ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 4, April 2017

Effects of Impact Angle in Erosion Rate of HVOF (WC-Co-Cr) Coated Navel Brass in Slurry Erosion

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ABSTRACT: Modern industries such as marine, oil and gas production, and power generation often require seawater for cooling systems within generators and reactors. Sand particles entrained in the sea water greatly reduce the design life of metal components within such systems. Slurry erosion problems are important due to the increase in the number of solid particles impacting over the surfaces. This study is an investigation of the effect of impact angle on slurry erosion behavior of naval brass alloy and WC-Co-Cr coated naval brass. The erosion behavior of them at 30°, 60°and 90° impingement angle was investigated by slurry jet erosion tester. The effect of porosity and laminar structure on erosion resistance of WC-Co-Cr coatings at different impingement angle was investigated by using scanning electron spectroscopy. Fornavalbrass,theerosionresistancedecreaseswithdecreasestheimpactangleand the maximum erosion takes place at 60^0, with typical ductile erosion behaviour. Itis remarkably found that at all impact angles; the erosion rate of all coatings is much lower than that of naval brass and among the coatings. Under the 90° impact angle, theerosionratereachesamaximumvalueforWC-Co-Crcoatednavalbrass the maximum erosion rate measured under impact of the waterslurryliesatanglesbetween60°and90°forWC-Co-Crcoatings.

KEYWORDS: WC-Co-Cr,slurry erosion, HVOF, Naval Brass,

I. INTRODUCTION

Naval brasses consisting of the α–β duplex phases are a special kind of Cu-Zn alloys. They are known to have excellent corrosion resistance to sea water and marine conditions. Cu–Zn alloys (brasses) possess an attractive combination of properties, namely good corrosion resistance, good machinability, better resistance to befouling, high thermal and electrical conductivity. However Erosion loss will inevitably occur over time leading to the replacement of components [1]

Thermal spraying technique is used to modify and reinforce the surface functions instead of reforming the composition of the bulk material. It allows the engineers to improve the performance and extend the life of the engineering components .WC-Co cermet coating possesses exceptional combination of strength, hardness, wear resistance and fracture toughness owing to the presence of hard WC particles in the tough Co matrix .WC-Co coatings are extensively used in abrasion, sliding, fretting and erosion resistance applications .Nanofinished WC-Co coatings are widely used in a range of applications, such as main landing gear cylinders, landing gear pistons .diesel engine cylinder .and gloss calendar roll of printing industry[2-6]

The WC-Co cermet powder can be deposited using different thermal spraying techniques. HVOF spraying technique has been widely adopted in many industries owing to its ability to produce high quality carbide coatings. High particle

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Table 1 Chemical composition (wt. %) of substrate and coating materials

Cu	Zn	Pb	Fe	Sn
61.3	35.6	2.56	0.2667	0.042
Material	**W**	**Co**	**Cr**	
WC–Co–Cr	86	10	4	

velocity in HVOF spraying technique leads to good coating properties like high density, good coating bond strength and hardness.

However, surface roughness of WC-Co coating is higher than the acceptable limit for many applications. Therefore, the coating surfaces are required to be finished suitably in order to achieve desired surface roughness and to improve the surface properties. The reason HVOF is the preferred thermal spray process for chrome replacement is because it produces low porosity (>1%), low oxide content (>1%), and highly adherent coatings (bond strength >70 MPa), and has a significantly lower environmental impact[7-8].

In this paper, the effects of impact angle on the erosion rate of the HVOF sprayed WC–10Co–4Cr coatings on naval brass alloy in slurry erosion testing environment.

II. EXPERIMENTAL WORK

2.1 Materials

In this investigation, commercial grade copper based naval brass a high good corrosion resistance material having greater strength and rigidity was used. The coating powder material used in this investigation was commercially available agglomerated and sintered WC-Co-Cr (AMPERIT 558.074, supplied by: Metalizing Equipment Corporation, Jodhpur, India) and the chemical composition of naval brass substrate conforming to specification ASTM B171. The chemical composition of base material and coating material was used for this study are shown in Table 1.

