Numerical simulation of the thermal performances of graphene-based lubricants

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Abstract

Nanofluids, which are stable colloidal suspensions obtained by adding nanometer-sized particles to a base fluid, have shown superior thermal and tribological properties, making them suitable for many engineering applications [1,2]. Graphene (G) and Graphene Oxide (GO) as dispersed phases in nanofluids have been the object of several experimental investigations, which have highlighted an improvement in thermal conductivity and a non-Newtonian rheological behaviour [3,4]. Recent experiments have verified the enhancement in friction and anti-wear properties of G- and GO-based oil lubricants [5,6].
In the present study, we focus our attention on the evaluation of the thermal performances of such lubricants, carrying out laminar Computational Fluid Dynamics (CFD) simulations in ANSYS® Fluent® [7]. We implement single-phase nanofluid models [8], which have been widely employed in literature [9-11] and allow to easily describe a nanofluid without making use of multiphase models or more complex numerical methods.
In particular, we apply the Xue's relation for carbon nanotube-based composites [12] to estimate the overall thermal conductivity of the lubricant. All the thermophysical data of G and GO are taken from the literature [3,4,13], while a standard SAE 10W40 oil is considered as base fluid. Then, we compute numerically the convective heat transfer coefficient for the fluid flow inside a circular pipe [14], demonstrating the expected increase in performances with respect to the pure fluid. Finally, we use CFD for the study of hydrodynamic lubrication of a simple plane slider bearing geometry, for which well-known analytical solutions are available [15]. The effect of G and GO addition to the standard oil lubricant is presented, showing their impact on the load carrying capacity of the bearing and on the adiabatic temperature rise of the fluid. The temperature dependence of the main nanofluid properties (i.e. density, dynamic viscosity and thermal conductivity) is always taken into account during the numerical simulations.
In conclusion, we believe the results of the present study provide a useful insight for the future development of graphene-based lubricants.

References

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