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Editorial

Advanced Industrial Lubricants and Future Development Trends of Tribo-Systems for Tribological Performance Evaluation

Simon C. Tung [1,*], George Totten [2,*] and Undrakh Mishigdorzhiyn [3,*]

[1] Innovation Technology Consulting Inc., Glenview, IL 60026, USA
[2] Department of Mechanical and Materials Engineering, Portland State University, Portland, OR 97201, USA
[3] Institute of Physical Materials Science, Russian Academy of Sciences, Siberian Branch, Ulan-Ude 670047, Russia
* Correspondence: simontung168@gmail.com (S.C.T.); getotten@getottenassociates.com (G.T.); mishigdorzh@gmail.com (U.M.)

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It is possible to solve challenges in the global automotive and manufacturing industries by using a multidisciplinary approach to advanced industrial lubricants, their tribological performance evaluation, and new surface engineering techniques for prospective tribo-systems. Three types of approaches are reported in this Special Issue (SI):

(1) Advance surface engineering technologies and protective coatings [1–4];
(2) Multipurpose lubricants with nano-additives for better performance [5–8];
(3) Oil degradation simulation thermo-oxidative ageing and dynamic degradation processes [9–12].

Most machinery and industrial failure is the result of surface degradation processes caused by erosion, pitting, wear, corrosion, and their combination (tribo-corrosion). Surface engineering enhances the resistance to the aforementioned degradation processes by making the surface durable to the environment in which it will be used. The diversity of topics that represent surface engineering includes plating technologies, PVD, CVD, thermal–chemical treatment or surface hardening, surface alloying and cladding, and surface characterization and testing.

Diamond abrasives have been widely used to manufacture cutting and grinding tools due to their extraordinary properties. However, even this kind of material needs to be protected. Coatings extend the holding force between diamond particles and the matrix, lower thermal stress and oxidation, and increase heat dissipation, reducing the diamond from graphitization in high-speed cutting. Ma et al. [1] found that electroless deposition can be adopted as a simple and cost-effective method to synthesize Ni-P coatings on diamond particles with complex morphology. The results obtained are beneficial in the field of semiconductor manufacturing for the production of high-precision diamond cutting wheels for the effective cutting of silicon slices. Pitting is one of the most common and unpredictable failures for oil and gas pipelines. Tribo-corrosion testing of Type 2205 duplex stainless steel conducted by Renner et al. [2] provides a comprehensive understanding of the mechanisms of pitting under conditions involving both abrasion and corrosion. The results by the aforementioned authors showed that the length-to-width aspect ratio of the pits increased exponentially when the normal load during the tests was increased. This phenomenon could be a reason for potential catastrophic failure in underground oil and gas and deep ocean pipelines. Another type of coating described in this Special Issue is boron-containing coatings and layers used for enhancing the tribological performance of tools and machine parts made of carbon and alloy steels [3,4]. Boriding is one of the most common methods of thermal-chemical treatment (TCT) due to the excellent hardness and wear resistance of the produced diffusion layers. However, it has limited application because of its fragility and chipping tendency. Electron beam surface alloying and multicomponent TCT have been reported as promising methods to solve this problem. The obtained coatings and layers ensure the high mechanical properties of the treated steels. The results obtained are beneficial for different tribo-pair systems or three-body wear with abrasion and minimum impact loads in mechanical engineering, automotive engineering, medical technology, aerospace engineering, and related industries.

The second group of papers included in this Special Issue is devoted to multipurpose lubricants with the addition of nano-additives for better performance. Duc et al. [5] optimized the minimum quantity cooling lubrication (MQCL) technique to use a small amount of cutting oil for Hardox 500 steel milling. A natural biodegradable oil with Al_2O_3/MoS_2 hybrid nanofluid was used as the cutting oil. A good surface quality and a cutting speed growth of 2.55–2.80 times compared to the recommended values were obtained due to the better cooling and lubricating effects from the MQCL system with the Al_2O_3/MoS_2 hybrid nanofluid. The technical recommendations for Hardox 500 steel machining were provided based on the conducted research. Kosarchuk et al. [6] report on increasing the wear resistance of heavy-loaded friction pairs through the modification of lubricants with metallic nanopowders based on copper, magnesium alloy, and carbon. The proposed method of lubricant modification can be used to improve the efficiency of "wheel–rail" friction pairs in railway rails and rolling stock wheels. Oumahi et al. [7] investigated the impact of fatty triamine (Triameen YT) on the friction reduction performance of a molybdenum dithiocarbamate (MoDTC) lubrication additive. The formulations containing polyalphaolefin synthetic base oil (PAO) and zinc dialkyldithiophosphate (ZDDP) were used as base lubricants. Triamine improved the performance of MoDTC but in the MoDTC—Triamine—PAO solutions, a chemical reaction resulted in reddish precipitation that impaired tribological performance. This drawback can be eliminated by the dispersion of the precipitate in PAO, resulting in the recovery of the low friction coefficient. Dembelova et al. [8] studied the viscoelastic properties of samples of silicon dioxide nanoparticle suspensions based on polyethylsiloxane (silicone oil) by employing the acoustic resonance method. The results showed an increase in the tear strength of the lubricating film, leading to improved tribological properties of the modified polyethylsiloxane.

The third group of papers is devoted to oil degradation simulation, thermo-oxidative ageing, and dynamic degradation processes. Yan et al. [9] proposed an evaluation method for the oil change interval in a gearbox. The oil's physicochemical properties such as the iron debris concentration, kinematic viscosity, and total acid number were considered for the oil dynamic degradation process. The proposed method increases the oil change interval by 50% and reduces the operating costs for vehicle maintenance. Hong et al. [10] investigated the change in the state of hydraulic oil caused by the presence of major pollutants in construction equipment. The degree of contamination of the hydraulic oil was evaluated using an integrated oil sensor that could measure the absolute viscosity, density, temperature and dielectric constant. Monitoring of the oil conditions was performed using an integrated oil sensor that provides useful information regarding lubricant and machine conditions. Besser et al. [11] introduced a new nitrative thermo-oxidative ageing method for closer-to-reality simulation of engine oil alteration with the intention to achieve the reproducibility of aged oils for subsequent ICE bench testing. The presented method provides valuable benefits for the closer-to-reality ageing of engine oils in reasonable periods with moderate costs. Ronai et al. [12] carried out an "oil chute" laboratory test to study the high-temperature deposit formation tendency of various paraffinic and naphthenic base oil blends. Moreover, the thermo-oxidative stability of the oil blends was investigated using an artificial alteration method. According to the study, finding the right balance between paraffinic and naphthenic base oil components will allow for the formulation of gas engine oils.

Further advancements in industrial lubricants will require more reliable and efficient methods of tribo-system evaluation. The automatic control of critical lubricant parameters will therefore optimize lubricant and subsystem performance. These significant challenges to our automotive and petroleum industries can be seriously considered as the primary drivers for our ongoing research and development efforts. The end goal of this Special Issue is to provide an update on the current developments and future trends in industrial lubricants for industrial machinery and manufacturing equipment, while at the same time, significant gains are being made in equipment safety, resource utilization, technology advancement, and environmental stewardship.

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