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Role of WS_2, WS_2+CrC and bonded coatings on damage and friction of Inconel 718 flat rough surfaces at high temperature

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ABSTRACT

Inconel 718 flat rough surfaces were tested under fretting conditions at room and high temperature (600 °C). Analysis were focused on friction coefficient, damage and fretting regime. Several coatings were tested, and showed significant differences depending on the test temperature. The bonded coating offers good protection against fretting wear at ambient temperature but loses its properties at 600 °C where the CrC shows excellent durability and lower friction thanks to the formation of a few micrometers thin glaze layer. WS_2 solid lubricant layers also show a similar protective behaviour at high temperature but under lighter normal loads and for a lower lifespan.

1. Introduction

The industrial framework for this study is a self-locking endoscope stopper (Fig. 1) located near aircraft engines, and thus exposed to severe thermo-mechanical stresses. Borescope ports are included in engine casings and frames in order to periodically inspect the condition of the core parts of the engine. This stopper owes its self-locking function to interlocking teeth between a rotating and a fixed plate maintained by a spring. The teeth undergo fretting damage during high temperature flight phases, preventing the unplugging of the device without destroying it. Engine vibratory regime activates small amplitude oscillatory sliding motion between the teeth which can result in fretting wear or fretting fatigue damage.

Considering the severe thermal constraints (450–600 °C), solids lubricants such as transition metal dichalcogenide (TMD) thin films (MoS_2 and WS_2) are recommended [2,3]. They can be found under different forms such as graphene-like nanosheets [4], fullerene-like structures [5] or nanotubes [6]. They may be used both as stand-alone solid lubricants or additives in liquid lubricants [7–9] or solid layers [10]. We will focus on WS_2 coatings since they maintain their tribological performances up to 600–650 °C (versus only 300–400 °C for MoS_2) and their chemical reactivity in high relative humidity is lower than that of MoS_2.

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Hard coatings are also used to prevent seizure. At 600 °C some coatings like CrC (chromium carbide) and CrN (chromium nitride) offer high wear, abrasion, and oxidation resistant layers. Their development led to the replacement of less efficient titanium based ceramic coatings (TiC or TiN). CrC and CrN behaviour is similar (low friction coefficient, high hardness, high toughness, good wear resistance and a high corrosion resistance under extreme temperature conditions) on many aspects as shown in scientific literature [11–14]. It seems that CrC coatings deposited on steel show better results regarding friction and wear. Like other hard coatings these layers are sensitive to internal stresses generated during the elaboration processes (machining, finishing and coating). Part of these internal stresses comes from differential thermal dilatation. CrC thermal properties are closer to those of steel than CrN, partly explaining its better behaviour [14].

These different coatings seem to be good candidates to reduce friction and adhesive wear at high temperature and we have chosen to test them to improve behaviour of an interface between two Inconel 718 parts in order to replace a bonded coating currently used for the borescope plug. These coatings perform better when deposited on smooth surfaces, and after a post-deposit polishing [12]. In our case they are implemented on an extremely rough surface without any finishing process. To evaluate the capability of the proposed multi-layered materials two criteria will be discussed: friction coefficient and damage of the top surface.

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2. Experimental study

2.1. Test rig

The tribometer (Vibro Thermo Tribo Meter - VTTM) used for the fretting tests has received a detailed description elsewhere [15]. This bench was specifically designed for plane-on-plane contact configurations. It applies two independent loadings: a static normal load and a cyclic tangential one to reproduce the fretting phenomenon. No bulk fatigue loading is exerted on the specimen. The static normal load is applied to the pin through hanging weights or a traction cable while the track support is set into motion by an electromagnetic vibrator. Oscillatory sliding motion between the plane specimen and the pin is measured by a contactless Eddy current sensor. A particularity of this test bench is that both the transmitted tangential load at the contacting interface and the tangential load exerted by the vibrator are measured using piezo-electric sensors. This set up allows a constant energy piloting protocol similar to the free displacement presented by Sabeya et al. [16].

