Advanced tribological coating solutions for next generation mechanical systems in extreme environments

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The lifetime of numerous structures within a gas turbine engine is limited by the tribological performance of the employed materials and coatings due to the large number of complex contacting and moving mechanical assemblies in the engine [1]. Generally, such contacting interfaces can be classified into two categories: 1) clearance control and 2) tribological interfaces [1]. The main purpose of this talk is to provide an overview of material systems used for such tribological interfaces at a wide range of temperatures with the purpose to maintain wear control and tailor the friction coefficient.

Keywords: aerospace tribology, thermal spray coatings, gas turbine engines, extreme environments

1. Introduction

The advancement of durable gas turbine engine components depends heavily on the development of high-performance materials that can withstand extreme environmental and contact conditions (e.g. large temperature ranges, high contact pressures, and continuous bombardment of abrasive particles, all of which degrade the physical properties) [1]. In particular, due to the large number of complex contacting and moving mechanical assemblies in the engine, the lifetime of certain structures is limited by the tribological performance of the employed materials and coatings (see Figure 1). Materials capable of operating efficiently under these harsh conditions will help overcome many of the challenges ranging from improving durability of the aircraft and premature failure of the components to developing novel gas turbine engines.

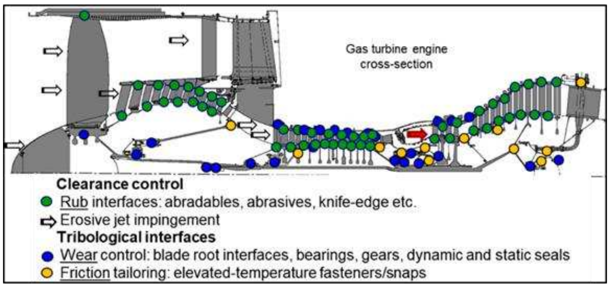

Figure 1 Cross-section of a gas turbine engine slowing a wide range of contacting mechanical-assemblies [1].

2. Methods

A series of studies on the friction and wear behavior of Ni-based and Co-based superalloys was conducted using a custom build high temperature fretting wear apparatus. This instrument is also equipped with a heating chamber, allowing elevated temperature testing. In some instances, wear and roughness measurements were performed after a given number of cycles and correlated to the friction behavior. In addition, ex situ analysis was performed on the worn surfaces using X-ray photoelectron spectroscopy (XPS), AFM, and cross-sectional SEM imaging of the near-surface region.

3. Results

A wide range of coatings and materials used to minimize fretting type of wear in different locations of the gas turbine engine were evaluated in terms of their friction and wear performance. The results showed a clear correlation between the third body formation process (e.g. oxide layer formation, transferfilms) and the tribological behavior of the superalloys as a function of temperature. The low friction and wear of these material systems at elevated temperatures is attributed to the formation of a lubricious 'glaze layer' [2,36]. Depending on the contact conditions, stable lubricous oxides will form above a critical temperature and provide sufficient wear resistance as long as the system continuously operates at these temperatures.

Self-lubricating coating systems were also evaluated at lower temperatures ranges. The friction and wear of these systems was significantly reduced with the addition of a solid lubricant on the surface at the beginning of the test [1]. However, upon further operation, the lubricant is eventually removed from the surface resulting in high catastrophic wear. Additional testing with re-application of the lubricant showed overall the lowest steady-state friction.

4. References

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