Ionic-liquid Lubrication of Electrical Slip-rings

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Introduction

>> Electrical slip-rings are used in space satellites, radars, industrial robots, windmills and wherever else signal or power current is passed from a stator to a rotor. Because of wear and other tribological phenomena, the electrical resistance and noise increase with time, leading to reduced performance and failure. Pin-on-disk tests with ionic liquid and Buckminster gel lubrication where performed and compared with commercial lubrication.

Ionic Liquids

>> Ionic liquids (IL) are organic salts that remain liquid at room temperature and below. Besides having negligible vapour pressure, good electrical conductivity and excellent temperature stability, they also exhibit outstanding tribological properties.1 8mmi TFSI (shown right) was used because of improved conductivity, lubrication and water-repelling properties.

Buckminster Gel

>> Adding 0.5% carbon nanotubes in ionic liquid forms a Buckminster gel. The tubes are very conductive, and they permit an increased conductivity by creating a network inside the IL.2 Electrochemical impedance spectroscopy measures at rest-state indicated a three-fold conductivity improvement compared to plain IL. The Buckminster gel presents a shear-thinning behaviour, which is due to alignment of the nanotubes.3,4

Results

>> Pin-on-disk tribological measurements (right and below) showed that precious metal coated samples tested with high load and without lubrication presented important wear, friction, resistance and electrical noise because of slip-stick effects. All lubricated samples exhibited a three-fold decrease of friction, negligible wear, stable electrical resistance and no measurable electrical noise thanks to the annihilation of the slip-stick effect.

>> The upper-right Strubeck curve (friction coefficient vs. speed · viscosity / charge) shows a minimum at point X. On the left of X, the system is in boundary lubrication state and the pin remains in contact with the disk. On the right of X, the setup is in hydrodynamic lubrication and the pin is separated from the disk by a film of lubricant. The lower-right electrical resistance curve is stable while the slip-ring is in boundary lubrication, showing metallic or tunnelling conduction. Variations are due to the presence of additives in commercial lubricants. In hydrodynamic lubrication, the resistance increases with the distance, displaying ionic conductivity through the ionic liquid.

>> The Buckminster gel presents an increased resistance notwithstanding its improved conductivity. This is explained by the inability of the nanotubes to form conductive networks while under the influence of the high shear rate present at the contact point.

Conclusion

>> The use of any of the tested lubricants is highly beneficial to slip-rings as it reduces the electrical noise, the wear and the friction coefficient. It enables thus an enhanced signal quality, an increased lifetime and a reduced torque for electrical slip-rings.

>> The conducive properties of lubricants have no measurable effect on electric slip-ring resistance while the system is in boundary lubrication. They play nevertheless a role in hydrodynamic lubrication. The state of lubrication can however be easily changed by varying the load of the pin, the viscosity of the lubricant or the speed of the setup.

>> The presence of carbon nanotubes is not beneficial in a pin on disk setting, because of the shear forces preventing any alignment of the tubes. It increases the resistance, and the torque of the slip-ring. The nanotubes may nevertheless be useful in other setups, where shear forces are weaker.

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