Laser ablated magnetic nanoparticles as lubricating additive for anti-wear purposes

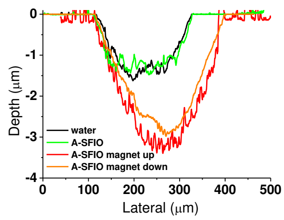
V. Piotto[1)], V. Zin[2)*], S.M. Deambrosis[2)], E. Miorin[2)], M. Meneghetti[1)]

[1)]University of Padova, Department of Chemical Science, Via Marzolo 1, 35131 Padova, Italy
[2)]CNR-ICMATE, C.so Stati Uniti 4, 35127 Padova, Italy
*Corresponding author: valentina.zin@cnr.it

Magnetic nanoparticles with a mixed phase of magnetite and strontium ferrite were synthesized by laser ablation method, to produce water-based nanofluids for lubrication and anti-wear purposes. According to the choice of the solvent of the synthesis, two different structure types were obtained: one consisting of a carbon matrix embedding nanoparticles, and one without organic phase. Tribological tests were carried out to investigate anti-friction and anti-wear performance of produced nanofluids, by applying a magnetic field within the contact zone. It resulted that magnetic nanoparticles, covered with graphitic material, were forced to remain in the contact area by the external magnetic field, favouring the anti-wear action of the graphite, while similar beneficial behaviour was not observed with nanoparticles alone.

Keywords: nanolubricant, magnetic nanoparticles, wear

Magnetic nanofluids are heterodispersed systems where nanomagnets are colloidally suspended in a host liquid. A magnetic fluid-lubricated mechanical coupling can operate without leakage and any feed system under the effect of an appropriate designed magnetic field, which can actively control and fix the lubricant at specific places, where it is needed [1]. The main advantage of using such systems is the reduction of the maintenance for the lubricant supply, because the fluid is prevented from leaving the contact zone of the tribological pair [2]. Moreover, magnetic lubricants can counteract the effects of gravity and centripetal force during the lubrication process, thus preventing leakage and external contamination [3].
Laser ablation synthesis in solution (LASiS) represents a green approach to produce clean and stable nanoparticles without using any surfactant [4]. The laser ablation of a strontium ferrite ($SrFe_{12}O_{19}$) target allowed to obtain a mixed phase between strontium ferrite and magnetite useful for tribological applications. Two different ferrite types have been used for nanofluid preparation: in the first case, the nanoparticles were embedded in a carbon matrix acting as a sponge that traps them, while in the second case they were free.
The two suspensions have been tribologically characterized by means of ball-on-flat experiments, in order to estimate the friction coefficient and the mean wear rate. Coupled materials were Al_2O_3 balls sliding against a (100) silicon wafer. These materials were selected to exclude any interaction with the colloidal sample and to clearly identify any residue detected in post-mortem analyses. A 50 mT axial ring magnet generated the magnetic field within the sliding zone and two different configurations were explored orienting the magnetic field entering or exiting from the plane of Si wafer. Results were compared with those obtained without the magnetic field and using both the nanofluid and water, as a reference.
For nanoparticles produced without the presence of the carbon matrix, the comparison between water and magnetic nanofluid without any applied magnetic field showed that ferrite nanoparticles did not exhibit particular tribological properties, as visible in Fig. 1(a). Instead, by applying the magnetic field, in both tested configurations, an increase of wear phenomena was observed, with extensive damage of the Si substrate. This effect was related to the presence of large aggregates, endorsed by the magnetic field that lead them to accumulate in the contact region, thus amplifying wear by means of abrasive action.
For nanoparticles embedded in organic matrix, similar results were obtained without a magnetic field. However, when the magnetic field was applied, anti-wear action was much weightier as visible in Fig. 1(b). This effect was almost independent from the direction of the applied field.



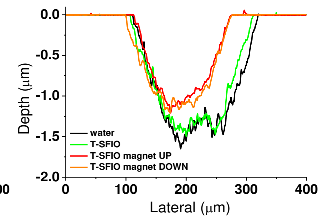


Fig. 1. Analysis of the wear scars for (a) free nanoparticles and (b) nanoparticles embedded in C matrix

It could be concluded that the magnetic nanoparticles, covered with the graphitic material, were forced to remain within the contact area by the external magnetic field, favouring the action of the graphite as an anti-wear additive, which protected the substrate during sliding. At the same time, the significant magnetic response of ferrite nanoparticles in presence of a magnetic field gradient allowed the beneficial carbon phase to stay located within the contact region, avoiding further dispersion that could low the protecting action.

References

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