DEFECT ANALYSIS OF NICKEL ALUMINIUM BRONZE (NAB) IN THE SEA WATER

Sachindra Nath Saha[1],Souvick Chakraborty[2], Satyajit Roy[3], Subhajit Roy[4]
Department of Mechanical Engineering
Dr. B. C. Roy Polytechnic, Durgapur – 713206. West Bengal, India.
Email id – sachindranath.saha@bcrec.ac.in

Abstract: ***Nickel-aluminium bronze (NAB) alloys are commonly used for marine applications, such as different types of Pumps, valves, propellers etc. These NAB materials are conventionally manufactured by using casting techniques. The following literature review is discussion about the defects analysis of NAB alloys castings (nominally) [Cu-9Al-5Ni-4Fe-1Mn] composition. This composition of castings alloy is widely applied for marine applications due to its corrosion resistance, mechanical strength and good cast ability. It has been observed that the turbulence and filling velocity are determining factors that majorly impact on casting performance and due to, the casting defects are generated. After a long study of UNS C95810 alloy castings or NAB materials, it has been observed that the corrosion rate of the alloy is higher in seawater and an investigation was conducted by weight loss determination, scanning electron microscopy (SEM), confocal laser scanning microscopy (CLSM), X-ray diffraction (XRD) and electrochemical testing of the specimen collecting from the damaged materials used in ship yard and observed that no changes found in the chemical composition the corrosion is so high.***

Keywords: ***Nickel-Aluminium Bronze, cast defects; Additive Manufacturing, and Hybrid Manufacturing, electrochemical corrosion***

I. INTRODUCTION

Nickel Aluminium Bronze (NAB) alloys is widely used to marine applications such as ship propellers, pumps and valves due to its good mechanical properties, corrosion fatigue resistance, cavitations resistance and toughness, allowing them to withstand repeated collisions with water [1] [2]. Nickel aluminium bronze alloys contain 8.5- 11.5% aluminium, 3-5% iron and 3-6% nickel increases the resistance to corrosion and the yield strength of alloys [3]. Iron also improves the fineness of the grain structure and tensile strength. While low stacking fault energy of some elements like Cu is the main reason for cavitations resistance, the formation of protective layers is mainly the cause of the resistance to erosion corrosion. Now the days NAB alloys have focused on applications of additive manufacturing (AM) techniques, such as arc-wire directed energy deposition (AWDED), also commonly referred to as wire arc additive manufacturing (WAAM), where several studies have shown that additively manufactured NAB materials exceed the properties of conventional NAB castings but the defects in NAB castings remain same, during turbulent filling of sea water, and the complex solid state transformations the character of (Cu-9Al-5Ni-4Fe-1Mn) alloys during cooling, which are degrading its strength and erosion resistance [4] . For low cooling rates, NAB goes through several phases, which are combinations of an alpha phase (α), a beta phase (β), a gamma phase (γ), and a kappa phase (κ). The β phase is unstable at lower temperatures due to it has a martensitic structure and is rotting into α and γ phases . A body centred cubic (BCC) β phase forms, which typically transforms to a face centred cubic (FCC) α phase interspersed with various κ precipitates upon cooling. Studied the corrosion behaviour of NAB in a 3.5% NaCl solution with deferent pH values. It was found that the k phase is preferentially corroded when the pH<4 but the α phase dissolves first when the pH >4.

The α phase is desirable due to its FCC copper structure which is resistant to seawater corrosion. On the other hand, the γ phase is undesirable because it is selectively attacked by salt water. However, when the aluminium percentage is held below 11%, a κ phase forms instead of the γ phase. This κ phase is a BCC nickel iron and aluminium phase which increases both the strength and the corrosion resistance of the alloy.

II. ANALYSIS

UNS C95810 alloy castings or NAB materials are generally known as the most resistant copper-based alloys to corrosion under the sea water, although, the higher velocities of water or higher turbulence levels may damaged their protective oxide layer and welcome affected badly [5]. NAB alloys are then nowunable to fight against higher turbulent flow of sea water and erosion damage occurred. The damage are increases with the velocity of sea water gradually. However, in the case of Persian Gulf seawater, the tedious effect of pollution on erosion and cavitations should also be considered. This study aimed triesto find out the causes of major failure of NAB castings materials under the sea water. For this purpose, we need to chemical analysis Table 1, macroscopic and stereo microscopic evaluations of defected materials were performed under the sea water.

