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Nanocrystalline glaze layer in ceramic-metallic interface under fretting wear

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A B S T R A C T

A silicate ceramic and a Co-based superalloy are put in contact at 700 °C and are submitted to fretting wear (small amplitude reciprocating movements). The present interface is a plane to plane 4 mm contact that is studied in cross section through SEM-EDX, high resolution TEM and XPS. The tribological test results in the formation of thick (20 μm), compact third body that adheres on both counterparts in the interface. This third body, which is formed from mixed, grinded and sintered debris reacting with surrounding oxygen, is a glaze layer. The glaze layer created on the ceramic seems homogeneous at microscale but evidences a nanostructure of metallic 20 nm crystalline grains embedded in an amorphous oxidized matrix. This structure is similar in the layer adhering on the alloy but the matrix is crystalline, suggesting that the amorphization is promoted by ceramic elements. The main wear process argued is the wrenching of metallic grains that undergo further grinding without recrystallization, associated with diffusion and selective oxidation of some metallic elements.

1. Introduction

Due to mechanical solicitations, dry sliding contacts between two ductile materials undergo surface alterations and wear. This issue has been studied through different theories. A first approach is to describe the near contact surface as a plastically deformed and recrystallized structure named Tribologically Transformed Structure (TTS) [1]. Otherwise, the deformed structure breaks into particles that are mixed with counterparts debris in the interface, forming a Mechanically Mixed Layer (MML) [2]. According to Rigney, the formation of the MML is possible only with chemical interactions with ambient atmosphere or counterface material. In general, the MML is observed at low temperatures, whereas an increase of temperature makes favorable oxidation reactions of debris that can create a third body [3]. Under some elevated temperature conditions, a third body also called "glaze layer" is formed [4–5]. Introduced by Stott [6], the glaze layer is a third body made of compacted oxidized debris acting as a buffer layer between the two parts, promoting both low friction [7] and low wear [8]. According to Jiang [8], the wear-protective glaze layer is obtained thanks to oxygen that enables the formation of fine wear debris whose small size promotes the formation of a compact body. The tribo-sintering of debris supported by high temperature and pressure is also argued [9], as well as diffusion processes [10]. Such considerations for metal-metal contacts are also partially valid for metallic alloy-ceramic interfaces as studied in the present paper. It was found that the metallic part has higher worn volumes than the ceramic [11] but for sufficiently high temperatures, a glaze layer is still depicted on both counterparts [12].

The aim of this paper is to characterize the third body formed at 700 °C in a silicate ceramic versus HS25® alloy contact under fretting solicitations. Fretting is a surface degradation that occurs at the contact between two parts when they are subject to small amplitude reciprocating movements, basically induced by vibrations. In hot stages of motors at the blade/disk contact in a turbojet turbine, fretting leads to specific wear damage [12–13]. Some hard ceramic coatings are investigated to reduce severe adhesion between blade and disk thanks their better temperature-bearing properties. Besides, fretting wear at high temperatures is very likely to involve tribochemical reactions with the surrounding elements [14]. The glaze layer formed may also be the result of complex mechanical mixing and diffusion processes, as suggested before. The present work investigates first the glaze layer genesis in the early stages of fretting solicitations, in order to understand the microscopic structure, composition and the formation process. Then, the

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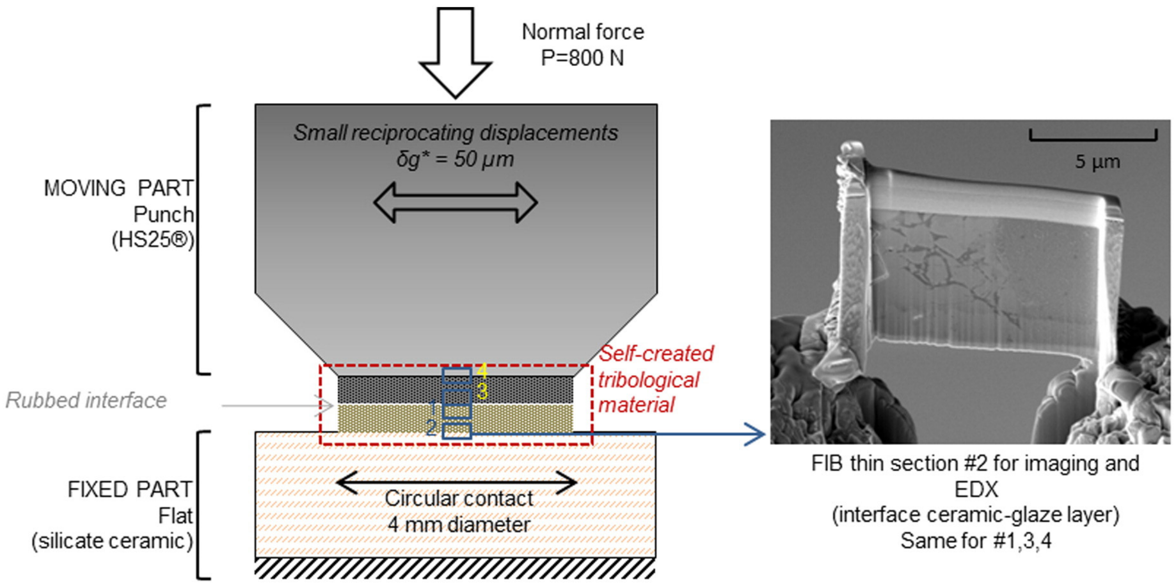

