ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijircce.com

Vol. 5, Issue 6, June 2017

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

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

Lecturer, Department of Mechanical Engineering, Government Polytechnic College, Valangaiman, Tamilnadu, India[1]

Associate Professor, Department of Mechanical Engineering, Arunai Engineering College, Tiruvannamalai, Tamilnadu, India[2]

ABSTRACT: In Naval application the components are damaged under high speed water (with or without solid particles) impingement, thus interrupting smooth functioning of system. Hence, it is important to develop more erosion resistant system to combat water jet erosion. Water jet erosion problems are important due to the increase in the number of solid particles impacting over the surfaces with water. This study is an investigation of the effect of impingement angle on water jet 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 water jet erosion tester. Itis remarkably found that at all impingement 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, theerosionratereachesamaximumvalueforWC-Co-Crcoatednavalbrass the maximum erosion rate measured under impact of the waterslurryliesatanglesbetween60°and90°forWC-Co-Crcoatings.

KEYWORDS: WC-Co-Cr,water jetErosion, HVOF, Naval Brass,

I. INTRODUCTION

Despite tremendous developments in the marine component design and material improvements, liquid jet impingement erosion still remains an unsolved problem. This phenomenon occurs in all the marine components: (a) propellers, hubs and rudders in case of ships, (b) high-speed pumps of all types, (c) regulators, valves and gate valves, (d) flow measuring equipment like orifices and ventures, (e) sudden enlargements and bends, etc.The marine components machinery have to tolerate perpetual high-speed water (with or without solid particles) impingement, and hence they must have excellent strength, toughness and erosion resistance. Naval application components are damaged under high speed water (with or without solid particles) impingement, thus interrupting smooth functioning of system. 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.[1-5]

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]

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

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

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijircce.com

Vol. 5, Issue 6, June 2017

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	

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

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 for coating the materials [10]

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.