2.2 HVOF Thermal Spray

HVOF (HIPOJET-2700, Make: Metallizing Equipment Co. Jodhpur, India) spraying system available at Annamalai University, India, was used to deposit WC-10Co-4Cr coatings with a thickness of 180-200 µm. The thickness of the coatings was measured by digital micrometer (with an accuracy of 0.001mm) after each and every run conditions. Coatings were HVOF-sprayed from the feedstock powder using LPG as gaseous fuel. All coatings were deposited onto rectangular naval brass specimens for tests. The substrates were grit-blasted before spraying. All specimens were mounted on the circumference of a horizontally rotating turntable and cooled during and after spraying with compressed air jets From our previous work, optimized HVOF spray parameters are used to coating the materials [10]

2.3 SLURRY EROSION

Slurry erosion mass loss of the coated and uncoated specimens was determined using slurry erosion tester (Model:TR-411, Make:DUCOM, India).Shown in fig 1. Erodent used in the water jet erosion and slurry erosion tests was Quartz sand of 50 µm sizes and its SEM image is shown in Fig. 2. The uncoated and WC-10Co-4Cr coated test specimens are shown in fig. 3 and 4.The tests are carried-out by measuring the loss of mass of the specimen by after the process in the tester shown in Fig. 5 and 6. Naval brass specimens were polished ultrasonically cleaned using acetone and weighed prior to test and post-test to find weight loss from which the erosive wear was calculated. The specimen to be tested is first thoroughly cleaned and weighed in using a precision weighing machine. These specimens having a standard size are fixed onto the disc with the help of clamps at the desired radial distance. The disc along with the specimen is dipped

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into the slurry contained in the container. The motor is then started and the specimens are rotated at the desired speed for a given duration. The specimen is removed, cleaned and weighed after the test is over. The rate of erosion is calculated at the rate of loss of mass with respect to various experimental parameters.

