Effects of Erodent DischargeinErosion Rate of HVOF (WC-Co-Cr) Coated Navel Brassin Water Jet Erosion

K.Murugan[1,], S.Karthikeyan[2]*

1Lecturer, Department of Mechanical Engineering, Government Polytechnic College, Valangaiman, Tamilnadu, India
2 Associate Professor, Department of Mechanical Engineering, Arunai Engineering College, Tiruvannamalai, Tamilnadu, India

*Corresponding author email: *murugan.thermal@gmail.com*

ABSTRACT

Despite great developments in the marine component design and material improvements, liquid jet impingement erosion still remains an unsolved problem. Hence, it is important to develop more erosion resistant system to combat water jet erosion. Carbide based ceramic materials have a greater erosion resistance than metallic materials, which makes them good candidates for components that are subjected to the highly erosive environment. In this work WC-Co-Cr Ceramic coating applied over the naval brass alloy using high velocity oxygen fueled (HVOF)-spraying method and study the effects ofErodent Discharge on water jet erosion behavior of naval brass alloy and WC-Co-Cr coated naval brass. The erosion behavior of them at 500, 1500, and 2500 gpm discharge of Erodent was investigated by water jet erosion tester. Itis remarkably found that at all Discharge of Erodent; the erosion rate of WC-Co-Cr coatings is much lower than that of naval brass and among the coatings. Erosion rates are found to be increasing in a linear manner with increasing erodent discharge and decreases with an increase in the angle of impingement. However, increase in erodent discharge makes an effect on the crater shape and the effect of particles influences on wear rate.

Keywords –WC-Co-Cr,water jetvelocity, HVOF, Naval Brass

1. INTRODUCTION

Erosion is a process of progressive removal of material from a target surface due to repeated impacts of solid particles. It is encountered in numerous industrial applications such as marine components, crude oil processing equipment, hydro transport pipelines and coal handling plants where coal is carried by mixing it in water or oil. Solid particles suspended in a flow of solid–liquid mixture cause gradual erosion in slurry transport systems. For designing and operating a slurry transport system, a good estimate of the rate of erosion in pipes and pump components is essential. Various types of tests are conducted to understand the mechanism and rate of erosion.[1-3]

These industries expend the equivalent of millions of pounds every year to repair erosion damage caused by solid particle impingement and cavitations. Typical examples of this kind of material destruction are erosion–corrosion damage to pumps, impellers, propellers, valves, heat exchanger tubes and other fluid handling equipment. Hence, it is important to develop more erosion resistant system to combat water jet erosion. Carbide based ceramic materials have a greater erosion resistance than metallic materials, which makes them good candidates for components that are subjected to the highly erosive environment.[4-5]

Ceramic coating materials with a high erosion resistance have recently been developed using high velocity oxygen fueled (HVOF)-sprayed processes and ion plating with physical vapour deposition (PVD). Although there is a lot of research concerning the behaviour and mechanisms of erosion damage caused by water jet impingement, the selection of materials remains difficult without a comparative evaluation of impingement parameters between experimental and practical conditions. [6]

High-velocity oxy-fuel (HVOF) coating process can deposit coatings with very good mechanical properties. This process uses very high kinetic energies and relatively low temperatures (about700^{0}c), which result into a very good cohesive strength between deposited feed stock powder particles. Adhesion at the coating and substrate interface for a typical HVOF coating can be 10 times higher than that obtainable from other flame spraying processes [7-8].

The present work describes the effects oferodent dischargein water jet erosion resistance of uncoated and WC-Co-Cr coated naval brass.Under various experimentalconditions using a water jet erosion apparatus.

2. 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.

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

Cu	Zn	Pb	Fe	Sn	Al	Si	Others
61.3	35.6	2.56	0.2667	0.042	0.018	0.015	0.178
Material	**W**	**Co**	**Cr**				
WC–Co–Cr	86	10	4				-

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 for coating the materials [9]

2.3 Water Jet Erosion

Water jet is generated by pressurizing water to high-pressure levels (1,000 psi – 20,000 psi) using a high-pressure water blaster, which is basically a triplex pump, and then accelerating it through a small nozzle opening. Figure 1 depicts the schematic diagram of Water jet erosion test rig. Figure 2 shows the water jet erosion tester (Make: DUCOM, India, Model: TR- 411) used in this investigation. The test is carried out by measuring the loss of mass of the specimen by weighing it before and after the process in the tester.
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 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.

