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An investigation on erosion behavior of HVOF sprayed WC–CoCr coatings

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ABSTRACT

Present work is an investigation of slurry erosion behavior of WC–CoCr cermet coatings deposited with two different WC grain sizes. HVOF thermal spray process was employed due to its high velocity and low flame temperature characteristics resulting in quality coating. HVOF spraying was assisted with in-flight particle temperature and velocity measurement system to control its heating. Slurry erosion testing was performed using a pot-type slurry erosion tester to evaluate slurry erosion resistance of the coatings. Two parameters were considered for testing viz. erodent particle size and slurry concentration. Surface morphology was examined using SEM images and phase identification was done by XRD. The erosion behavior and mechanism of material removal was studied and discussed based on microstructural examination. It was observed that WC–CoCr cermet coating deposited with fine grain WC exhibits higher slurry erosion resistance under all testing conditions as compared to conventional cermet coating.

1. Introduction

The most common and unavoidable problem of mechanical components of automobiles, power generation units construction equipments, aircraft engine, chemical processing equipments is wear. It not only affects the life of a component but also reduces its performance. To overcome this problem, wear resistant alloys or suitable wear resistant coatings deposited by thermal spray technique are generally used. Now-a-days thermal spray coatings are gaining popularity due to exceptional wear resistance property, weight reduction and cost effectiveness [1]. For industrial applications, WC based cermet coatings are widely used for surface modification to enhance the wear resistance of mechanical components.

WC–Co coating is most suitable for room temperature wear conditions. It is mainly deposited either by air plasma spraying (APS) or high velocity oxy fuel (HVOF) spraying. HVOF spraying is well proven method for the deposition of WC–Co cermet coatings due to its exceptional characteristics such as higher velocities and lower flame temperature that results in less decomposition of WC during spraying [2]. It has been observed that the wear resistance of WC–Co cermet increases significantly by reducing the size of carbide grains to the nanometers in the ductile cobalt matrix [3]. In case of nanostructured coatings, significant fraction of atoms resides at grain boundaries, which contribute for the high hardness and toughness [4], so these coatings can be a better option than conventional coatings for tribological applications in the near future. But there are some problems associated with these nanostructured coatings such as higher decomposition of WC phase due to higher surface area to volume ratio of carbide grains in starting powder that results in decreased performance [2].

Although WC–Co coatings are successful in most of the wear conditions, but not suited for corrosive environment as compared to WC–CoCr coatings [5]. Some studies on cyclic impact, abrasive wear and sliding wear of WC–CoCr have been reported in the literature [5,6]. Slurry erosion resistance of WC–10Co–4Cr AC–HVAF sprayed coated samples has improved by the addition of 15% nano WC–12Co powder into the coatings [7]. However, the studies on slurry erosion of nanostructured WC–CoCr coatings are scarce in the literature.

Mostly there are two types of testing systems for calculating the slurry erosion resistance of materials. These are jet impingement system and slurry pot system; both have their own advantages and limitations. In slurry pot system, test specimens are clamped in a fixture and rotated at constant speed within a pot-type apparatus filled with slurry medium. The slurry is composed of standard concentration and erodent particle size. The rotation of specimens within the slurry medium produces a relative motion between slurry system and specimens and impact caused by erodent particle causes the erosion of test specimens [8,9].

In pot-type slurry erosion testing, it is very difficult to control the flow conditions and certain important parameters like particle

