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EVALUATING EFFECTS OF WATER JET EROSION PARAMETERS ON EROSION BEHAVIOUR OF NAVAL BRASS ALLOY

*** Murugan K[1], RagupathyA[2] , Balasubramanian V[3] and Sridhar K[4]**

[1]Assistant professor, Department of Mechanical Engineering, Annamalai University, Annamalai nagar, India
[2]Professor, Department of Mechanical Engineering, Annamalai University, ,Annamalai nagar, India
[3]Professor and Director, Centre for Materials Joining and Research, Department of Manufacturing Engineering, Annamalai University, Annamalai nagar, India
[4]K.Sridhar, Scientist-F, Marine Materials Department, NMRL, Ambernath, India

ABSTRACT

The minimization of cost and the enhancement of reliability of rotating and stationary fluid machinery equipment that are subjected to highly erosive environments are mandatory in the marine hardware components. This can be achieved by minimizing the material damage resulting from the solid particle impingement. Naval brass components are very common in the marine applications. Primary understanding of interaction between process parameters like jet velocity, slurry concentration, angle of impingement and time duration have a significant influence of water jet erosion. In this study, the erosion characteristics of naval brass were tested in a jet impingement rig under fluid containing silica sand. Weight loss measurements were used to provide a measure of the amount of material loss that each surface experienced, and the influence of process parameters was taken into consideration. Results showed a maximum variation of mass loss with jet velocity and angle of impingement.

Keywords: *Solid particle erosion, water jet erosion testing, naval brass*

1. Introduction

The material loss in hydraulic machines is very complex and involves damage by various factors such as suspended solid particles, water jet erosion phenomenon and corrosion. Most materials evaluation procedures focus on individual damage contributions. Slurry erosion and water jet erosion have been studied separately in the evaluation of hydro-machinery materials. The evaluation processes relied on field tests, which were too long and took several years. Researchers also evaluated the materials based on physical models that were scaled down. Stauffer sand water jet erosion machine was developed in the late 1950s to test for sand erosion and subsequently it underwent many minor design alterations [1,2]. The water jet erosion tests are conducted on vibratory accelerated water jet erosion test setup, pioneered in 1935 by Hun sacker and Peters [3]. Studies involving combined action of two or more of the above damage contributing factors are scarce. Combined actions of slurry erosion and water jet erosion are treated as serious and severe problem in many hydraulic machinery materials. The slurry erosion damage is due to the erosive action of solid particles suspended in water. Water jet erosion damage near the surface occurs by the stresses generated due to the collapse of bubbles because of pressure fluctuations in water [4,5]. Further damage may result by water jet erosion induced acceleration of the solid particles impinging the surface causing the fatigue damage. Studies on water jet erosion are extensively carried out by marine engineers because it is acumen problem in ship propellers and marine hardware. Many studies show the occurrence of water jet erosion with variations in velocity or pressure in fluid flow behind the bluff bodies. Triangular, cylindrical, rectangular prismatic and spherical shaped bluff bodies are used to perform water jet erosion studies [6, 7]. Considering its importance, there is a need for test method, which closely simulate the real service conditions for the laboratory test specimen. The test method should also be simple in design, short in duration, and easily reproducible. With this objective, an attempt is made to investigate the synergy of sand particle erosion and water jet erosion using a novel and simple test setup. This work experimentally examines and compares the individual and combined effect of water jet erosion induced erosion of the brass test material in an aqueous medium.

**Corresponding Author - E- mail: murugan.thermal@gmail.com, sureshab2004@yahoo.co.in*

2. Experimental Details

2.1 Materials used

Naval brass with the dimension of 15 mm × 10 mm × 8 mm were used as shown in Fig. 1(a).The naval brass specimens were received with a very rough surface and were subsequently ground and polished to achieve a smooth surface. This involved a grinding process using 60 grit SiC paper on a dry flatbed grinder, with intermediate cooling, followed by wet grinding with 240 grit SiC paper on a rotating wheel. The SEM image of silica particles used for water jet erosion test is shown in Fig. 1(b). The chemical composition of naval brass material are given in Table 1