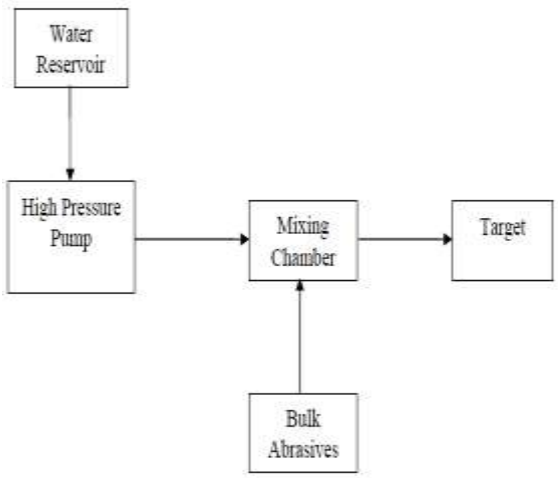

Fig. 1 Schematic Diagram of Water Jet Erosion Test Rig

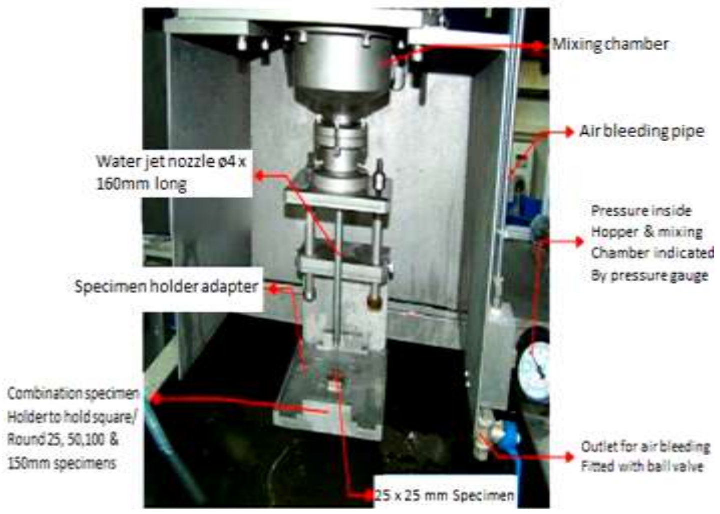

Fig. 2Water Jet Erosion Test Setup

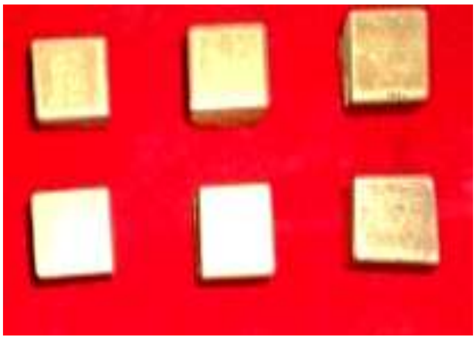

Fig. 3Uncoated Naval Brass

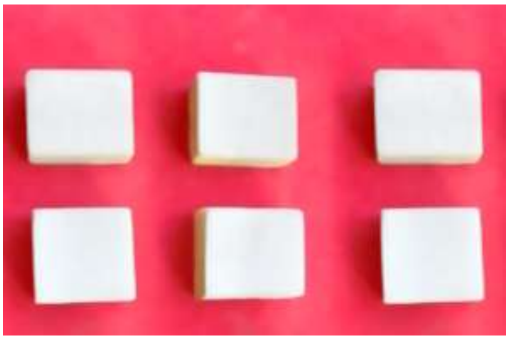

Fig. 4HVOF Sprayed WC-Co-Cr coated naval brass

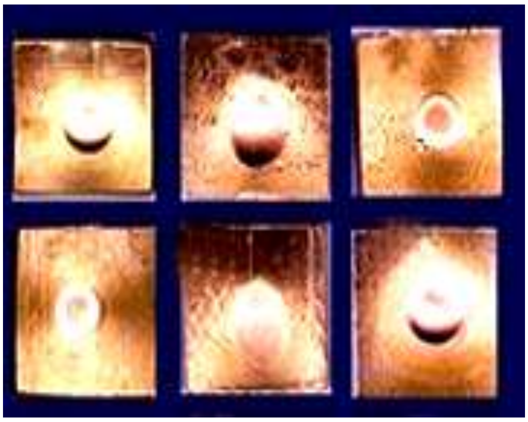

Fig. 5 Slurry Eroded Test Specimens of UncoatedNaval Brass

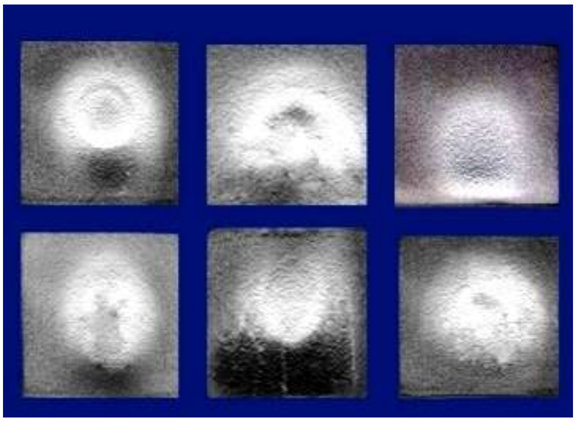

Fig. 6 Slurry Eroded Test Specimens of WC-Co-Cr Coated Naval Brass

Rate of Uncoated And Coated Naval Brass

3. RESULT AND DISCUSSION

3.1EFFECT OF ERODENT DISCHARGE

In order to study the effect of erodent discharge of500,1500,2500gpmwithWater impingement angle , jet velocityStand-off Distance, and Erodent