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# Effects of Rotational speed in Erosion Rate of HVOF (WC-Co-Cr) Coated Naval Brass in Slurry Erosion

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**ABSTRACT:** In the present work, erosion wear due to slurry mixture flow has been investigated using a slurry erosion pot tester. Erosion tests are conducted on uncoated and WC-Co-Cr coated naval brass alloy, to found the effects of rotational speed, with constant impact angle, slurry concentration, and time period. In order to increase erosion wear resistance of naval brass alloy, a high-velocity oxy-fuel (HVOF) coating technique is used to deposit a WC-Co-Cr coating on the surface of naval brass alloy materials. The erosion behavior of them at 500 rpm, 1000 rpm and 1500 rpm rotational speed was investigated by slurry jet erosion tester. The effect of rotational speed on microstructure on erosion resistance of WC-Co-Cr coatings at different rotational speed was investigated by using scanning electron spectroscopy. Experimental investigation results show that rotational speed is a most influencing parameter for the erosion rate as compared to other slurry erosion parameters. WC-Co-Cr HVOF coating improved the erosion resistance of naval brass alloy remarkably.

**KEYWORDS:** WC-Co-Cr, slurry erosion, rotational speed, Naval Brass,

## I. INTRODUCTION

Thermal spray coating in which a combination of fine hard metal or ceramic particles and metallic binder materials are coated on the metal substrates via extremely high velocity spraying provides many engineering applications by means of the surface modification and the corresponding mechanical properties. Of several thermal spray coating materials, a system consisting of tungsten carbide (WC) particles with metallic binders of Co, Ni or Co-Cr has been paid much attention due to its excellent combination of wear resistance and high temperature mechanical properties.[1-3] To apply such excellent coatings for the marine components to be used in severe and aggressive service environment .however, they must exhibit the acceptable corrosion resistance. The exact prediction of erosion wear rate is very imperative for the slurry erosion behaviour of various materials .Over the years, various bench scale setups have been developed to simulate the erosion wear mechanism at the laboratory scale. Most of the researchers have found that particle size distribution, Impact angle rotational speed, and slurry concentration are the most important factors that influence the material's erosion wear rate. Some investigators have suggested that the erosion wear can be minimizing by using protective coatings on piping materials. These coatings can provide a hard layer of carbides, oxides, and nitrides of Cr, W, Al, and Ti. The high-velocity oxy-fuel (HVOF) technique can be applied to deposit coatings with high cohesive strength and superior mechanical properties.[3-5]

In the present work, to study the erosion wear behavior of naval brass alloy, have been analyzed with and without a HVOF-sprayed WC-10Co-4Cr coating. The erosion Experiments are carried out at three different speeds, namely 500, 1000, and 1500 rpm with constant impact angle, time and slurry composition.

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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	

## 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: Metallizing 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  $\mu\text{m}$ . 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.

### 2.3 Slurry Erosion

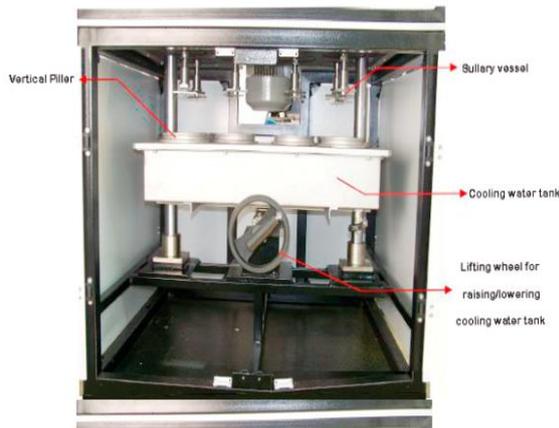
Slurry erosion mass loss of the coated and uncoated specimens was determined using slurry erosion tester (Model:TR-411, Make:DUCOM, India). Shown in Fig 1. Erodent used in the water jet erosion and slurry erosion tests was Quartz sand of 50  $\mu\text{m}$  sizes and its SEM image is shown in Fig. 2. The uncoated and WC-10Co-4Cr coated test specimens of size 25.4 x 76.2 x 5 mm for Slurry erosion testing was conducted on naval brass 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 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

