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Effect of graphite addition on the microstructure, hardness and abrasive wear behavior of plasma sprayed NiCrBSi coatings

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HIGHLIGHTS

- Effect of graphite on microstructure, hardness & abrasive wear of NiCrBSi coatings investigated.
- XRD analysis reveals coatings are composed of γ-Ni, CrB & Cr_7C_3.
- Graphite addition in thermal spray coatings improve wear resistance.
- NiCrBSi–8 wt % C coating has excellent abrasion resistance.

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ABSTRACT

Plasma sprayed coatings have been considered as one of the important surface modification processes to improve the tribological properties of materials used in extreme conditions. NiCrBSi composite coatings on stainless steel are known to offer good abrasive wear resistance in service conditions. Graphite is the material which has many potential advantages when processed and used in different forms. This paper describes the effect of graphite addition on the microstructure; hardness and abrasive wear behavior of plasma sprayed NiCrBSi coatings. The mechanical and tribological properties of the coatings can be significantly improved by refinement of grain structure of the coatings. The XRD results show that the NiCrBSi–graphite composite coatings are mainly composed of γ-Ni, CrB and Cr_7C_3. With addition of graphite, phases such as CrB, Cr_7C_3 emerge in composite coating. The study was conducted, using an abrasive wear test rig according to ASTM G65 on uncoated as well as coated SS304 samples at room temperature. The samples were analyzed for volume loss and wear rate with respect to increasing content of graphite in the coatings. The results suggest that addition of graphite in the coatings resulted in reduction of volume loss and wear rate significantly. The NiCrBSi–8 wt %C composite coating presents excellent abrasion resistance.

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1. Introduction

Abrasion, or abrasive wear, is a type of wear experienced in many industries, particularly in the fields of agriculture, mining and mineral processing [1,2]. Ni and Co based alloys that exhibit high strength, hardness and excellent wear and corrosion resistance have been recently employed as coating materials for applications in the industries [3,4]. Nickel based alloy coatings containing typically, a combination of NiCrBSi are used in mill rolls, high capacity pumps, piston extruders and glass moulding industries, where wear resistance combined with oxidation or hot corrosion resistance is required. Nickel provides ductility and enhances the corrosion resistance. Chromium provides good resistance to wear and corrosion. Boron enhances wear resistance and silicon reduces the eutectic melting point of the alloy and improves the self fluxing properties of the coating. Abrasion is a complicated phenomenon influenced by different factors such as the properties of the materials coming into contact with each other, the service conditions or the environment all play their part in abrasive wear [5]. Abrasive

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wear behavior of a coating is determined by a number of test parameters like applied load, abrasive size, environment, the size, shape and distribution of hard phase precipitates, volume content of the hard phase, hardness of the matrix etc [6]. Many researchers have reported the improvement in hardness of Ni based alloys by incorporation of hard carbides such as WC, TiC and rare earth oxides such as cerium oxide and lanthanum oxide. The hard carbides such as WC and TiC increase the hardness of the coatings at the cost of toughness. Addition of rare earth elements improves hardness and toughness besides enhancing the corrosion and oxidation resistance of the coatings [7–17]. Refinement in microstructure, increase in micro-hardness and abrasive wear resistance of NiCrBSi flame sprayed coatings with the optimum addition of CeO_2 (0.8 wt.%) has been reported by the Sharma et al. [18]. Ahmad khan et al. have reported that Ni powders, which belong to the Ni–B–Si, with chromium addition, increase the hardness of the coating by the formation of hard carbides with improved oxidation and corrosion resistance at elevated temperatures. Boron supports the formation of carbides by depressing the melting temperature, and addition of silicon promotes the self-fluxing properties [19]. Gil et al. reported that the nickel based self-fluxing thermal sprayed alloys have been used in many applications to protect machinery parts against wear and corrosion [20]. The NiCrBSi with addition of Ta in the coating exhibited higher fracture toughness, and higher abrasive and adhesive wear resistance than the NiCrBSi coating as suggested by Tu et al. [21]. Bolleli et al. have reported that HVOF coatings on stainless steel have improved the mechanical and tribological properties of the coatings [22]. Santana et al. suggested improved elastic modulus and hardness for the HVOF coatings [23]. Nicolas et al. has done a detailed study on the microstructures of metallic NiCrBSi Coatings manufactured via Hybrid Plasma Spray and In Situ Laser Remelting Process [24].