Dischargewas kept constant at 60 degree ,30 m/s and45mmwhile the erodent discharge was varied from 500-2500 gpm. From the experimental results and fundamentals, it is acknowledged that the higher erodent discharge can reduces erosion rate and lower impact angle exhibits highererosion loss in both coated and uncoated naval brass as shown in fig. 7.

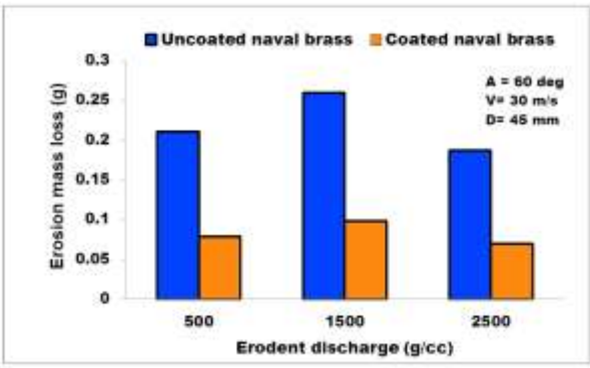

Fig. 7 Effects of Erodent Discharge on Erosion

The effect of erodent discharge on the erosion scar of the uncoated naval brass and the coated naval brass is displayed in Fig 8.

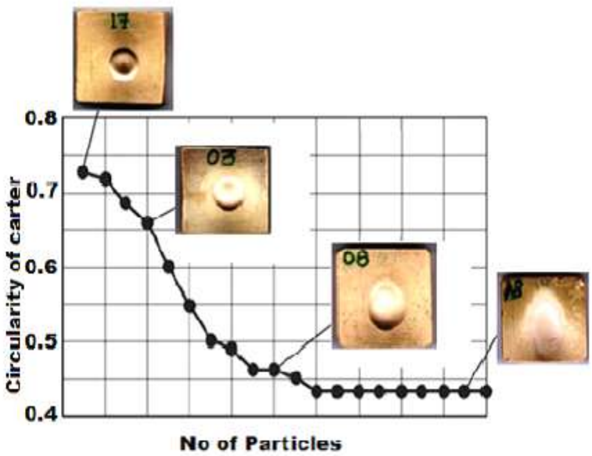

Fig. 8. Effect of Erodent Discharge on crater formation

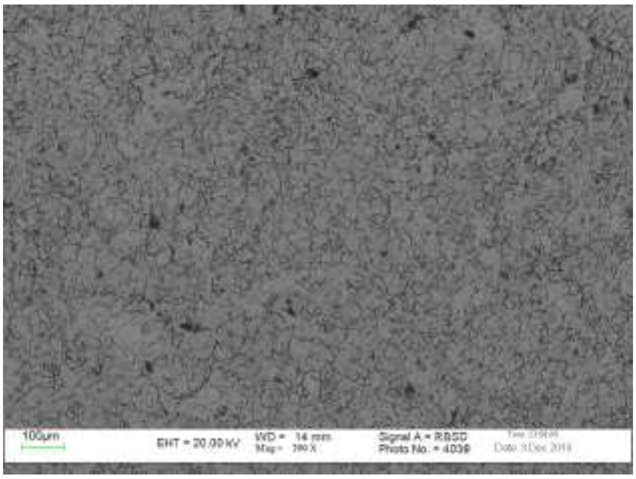

Fig. 9(a) SEM Image of Uncoated Naval Brass at lower Erodent Discharge (500 gpm)