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijircce.com

Vol. 5, Issue 6, June 2017

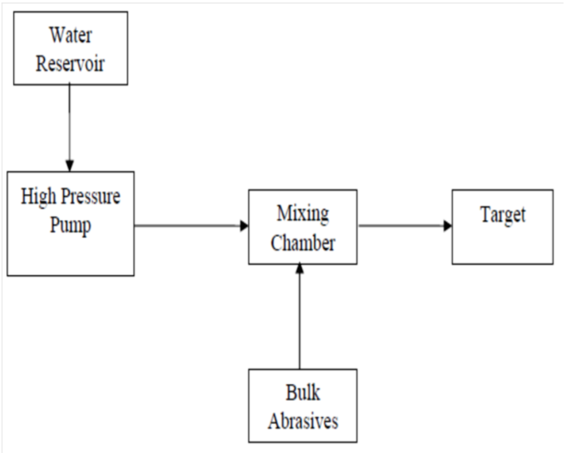

Fig. 1 Schematic Diagram of Water Jet Erosion Test Rig

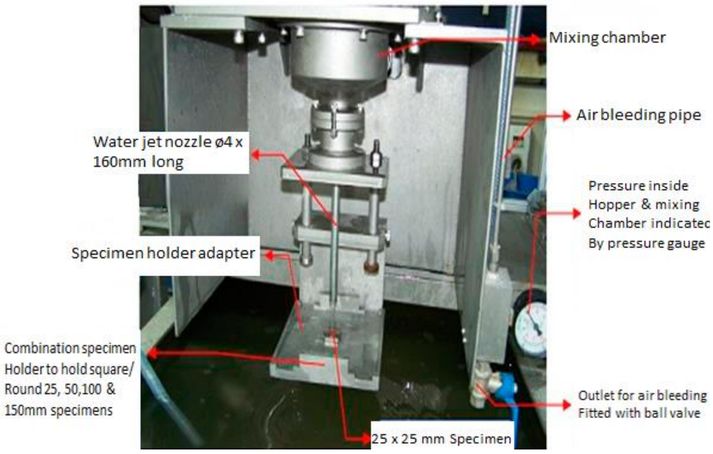

Fig. 2Water Jet Erosion Test Setup

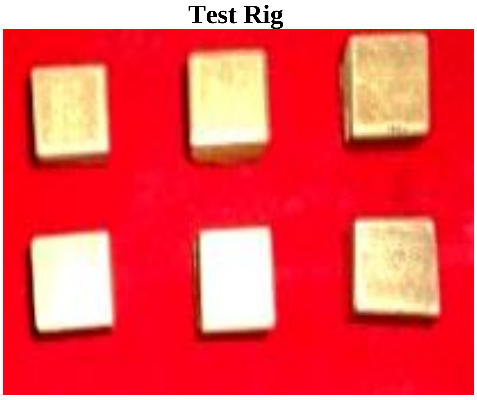

Fig. 3Uncoated Naval Brass

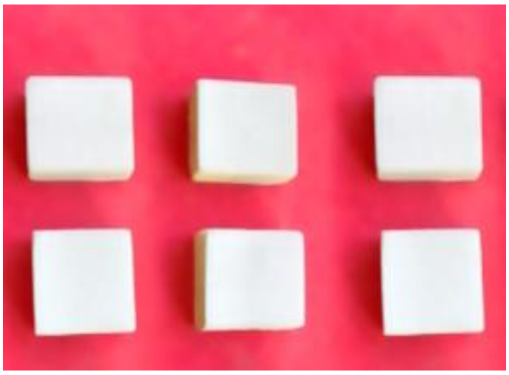

Fig. 4HVOF Sprayed WC-Co-Cr coated naval brass

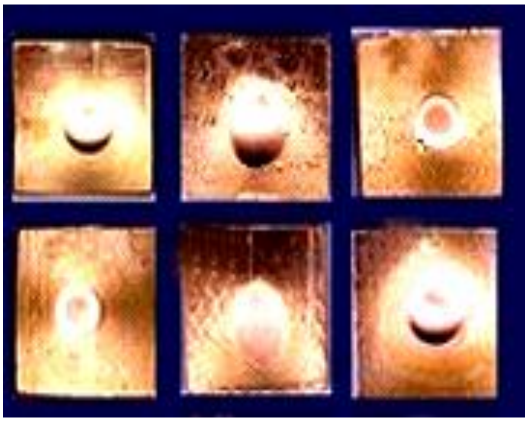

Fig. 5 Slurry Eroded Test Specimens of UncoatedNaval Brass

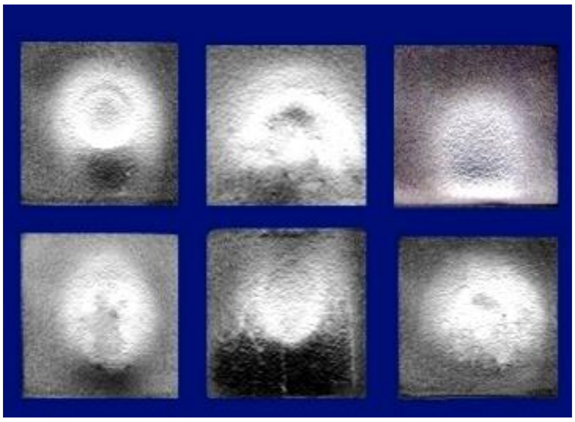

Fig. 6 Slurry Eroded Test Specimens of WC-Co-Cr Coated Naval Brass

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijircce.com

Vol. 5, Issue 6, June 2017

III. RESULT AND DISCUSSION

3.1EFFECT OF IMPACT ANGLE

In order to study the effect of impact angle of 30, 60,90withWater jet velocity, Stand-off Distance, and Erodent Dischargewas kept constant at 30m/s, 45mm and 1500gpmwhile the impingementangle was varied from 30-90 degree. From the experimental results and fundamentals, it is acknowledged that the higher impingementangle can promotes erosion rate and lower impact angle exhibits moderate erosion loss in both coated and uncoated naval brass as shown in fig. 7.

