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Structure and cavitation erosion behavior of HVOF sprayed multi-dimensional WC−10Co4Cr coating

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Abstract: A new kind of multi-dimensional WC−10Co4Cr coating which is composed of nano, submicron, micron WC grains and CoCr alloy, was developed by high velocity oxy-fuel (HVOF) spraying. Porosity, microhardness, fracture toughness and cavitation erosion resistance of the multi-dimensional coating were investigated in comparison with the bimodal and nanostructured WC−10Co4Cr coatings. Moreover, the cavitation erosion behavior and mechanism of the multi-dimensional coating were explored. Results show that HVOF sprayed multi-dimensional WC−10Co4Cr coating possesses low porosity (≤0.32%) and high fracture toughness without obvious nano WC decarburization during spraying. Furthermore, it is discovered that the multi-dimensional WC−10Co4Cr coating exhibits the best cavitation erosion resistance which is enhanced by approximately 28% and 34%, respectively, compared with the nanostructured and bimodal coatings in fresh water. The superior cavitation resistance of multi-dimensional WC−10Co4Cr coating may originate from the unique micro−nano structure and excellent properties, which can effectively obstruct the formation and propagation of cavitation erosion cracks.

Key words: WC−10Co4Cr; cavitation erosion; multi-dimensional coating; high velocity oxy-fuel (HVOF) spraying; microstructure

1 Introduction

Cavitation erosion is the predominant cause for overflow part failure and can be frequently observed in fluid machinery such as ship propellers, rudder blades, turbine impellers and various pumps. It has become the key technical problem which affects the safety of fluid equipment, reduces the efficiency and increases the production cost [1,2]. Up to date, surface engineering and coating techniques are the most effective protection methods because cavitation erosion occurs only on component surface [3]. Thermally sprayed WC based cermet coatings have shown excellent wear resistance on different industrial components, which has drawn much attention in the research of cavitation protection since the coatings demonstrate high hardness and high toughness [4]. In comparison with WC−Co coatings, WC−CoCr coating possesses more excellent corrosion resistance and higher coating strength, making it a promising solution to the cavitation erosion problem [5].

WC grain size is one of the most critical factors to influence the mechanical properties and wear performance of WC based cermet coatings [6,7]. It is suggested that WC based cermet coatings with a high volume fraction of ultrafine WC particles would exhibit high wear performance [8,9], leading to extensive studies of nano WC based coatings [10,11]. Although some researches showed that the hardness and toughness of nanostructured materials can be improved simultaneously [12,13], other researchers presented some controversial and much disputed results due to different coating fabrication processes and parameters [14,15]. Several researches also revealed the decrease in the fracture toughness of coating with decreasing WC size because of decarburization of nano WC owing to the formation of unwanted carbides such as W_2C, complex Co−W−C and W, which can also lower other mechanical properties of nano WC based coatings [16−18]. In order to prevent the decarburization and reduce the high cost of nano coatings, a bimodal WC based coating composed of nano and micron WC particles has been

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proposed [19,20], which can achieve denser structure, more excellent abrasive wear resistance and anti-cavitation performance [21,22]. Nevertheless, it was found that decarburization still occurred to certain extend and the fracture toughness of coatings was below satisfaction [19]. Furthermore, the structures and properties of such coatings, e.g. hardness, fracture toughness and mechanism of cavitation erosion, have not been fully understood.

WC based cermet coatings are mainly deposited by thermal spraying processes. Among these processes, HVOF spraying can result in less decarburization of WC phase due to the characteristics of high velocity and moderate temperature of flame during spraying, therefore HVOF process is an ideal method to prepare various structured WC−CoCr cermet coatings [22−25].

In this work, a new multi-dimensional WC−10Co4Cr cermet coating in which the carbides are composed of nano, submicron and micron WC grains was deposited by HVOF spraying. Reduction of nano sized WC decarburization, improvement of the hardness and toughness, and enhancement of the coating cavitation erosion are expected to be obtained by the multi-dimensional coating simultaneously. Analysis of the cavitation erosion behavior and the mechanism of the multi-dimensional coating were carried out. The results can provide important reference for WC−CoCr anti-cavitation coating design and application.