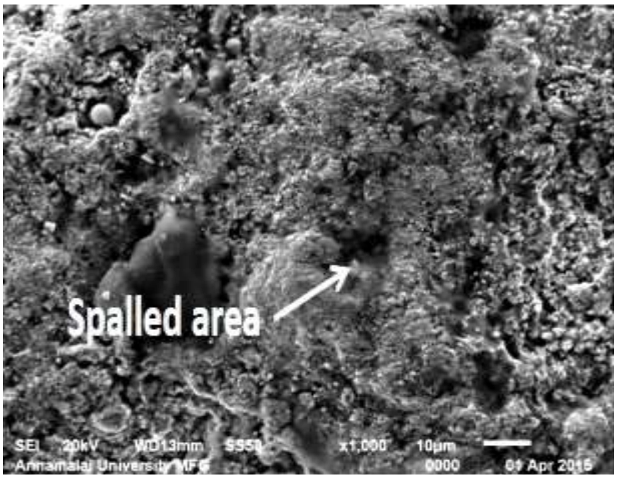

Fig. 9(b) SEM Image of Coated Naval Brass at lower Erodent Discharge (500 gpm)

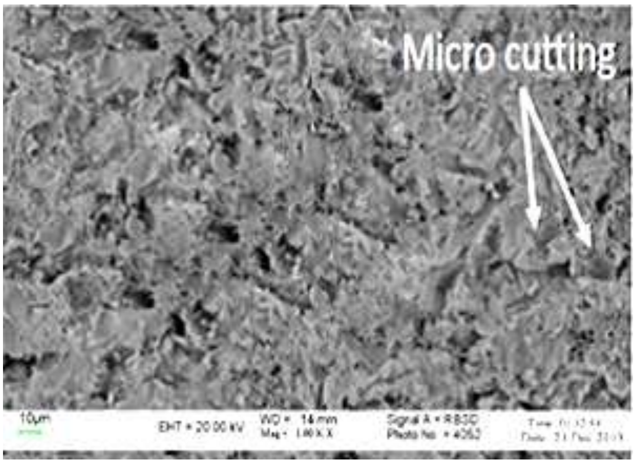

Fig. 10(a) SEM Image of Uncoated Naval Brass at moderate Erodent Discharge (1500 gpm)

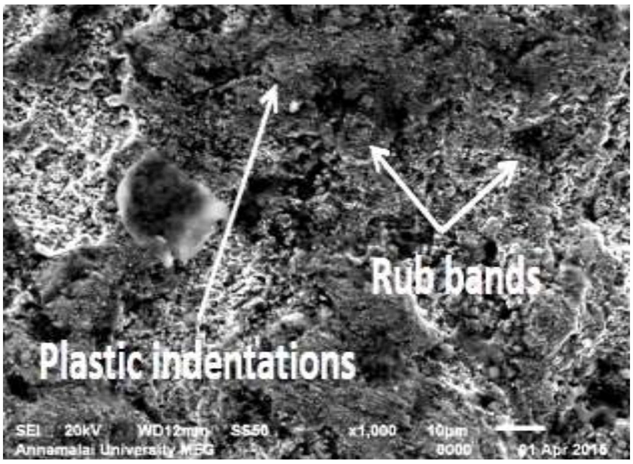

Fig. 10(b) SEM Image of Coated Naval Brass at moderate Erodent Discharge (1500 gpm)

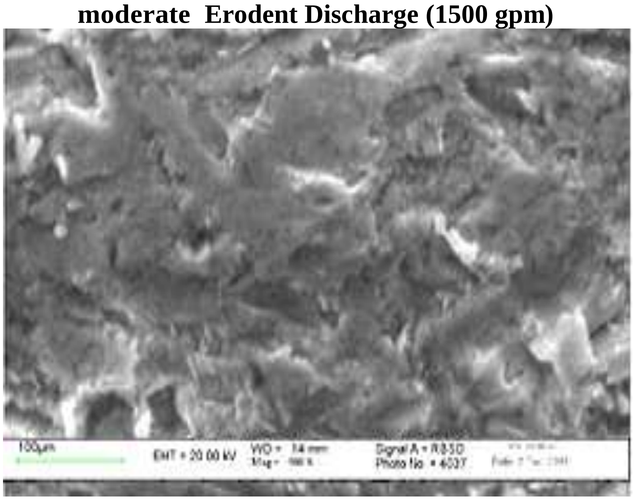

Fig. 11(a) SEM Image of Uncoated Naval Brass at higher Erodent Discharge (2500 gpm)

