

Synthesis of the PhD Thesis

Graphene is a nanomaterial of great interest in many research fields due to its unique properties different from bulk graphite. Recently, graphene has also found potential applications in the field of tribology. Graphene has been exploited to synthesize innovative atomically thin coatings, produce composite materials, or as an additive to functionalize traditional lubricants. Despite the great interest at the research level, the massive industrial application of graphene is still missing because proven benefits compared to the traditional solutions have not been fully substantiated yet. This PhD thesis aims to bridge this gap and further investigate whether graphene can positively affect friction and wear by comparing the results of simplified laboratory tests with component tests in close-to-service conditions. Graphene was investigated in two forms for this research: as a lubricious 2D coating and as a nano-additive for lubricating grease.

Graphene-based nano-coatings are intended for tribological applications in electrical environments. The main asset expected from these coatings is to combine high lubricity and high electrical conductivity while leaving the mechanical strength of the substrate unaffected. Different types of graphene coatings were deposited on conductive substrates for electro-mechanical applications (Cu and Al alloys) and tested to correlate their tribological performance with the deposition method. The deposition method affects the crystalline structure of the carbon film, indeed, which in turn affects the durability of the coating itself at the contact interface. The results of pin-on-disc tests revealed that the performance of the tribological system is improved as long as the nano-coating can withstand the shearing action of the sliding interface. However, adhesion to the substrate and durability are still issues to be dealt with for scalability to industrial applications.

Graphene-based additives into lubricants are expected to improve both the thermal properties of the lubricant and its tribological performance in demanding operating conditions, for instance, when boundary lubrication prevails. Graphene-grease compounds were prepared with a commercial, high-performance, fully synthetic lubricating grease for bearings and commercial graphene nanoplatelets (GNPs). Several compounds were prepared by increasing the percentage of the nano-additive from 0.5% and 5% wt. The effect of the solid nano-additive on the reduction of sliding wear, rolling friction and grease useful life was investigated to assess whether the presence of the additive is beneficial for the lubricant. Pin-on-disk tests and simplified rolling friction tests were carried out to investigate the impact on friction and wear under conditions of grease lubrication. Grease endurance tests were also

carried out through a dedicated test rig for bearings to assess whether the presence of the additive is beneficial for the lubricant itself.

Results revealed that graphene could stabilize and strengthen the boundary lubrication film in sliding contacts, thus smoothening the friction curve and reducing the likelihood of severe lubricant shortage events. Sliding wear may be significantly reduced as well. The quantity of nano-additive is a major factor in optimising grease performance; the optimum percentage for the selected grease was between 0.5% GNPs and 1% GNPs. On the other hand, rolling friction tests revealed that the presence of graphene is detrimental to rolling friction, and the higher the percentage of nano-additive, the higher rolling friction.

In grease endurance tests, the presence of a lubricious layer rich in graphene inside the rolling track of the spheres systematically correlated with the increase of lubricant life. Grease life doubled during bearing tests with 5% GNPs grease because this layer always formed. The 0.5% and 1% GNPs greases brought about a slightly reduced grease life, except when the lubricious layer could originate. Few repetitions of the long-lasting endurance tests make these results a preliminary assessment of the effect of graphene on the useful life of lubricating grease because grease lubrication is known to be a chaotic phenomenon.