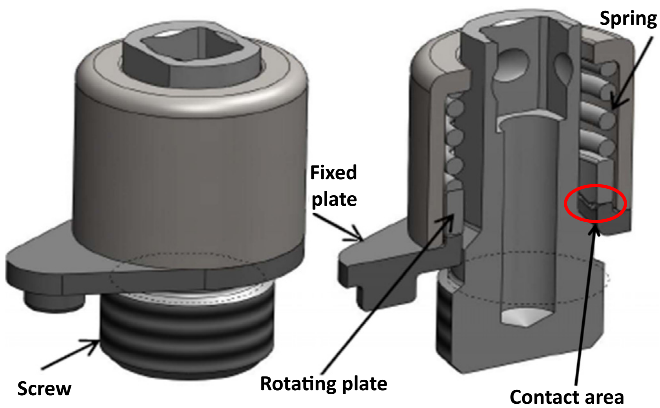
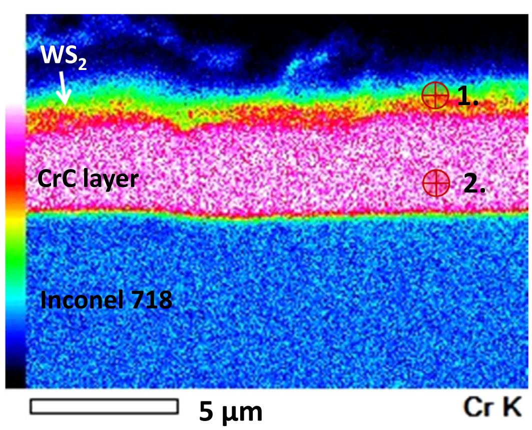


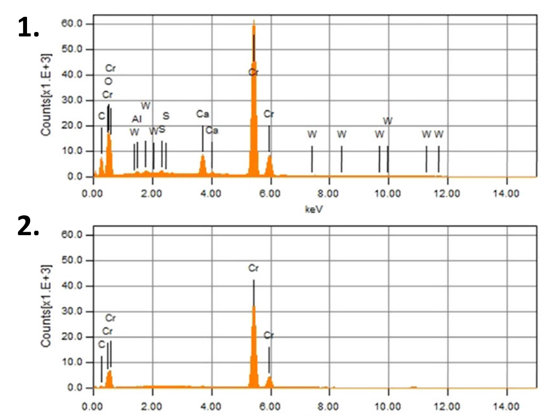
Fig. 1. Schematic view of the borescope plug [1].

2.2. Materials and coatings

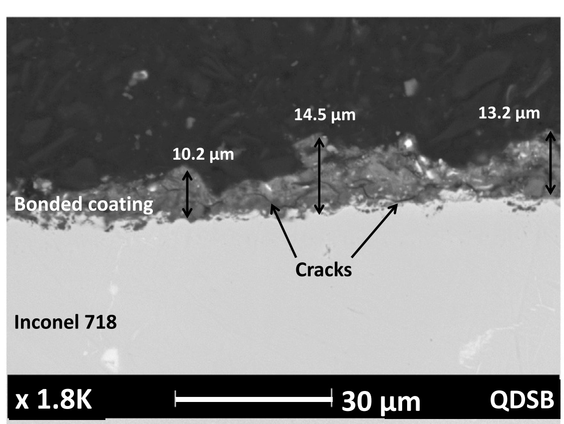
The bulk material of the tracks and pins is a nickel based alloy (Inconel 718). The study involves flat on flat circular (⌀ 3.5 mm) contact surfaces resulting from raw molding according to the industrial process used for the borescope plugs. A commercial WS_2 solid lubricant coating was applied via ion implantation either directly on the Inconel 718 substrate, or on top of a CrC sublayer. The use of a CrN sublayer was experimented in [17], but higher friction than uncoated contact was measured which led us to eliminate this coating. The behaviour of these coatings was compared to that of the raw surfaces, and to the commercial bonded coating currently used by the industrial partner.



(a) WS_2 with CrC sub-layer : Cr element



(b) EDS



(c) Bonded coating

Fig. 2. Chemical contrast and EDS analysis on a transversal cut for a bonded coating (industrial reference solution) and a WS_2+CrC layer. (For interpretation of the references to colour in this figure caption, the reader is referred to the web version of this paper.)

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