SMOOTH SLIDING

Consulting company providing engineering services on issues related to sliding bearings

Solid Lubricants

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1. Forms of Solid Lubricants

Solid lubricants are solid materials, which reduce coefficient of friction and wear of rubbing parts preventing direct contact between their surfaces even under high loads.

Solid lubricants may be present in the friction area in forms of either dispersed particles or surface films:

- Coating (film) of a solid lubricant applied on the part surface.
- Composite coating consisting of particles of a solid lubricant dispersed throughout a matrix.
- Particles of a solid lubricant dispersed throughout the bulk of the part material (composite material).
- Powder of a solid lubricant delivered to the rubbing area (dry lubrication).
- Additives in lubricating oils or greases.

2. Requirements for Solid Lubricants Properties

- Low shear strength in the sliding direction. This property provides low coefficient of friction due to easy shear movement of the lubricant material.
- High compression strength in the direction of the load (perpendicular to the sliding direction). A solid lubricant possessing high compression strength is capable of withstanding high loads without sufficient direct contact between the rubbing surfaces.
- Good adhesion of the solid lubricant to the substrate surface. This property provides a presence of the solid lubricant on the part surface even at high shear stresses.

The best combination of the first two properties possess anisotropic materials like graphite, molybdenum disulfide or boron nitride having lamellar crystal structure.

3. Characterization of Solid Lubricants

Advantages of solid lubricants:

- Ability to work under high loads.
- High thermal stability.
- Diversity of the application forms

Disadvantages of solid lubricants:

- Higher coefficient of friction and wear as compared to hydrodynamic regime.
- Low stability of the lubrication film.
- Less convenient system of the lubricant delivery to the friction surfaces. In contrast to solid lubricants fluid lubricants are continuously supplied, filtered and cooled.

4. Classification of Solid Lubricants

- **Inorganic lubricants with lamellar structure.**

The crystal lattice of these materials has a layered structure consisting of hexagonal rings forming thin parallel planes. Within the plane each atom is strongly bonded (covalent bonding to other atoms. The planes are bonded to each other by weak Van der Waals forces.
The layered structure allows sliding movement of the parallel planes. Weak bonding between the planes determines low shear strength and lubricating properties of the materials.
The most commonly used inorganic solid lubricants with lamellar structure are graphite, molybdenum disulfide (**MoS_2**) and boron nitride (BN).

Other examples of such materials are sulfides, selenides and tellurides (chalcogenides) of molybdenum, tungsten, niobium, tantalum, titanium (eg. **WS_2**, **WS_2**, **$MoSe_2$**, **$TaSe_2$**, **$TiTe_2$**), monochalcenides (**GaS**, **GaSe**, **SnSe**), chlorides of cadmium, cobalt, lead, cerium, zirconium (eg. **$CdCl_2$**, **$CoCl_2$**, **$PbCl_2$**, **CeF_3**, **PbI_2**) and some borates (eg. **$Na_2B_4O_7$**) and sulfates (**Ag_2SO_4**).

- **Oxides.**

Examples: **B_2O_3**, **MoO_2, ZnO**, **Re_2O_7**, **TiO_2**, **CuO-MoO_2**, **NiO-Mo_2**, **PbO-B_2O_3**, **CuO-Re_2O_7**.

- **Soft metals.**

Due to their low shear strength and high plasticity some soft metals possess lubrication properties: lead (**Pb**), tin (**Sn**), bismuth (**Bi**), indium (**In**), cadmium (**Cd**), silver (**Ag**).
Soft metals are used in pure form or as alloys, in form of coatings (Lead based engine bearing overlays, Tin based engine bearing overlays) or the second phase in Metal Matrix Composites (Copper based bearing materials, Aluminum based bearing materials). Coatings from soft metal lubricants are produced by the methods of Electroplating, Vapor deposition and Thermal spraying.
Composites containing soft metal lubricants are prepared by casting or sintering methods.
Soft metal are widely used as solid lubricants in Engine bearing materials.

- **Organic lubricants with chain structure of polymeric molecules.**

Polytetrafluoroethylene (PTFE) and polychlorofluoroethylene are the typical examples of such materials.
The molecular structure of the materials consist of long-chain molecules parallel to each other.
The bonding strength between the molecules is weak therefore they may slide past one other at low shear stresses.
The strength of the molecules along the chains is high due to strong bonding between the atoms within a molecule.
Such anisotropy of mechanical properties provides good lubrication properties of the materials.
Chain structure lubricants are used in form of coatings (films) applied on the substrates surfaces (Polymer based engine bearing overlays).

- **Soaps.**

Soaps are metals (lithium, calcium, sodium, potassium) salts of fatty acids.
Soaps are prepared by chemical treating of oils and fats by strong alkaline solutions.
A soap molecule is composed of a long non-polar hydrocarbon tale, which is hydrophobic (repelled by water) and the salt polar end, which is hydrophilic (water soluble).
The soap molecules attached to the substrate surface provide good adhesion of the soap lubricant and low coefficient of friction.