How impregnation can modify tribological performances of a pair of rings in silicon carbide and carbon-graphite during dry sliding.

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1. Introduction

Tribological behavior of silicon carbide (SiC) had been intensively studied in lubricated condition. However, in dry sliding condition, the degradation of a pair of SiC rings became catastrophic [1-2]. To avoid this impracticable situation, we selected two candidates for the replacement of one counter-face with impregnated carbon-graphite (CG) ring. In this study, we had examined the effect of the antimony and PTFE impregnation in CG rings. SEM coupled with energy dispersive X-ray spectroscopy (EDX) and Raman spectroscopy were used to identify the chemical composition of tribofilm, show the evolution of the particle size and the evolution of the mechanical stress at the surface of the rings.

2. Materials

The aim of the impregnation of antimony (Sb) and Polytetrafluoroethylene (PTFE) in CG rings is to permit a favorable tribological behavior by the apparition of benefit material in the interface. Antimony is known to be a soft metal and could be appropriate for the accommodation of the surface of the two rings during sliding motion. It also enhances the rigidity of the ring. The PTFE have a weak surface energy.

Table 1 Mechanical properties

Material	SiC	CG	$CG_{(Sb)}$	$CG_{(PTFE)}$
Density (kg/m^3)	3150	1680	2330	1670
Flexural Strength (MPa)	400	78.5	128	79
Hardness (GPa)	2200 ($HV_{0.5}$)	105-109 (Sh. A)	105-109 (Sh. A)	105-110 (Sh. A)

Four pairs of rings were tested: SiC/SiC, SiC/CG, $SiC/CG_{(Sb)}$ and $SiC/CG_{(PTFE)}$. Their mechanical properties of each material are given in Table 1

3. Tribometer

Tribological tests were run on rotating tribometer coupled with a furnace. The environmental temperature can be 25°C and raise to 150°C and 200°C, using a 2 hours duration with a speed of 0.43 m/s and 0.5, 0.75 and 1 MPa contact pressure. Wear was measured from weight loss using high precision balance.

4. Results and discussion

An important reduction of friction coefficient and wear rate is observed between SiC/SiC pair and all pairs realized with carbon-graphite (Table 2). The lowest friction coefficient is obtain for $SiC/CG_{(PTFE)}$ and both antimony and PTFE impregnation improve wear resistance of the pair. The surface of the rings was analyzed using SEM and EDX. It allowed us to identify the morphology and chemistry of the tribofilm.

Table 2 Coefficients of friction and wear rate (ambient temperature, 0.46 m/s and 1 MPa) in the case of SiC/SiC speed is 0.23 m/s

Pairs	SiC/ SiC	SiC/ CG	SiC/ $CG_{(Sb)}$	SiC/ $CG_{(PTFE)}$
Coefficient of friction	0.68	0.24	0.31	0.16
Wear rate $mm^3/(N \cdot m)$	$95.8 \cdot 10^{-6}$	$23.9 \cdot 10^{-6}$	$18.6 \cdot 10^{-6}$	$30.4 \cdot 10^{-6}$

The tribofilm is present on both surfaces: SiC and CG, it looks compact, continuous and contains antimony or PTFE depending on the case. The amount of oxygen has increased and Raman spectroscopy reveals the appearance of new compound at the interface, like antimony trioxide for $SiC/CG_{(Sb)}$.
Raman spectroscopy permits to identify the amorphization of graphite particles at the interface [3-4]. In agreement with Liu and Vohra's works [5-6], we also measure the distribution of surface mechanical stress on SiC and CG surfaces and see the decrease of the constraints at both surfaces of SiC and CG rings.

5. Conclusions

Tribofilm with graphite particles has reduced the mechanical constraints at the surface of the SiC and avoid the formation of cracks. This effect is reinforced by the presence of antimony or PTFE at the interface.

6. References

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