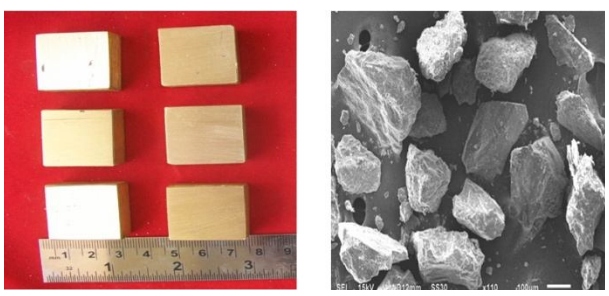


Fig. 1(a) Naval brass (b) Slurry particles

Table 1. Chemical composition of Naval Brass (wt%)

Element	Cu	Zn	Pb	Fe	Sn	Al	Si	other
Naval Brass	**61.3**	**35.6**	**2.56**	**0.267**	**0.042**	**0.018**	**0.015**	**0.178**

2.2 Test setup

An impingement jet system, as shown in Fig. 2, was developed to perform erosion tests. It consisted of a tank used as a reservoir, a high pressure pump, a flow velocity controller, a sand concentration controller, a stirrer, and valves. When the fluid entered the ejector at a high speed, it produced a partial vacuum due to the venting effect. The sands underneath the valve could be mixed with the flowing fluid by means of suction. A speed-adjustable mechanical stirrer was used to ensure the homogeneous mixing of sands in the solution.

2.3 Test conditions and parameters

From the literature [8-12] and our own laboratory investigations the predominant factors having significant influence on the performance of erosion were identified. They are, angle of impingement (A), water jet velocity (V), erodent discharge (E), and stand of distance (D). Since these process variables have greater influence on erosion and it is necessary to find out the optimum levels of these variables. A large number of trial experiments were conducted on naval brass substrate to determine the working range of the above factors by varying one of the parameters and keeping the rest of them at constant value. The working range was fixed in such a way by considering the erosion influence. Every variable at five coded levels (-2, -1, 0, 1, 2) values was shown in Table 2.

Table 2 Important factors and ranges

S. No	Factors	Unit	Level				
			-2	**-1**	**0**	**1**	**2**
1	Angle of Impingement	Deg	30	45	60	75	90
2	Flow Velocity	m/s	10	20	30	40	50
3	Erodent Discharge	g/cc	500	1000	1500	2000	2500
4	Standoff Distance	mm	35	40	45	50	55

In this study, four variables were considered, so $k = 4$, $\alpha = (2k)\ 1/4 = 2$ (15). According to this design, the total number of experimental runs was $2k + 2k + x_0$, where k is the number of variables and x_0 is the number of repetitions of the experiments at the center point. Thus, for this design, 30 experiments were performed according to the central composite design given in Table 3.