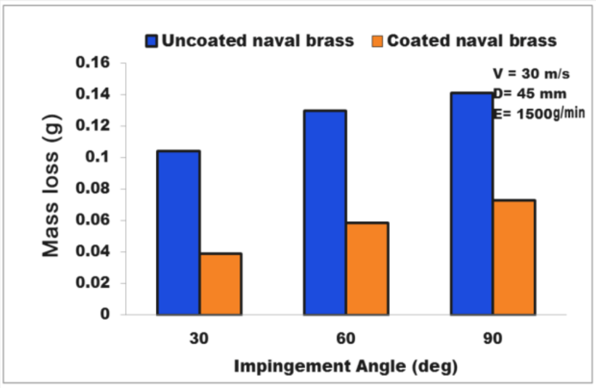

Fig. 7 Effects of Impingement Angle on Erosion Rate of Uncoated And Coated Naval Brass

3.1.1 Effect of Lower ImpingementAngle 30^0

Under low impingement angles, the erodent particle will have the tendency to slide over the surface and as it slides, it will plough the material as observed in Figure 8 (a). The sequent sliding of the particle will remove the material from the surface; in other words, a certain portion of the volume swept out at low angles of incidence will simply be deformed and displaced in a ploughing action. Since 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. However, small rubbing action was observed in coated surface at low impingement angles that removes small volume of material as shown in Fig. 8 (b).

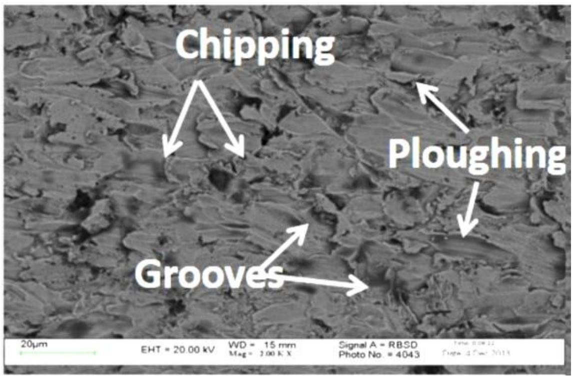

Fig.8(a) SEM Image of Uncoated Naval Brass at Lower Impingement Angle(30^0)

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijircce.com

Vol. 5, Issue 6, June 2017

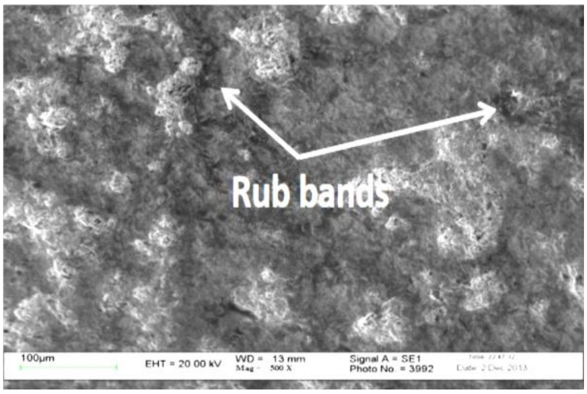

Fig.8(a) SEM Image of Coated Naval Brass at lower Impingement Angle(30^0)

3.1.1 Effect of ModerateImpingement Angle 30^0

Figure 9(a) shows the micro cutting and wedges in SEM images At moderate angles, ductile metallic material show such kind of pattern. It is evident that at shallow impingement angles, erosion damage is dominated by both splat ejection and plastic deformation of the lamellae. Further, in the plastically deformed areas, grooves or plough marks are often observed. The plastic grooves, in many instances, are similar to scratches produced on coated surfaces by a sharp and hard indenter and they tend to lie along the particle-colliding direction.

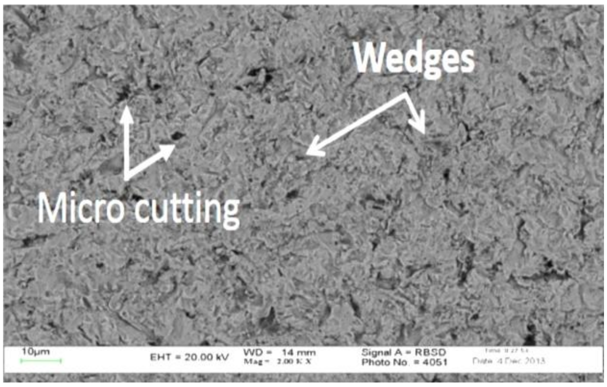

Fig. 9(a) SEM Image of Uncoated Naval Brass at Moderate Impingement Angle(60^0)

