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Advances towards macroscale effective solid lubrication using graphene and novel carbide-derived carbon nanoparticles

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A simple, low-cost technique was used to apply graphene and a novel homemade carbide-derived carbon nanoparticle directly onto low carbon steel substrates. Two methods using SEM and white light interferometry were developed to precisely quantify the number of nanoparticles deposited. The influence of topography and the amount of solid lubricant were tribologically assessed via scuffing resistance and wear rate tests followed by wear marks characterization. Quantification of solid lubricant particles revealed a minimum amount needed to achieve good tribological performance with mild wear and low friction coefficients (~0.08). An optimum roughness level was identified, significantly improving the scuffing resistance of systems.
Keywords: solid lubricant, macroscale, graphene, carbide-derived carbon, tribology

1. Introduction

Solid lubrication is an important branch of tribology. It is limited in many applications due to the high costs of coatings and self-lubricant composites which are complex to manufacture and integrate into the industry [1]. The main aspects related to the tribological performance of solid lubricant nanoparticles in the macroscale remain largely uncharted due to the absence of quantitative comparison criteria and evaluation tools. Therefore, the goal of this work was the development of a simple, low-cost, replicable, and efficient method to apply and evaluate solid lubricant nanoparticles in the macroscale.
Homemade Carbide-derived Carbon (CDC) and ammonia functionalized graphene nanoparticles were directly deposited onto AISI1020 steel substrates via drop-casting. Two methods that allow quantifying the number of nanoparticles effectively deposited were developed. A complete tribological investigation on the influence of the initial supply of solid lubricant nanoparticles was performed using incremental load and constant load tests. Furthermore, the influence of the topography was also assessed by using specimens with different surface finishing in incremental load tests.

2. Methods

The nanoparticles used were ammonia functionalized graphene (HDPlas® - Graphene Supermarket) and proprietary CDC nanoparticles obtained via dissociation of Cr_3C_2 and B_4C. Specimens with different particle coverage were obtained by varying the number of drop-casting cycles (1, 5 and 10 times) using dispersions containing 0.05wt.% of nanoparticles. Each cycle consisted of applying 4 µl/cm² evenly spread over the entire surface of specimens, followed by the evaporation of the volatile solvent.

The coverage obtained in each specimen was evaluated via BSE image analysis using a tailor-made Python v3.0 script and via WLI with a protocol using the software MountainsMap® 7.4. Incremental load reciprocating ball on flat tests and constant load cylinder on flat tests were performed. Wear marks of tribosystems were investigated using SEM, OM, WLI, micro-Raman spectroscopy and EDS mapping.

3. Results

Figure 1 summarizes the main results obtained in the investigation conducted.

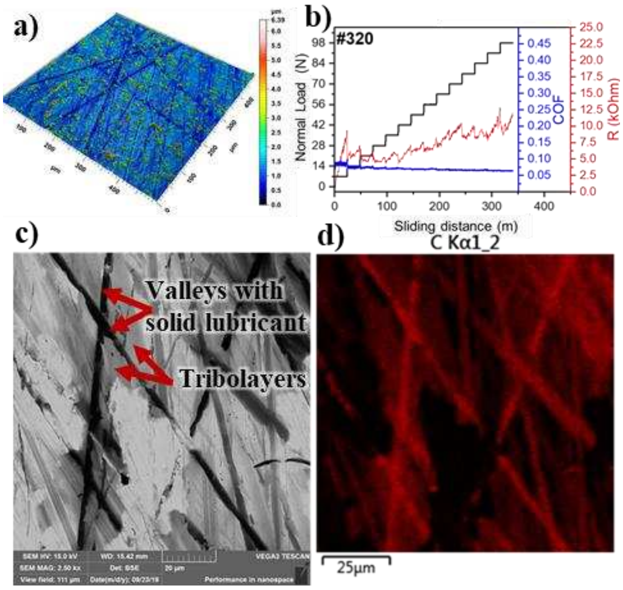

Figure 1: (a) Example of WLI axonometric projection with nanoparticles. (b) Scuffing resistance test with optimal topography condition. (c) BSE image and (d) EDS mapping of typical wear marks.

4. Discussion

Whereas the amount of solid lubricant had only a marginal effect on the scuffing resistance, the topography showed a remarkable effect with an increase of 935% on the best condition, revealing the presence of an optimal topography. Constant load tests revealed a minimum amount of solid lubricant needed to fill topography valleys and consistently cover contact areas with lubricious protective tribolayers.

5. References

[1] D. Berman, A. Erdemir, and A. V. Sumant, "Graphene: A new emerging lubricant," *Mater. Today*, vol. 17, no. 1, pp. 31–42, 2014.