INTRODUCTION TO TRIBOLOGY

This review is an attempt to consider the tribological aspects of alumina from the practical engineering point of view.
The oldest anti-friction application of aluminum oxide is the jewel bearings, in which alumina is used in its monocrystalline form (sapphire, ruby, corundum). Jewel bearings have been used in mechanical watches (17 jewels watches) and high-precision instruments since 1704.
The coefficient of friction of sapphire is 0.10-0.20, which is comparable with that of Solid lubricants (coefficient of friction of graphite is 0.1). Sapphire is also extremely hard and wear resistant. Excellent tribological properties of monocrystalline aluminum oxide present a great potential for its polysrystalline form as anti-friction material.
Polycrystalline alumina has been used in tribological applications for years due to its unique combination of properties: wear resistance, chemical and thermal stability, stiffness, biocompatibility and low weight. However the tribological applications of alumina are still limited in spite of the extensive scientific activities in this field and evident potential benefits.

2. Tribology

Tribology is the science and engineering of rubbing surfaces.

2.1 Friction

Friction is the resistance to sliding motion. There are two types of friction mechanisms:

- Adhesive friction caused by physical or chemical bonding between the opposing microasperities on the rubbing.
- Deformation friction caused by interlocking of the opposing microasperities followed by their displacement.

Friction force **F** is proportional to the normally applied load **W**:

$$F = \mu * W$$

where **μ** - the coefficient of friction.

2.2 Lubrication

The ratio of the squeeze film (oil film) thickness **h** to the surface roughness **Ra** determines the character of the contact between the microasperities on the friction surfaces and the type of the lubrication regime (Fig.1):

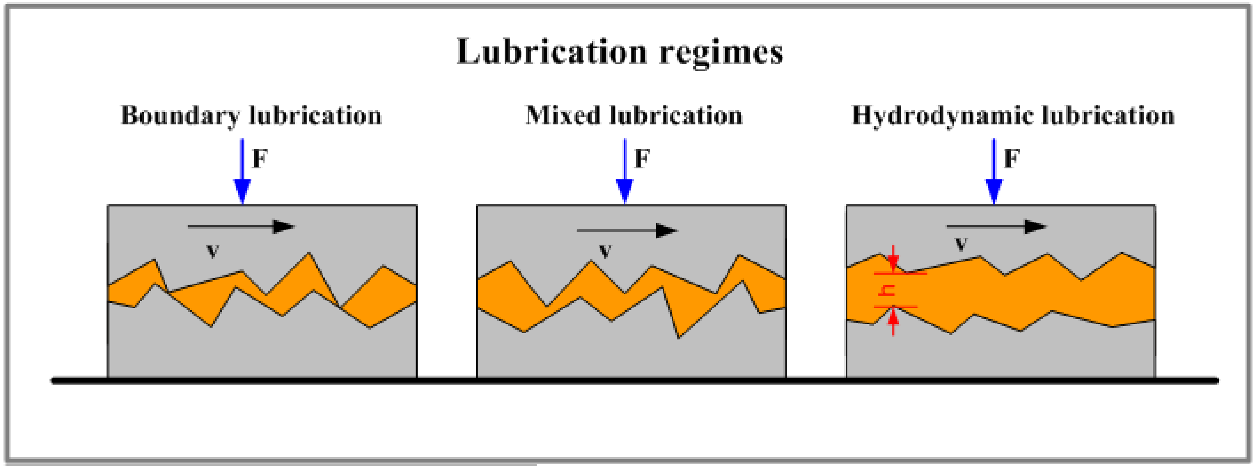

Fig.1 Lubrication regimes

Lubrication regimes:

- Boundary lubrication (**h<Ra**) : a constant contact between the mating surfaces.
- Mixed lubrication (**h~Ra**): intermittent contacts.
- Hydrodynamic lubrication (**h>Ra**): no contact.

2.3 Wear

Wear may combine effects of various physical and chemical processes proceeding during the friction between two counteracting materials: micro-cutting, micro-plowing, plastic deformation, cracking, fracture, fatigue, welding, melting, chemical interaction.

The two modes of abrasive wear are illustrated in the Fig.2.

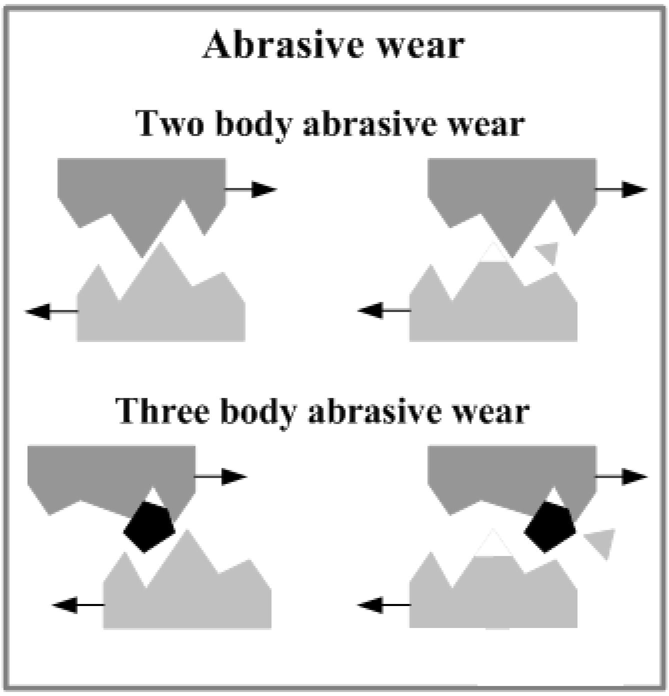

Fig.2 Abrasive wear

2.4 Tribology of alumina

Alumina ceramics like other Ceramics are brittle, and the prevailing mechanism of their wear is abrasion by microfracture mode, which is characterized by a formation of cracks in the subsurface regions surrounding the wear groove. It is different from Metals wearing mainly by adhesive mechanism when a strongmetallic bonding forms between the contacting microasperities and from Polymers dominating wear mechainism of which is abrasion caused by plowing and cutting actions.

Tribological characteristics and mechanism of wear of alumina were studied by S. Jahanmir and X. Dong. The authors showed that the tribological performance of alumina is controlled by one of the four different mechanisms: tribochemical reaction, plastic flow and plowing, microfracture and formation of glassy surface film. It was also concluded that increase of the fracture toughness, modification of the boundary phase composition and lowering the coefficient of friction will improve the tribological performance of alumina.

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