the presence of adsorbed moisture or vapors, which reside between successive layers atomic layers of graphite and reduce the bonding energy and hence reduce the tangential reduce force. At temperature lesser than 100^{0}C, the amount of water vapor adsorbed is significantly reduced to the point that low friction cannot be maintained, therefore graphite is not recommended as lubricant below 100^{0}C.

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Q.28. Under high pressure viscosity increases and load carrying capacity increases but friction also increases because of which temperature also increases because of which viscosity should decrease. What is the relation between temperature-viscosity and pressure-viscosity and which is more significant?

<u>Ans:</u> There are a number well established temperature viscosity and pressure-viscosity (i.e. Barus $\eta = \eta_0 e^{\alpha P}$) relations. Most popular temperature viscosity relations are: Vogel's relation and Walther's equation. As lubricant viscosity is very sensitive of temperature, therefore accounting temperature viscosity relation is more significant.

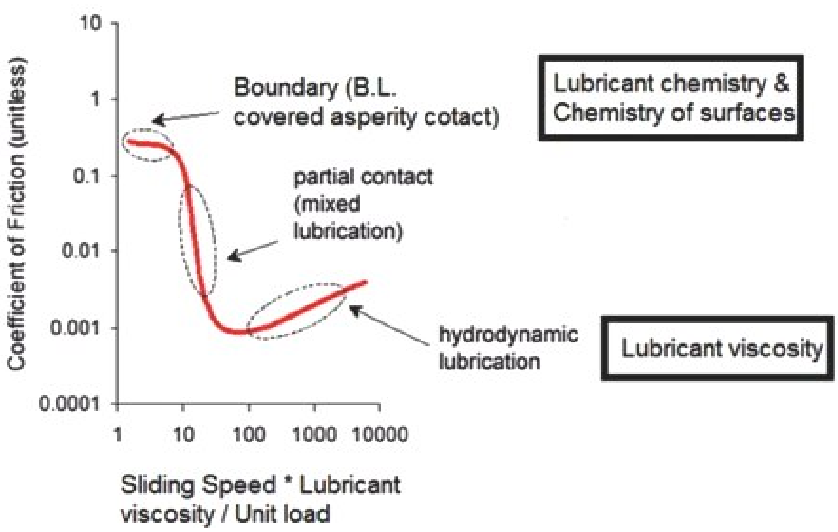
Q.29. If we consider a case in which the top surface is moving, then velocity can be considered to be zero at second surface and shear is maximum on the second surface and zero at the moving. In this case shear force is the minimum at the interface of moving surface; this means there will be no tribological use. Discuss. Does this mean we should always have both surface moving?

Ans: Tribological knowledge is useful only for relatively moving surfaces. There are two cases of relatively moving surfaces:

- Case 1: One surface is moving and other surface remains stationary.
- Case 2: Both the surfaces are moving, but at different velocities (i.e. V_1, V_2).

Case 2 can be treated like Case 1 by assuming one surface moving with velocity V_1- V_2, and other surface remain stationary. If V_1= V_2, we do not require tribological knowledge.

Q.30. According to the Stribeck curve hydrodynamic lubrication is better than boundary layer lubrication; even then in many applications we use boundary layer lubrication why? ALTERNATIVE QUESTION "If the region to the left of minimum (as shown in following figure) represents unstable lubrication than why do we use boundary layer and mixed lubrication?"



Ans: Hydrodynamic lubrication is achieved either by submerged lubrication or continuous supply of lubricant. Pump, motor, piping, fitting, etc. are required to supply lubricant continuously. While boundary lubrication does not require continuous lubricant supply therefore initial and running cost related to lubricant supply system can be saved. In other words, if cost related to boundary lubrication (boundary additives, intermediate supply, mild wear of contacting surface, etc.) is lesser than the cost related to hydrodynamic lubrication (initial and running cost of hydraulic system), boundary lubrication shall be preferred.