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijircce.com

Vol. 5, Issue 6, June 2017

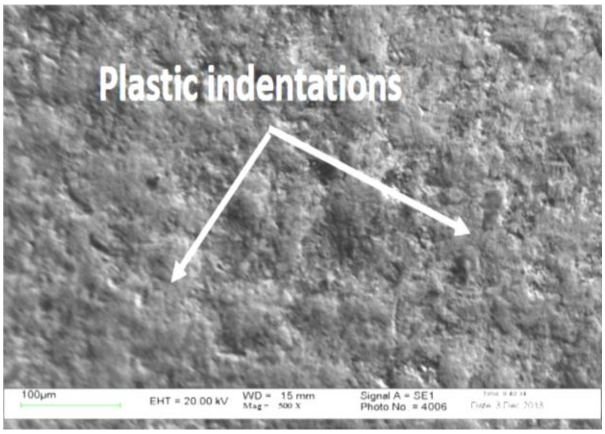

Fig. 9(b) SEM Image of Uncoated Naval Brass at Moderate Impingement Angle(60^0)

In the case of shallow angle eroded surfaces. Figures9 (d) shows the dominant material removal mechanisms such as splat ejection, which is caused-by grain lamellar micro cracking and plastic deformation followed by smearing of the deformed material. The mechanism by which material is removed from a surface upon erosion attack can be either ductile or brittle. In general, the ductile process (naval brass) is typified by maximum wastage at low impact angles. Most of metallic materials will erode by this mechanism.

3.1.1 Effect ofHigherImpingementAngle 90^0

Metals impacted at higher angles experiences drilling like cutting actions. Hence, Jet hits the target surface with particles makes small lips and plates in eroded uncoated naval brass as shown in Fig. 10 (a). On the other hand for the brittle (WC-Co-Cr coated naval brass) ceramic materials the erosion process is featured with maximum wastage at high impact angles, under which erosion occurs by cracking and chipping of surface material.

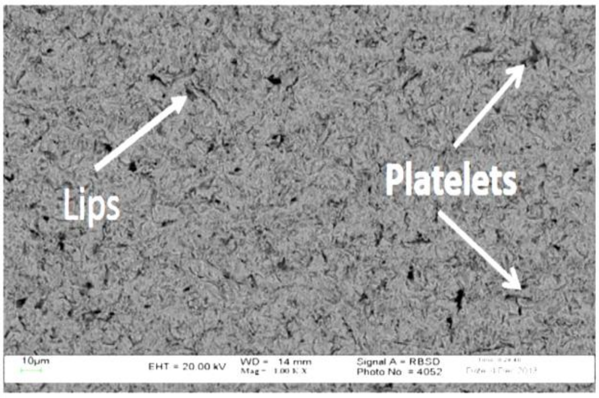

Fig. 10(a) SEM Image of Uncoated Naval Brass at Higher Impingement Angle(90^0)

Coating porosity is often located along the lamella boundaries not only will it influence the strength of the inter-lamella but may also initiate micro-cracking and macro cracking and leading to the loss of lamellae and thus coating removal. The erosion involved material removal by breaking of the splat boundaries and their pull out along the grooves from the surface.

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijircce.com

Vol. 5, Issue 6, June 2017

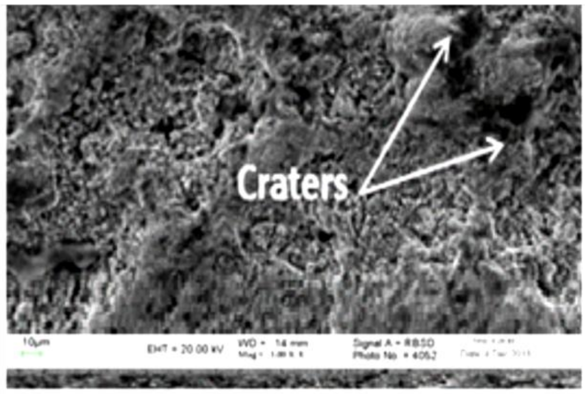

Fig. 10(b) SEM Image of Uncoated Naval Brass at Higher Impingement Angle(90^0)

The eroded surfaces revealed broken lamellae and fragmentation as well as large craters in the eroded zone (Fig 10(b)). The material removal of naval brass tested at a 30◦ impact angle was higher than that tested at a 90° of impact angle. Such erosion behaviour is typical of ductile materials. In contrast, all the coating eroded greater a material loss at a steep angle (α = 90°) than that at a shallow angle (α = 30°). Such behaviour is typical of brittle materials.