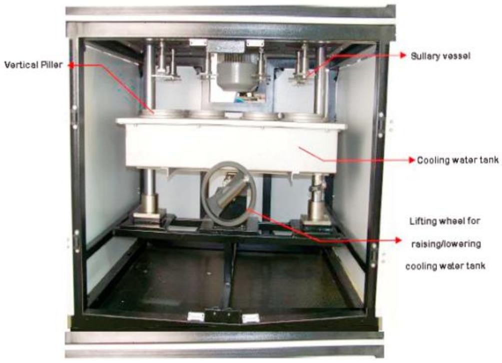

Fig.1 Slurry Erosion Test Setup

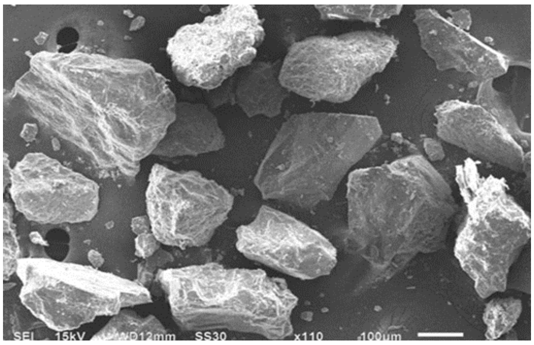

Fig. 2 SEM image of Quartz sand

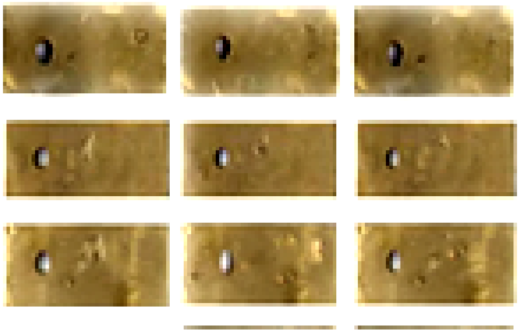

Fig. 3Specimens of Uncoated Naval Brass

Fig. 4HVOF sprayed WC-Co-Cr Coated Naval Brass

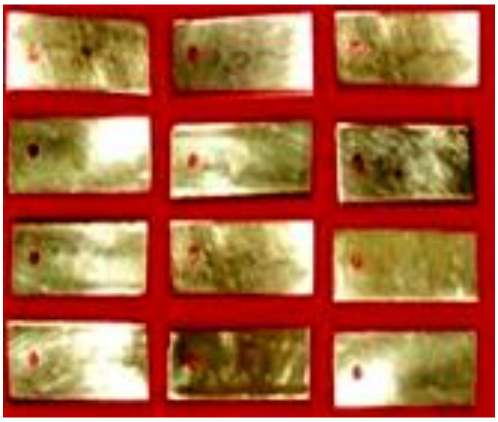

Fig. 5 Slurry Eroded Test Specimens of Uncoated Naval Brass

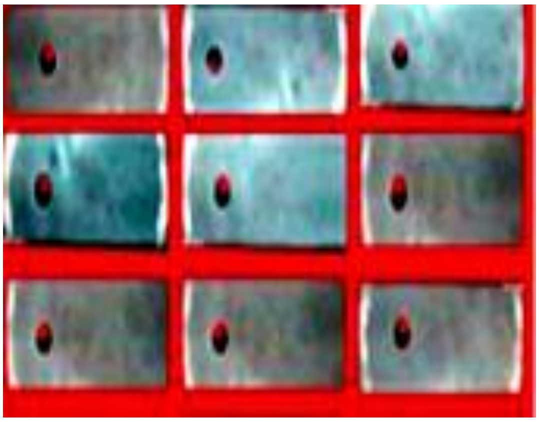

Fig. 6 Slurry Eroded Test Specimens

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III. RESULT AND DISCUSSION

3.1EFFECT OF IMPACT ANGLE

In order to study the effect of impact angle of 30,60,90 degree with rotational speed ,time and slurry composition was kept constant at 1000rpm, 90 minand 300 g/cc while the impact angle was varied from 30-90 degree. From the experimental results and fundamentals, it is acknowledged that the higher impact angle can promotes erosion rate and lower impact angle exhibits moderate erosion loss in both coated and uncoated naval brass. The erosion rate of uncoated and coated naval brass as shown in fig. 7.

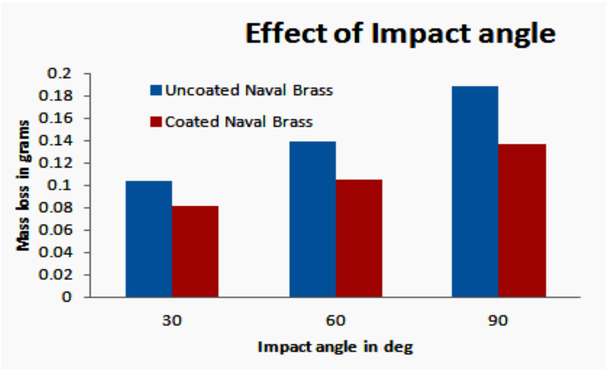

Fig. 7 Effects of Impact Angle on Erosion Rate Of Uncoated and Coated Naval Brass

3.1.1 Effect of Lower Impact Angle 30^0

The effect of impact angle on the erosion rate of the naval brass and carbide coatings are displayed in Figure 6.3. The worn surfaces of the naval brass and carbide coatings eroded less than 30° impact angle are shown in Figures 8 (a) and (b). The figure shows severe plastic shear deformation produced by the sliding action of erodent particles. There were evidences of rubbing, extrusion, ploughing, and cutting actions at low the impact particles.

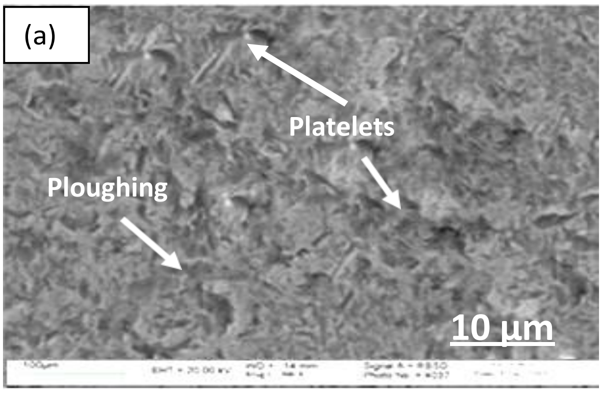

Fig.8(a) SEM Image of Uncoated Naval Brass at Lower Impact Angle(30^0)