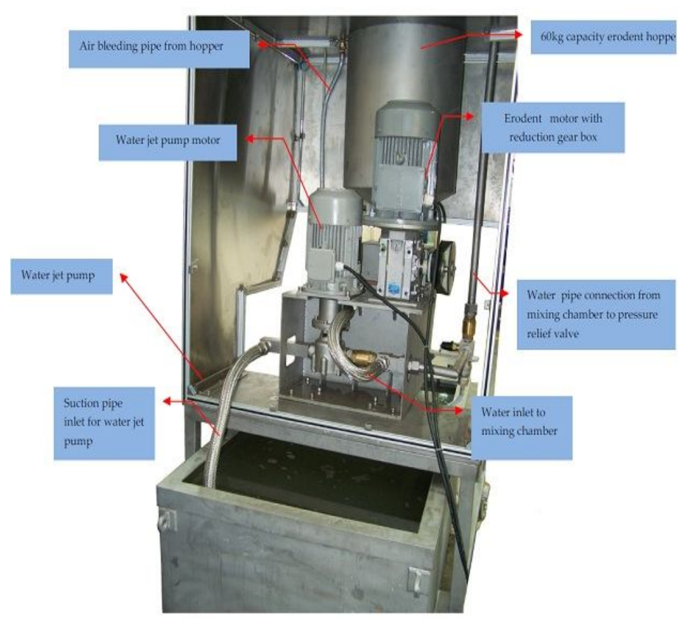


Fig. 2 Water jet erosion experimental setup

3. Results and Discussion

3.1 Weight loss measurements

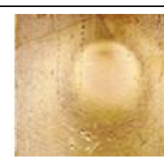
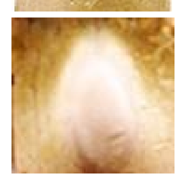
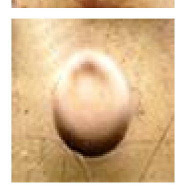
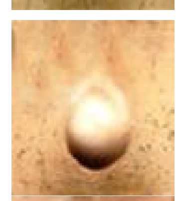
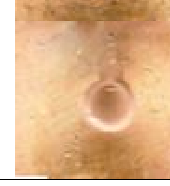
After the water jet erosion tests naval brass specimens were immersed in acetone for 1 min in room temperature, followed by complete rinsing and hot air drying. The weight of the specimen was then measured using an electronic balance with a precision of 0.1 mg. The experimental results are presented in Table 4. Table 4 shows photographs of naval brass wear scars at various impact angles. At 90° impingement, the wear scar is circular in appearance on the surface of the specimen. At shallower impact angles increases, the wear scar becomes elongated, as illustrated in figures in Table 4.

Table 3. Experimental design matrix for water jet erosion

S.no	Angle of impingement ^{0}C	Water jet velocity (m/sec)	Erodent Discharge (g/cc)	Standoff Distance (mm)
1	30	15	1000	40
2	60	15	1000	40
3	30	25	1000	40
4	60	25	1000	40
5	30	15	2000	40
6	60	15	2000	40
7	30	25	2000	40
8	60	25	2000	40
9	30	15	1000	50
10	60	15	1000	50
11	30	25	1000	50
12	60	25	1000	50
13	30	15	2000	50
14	60	15	2000	50
15	30	25	2000	50
16	60	25	2000	50
17	75	20	1500	45
18	90	20	1500	45
19	45	10	1500	45
20	45	30	1500	45
21	45	20	500	45
22	45	20	2500	45
23	45	20	1500	35
24	45	20	1500	55
25	45	20	1500	45
26	45	20	1500	45
27	45	20	1500	45
28	45	20	1500	45
29	45	20	1500	45
30	45	20	1500	45

table 4 shows that wear rate of naval brass reaches its maximum at impact angles ranging from 30° to 45°, that of naval brass. At a certain impact velocity, the maximum of naval brass is primarily determined by the shape of the particles – the sharper the particles the smaller the impact angle at which the curve reaches its maximum. The shape of the curve is also featured by the ratio between the maximum value of the wear rate and the value at normal impact (α = 30°) the rounder the particles the flatter the curve. The erosion is caused due to the sand particles suspended in water, by cutting and ploughing action along with plastic flow of the metal [13]. Photograph shows the scratches, pits protrusions making the surface rougher. These sharper features are formed by erosive action of sand particles contained in the water.

Table 4 Important results of Water Jet Erosion Tests

Experimental run	Parameters	Sample	Mass loss g
1	**A=30 ^{O}C** **V=15 m/s** **E=1000 g/cc** **D=40 mm**		0.1854
5	**A=30 ^{O}C** **V=15 m/s** **E=2000 g/cc** **D=40 mm**		0.224
8	**A=60 ^{O}C** **V=25 m/s** **E=2000 g/cc** **D=40 mm**		0.2884
S12	**A=60 ^{O}C** **V=25 m/s** **E=1000 g/cc** **D=45 mm**		0.1042
18	**A=90 ^{O}C** **V=20 m/s** **E=1500 g/cc** **D=45 mm**		0.1411

A **-** Angle of impingement ^{0}C V - Water jet velocity m/sec
E **-** Erodent Discharge g/cc D - Standoff Distance mm

