EFFECT OF GRAPHENE REINFORCEMENT ON THE TRIBOLOGICAL AND FRACTURE BEHAVIOURS OF SILICON-BASED NANOCOMPOSITES

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ABSTRACT

There is a strongly growing demand for highly wear-resistant and reliable ceramic-based materials that can be used for a wide range of industrial applications. For this reason, the development of ceramic-based, high-performance materials with superior tribological and high mechanical properties is of utmost interest. The aim of this work is to investigate the friction, wear and mechanical properties of novel graphene reinforced ceramic matrix nanocomposites (GCMC), more particularly silicon nitride (Si_3N_4) composite, that can be used for technical applications such as bearings and rotary seals. The quality of graphene and the homogeneity of its dispersion at the nanoscale significantly affect the mechanical properties and tribological behavior of the final composite[1,2]. Therefore, Few-Layered-Graphene-reinforced (FLG) sheets are deposited by chemical vapor deposition (CVD) directly on the silicon nitride grains, then they are sintered by spark plasma sintering (SPS). The special feature of this deposition process[3] is to produce a composite material whose silicon grains are perfectly enveloped by FLG controlling the covering rate and the number of graphene sheets. Different FLG-reinforced and non-reinforced Si_3N_4 samples were selected to investigate the effect of the graphene covering rate and sheets number on the mechanical properties, friction and wear behaviors. The tribological behavior is investigated under severe contact pressure in dry and water-based lubricated conditions using three different counterpart materials, tungsten carbide (WC), silicon nitride (Si_3N_4) and aluminum oxide (Al_2O_3). Furthermore, the mechanical properties of these materials were determined by means of a diametrical compression test (Brazilian test). The ultimate strength can be measured directly while the elastic properties were obtained by coupling displacement field measurements by the Digital Image Correlation technique (DIC) and a classical Levenberg-Marquardt algorithm. Then, the mechanisms of fatigue crack initiation and propagation are studied by analyzing the fracture surfaces using the scanning electron microscope.

By increasing the graphene content in the GCMC, a significant decrease in friction was observed whether in dry or water-based lubricated conditions, more particularly against WC and Al_2O_3 counterparts. On the other hand, wear does not only decrease with the variation of the graphene content in the ceramic matrix, but it is also strictly dependent on the lubrication conditions.

Results show that graphene reinforcement significantly improves the tribological performance even under severe contact pressure. On the other hand, it has an influence on the mechanical properties, which has to be taken into consideration for the industrial application. By investigating the tribological performance and mechanical properties of the new FLG-nanocomposites should make it possible to clarify the relationship between properties and structure and to optimize the deposition process.

REFERENCES

[1] P. Miranzo et al., From bulk to cellular structures: A review on ceramic/graphene filler composites, J. Eur. Ceram. Soc. 37. 10.1016/j.jeurceramsoc.2017.03.016.

[2] J. Balko et al., Wear damage of Si3N4-graphene nanocomposites at room and elevated temperatures, J. Eur. Ceram. Soc. 10.1016/j.jeurceramsoc.2014.02.025.

[3] A. Weibel et al., Fast and easy preparation of few-layered-graphene/magnesia powders for strong, hard and electrically conducting composites, Carbon 136 (2018) 270-279. doi: 10.1016/j.carbon.2018.04.085 https://oatao.univ-toulouse.fr/20140.