Wear and friction behaviour of SiC/graphene composites under isooctane lubrication: role of graphene addition and surface texture

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Synopsis

The tribological performance under isooctane lubricated conditions of SiC/graphene nanoplatelets (GNPs) composites has been studied. The composites with the highest amount of GNPs (20 vol.%) led to 25-30% reduction in the friction for all tested loads, as compared to the monolithic material, mainly due to the formation of a carbon-based lubricating tribofilm and the surface texture that would act as lubricant reservoirs. These composites also improved the wear resistance (~25%) at 50 N, although as the load increased up to 180 N the wear response for composites was considerably worse than for the reference material due a strong drop in the hardness of the composites with the GNPs content.

Introduction

Non-oxide structural ceramics such as silicon carbide (SiC) exhibit outstanding mechanical and tribological properties, which make them good candidates to be used in wear resistant applications. One of them could be as component in gasoline direct injection (GDI) systems, although the demanding working conditions of these engines (high injection pressures) would require enhancing the current tribological performance of SiC ceramics. Therefore, our approach to fulfill this challenge is to introduce graphene fillers into the ceramic matrix, considering that promising results were obtained under dry tribological testing conditions [1].

Results and Discussion

A set of SiC/GNPs nanocomposites was manufactured by liquid-phase spark plasma sintering, adding 5, 10 and 20 vol.% of GNPs (labelled as SiC5GNP, SiC10GNP and SiC20GNP, respectively). A reference material (0 vol.%, labelled as SiC) was equally processed. In order to simulate GDI testing conditions, linear reciprocating ball-on-plate tests under isooctane lubrication were carried out using silicon nitride balls as counterbody. The tests were performed at loads between 50 and 180 N, frequency of 20 Hz, stroke length of 2.5 mm, and total sliding distance of 360 m. The friction coefficient ($\mu$) and the wear volume ($W_V$) were assessed for all materials/testing conditions, while worn surfaces were characterized by scanning electron microscopy (SEM) and micro-Raman spectroscopy.

For SiC20GNP composite, $\mu$ decreased about 25-30%, as compared to the monolithic material, independently of the applied load (Fig. 1a). However, composites containing lower amount of GNPs exhibited $\mu$ values quite similar than those obtained for the reference SiC ceramics. Therefore, it seems that a minimum GNPs content (>10 vol.%) is required to lubricate the tribosystem. Besides, GNPs promoted the surface texturing of the composites, allowing their use as active lubricant reservoirs. Conversely, the monolithic material showed better wear response than composites, except at 50 N, where SiC20GNP composite reduced $W_V$ in about 25% (Fig. 1b). This wear performance could be related to a strong decrease in the hardness with the GNPs content (Fig. 1c), playing a more decisive role as the testing load augmented. Anyway, a mild wear process occurred for all materials, with wear coefficients in the order of $10^{-7}$ to $10^{-6}$ mm$^3$·N$^{-1}$·m$^{-1}$. It seems that, under the selected testing conditions, there is a competitive tribological process between the lubricating effect of the
GNPs and the surface texture and the hardness of the composites. While at low loads the tribological properties are mostly controlled by the carbon-based tribofilm and the surface texture, at higher loads, the wear process would be mainly controlled by the hardness of the tested materials despite the tribofilm was clearly formed (Fig. 1d).

![Image](image_url)

Figure 1 – A) Steady-state friction coefficient ($\mu_{ss}$) of the different composites at 50, 100 and 180 N load, B) Wear Volume ($W_v$) of the plates at 50 N, C) $W_v$ of the plates at 100 and 180 N related to the materials hardness, and D) SEM micrograph of SiC20GNPs composite worn surface tested at 180 N.

Conclusions

The addition of 20 vol.% of GNPs to SiC matrices decreases the friction coefficient (25-30%) for all tested loads, as compared to the reference material, enhancing the wear resistance (25%) at low loads as well. However, monolithic SiC exhibited a better wear performance than the composites as the load increased. The tribological response of SiC-based materials is controlled by a competitive process between the formation of a lubricating carbon-based tribofilm jointly with the surface texturing of the materials and their hardness.

References