3.2 Effect of Impingement Angle

An important parameter influencing the erosion rate is the angle between the velocity vector of particles and the target surface. Although researchers used different types of testing devices, as far as the influence of α is concerned, similar curves with a maximum erosion rate were obtained. The figures in Table 4 shows that wear rate of naval brass reaches its maximum at impact angles ranging from 30° to 45°, that of naval brass. At a certain impact velocity, the maximum of naval brass is primarily determined by the shape of the particles – the sharper the particles the smaller the impact angle at which the curve reaches its maximum. The shape of the curve is also featured by the ratio between the maximum value of the wear rate and the value at normal impact (α = 90°) the rounder the particles the flatter the curve [12].

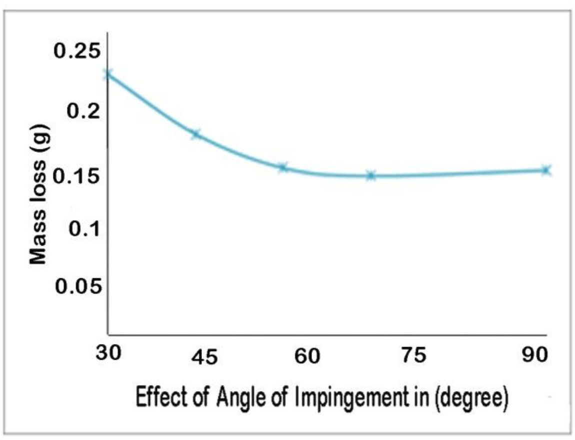


Fig. 3 Effect angle impingement

3.3 Effect of Erodent Discharge

The term "particle concentration" (also known as "phase density") is very often interpreted as the percentage content by weight or by volume of the particles in a gaseous or fluid medium. Erosion by fluid or gas streams having a small abrasive content is linearly dependent on the abrasive content. With an increasing abrasive content, erosion increases linearly up to a certain point; thereafter a change in the linear dependence is observed. The effect of particle concentration was also observed in the processes of erosion by abrasive particles in a fluid stream as shown Figure 4.

At high particle concentration, before impinging on the specimen, attacking particles have to penetrate a "cloud" of rebounding particles and fragments [14]. The probability of collision between attacking and rebounding particles in such a "cloud" is high, resulting in the retardation of the former. This, in turn, causes not only a loss of velocity, but also changes in the direction of the attacking particles. Figure 4 shows the variation of weight loss due to fluid condition (pure water/ 10 to 30% silica sand). In all cases, the weight loss increased by approximately 50% when there is increase in silica sand. However, the weight loss increased significantly for the naval brass substrate.

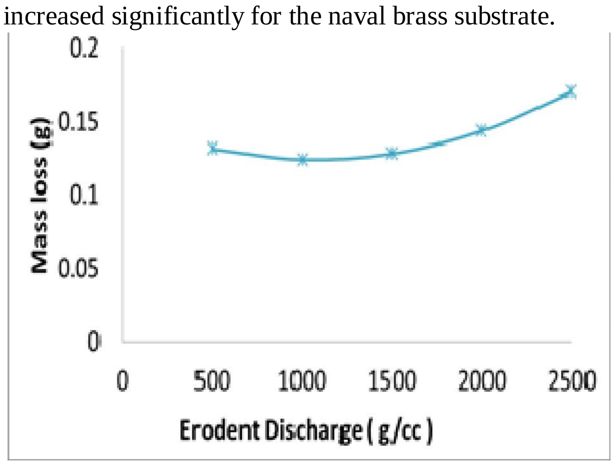


Fig. 4 Effect of erodent discharge on mass loss

3.4 Effect of Water Jet Velocity

Particle velocity at the moment of hitting the target surface has the highest influence on erosion rate. Particle velocity was assumed to be equal to the velocity of the water stream that was changed within the range of 10 to 50 m/s. If the velocity is low then the mass loss is less and if the velocity is high then the mass loss in naval brass is also increase (i.e., velocity is directly proportional to the mass loss in naval brass). Figure 5 shows the mass loss of naval brass steeply with increase with increase in velocity [15]. An excessive material removal is observed in naval brass at every hours. This can be attributed mainly to its lower hardness and poor erosion resistance of naval brass alloy.