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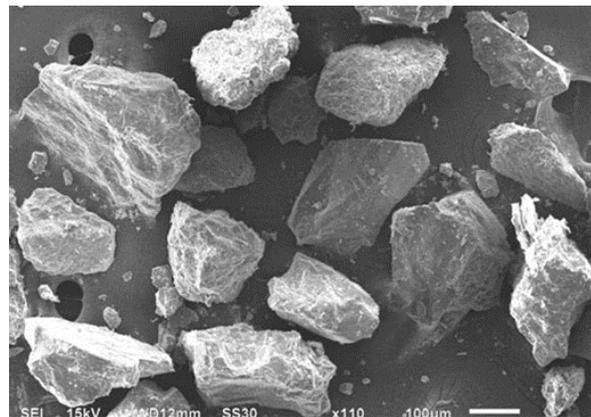
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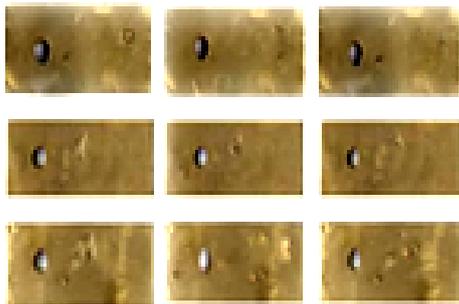
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**Fig.1 Slurry Erosion Test Setup**



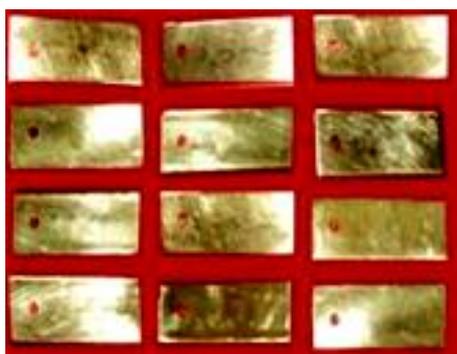
**Fig. 2 SEM image of Quartz sand**



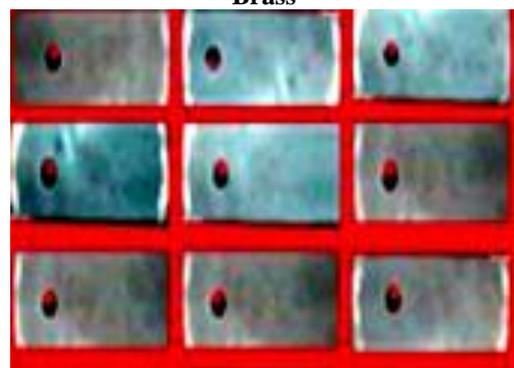
**Fig. 3 Specimens of Uncoated Naval Brass**



**Fig. 4 HVOF Sprayed WC-Co-Cr Coated Naval Brass**



**Fig. 5 Slurry Eroded Test Specimens of Uncoated Naval Brass**



**Fig. 6 Slurry Eroded Test Specimen of WC-Co-Cr Coated Naval Brass**

## III. RESULT AND DISCUSSION

### 3.1 EFFECT OF ROTATIONAL SPEED ON EROSION RATE

In order to study the effect of rotational speed of 500, 1000, 1500 rpm with constant impact angle, time and slurry composition was kept constant at  $60^\circ$ , 90 min and 300 g/cc while the rotational speed was varied from 500-1500 rpm..

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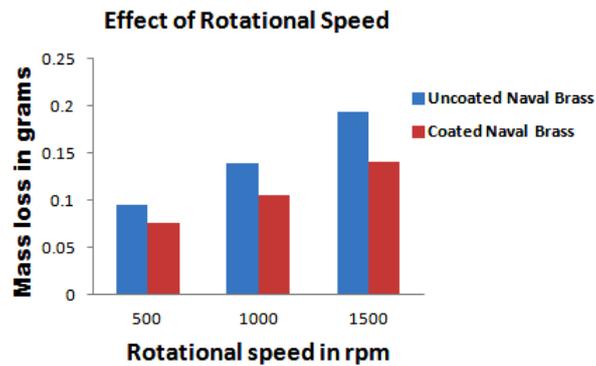


Fig. 7 Effects of Rotational Speed on Erosion Rate of Uncoated and Coated Naval Brass

From the experimental results and fundamentals, it is acknowledged that the higher Impact angle can promote erosion rate and lower impact angle exhibits moderate erosion loss in both coated and uncoated naval brass.

Many researchers have found that rotational speed, solid concentration and particle size distribution are some of the major factors that influence the erosion wear rate. The following empirical correlation has been used to predict the erosion wear by using experimental data, and has also been discussed. It is generally recognized that  $Erosion = K \times (velocity)^n$ , where constant 'K' depends upon impact angle and particle size and 'n' is the velocity exponent.

