Tribology
Module5: Fluid film lubrication

Q1. What percentage of the total area of the tribo-pair is in contact in normal operating conditions and what are the stress conditions at those areas of contact?

Ans: In normal conditions real area of contact between tribo-pair is hardly ten percent of apparent area. With such low contact area, stress-state always exceeds the elastic/fracture point of all known solids. It results in plastic deformation in ductile materials, while generates cracks in brittle materials. In such conditions, relative motion between surfaces causes excessive wear.

Q2. What are incompressible fluids?

Ans: In incompressible fluid density remains constant for isothermal pressure changes. In other words the coefficient of compressibility of fluid is zero.

Q3. What is laminar flow and how it is related to Reynolds number?

Ans: In laminar flow fluid particles move along straight parallel paths in layers or laminae, such that paths of the individual fluid particles do not cross those of neighboring particles.

Reynolds number is a dimensionless quantity and is denoted by

$$\mathrm{Re} = \frac{\rho \mathbf{v} L}{\mu} = \frac{\mathbf{v} L}{\nu}$$

Where

$\mathbf{v}$ is the mean velocity of the object relative to the fluid (SI units: m/s)

L is a characteristic linear dimension, (travelled length of the fluid; hydraulic diameter when dealing with river systems) (m)

μ is the dynamic viscosity of the fluid (Pa·s or N·s/m² or kg/(m·s))

ν is the kinematic viscosity ($\nu = \mu / \rho$) (m²/s)

ρ is the density of the fluid (kg/m³).

If case of circular pipe if Re < 2000 the flow is said to be laminar.

Q4. What is Petroff's equation and what parameter can be calculated from Petroff's Equation?

Ans: Petroff's equation provides crude estimation of friction loss in sliding bearing. Friction force and coefficient of friction parameters can be calculated from Petroff's equation. Petroff's equation can be further used to calculate heat generated due to friction.

Q5. Which equation is used to model pressure distribution between spherical contacts in elastohydrodynamic lubrication?

Pressure distribution in EHL between spherical object can modeled using:

$$p = p_{\max} \sqrt{\left[1-\left(\frac{r}{b}\right)^2\right]}$$

Where

P_{max} is the maximum fluid pressure,

2b is total contact patch perpendicular to normal load

r varies between zero to value b

Q6. What is the FDM in numerical analysis?

Ans: In mathematics, finite-difference methods(FDM) are numerical methods for approximating the partial differential equations. FDM are based on Taylor series and classified as "Forward difference method", "Central difference method" and "Backward difference method". Central difference method provides better accuracy compared to other two FDMs. Usage of these methods depend on the available boundary conditions. Iterative scheme along with FDM is essential to achieve reliable solution of partial differential equations.

Q7. What is thermo-hydrodynamic lubrication and why is it necessary to consider thermal aspect hydrodynamic lubrication?

Ans: The analysis of a hydrodynamic lubrication problem with allowance for viscous heating and dissipation of thermal heat is commonly known as thermo-hydrodynamic lubrication. It is important to consider the thermal effect because several lubricants show reduction in fluid viscosity on increasing temperature, which may reduce load carrying capacity.

Q8. Which energy equation is commonly used in fluid mechanics?

Ans: The energy equation is a simplified form of the heat transfer equation commonly used in fluid mechanics:

$$\rho C_p\left(\frac{\partial T}{\partial t}+u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}+w\frac{\partial T}{\partial z}\right)=\frac{\partial}{\partial x}\left(k\frac{\partial T}{\partial x}\right)+\frac{\partial}{\partial y}\left(k\frac{\partial T}{\partial y}\right)+\frac{\partial}{\partial z}\left(k\frac{\partial T}{\partial z}\right)+\Phi$$

In the lubrication case $\Phi = \tau(\delta u/\delta y)$. For Newtonian fluid $\Phi = \eta(\delta u/\delta y)^2$ where

- u lubricant velocity in the direction of sliding [m/s];
- p lubricant density [kg/m3];
- C_p is the specific heat of the lubricant [J/kg K];
- K is the thermal conductivity of the lubricant [W/mK];
- w is the lubricant velocity in the 'z' direction [m/s];
- x is the co-ordinate in the direction of sliding [m];
- y is the co-ordinate normal to the horizontal plane of the lubricant film [m].

Q9. Explain continuity equation for fluid flow. How can the continuity equation be expressed for incompressible fluid?

Ans: Continuity equation is based on the law of conservation of mass which states that matter cannot be created nor destroyed. In other words, matter or mass is constant.

$$\frac{\partial(\rho u)}{\partial x}+\frac{\partial(\rho v)}{\partial x}+\frac{\partial(\rho w)}{\partial x}=0$$

The continuity equation for incompressible fluid (in which density remain constant) in differential form is

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0$$