TRIBOLOGY
(Professional Elective - I)

I Semester

Course Code: 19ME2152

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Course Outcomes: At the end of the course, the student will be able to
CO1: Demonstrate friction, adhesion, wear and related interfacial phenomenon.
CO2: Describe the viscosity and the laws of fluid flow reference to lubrication.
CO3: Analyze the mathematical approach to fluid film lubrication and hydrodynamic lubrication in thrust bearings.
CO4: Analyze the mathematical approaches of hydrodynamic and hydrostatic lubrication.
CO5: Demonstrate the recent developments in tribology and develop an idea on the working of various measurement tools.

UNIT-I **(10-Lectures)**

Friction: Origin of friction, history, adhesion, deformation, friction theories: Bowden and Taylor's simple adhesion theory, Modified Adhesion Theory: Junction growth, Deformation theory: Ploughing, friction measurement methods, friction of metals and non-metallic materials.

Wear: Types of wear, minor forms of wear, delamination theory of wear, wear debris analysis, wear testing methods, wear of metals, ceramics and polymers, systems approach to wear reduction.

Learning outcomes:
1. Associate with Adhesion theories. (L2)
2. Determine friction and wear. (L3)
3. Determine the wear reduction methods. (L3)

UNIT-II **(10-Lectures)**

Liquid lubricants - Properties and Measurement: Oil lubricants: Natural organics, Synthetic organics; Greases, Viscosity: Effect of temperature, pressure and shear rates on viscosity, viscosity measurement.

Boundary lubrication: Introduction, mechanism of boundary lubrication, metal working lubrication, solid film lubrication, solid lubrication models, solid lubricants.

Learning outcomes:
1. Select appropriate lubricant and lubrication systems. (L4)
2. Interpret the mechanism of boundary lubrication. (L2)
3. Interpret the mechanism of solid film lubrication. (L2)

UNIT-III **(10-Lectures)**

Basic equation for fluid film lubrication: Navier-Stokes equation: Surface forces, body forces, Inertia forces, Equilibrium, Continuity equation, Reynolds equation, from Navier- Stokes and continuity equations, from principle of mass conservation and laws of viscous flow, Dimensionless number: Reynolds number, Taylor number, Froude Number, Euler Number, flow rate and shear force.

Hydrodynamic thrust bearings: Introduction, pressure development mechanism, plane slider bearing with exponential film profile, fixed inclination slider bearing, tilting pad slider bearing, parallel step slider bearing, finite width thrust bearings.

Learning outcomes:

1. Model basic equations for fluid film lubrication. (L3)
2. Describe the pressure development mechanism in thrust bearings. (L2)
3. Define the dimensionless numbers. (L1)

UNIT-IV **(10-Lectures)**

Hydrodynamic Journal bearings: Infinitely long Journal bearing: Full Sommerfeld boundary condition, Half Sommerfeld boundary condition, Reynolds boundary condition, Infinitely short journal bearing, Finite length journal bearing: numerical solution, effective temperature of lubricants, design procedure, hydrodynamic instability, oil supply grooves.

Hydrostatic Bearings: Introduction, circular step thrust bearings, annular thrust pad bearings, rectangular thrust bearings, hydrostatic journal bearings.

Learning outcomes:

1. Categorize boundary conditions and know how to apply them to the practical engineering problems. (L4)
2. Use the skills for tribological analysis. (L3)
3. Evaluate numerical solutions and effect of temperature of lubricants. (L5)

UNIT-V **(10-Lectures)**

Gas lubricated bearings: Introduction, Governing equations; Extremely low velocity, Extremely high velocity, slip flow, surface roughness effects, infinitely long plane slider bearing, Infinitely long journal bearing, Finite journal bearing: Low bearing numbers, high bearing numbers, pressure perturbation method, linearization 'P_H' method, tilting pad journal bearing, spiral groove thrust and journal bearings, foil bearing, externally pressurized bearings, squeeze film lubrication, instabilities in gas lubricated bearings.

Nanotribology: Introduction, measurement tools, surface force apparatus, scanning tunneling microscope, Atomic force microscope/ Friction force microscope, measurements, fabrication techniques for MEMS/NEMS.

Learning outcomes:

1. Recall the methods to reduce the friction for the engineering surfaces. (L1)
2. Explain with measurement tools and different types of microscopes used. (L2)
3. Model the fabrication techniques for MEMS/NEMS. (L3)

TEXT BOOKS:

1. Prasanth Sahoo, *Engineering Tribology* , PHI Learning Private Ltd., New Delhi, 2011.

2. B. Bhushan, *Principles and Applications of Tribology*, John Wiley and Sons, New York, 2002.

REFERENCE BOOKS:

1. B.C. Majumdar, *Introduction to Tribology of Bearings*, 2nd Edition, S. Chand & company Ltd., 2008.

2. G. Stachowiak and A.W. Batchelor, *Engineering Tribology*, 3rd Edition, Elsevier, 2005.