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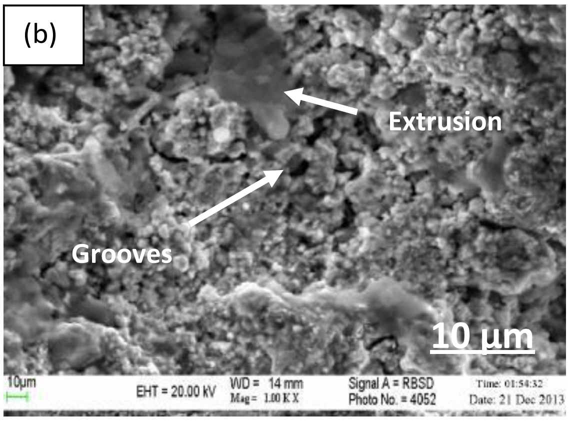

Fig. 8 (b) SEM Image of Coated Naval Brass at lower impact angle(30^0)

There is also evidence of brittle cracking, which finally led to the fragmentation of material. In the micrograph, one can see plastic shearing and rub bands which were produced by the erodent particles that rubbed the surface during erosion

3.1.2 Effect of Intermediate Impact Angle 60^0

An erosion pit was formed by cracking, which can be seen in the micrographs. At the impact angle of 60^0, the contact of erodent particles with target surface contributed mainly to ploughing and very little to brittle cracking, the erosion at this impact angle is moderate, as seen in Figure 9 (a) and (b). It is considered that the highly deformed material formed into "chips" at low impact angles or crater "lips" Formed at angles close to normal incidence . Under moderate angles, the erodent particle will have the tendency to slide over the surface and as it slides, it will lip the material as observed in Figure 9 (b). The sequent sliding of the particle will remove the material from the surface or in other words,a certain portion ofthe volume swept out at low angles of impact could simply be deformed and removed in a ploughing action. The erodent particles are being in contact for long time on the surface during sliding, the wear rate is much high. Because of the different impingement angles of the sand particles, the eroded scars have different lengths and shapes.

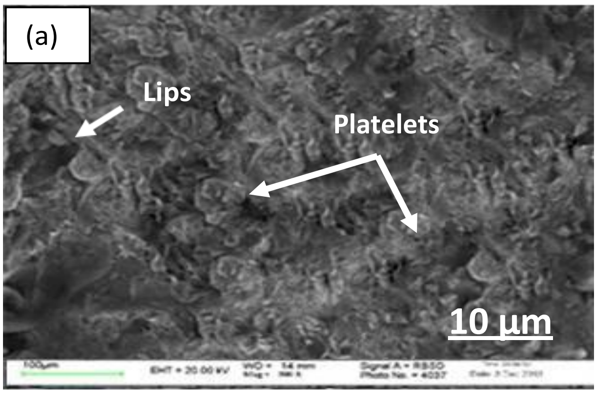

Fig. 9(a) SEM Image of Uncoated Naval Brass at Moderate Impact Angle(60^0)

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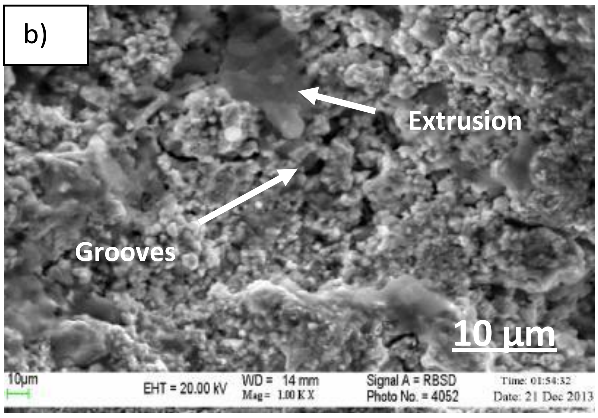

Fig. 9(b) SEM Image of Coated Naval Brass at Moderate Impact Angle(60^0)

3.1.3 Effect ofHigher Impact Angle 90^0

This mode is designated as the cutting mode cracks and lips are depicted in Fig. 10 (a) As shown in Fig. 10(b), the maximum erosion rate measured under impact of the water slurry lies at angles between 60° and 90° for WC-Co-Cr coatings. In the studies of erosion behaviour on tungsten by tap-water slurryalso demonstrated that the maximum erosion rate appears at angles between 30° and 60°. For the brittle materials, the fatigue cracking and brittle breaking are the main reasons of the surface materials loss, with the maximum erosion appearing at higher impact angle.