2 Experimental

2.1 Materials

Multi-dimensional, bimodal and nanostructured WC−10Co4Cr cermet powders containing nano-sized WC were used as feedstock (marked as MP, BP and NP, respectively) in the present work, and were manufactured by an agglomeration-sintering method. In the multi-dimensional WC−10Co4Cr powder (T64T440, Ganzhou Achteck, China), the WC original crystal grains are composed of 20% nano WC (80−180 nm), 30% submicron WC (0.4−0.6 μm) and 50% micron WC (~2.5 μm) (volume fraction). The procedure of multi-dimensional powder fabrication involved ball milling of a mixture of different sized WC, Co, Cr_3C_2 and some addictive, followed by spray drying and sintering. The multi-dimensional powder size is in the range of 20−53 μm, while the bimodal and nanostructured WC−10Co4Cr powder sizes are in the range of 15−45 μm. In the bimodal powder (T64D530, Ganzhou Achteck, China), the volume ratio of WC original crystal of micro-sized (~1.5 μm) to nano-sized (80−180 nm) WC particles is 7:3. In nanostructured WC−10Co4Cr powder (S7410, Inframat, USA), the WC original crystal size is 100−500 nm. Figure 1 illustrates the SEM micrographs of the multi-dimensional WC−10Co4Cr cermet powders. It can be observed that the powder is highly spherical (Fig. 1(a)). Meanwhile, nano, submicron, micron WC grains and some voids on the surface can be observed clearly at high magnification (Fig. 1(b)).

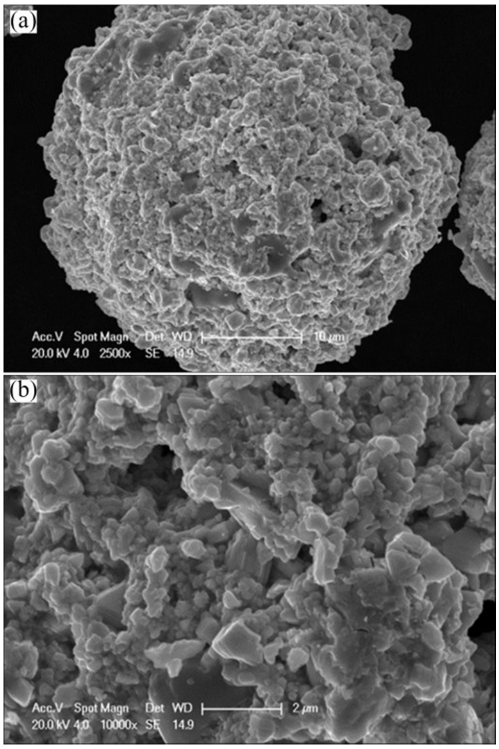

Fig. 1 Micrographs of multi-dimensional WC−10Co4Cr powder at different magnifications

2.2 Coating fabrication

The multi-dimensional, bimodal and nanostructured WC−10Co4Cr coatings (marked as MC, BC and NC, respectively) were deposited with JP8000 HVOF system (Praxair, USA), using kerosene fuel and oxygen gas, and optimized parameters are listed in Table 1. 304 stainless steel was chosen as coating substrate material and counterpart material for evaluating the cavitation erosion resistance of various HVOF sprayed WC−10Co4Cr coatings.

Prior to spraying, the surface of the substrate was degreased and grit blasted with 60 mesh Al_2O_3. The

Table 1 Main spray parameters of WC−10Co4Cr coatings by HVOF spraying

Coating	Powder type	Gun length/mm	Fuel flow rate/($L\cdot h^{-1}$)	Oxygen flow rate/($m^3\cdot h^{-1}$)	Powder feed rate/($g\cdot min^{-1}$)	Stand-off distance/mm
MC	MP	152	22.7	55.2	75	380
BC	BP	152	22.7	56.6	75	380
NC	NP	152	22.7	56.6	75	380