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Cold-Sprayed Metal Matrix Composites and Their Third Bodies

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Cold spray is an environmentally friendly process for making metal matrix composite (MMC) coatings. The ceramic retention for cold spray is less than other coating techniques but the tribological performance for various coating systems (e.g. Al-Al_2O_3, Ni-WC, Ti-TiC) is acceptable for repair or primary coating technologies. Wear resistance for cold-sprayed MMCs was studied using a reciprocating pin-on-disc tribometer. Post-characterization included cross-sectional observation of third bodies by electron microscopy. Nanoindentation was used to determine property differences between third bodies and parent materials. The role third bodies have on wear resistance of MMCs is discussed in terms of their structure and properties.

Keywords: metal-matrix composite, wear, third bodies, nanoindentation

1. Introduction

Metal-matrix composites (MMC) are increasingly used as engineering materials for enhanced mechanical and tribological properties compared to pure metals and alloys. However, fabrication of bulk MMCs is challenging and expensive. When the priority is wear resistance and surface properties, MMCs may alternatively be fabricated as coatings [1].

Improved wear resistance for MMCs is often attributed to "load support," where improved mechanical properties leads to a reduction in contact size. Another mechanism is the formation of hard, wear-resistant tribolayers, which are often oxidized and exhibit nanocrystalline or amorphous structure [2]. For MMCs, the tribolayers can form more rapidly due to the ceramic reinforcements.

This paper explores the mechanisms for wear resistance of cold-sprayed MMC coatings, focusing on the structure and properties of third bodies. Three systems are studied, Ti (or Ti6Al4V)-TiC, Ni-WC and Al-Al_2O_3.

2. Methods

Specimens were cold sprayed at the McGill Aerospace Materials and Alloy Design Center (MAMADC) at the National Research Council Laboratory in Boucherville, QC. Powders were either mechanically mixed powders prior to spraying or dual fed to the cold spray gun from separate hoppers. Two different cold spray systems were used, a Plasma Giken PCS-800 (Japan) and a CGT Kinetics4000 (Germany), both with nitrogen as the accelerating gas. Figure 1 presents example microstructures for three of the MMCs studied here.

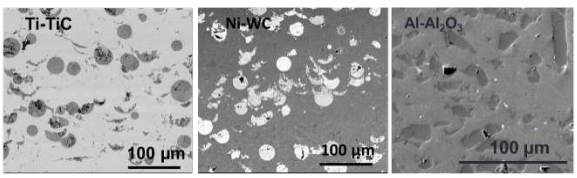

Figure 1: Example microstructures obtained for Ti-TiC, Ni-WC and Al-Al_2O_3 cold-sprayed MMC coatings.

Specimens were tested on a custom-built pin-on-disc reciprocating tribometer using between 1-12 N downforce. Sliding speeds were between 1-3 mm/s. Counterface materials were 6.35 mm dia. spheres of alumina, tungsten carbide or hemispheres of sapphire when conducting *in situ* testing.

After wear testing, third body microstructures were examined with scanning electron microscopy (SEM) and transmission electron microscopy (TEM). For nanoindentation, cross-sections of wear tracks were made by mechanical polishing to 0.05 micron colloidal silica. Indentation testing on third bodies was done with a Hysitron Triboindenter (Minneapolis, USA).

3. Discussion

Figure 2 presents the wear rate at end of test versus the measured tribofilm hardness. Harder tribofilms result in better wear resistance. The test conditions were varied among the data plotted in Figure 2 and are compiled in Ref. 2. To better understand correlation of third body properties to wear resistance, the microstructure must also be examined (Figure 2). TEM results show oxidation, formation of amorphous phases and inclusion of components of the original microstructure.

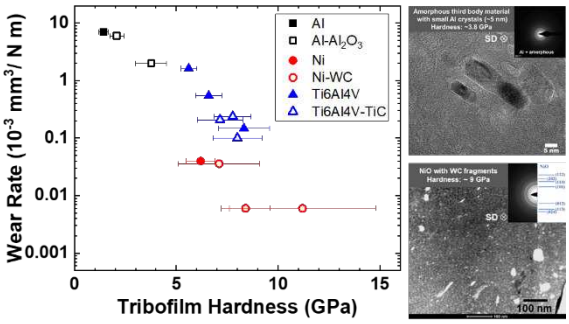

Figure 2: Wear rate versus tribofilm hardness for cold sprayed MMCs. Third body microstructures for Al-Al_2O_3 and Ni-WC coatings.

4. References

[1] Chromik, R.R., et al., "Tribological coatings prepared by cold spray," in Cold Spray Coatings, edited by P. Cavaliere (Springer, Cham, 2018), pp. 321-48.

[2] Chromik, R.R. and Zhang, Y., "Nanomechanical testing of third bodies," Current Opinion in Solid State & Materials Science 22, 2018, 142-55.