It has been observed that WC-10Co-4Cr coated naval brass exhibits higher erosive resistances as compared to uncoated naval brass at all speeds. Hence, it is clear that erosion wear is highly dependent on rotational speed. The kinetic energy of erodent particles increases with rotational speed. This increase in kinetic energy will lead to more localized attacks at several spots on the target material and can cause severe plastic deformation, which leads to more erosion wear. It has also been realized that the uncoated naval brass specimen exhibits higher erosion wear rather than WC-10Co-4Cr coated naval brass alloy than at all rotational speeds. This is anticipated due to the much harder WC-10Co-4Cr coated naval brass alloy as compared to uncoated naval brass alloys shown in fig.7.

### 3.1.1 Effect of Lower Rotational Speed.

The maximum rotational speed occurs at the first contact surface of the flowing fluid and falls off rapidly as the remaining edges are approached. Given the power law relationship between the erosion rate and rotational speed, a small decrease in rotational speed will, therefore, result in an amplified reduction of the slurry erosion rate. When

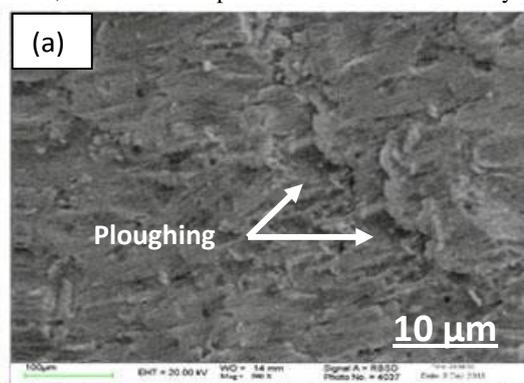


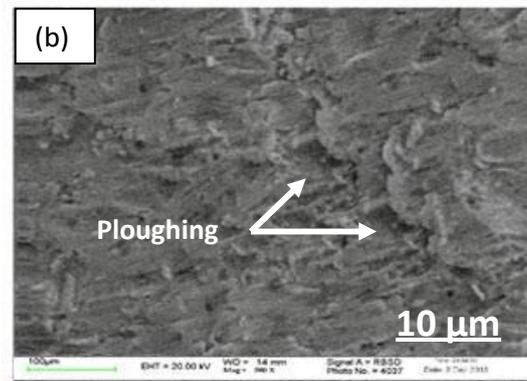
Fig.8(a) SEM Image of Uncoated Naval Brass at Lower Rotational Speed (500rpm)

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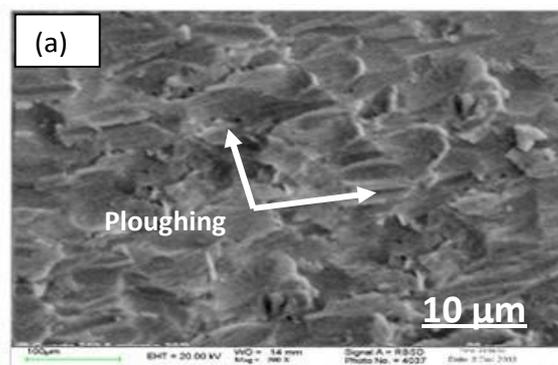


**Fig.8(b) SEM Image of Coated Naval Brass at  
Lower Rotational Speed (500rpm)**

The rotational speed is decreased; the kinetic energy transferred to the particles is decreased. The lower the kinetic energy, the less the chance of a positive result (the erosion decreases) from a single impact. Further, under low velocities, the particle flow divergence decreases under such circumstances, these slurry particles impinge upon the surface with low kinetic energies, or at unfavourable incidence angles, or have most of their translational kinetic energy turned into rotational kinetic energy (particle rotation). Hence the material removal will be minimum both naval brass and coatings. Micro cutting is observed in naval brass (Fig. 8 (a)). Less lateral cracks are generated in the lamellae of the carbide coatings (Fig. 8 (b)), when the impact energy is lowered.

### 3.1.2 Effect of Intermediate Rotational Speed.

At the modest energy, lateral cracks were rare and never smooth as seen in Figs. 9(a) and (b). for uncoated and coated naval process. When rotational speed is slightly increased, eventually the particles are not able to initiate cracking and will only deform the coatings. In the case of the uncoated naval brass substrate, the lower momentum of the particle means that it will tend to roll on the target resulting in surface deformation and small lips can be seen in Fig. 9 (a) and (b).