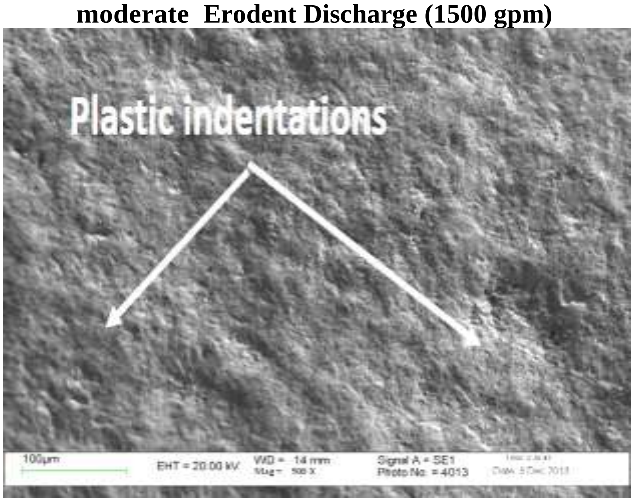

Fig. 11(b) SEM Image of Uncoated Naval Brass at higher Erodent Discharge (2500 gpm)

Erodent discharge is usually defined as the mass of particles striking the target surface per unit area per unit time. Erosion rates are found to be increasing in a linear manner with increasing erodent discharge and decreases with an increase in the angle of impingement. However, increase in erodent discharge makes an effect on the crater shape and the effect of particles influences on wear rate.SEM images of eroded specimen shows micro cutting, plouging and platted type failures due to the interaction of erodent particles on the target surface as shown in Figure 9(a-b). At low erodent feed rate, the incident energy (impact energy) was higher. When the erodent discharge at impact is reduced, the amount of erosion damage per unit mass of abrasive striking the target increases. When the erodent discharge is low, the mean free path of the water jet erodent particles S is quite long and thus the probability of collision between the rebounding particles and the incident particles is very low. When the particle concentration decreases and the conveying velocity increases there is an increased occurrence of erosion damage. When the erodent discharge value is too high, hydrodynamic particle interactions occur in the nozzle arid becomes more noticeable as the erodent discharge increases further. As the flux increases, the probability of collision between particles increases exponentially and hence the erosion rate would be expected to decrease. This turbulence attenuation increases the water jet spreading rate and causes a faster decay of the jet mean centerline velocity, thereby reducing the erosion rate. From the SEM images, it is observed that the naval brass possessed dough marks, micro cutting and wedge formation as shown in Fig. 10 (a-b). WC-Co-Cr coatings show (Fig. 11-a-b) cracking, splat ejections and lamelle spallation.

From the water jet erosion test, it is obvious that the erosion rate is low at the highest particle concentrations compared to low flux conditions. This could possibly be explained through a realization that greater numbers of inter-particulate and particle – wall collisions will occur at a higher particle concentration.

4. CONCLUSION

In this paper, the focus has been to evaluate the effect of Erodent Dischargeof naval brass alloy and HVOF (WC-Co-Cr) sprayed naval brass alloy on the water jet erosion behaviour. From the examination of the microstructures of the coated and uncoated naval brass samples after erosion, the following conclusions are made

1. From the water jet erosion test, it is obvious that the erosion rate is low at the highest particle concentrations compared to low flux conditions. This could possibly be explained through a realization that greater numbers of inter-particulate and particle – wall collisions will occur at a higher particle concentration.
2. Erosion rates are found to be increasing in a linear manner with increasing erodent discharge and decreases with an increase in the angle of impingement. However, increase in erodent discharge makes an effect on the crater shape and the effect of particles influences on wear rate
3. .When the erodent discharge value is too high, hydrodynamic particle interactions occur in the nozzle arid becomes more noticeable as the erodent discharge increases further
4. As the flux increases, the probability of collision between particles increases exponentially and hence the erosion rate would be expected to decrease.

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