Self-Adaptive Lubricants for Extreme Space Mechanism Applications

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This work aims to achieve the self-lubricating capability of the alumina (Al_2O_3) based ceramic composites for moving mechanical assemblies, such as bearings, bushings, and gears. Al_2O_3 possesses a combination of properties, such as high melting point, hardness, and corrosion resistance. However, the friction and wear properties of Al_2O_3 limit its tribological applications. In this research, Al_2O_3-based ceramic composite is engineered by utilizing the specific phase transformation during synthesis. Based on thermodynamic considerations, boron oxide (B_2O_3) was added to the Al_2O_3 matrix. The lubrication behavior of the Al_2O_3-B_2O_3 composite was evaluated. Results showed that B_2O_3 addition led to improved wear resistance with a deteriorated friction compared to pure alumina. Also, the addition of B_2O_3 hindered sintering and generated porosity in the Al_2O_3-B_2O_3 composite. To reduce porosity, CuO and CaO were added as sintering additives. The addition of these oxides improved the density and wear resistance, however, friction increased significantly. To mitigate the adverse effect on friction by sintering additives, hexagonal boron nitride (hBN) was added as a solid lubricant in the ceramic matrix. The lubrication mechanism of these multi-oxide systems was studied by combining the crystal-chemical approach and polarization theory for the oxide systems. The combined approach can also bridge the technological gap to develop multi-oxide systems for tribological applications. Furthermore, two novel strategies were utilized to enhance the lubrication performance of Al_2O_2-B_2O_3 composites. One of these strategies pertains to the deposition of amorphous B_2O_3 as a source of solid lubricant on Al_2O_3-B_2O_3 ceramic by laser processing. The results revealed that the amount of amorphous B_2O_3 depends on laser power that provided lower friction and wear rate. Additionally, the Al_2O_3-B_2O_3 composite contained inherent porosity, which was capitalized by the impregnation of ionic liquid lubricants. The liquid lubricant impregnated Al_2O_3-B_2O_3 composite showed excellent tribological performance. Furthermore, atomistic modeling efforts were carried out to gain a fundamental understanding of the structural properties and lubrication performance of the Al-B-O compound.

This research is of great importance to the further development of coatings for MMAs. It is expected to facilitate research and development in advanced manufacturing, surface engineering, tribology, and thermal science for aerospace, automotive, and biomedical industries. Additionally, project material was demonstrated in the existing tribology and manufacturing courses at UNR and during the project internship program.