For naval brass, the erosion resistance decreases with decreases the impact angle and the maximum erosion takes place at 600, with typical ductile erosion behaviour. It is remarkably found that at all impact angles; the erosion rate of all coatings is much lower than that of naval brass and among the coatings. Under the 90° impact angle, the erosion rate reaches a maximum value for WC-Co-Cr coated naval brass

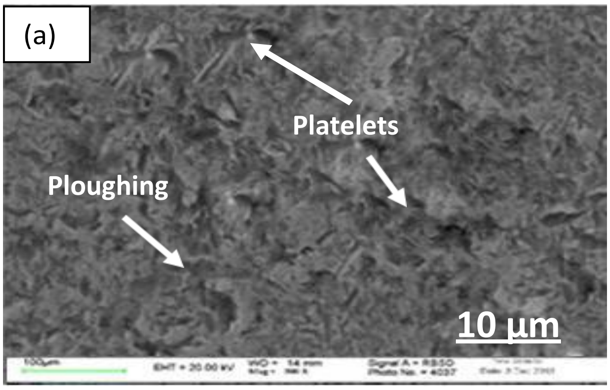

Fig. 10 (a) SEM Image of Uncoated Naval Brass at Higher Impact Angle(90^0)

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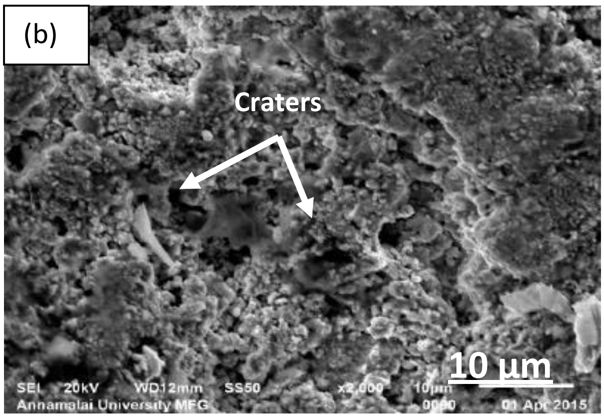

Fig. 10 (b) SEM Image of Coated Naval Brass at Higher Impact Angle(90^0)

IV. CONCLUSION

WC-Co-Cr coatings were developed over Naval Brass alloy by HVOF spray method. The effects of impact angle in erosion rate in slurry erosion method at constant rotational speed and time were studied and following conclusions were obtained,

1. In naval brass and carbide coatings eroded under 30° impact angle the severe plastic shear deformation produced by the sliding action of erodent particles. There were evidences of rubbing, extrusion, ploughing, and cutting actions at low the impact particles.
2. At the impact angle of 60^o, the contact of erodent particles with target surface contributed mainly to ploughing and very little to brittle cracking, the erosion at this impact angle is moderate. Under moderate angles, the erodent particle will have the tendency to slide over the surface and as it slides, it will lip the material
3. The maximum erosion rate measured under impact of the water slurry lies at angles between 60° and 90° for WC-Co-Cr coatings. In the studies of erosion behaviour on tungsten by tap-water slurry, also demonstrated that the maximum erosion rate appears at angles between 30° and 60°.
4. For naval brass, the erosion resistance decreases with decreases the impact angle and the maximum erosion takes place at 90^0, with typical ductile erosion behaviour
5. It is remarkably found that at all impact angles; the erosion rate of WC-Co-Cr coatings is much lower than that of naval brass and among the coatings. Under the 90° impact angle, the erosion rate reaches a maximum value for WC-Co-Cr coated naval brass.

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