However, little literature is available on the study of graphite addition and the effect of graphite addition on the NiCrBSi plasma sprayed coating on microstructure, hardness and abrasive wear resistance. In the light of above an attempt has been made in this investigation to study the effect of addition of graphite in the NiCrBSi plasma sprayed coatings on microstructure, hardness and abrasive wear resistance.

2. Materials and methods

2.1. Specimen preparation

The NiCrBSi–graphite composite is composed of NiCrBSi powders and graphite powders. The chemical compositions of the NiCrBSi and graphite powder are shown in the Table 1.

The particle sizes were in the range of 100–110 μm. The purity of graphite powders with sizes less than 250 μm was 98%. The composite spray powders were made by mixing the Ni-based alloy powders and the graphite powders in ball mill for 1 h. SS 304 was chosen as the substrate, and was pretreated by sand blasting. The plasma spray coating was done at Spraymet coating industries, Bangalore, India. The spray technological parameters were electric current of 500 A, voltage of 65–75 V and spray distance of 100–150 mm. The thickness of the spray coating was approximately 200 ± 15 μm with surface roughness of 0.9–1.5 μm.

2.2. Microhardness and surface roughness tests

Vickers microhardness equipment (Matsuzawa MMT-X7 B type, Japan) was used to measure microhardness by performing indentations at a loading force of 100 gf and holding time of 15 s. At least 5 measurements were conducted and the ranges of microhardness values for the samples are shown in the Table 2. Surface roughness of the samples was measured using Mitutoyo Surftest equipment and the average surface roughness was reported in the Table 3.

2.3. X-ray diffraction studies

X-ray Diffraction studies were conducted to analyze the coating powders using a Rigaku D/Tex Ultra diffractometer with a Cu Kα radiation (1.5405 Å). The scanning angle (2θ) ranged from 20° to 80° with a step size of 0.02° and counting time of 2 s/step. The diffraction patterns obtained were indexed and compared with the

Table 1
Chemical composition of the powder.

Coating	Chemical composition (wt%)					
	Ni	Cr	B	Si	Fe	Graphite
NCB-4G	69.03	14.93	2.97	3.99	3.91	4
NCB-6G	67.59	14.62	2.91	3.91	3.82	6
NCB-8G	66.15	14.31	2.85	3.82	3.74	8

Table 2
Micro hardness values of the samples.

Sample	Avg. Vickers hardness (Hv)	Standard deviation
Uncoated	259.2	0.1237
NiCrBSi-4%Graphite	570.9	0.1339
NiCrBSi-6%Graphite	512.9	0.1857
NiCrBSi-8%Graphite	488.7	0.1448

Table 3
Surface Roughness values of As-Coated specimen.

Sample	Avg. Surface roughness	Standard deviation
NiCrBSi-4%Graphite	5.3292	0.3887
NiCrBSi-6%Graphite	5.2328	0.4939
NiCrBSi-8%Graphite	5.8926	0.2985

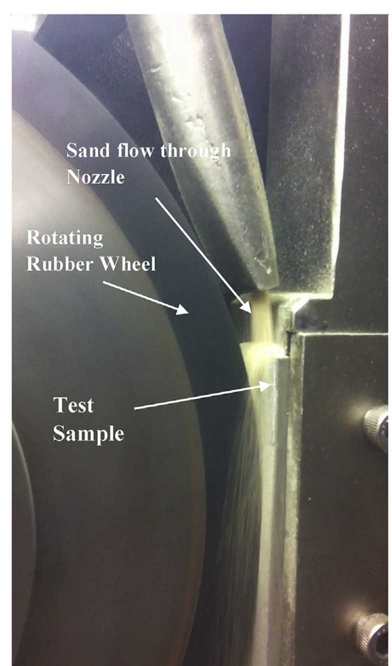

Fig. 1. Testing under progress.

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