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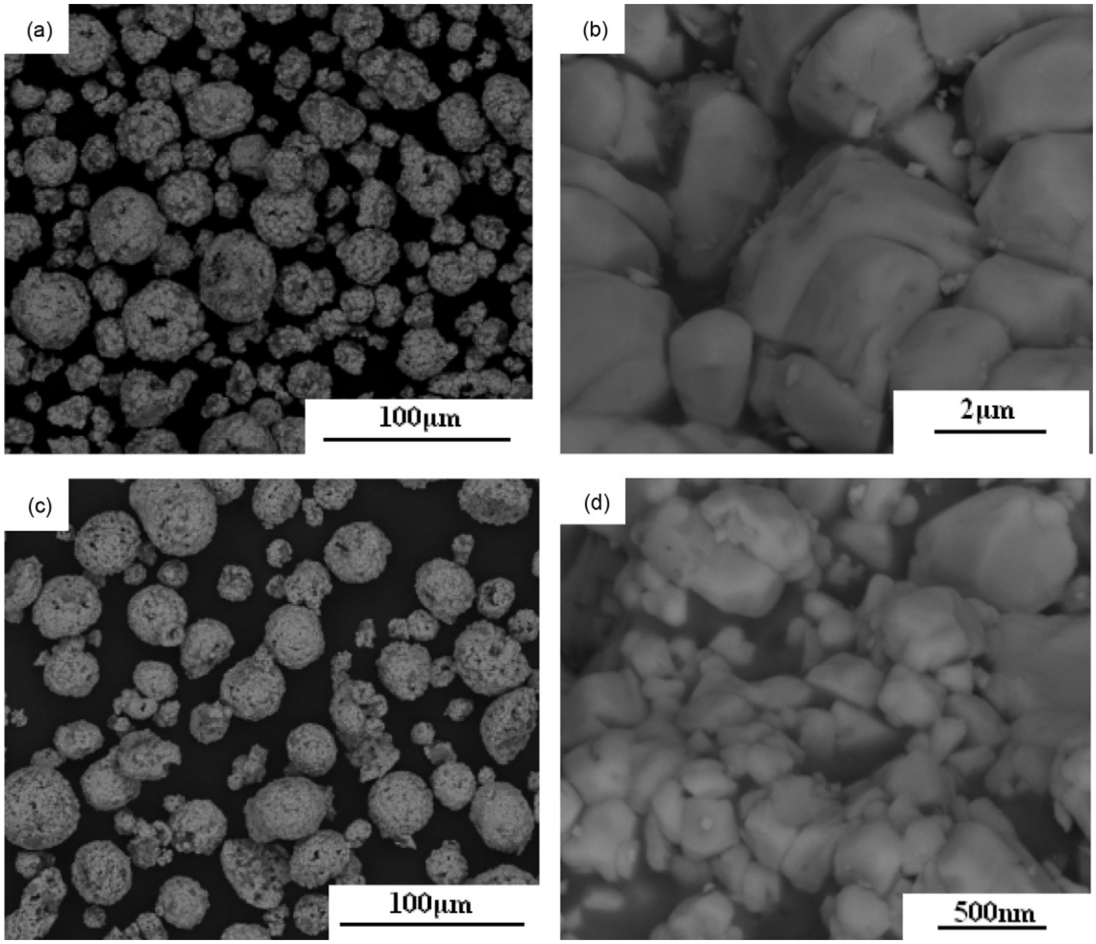

Fig. 1. SEM-BSE images of agglomerated particles of (a and b) WC–10Co–4Cr conventional powder, (c and d) WC–10Co–4Cr nanostructured powder.

concentration, particle velocity and impact angle, which affect the erosion rate [10,11]. In a jet type tester, a calculated quantity of slurry is allowed to impinge over the specimen though a nozzle at various velocities and at different angles which causes the erosion of material [12]. Jet type erosion testing is very complex and expensive but on the other hand, pot type slurry erosion tester is simple in construction, easy to operate, and inexpensive and provides a quick grading of different materials as per their slurry erosion resistance.

Some work of jet type slurry erosion testing has been done on WC–Co and WC–CoCr coatings. The researchers have conducted a study to compare the slurry erosion resistance of different materials using a water jet impingement erosion tester and the best erosion resistance has been shown by the HVOF sprayed WC–CoCr coating [13]. There is a scarcity of work on pot type slurry erosion testing.

Therefore, in this present study WC–Co–Cr coatings with two different powder particles, conventional and nanostructured have been deposited by HVOF process on alloy steel substrate The slurry erosion behavior of conventional and nanostructured coatings has been investigated using an in-house fabricated pot-type slurry erosion tester and the performance of both the coatings were compared under the influence of two varying parameters; erodent size and slurry concentration.

2. Experimental procedure

2.1. Materials

In this study, two different thermal spray agglomerated powders were used for depositing WC–CoCr based coatings on AISI 304 stainless steel substrate by HVOF technique. The first commercially available feedstock material was a conventional, crushed, spray dried and sintered WC–10Co–4Cr wt% powder (primary carbide size 2–4 μm) and second feedstock material selected was WC–10Co–4Cr wt% powder (primary carbide size 200–500 nm approximately) in crushed, spray dried and sintered form. These two powders had an agglomerated particle size of −15/+45 μm for the ease of flow during coating process. Fig. 1a and b shows scanning electron microscopy (SEM-BSE) micrograph of the conventional powder, exhibiting spherical and agglomerated particles. Fig. 1c and d shows scanning electron microscopy micrograph of the nanostructured powder, exhibiting a spherical morphology. The overall elemental distribution in both the powder particles was ascertained through X-ray elemental analysis as shown in Fig. 2a and b.

As the primary carbide size of second powder is above 100 nm, it cannot be called as pure nanostructured powder but a *near nanostructured* WC–CoCr cermet powder and hence the resulting coating is a *near nanostructured* WC–CoCr (NWC) coating.

2.2. Thermal spray coating deposition

Prior to the coating deposition, alloy steel substrate was degreased with acetone and grit blasted using alumina 300 μm to give surface roughness Ra ≈5 μm. The substrate size was 20 mm × 15 mm × 5 mm for the deposition of coating using HVOF process. The conventional WC–10Co–4Cr (CWC) and NWC coatings were deposited using the Praxair-Tafa JP5000 HVOF torch with process parameters listed in Table 1 and coating thickness