Anti-Wear Performance of NiCrBSi/NiCrBSi-WC Coatings Produced by Flame Thermal Spraying Process

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Abstract

NiCrSiB is a Ni-based alloy universally recognized for its superior mechanical properties, attributed to the presence of hard-dispersed carbides and borides, which is dependent on the deposition technique. Moreover, Metal Matrix Composites (MMC) materials will aim to combine the resilience of metals with high wear resistance specific of ceramics which made them innovative for a large wide of wear resistance applications. In this paper, thick NiCrBSi and NiCrBSi-WC coatings were produced onto mild steel substrates S235JR using an oxyacetylene flame-spraying torch (SuperJetEutalloy, Castolin Eutectic). Addition effects of WC reinforcing ceramic phase on the microstructure and wear resistance of the coatings have been investigated by two different wear tests, namely the sand/wheel erosive wear test in dry conditions and the pin-on-disc abrasive wear test in continuous motion. The results show that the presence of ceramic phase affects the wear resistance of the coating. For both wear tests, the metallic alloy coating has an enhanced wear resistance than the reinforced ones. WC reinforcement does not play the protective role of the matrix against wear but improve the hardness. Wear mechanism is mainly controlled by the scratching and by the pull out of WC particles because of their faceted shape.

Keywords: Ni-basedalloy; Metal Matrix Composites; coatings; flame-spraying; wear resistance; hardness

1. Introduction

Thermal spraying is one of the most widely used techniques of surface treatment against wear and corrosion. Especially, flame spraying process due to its advantages, such as its being more economical, easier to implement and more adaptable to a wide range of materials. However, mechanical performances are not always satisfactory because of high porosity, cracks and weaker adhesion. To obtain hard wear and corrosion-resistant coatings, the most suitable materials are those like Nickel, Cobalt-based alloys, hardmetals and ceramics [1-3]. Because of their high melting points, ceramics are in preference deposited by plasma spraying technique, while HVOF spraying technique is used for the deposition of metals and hard metals materials. Ni-based alloy is used to improve the performances of components whose surface is subjected to wear and/or corrosion. It can be also used to replace hard chrome coating which endangering human health and environment [4]. Many studies are reported on tribological properties of Ni-based coatings produced by thermal spray and laser cladding techniques [5-9]. Ni-based alloy with an amount of hard ceramic phase is reported as more advantageous than the metal material deposited alone. Tungsten carbide (WC) and chromium carbide Cr_3C_2 are the most commonly recommended phase reinforcement. Wear resistance is enhanced by Ni-based alloy and reinforced Ni-based alloy produced by thermal spraying process.

To quantify the wear of coating, it is necessary to perform tests under conditions similar to those of the operative regime, but laboratory tests are commonly used as a quantitative tool to describe the wear behaviour of the material tested [10]. For this, a large number of tribological tests are available. The results of tribotest are strongly related not only to the characteristics of the materials couple, but also to the whole mechanical system and its environment. Consequently, the process of selecting the most appropriate test for a specific purpose is fundamental to making meaningful interpretations. Several studies have already exposed the tribological behaviour of the Ni-based and composite coatings under different conditions, such as dry sliding [4, 7, 11-13], slurry erosion [14], liquid impingement erosion [15], solid-particle erosion [16] and others. In fact, in several cases, composite coatings offer the best wear performances, thanks to the hardness conferred by carbide particles and to the toughness provided by the metal matrix.The most commonly used techniques to evaluate wear are weighing and measurement of changes in dimensions. Weighing may often be difficult if the worn volumes are small compared to the weight of the component. To determine the wear mechanism, which caused the surface damage, the study of worn surfaces with microscopy or surface topography techniques becomes an integral part of the evaluation of coatings.

The aim of this paper is to verify if the addition of hard ceramic particles can effectively improve the dry sliding performance of NiCrBSi coatings produced using a commercially available materials. Two wear tests namelythe dry sand/wheel erosive wear test and the pin-on-disc abrasive wear test in continuous motion, have been carried out on two different flame sprayed coating deposited on mild steel substrate: NiCrBSi alloy and the same material reinforces with WC hard particles. After the wear tests, the wear resistance was investigated. Furthermore, the worn surfaces were characterized using digital microscope and Scanning Electron Microscope (SEM) and by energy dispersive X-rays spectrometry to determine the main mechanism responsible for wear behaviour.

2. Experiments

2.1 Test materials and procedure

Two commercially powders used as feedstock material were identified from Castolin Eutectic Company. The first powder is Ni-based alloy powder, designated Borotec 10009, with spherical morphology, hardness of 58 HRC and nominal chemical composition: Cr 14,8%, B 3,1%, Si 4,3%, Fe 3,7%, C 0,75%, and Ni balance. A second powder consisting of a mixture of NiCrBSi matrix with 60%-wt. of WC designated Eutalloy 10112 with a non-spherical angular morphology and hardness of 63 HRC. This latest has nominal chemical composition: WC 60%, Cr 7,3%, B 3,3%, Si 4,5%, Fe 6,3%, C 0,25% max, and Ni balance. Mild steel S235JR was used as substrate and the nominal chemical composition is: C 0.17% max., S 0.045% max., Mn 1.40% max., P 0.045% max., N 0.009% max. and Fe balance. Before the coating process, specimens are manufactured from mild steel S235JR bars that were cut and then machined into discs with 50mm in diameter and 10mm in thickness.

2.2 Wear tests

Two different wear tests were conducted as part of this work in Belgian Ceramic Research Centre (Mons, Belgium). It is important to note that these tests are carried out without any lubrication to study the wear behavior under severe conditions. In addition, all samples have been polished and properly cleaned before performing the tests. In the dry sand/wheel test, the test specimen is pressed against the rotating wheel at a specified force by means of a lever arm while a controlled flow of grid abrades the test surface. The rotation of the wheel is such that its contact face moves in the direction of the sand flow.

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