SELF-LUBRICATING CERAMIC COMPOSITES

Strong ionic or covalent bonds between the atoms of ceramic materials determine their strength, hardness, high melting point, modulus of elasticity (rigidity), temperature and chemical stability.

In many friction applications where high strength, corrosion resistance and refractoriness should be combined with good tribological properties (coefficient of friction, wear resistance.

Ceramic materials have an excellent resistance to different types of wear due to their high strength.
Coefficient of friction is lower in high surface finish ceramics with fine grain structure.

Liquid lubrication allows dramatically decrease the coefficient of friction.
Solid lubricants continuously supplied to the rubbing ceramic surface have a similar effect.
However use of lubricants is impossible in the applications in which the ceramic part operates under the conditions of high temperature, vacuum or corrosive environment.

Continuous supply of a solid lubricant to the ceramic surface may be provided by the ceramic material itself if it is a composite materialwith the ceramic (eg., alumina) matrix containing dispersed particles of the lubricant (self-lubrication).
During the friction action the solid lubricant smears over the contact surface and forms a transfer film reducing the coefficient of friction.

Solid lubricants, which are used or may be potentially used in self-lubricating ceramic composites:

- Graphite
- Hexagonal boron nitride
- Sulphides, selenides and tellurides (chalcogenides) of metals (eg., Molybdenum disulfide)
- Oxides: $\mathbf{B_2O_3}$, $\mathbf{MoO_2}$, **ZnO**, $\mathbf{Re_2O_7}$, $\mathbf{TiO_2}$, CuO.
- Soft metals (bismuth, tin, silver, indium, lead).

Examples of self-lubricating ceramic composites

- **Alumina-graphite composite**

Graphite is a solid lubricant relating to the class of Inorganic lubricants with lamellar structure.
The layered structure allows sliding movement of the parallel planes.

Alumina-graphite composite may be prepared by Isostatic Pressing.

According to (Yu and Kellett, Tribology of alumina-graphite composites, 1996) fine grain alumina-20%graphite composite has the coefficient of friction 0.25, which is a half of that of a pure alumina ceramic.

- **Silicon nitride-graphite composite**

Coefficient of friction and wear rate of silicon nitride-graphite composite was researched by A.Gangopathyay, S.Jahanmir and M.B.Peterson ("Self-lubricating ceramic matrix composites", Friction and wear of ceramics, 1994).

It was observed that the coefficient of friction of silicon nitride was reduced from 0.43 to 0.2 with the addition of graphite.

The wear rate was not changed with the addition of graphite up to 36%. Further increase of the graphite content led to increase of the wear rate.

- **Alumina-carbon nanotube composite**

Carbon nanotubes (CNTs) are carbon allotropes having cylindrical (tube-like) crystal structure.

Hot pressed alumina-CNT composites have higher fracture toughness than monolithic alumina ceramic due to the ability of the nanotubes to absorb energy through their highly flexible elastic behavior during deformation

Tribological effect of carbon nanotubes on the alumina matrix composites was studied by An, You and Lim, ("Tribological properties of hot-pressed alumina CNT composites", Wear of materials, 2003).

Increase of CNT content from 0 to 12% caused reduction of the coefficient of friction from 0.5 to 0.3. The lubricating effect of CNT in the composite is explained by the rolling motion of the nanotubes over the contacting surface.

- **Alumina-CaF_2 composite**

Calcium difluoride (CaF_2) (fluorite, fluorospar) possesses lubrication properties and can be used as solid lubricant operating at increased temperatures 750-1750°F (~400-950°C).

Tribological behavior of hot pressed composites: Al_2O_3-TiC matrix containing up to 15% of calcium fluoride was investigated inhttp://cat.inist.fr/?aModele=afficheN&cpsidt=16933325. It was found that CaF_2 releases and smears on the contacting surface acting as a solid lubricant. Presence of calcium fluoride in the composite causes decrease of the coefficient of friction. Wear rate of the ceramic composites also decreases with the increase of the CaF_2content up to 10%.

Ying Jin, Koji Kato and Noritsugu Umehara (http://www.springerlink.com/content/p786336941763901/\\) studied the lubrication effect of CaF_2 in alumina and alumina-silver based composites and found that calcium fluoride causes reduction of the coefficient of friction only in the temperature range 200-650°C (392-1202°F).

- **Nano-structured alumina-FeS composite**

FeS (Iron (II) sulfide, ferrous sulfide) has the hexagonal crystal structure similar to that of Graphite hexagonal boron nitride andmolybdenum disulfide.

Materials having hexagonal crystal structure are characterized by low shear strength and therefore low coefficient of friction.

X.Ma and D.Xiao (http://books.google.com/books?id=aHe4P1l0s5YC&pg=PA150&lpg=PA150&dq=%22nanocomposite+coatings+of+high+lubricity) investigated the tribological effect of FeS in the plasma sprayed nano-structured alumina-titania-FeS composite coating.

It was found that the coefficient of friction is decreasing with the increase of the FeS content up to 40-50%.

The wear rate of the composite containing FeS is lower than that of single FeS and of Al_2O_3-TiO_2 ceramic.

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