

WEAR OF α -ALUMINA IN HOT STEAM UP TO 300°C

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ABSTRACT

Selfmated α -alumina sliding couples have been investigated under oscillating sliding at 100 N load in different humidity conditions in air as well as in hot steam up to temperatures of 300°C and ambient pressures up to 4 bar. The results show that the wear behaviour is directly dependent on the amount of water in the environment. Two competing wear mechanisms are identified: 1) abrasion is predominant in the low water vapour regime i.e. dry air whereas 2) tribochemical wear is predominant, if enough water is available to form aluminium hydroxide, i.e. in moist air and steam.

Keywords: α -alumina, wear, steam, temperature, abrasion.

INTRODUCTION

According to the calculations of French company EXOES, the use of waste heat from exhaust gases in cars and especially in trucks corresponds to possible energy savings in the range of 5 - 15 %, due to less fuel consumption. This relates to a corresponding reduction of the emission of the green house gas CO₂. Technological solutions in this field are manifold, one of them is steam expansion using waste heat from the exhaust gas and converting it into electrical energy by a piston expander. The development of improved materials and lubricants for further increasing the efficiency needs testing devices suitable for steam environment. This paper describes wear testing of alumina in water vapour atmosphere hence in laboratory air as well as in steam up to temperatures of 300°C and 4 bar ambient pressure.

RESULTS AND CONCLUSIONS

When sliding against itself, wear of α -alumina is determined by the chemical equilibrium as stated by the following equation:



This equation has a negative Gibbs energy of formation at normal conditions of 25°C and 1 bar. Hence, in presence of water, Aluminium hydroxide in the form of Diaspore is formed and is the stable phase. The Gibb's energy of formation stays negative up to a temperature of about 205°C and 1 bar ambient pressure. According to the equation above the thermodynamic stability of the hydroxide phase is of crucial importance for the wear behaviour of selfmated alumina. Corundum is a phase of relatively high hardness of 2035 Vickers, whereas Diaspore has a much lower hardness of only about 1000 Vickers. Due to this difference the wear behaviour of alumina will depend on the amount of water present in the environment which can be seen in Fig. 1. The rough surface on the left side (Fig1a) is characteristic for predominantly abrasive wear. This is typical for wear of α -alumina under the conditions of low water content in the environment and relatively high coefficients of wear (Kong, 1992).

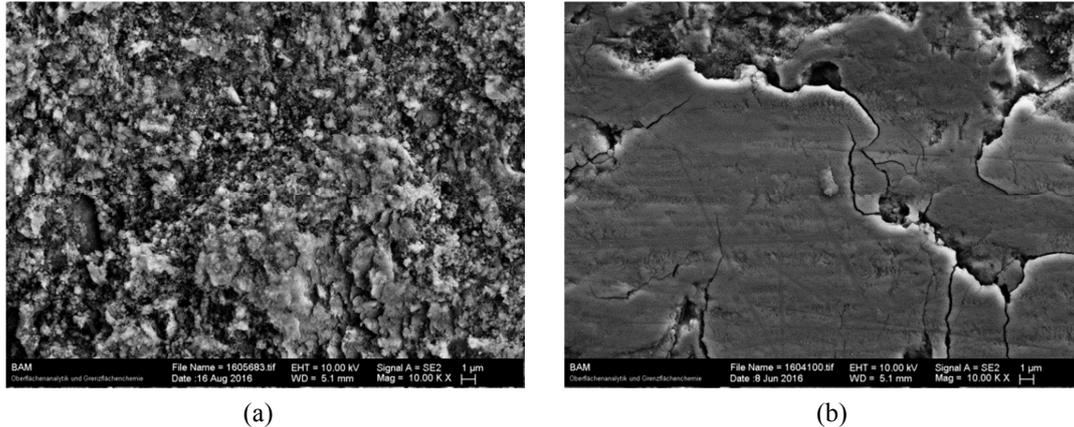


Fig. 1 - SEM micrographs of wear scars after 100,000 cycles under dry sliding at 200°C, a) in air, b) in steam

In high water vapour or steam environments, especially above 100°C, the chemical formation of hydroxide in the sliding interface causes a much smoother, less abraded surface with distinct lower wear coefficients characterized by predominantly tribochemical wear, see Fig 1b.

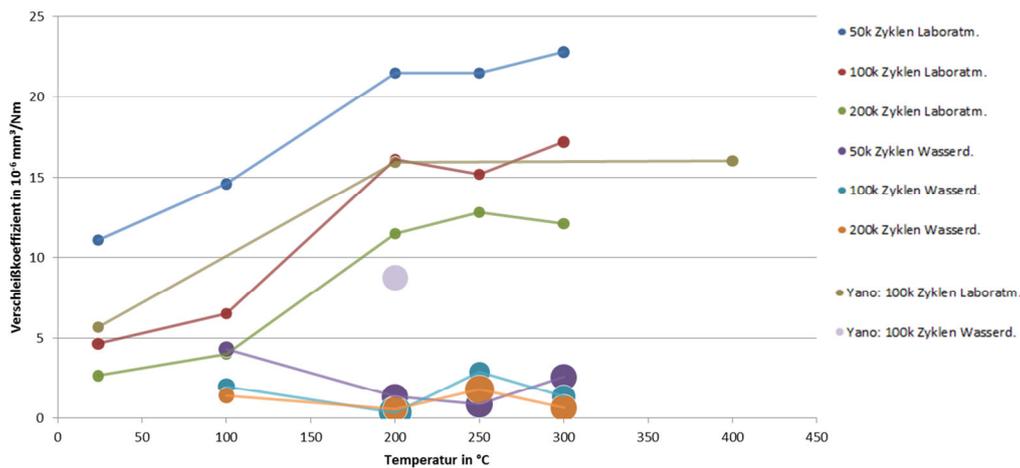


Fig. 2 - Wear coefficient as function of temperature

The amount of water in the environment determines how much hydroxide is formed. Consequently, the wear is predominantly abrasive with high wear rates if water content in the environment is low (dry air). With increasing water content (moist air or hot steam) wear becomes tribo-chemically modified due to the formation of hydroxide phase $AlOOH$ causing lower wear rates. This is seen in Fig 2, where wear rates increase with temperature corresponding to decreasing relative humidity. In water rich atmosphere it stays low due to the stability of hydroxide up to elevated temperatures. This is also observed during sliding in liquid water.

REFERENCES

[1]-Kong H, Ashby M F. Wear mechanisms in brittle solids, Acta metall. mater.,1992, 40 (11), pp. 2907-2920.