Fig. 1. Fretting contact geometry, parameters and FIB machining in the studied tribological material.

study zooms in to nanoscale inside the glaze layer that adheres on both ceramic and metallic parts. Indeed, crystalline structure, oxidation state of alloying elements and material organization at such an atomistic scope still has to be specified. The latter information will bring new speculations about the wear protective properties of ceramic-metallic glaze layers.

Table 1
Structure and properties of HS25.

Composition (at.%)	Moduli (GPa)	Density	Crystallography
54%Co[a], 24%Cr, 11%Ni, 5%W, 3.3%Fe, 1.6%Mn, 0.7% Si[b], 0.4%C	Dynamic modulus of elasticity: 225 (20 °C), 174 (700 °C)	8.94	εCo (hcp) αCo (fcc) Precipitates M_6C (W_3Co_3C prototype)

[a] As balance.
[b] Maximum (commercial data).

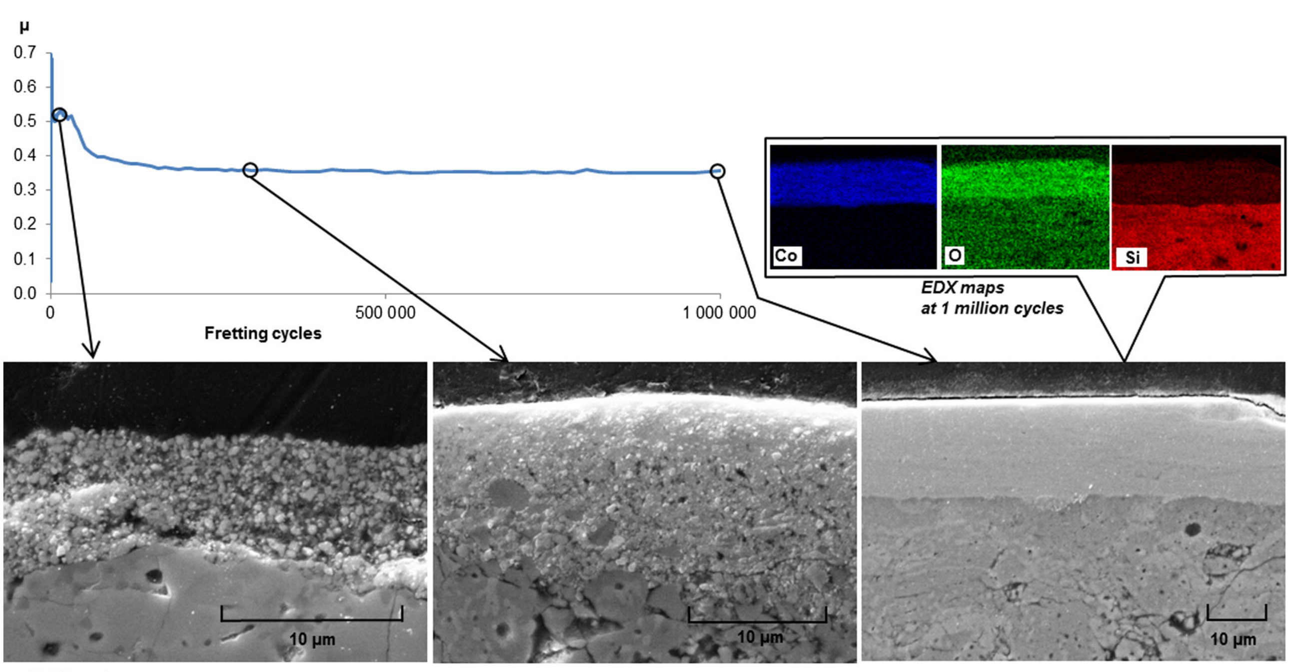

Fig. 2. Evolution of glaze layer microstructure on the ceramic flat coupled with friction coefficient during fretting test (T° = 700 °C, P = 800 N, $\delta_g{}^*$ = 50 μm, f = 50 Hz, N_c variable). On the right: EDX maps obtained at 1 million cycles.

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