IV. CONCLUSION

WC-Co-Cr coatings were developed over Naval Brass alloy by HVOF spray method. The effects of impingement angle in erosion rate in water jet erosion method at constant Water jet velocity, Stand-off Distance, and Erodent Dischargewere studied and following conclusions were obtained,

1. Under low impingement angle, the erodent particle will have the tendency to slide over the surface and as it slides, it will plough the material .The sequent sliding of the particle will remove the material from the surface.
2. At the impingement angle of 60^o ductile metallic material show such kind of pattern. It is evident that at shallow impingement angles, erosion damage is dominated by both splat ejection and plastic deformation of the lamellae.
3. The maximum erosion rate measured under impact of the water jet erosion 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 increase the impingement angle and the maximum erosion takes place at 90^0, with typical ductile erosion behaviour
5. It is remarkably found that at all impingement angles; the erosion rate of WC-Co-Cr coated naval brass is much lower than that of uncoated naval brass and among the coatings. Under the 90° impingementangle, the erosion rate reaches a maximum value for WC-Co-Cr coated naval brass.

REFERENCES

1) B.S. Mann, Vivek Arya An experimental study to corelate water jet impingement erosion resistance and properties of metallic materials and coatings *Wear 253 (2002) 650–661.*
2) N. Andrews a,n, L.Giourntas a, A.MGalloway a, A.Pearson Effect of impact angle on the slurry erosion-corrosion of Stellite 6 and SS316 *Wear320(2014)143–151.*
3) G.T. Burstein , K. Sasaki Effect of impact angle on the slurry erosion–corrosion of 304L stainless *steel Wear 240 (2000). 80–9435.*

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijircce.com

Vol. 5, Issue 6, June 2017

4) Y. Shidaand Y. Sugimoto Water jet erosion behaviour of Ti-Ni binary alloys *Wear, I46 (1991) 219-228.*
5) Jiyuegong , Thomas J. Kim An erosion model for abrasive Water jet milling of polycrystalline Ceramics Wear 199 (1996) 275-282.
6) Y. Wang, Y.G. Zheng , W. Kea, W.H. Sun , W.L. Hou , X.C. Chang , J.Q. Wang Slurry erosion–corrosion behaviour of high-velocity oxy-fuel (HVOF) sprayed Fe-based amorphous metallic coatings for marine pump in sand-containing NaCl solutions Corrosion Science *53 (2011) 3177–3185.*
7) K.S. Tan , R.J.K. Wood , K.R. Stokes The slurry erosion behaviour of high velocity oxy-fuel (HVOF) sprayed aluminium bronze coatings *Wear 255 (2003) 195–205.*
8) S. Hong, Y.P. Wu, W.W. GAO, J.F. Zhang, Y.G. Zheng, Y. Zheng, Slurry erosion corrosion resistance and microbial corrosion electrochemical characteristics of HVOF sprayed WC-10Co-4Cr coating for offshore hydraulic machinery, *Int. J. Refract. Met. Hard Mat. 74 (2015) 7–13.*
9) Wood and Wheeler. D.W (1998), Design and performance of a high velocity air–sand jet impingement erosion facility, *Wear*, *Vol.220, pp. 95–112.*
10) K. Murugan, A. Ragupathy, V. Balasubramanian and K. Sridhar (2014) Optimizing HVOF spray process parameters to attain minimum porosity and maximum hardness in WC–10Co–4Cr coatings.*Surface & Coatings Technology* Vol-247 PP 90–102.
11) Fabienne Mercier, StéphaneBonelli, Fabien Anselmet, Patrick Pinettes, Jean-Robert Courivaud and Jean-Jacques Fry. (2012), On the numerical modelling of the Jet Erosion Test, *ICSE6 Paris - August 27-31.*
12) Murthy. J.K.N, Bysakh. S., Gopinath. K and Venkataraman. B (2007), Microstructure dependent erosion in Cr_3C_2–20(NiCr) coating deposited by a detonation gun, *Surface & Coatings Technology*, *Vol.202, pp. 1 – 12*.
13) KyriakiManiadakiAristomenis Antoniadis and Nicholas Bilalis Effect of impact angle and velocity in crater circularity in abrasive water jet machining by means of multi-particle impact simulation *Int. J. Machining and Machinability of Materials, Vol. 10, Nos. 1/2, 2011*.