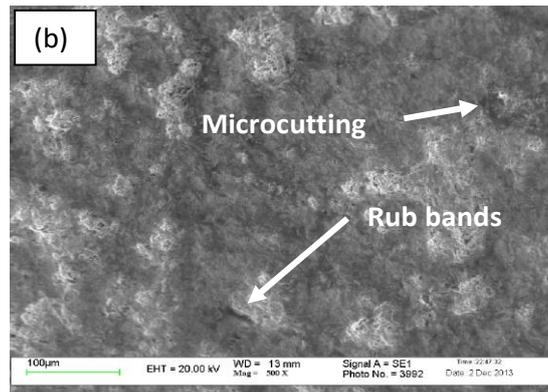
**Fig. 9(a) SEM Image of Uncoated Naval Brass  
at Intermediate Rotational Speed (1000rpm)**

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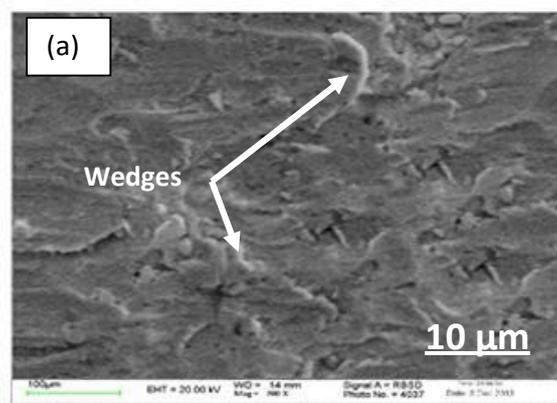
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**Fig. 9(b) SEM Image of Coated Naval Brass at Intermediate Rotational Speed (1000rpm)**

### 3.1.3 Effect of Higher Rotational Speed.

At high rotational speed conditions, the increase of slurry erosion rate of naval brass may be attributed to the enhanced mechanical damage as a result of erosion. However, a much higher hardness of the WC-Co-Cr than that of naval brass may significantly contribute to the high slurry erosion resistance at high flow velocities. With the higher initial rotational speed of slurry particle, the slurry erosion rate appears to increase explicitly. This means that the slurry erosion rate is linearly proportional to the square of velocity or the kinetic energy of the suspended particle. It is well known that larger area is removed under the higher rotational speed impact. When the shear strain exceeds the elastic strain limit of the target material, the particle penetrates the surface of the material and ploughs along the surface removing the material. As shown in Fig.10 (a) one can expect that the shear force applied by the suspended particle would increase as a result of an increasing contact velocity of the flowing particle. Thus develops lateral cracks in the coatings as shown in fig.10 (b)



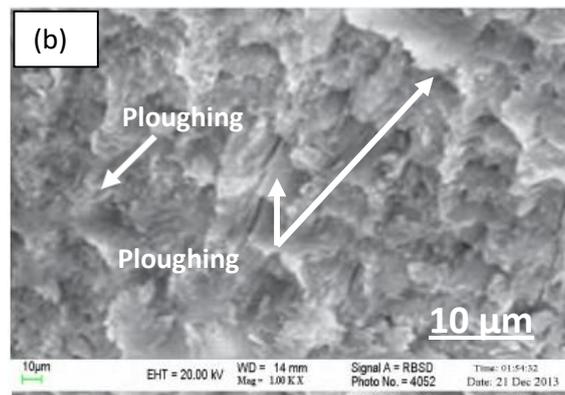
**Fig. 10(a) SEM Image of Uncoated Naval Brass at Higher Rotational Speed (1500rpm)**

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**Fig. 10(b) SEM Image of Coated Naval Brass at  
Higher Rotational Speed (1500rpm)**

### IV. CONCLUSION

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

1. On the basis of the experimental investigation, the following concise and precise forms of outcomes are found: WC-10Co4Cr coated naval brass alloy shows better erosion resistance as compared with uncoated naval brass alloy under all circumstances.
2. Rotational speed is found to be a highly influencing parameter for the erosion wear rate as compared to impact angle, slurry concentration and time duration.
3. WC-10Co4Cr HVOF coating improved the erosion resistance of naval brass alloy remarkably.
4. It is remarkably found that at all rotational speeds; the erosion rate of WC-10Co4Cr coatings is much lower than that of naval brass and among the coatings. Under the 1500 rpm rotational speed, the erosion rate reaches a maximum value for both uncoated and WC-Co-Cr coated naval brass.

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