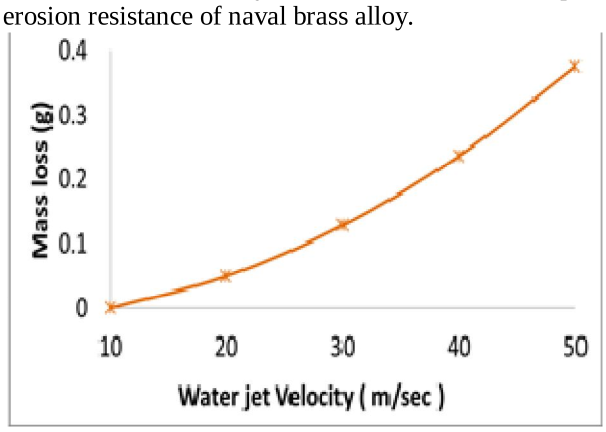


Fig. 5 Effect of water jet velocity

3.5 Effect of Stand of Distance

Figure 6 shows the effect of water jet standoff distance from substrate to jet outlet on naval brass erosion loss. It can be inferred from the Fig. 6, a small variation was observed on erosion loss while changing the standoff distance. The erosion loss of naval brass is highly dependent with slurry concentration and velocity of jet. Whenever the standoff distance changes over a small distance, its change in velocity impacting over the naval brass is negligible.

3.6 Surface characterization

At 30° angle of impingement, the head (the broader part) of the wear scar consists of a roughened surface. (Figure 7) and more hard phase is retained.

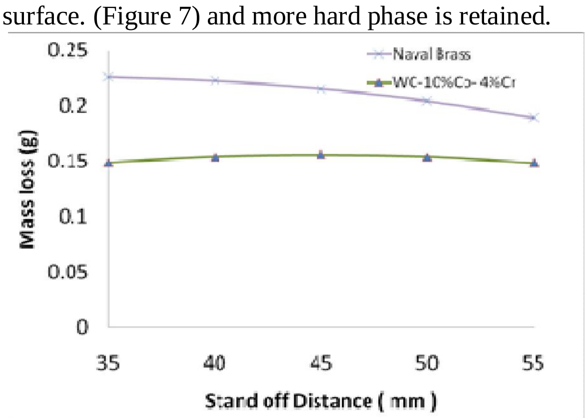


Fig. 6 Effect of standoff distance

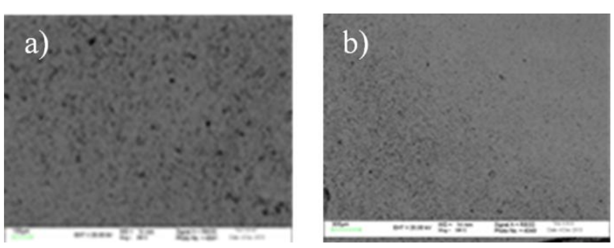


Fig. 7 (a) Eroded surface at 30^0; (b) at 60^0

When the angle of impingement is 60°, the wear scar does not appear to incorporate the 'craters' as before. Instead the surface has a rippled effect as a result of the solid particles ploughing the surface. The gouging of the material by the sand particles is more apparent in the middle of the scar where the craters have been extended into a trough-like shape. As the impingement angle is increased to 60°, the ploughing action from the solid particles becomes less apparent and craters appearing where the material has been removed [15]. However, at 45° impingement, the wear scar contains numerous craters similar to the wear scar after impingement at 60° as shown in figure.

4. Conclusions

1. In this study effect of water jet experimental parameters on erosion rate of naval brass was investigated. Among the investigated parameters slurry concentration and flow velocity dominates the naval brass erosion rate.
2. Naval brass eroded high at an angle of impingement of 30-45 0. It shows that naval brass erosion takes place in a ductile mode. Lower angle impingement produces rough surfaces whereas high angle impingement produces craters and surface cracks.
3. While changing the standoff distance no improvement was observed in naval brass erosion.

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