Table 1. Chemical Composition of the UNS C95810.

Elements	Cu	Mn	Fe	Al	Ni	Zn, Sn, Pb, C, Si, P, Sb
UNS C95810 (wt.%)	80.55	1.09	4.7	9.42	4.24	Trace

The measured yield strength 270 MPa, tensile strength 677 MPa and elongation were 29.0%, respectively. To electively control the unpredictability of the test the artificial seawater was used as a corrosive medium, and its main chemical composition from ASTM D1141 was listed in Table 2.

Table 2.Chemical components of artificial seawater(Mass Concentration (g/L)

NaCl	MgCl2	Na2SO4	CaCl2	KCl	NaHCO3	KBr	H3BO3	SrCl2	NaF
24.35	5.4	4.24	1.19	0.58	0.211	0.1	0.027	0.025	0.003

The instance with defects were taken from a UNS C95810 and observed under optical microscopy, it's determine that the Chemical reaction of affected surfaces with the sea water , an electron transfer known as oxidation. This means that the metal compound of bronze was combined chemically with the oxygen in the sea water to create an oxide. In this process, electrons were released at the anode (salt water) and taken up at the cathode (statue). Not only that,turbulence but also the major reason for failure. The Cavitations erosion (CE) and corrosion behaviour of NAB in artificial seawater have been widely investigated and found that the mechanical effect played a major role in the material damage under the action of CE in 3.5 wt.% NaCl solution, while the corrosion effect was relatively small.

III. PROCEDURES FOR ANALYSIS

Electrochemical Process: This process works on the principle of Faraday's laws of electrolysis, in this law three-electrode system including two working electrodes of equal samples and a saturated calomel electrode (SCE). Michael Faraday discovered that, if the two electrodes are placed in a bath containing a conductive liquid and DC potential (5-25V) is applied across them, metal can be depleted from the anode and plated on the cathode. Hereto measure of electrochemicaltest, there is typical two-electrode wareworkingof the surface ofsamplewith an area of 0.40 $cm^{2.}$ Platinum net and a saturated calomel electrode served as the counter and reference electrode, respectively. The test parameter was 100 ml. of artificial seawater. The polarization curves were recordedof 1 mV/s from -500 mV to 500 mV vs. The voltage perturbation was 10 mV. To avoidany inconsistency of the experiment, two or three repeated tests were carried out for each sample.The electrochemical experiment is a linear polarizationregion of approximately 10 mV around the resting potential.

Electrochemical noise (EN) is atechnique of investigation local corrosion.Mainly in pitting corrosion, stress corrosion and selective phase corrosion. EN monitors the corrosion behaviours of materials continuouslyin unstable states and random non-equilibrium fluctuations in the electrode potential or external measured current. With the help of EN, it has found the corrosion affect of magnesium alloy in alkaline chloride solution.

Electrochemical properties of NAB alloy with different immersion time in 3.5 wt % NaCl solution: (a) Open circuit potential (b) Potentiodynamic polarization curves (c) Bode plots with impedance and phase angle (d) Nyquist plots.

Radiographic Process: Radiographic Examination is a non-destructive testing (NDT) method for examining the internal structure of any component to identify its integrity. Radiographic Testing or RT uses x-rays and gamma-rays to produce a radiograph of the test specimen that shows changes in thickness, defects or flaws, and assembly details to ensure optimum quality. In this testing method, the testing part of the used or un used materials to be placed between the radiation source and a piece of sensitive film or detector. Once the x-ray or gamma-ray radiation is passes through the area of testing, the testing part will hinder some of the radiation by its material density and thickness. Thicker and denser material will allow less radiation to pass through the specimen. The film (or an electronic device) records the amount of radiation (known as a radiograph) that reaches the film through the testing area. After evaluating the radiograph films, defects can easily interpreted. If the material is sound without any defect, entire rays will evenly pass through the material and the area looks white. But for materials containing flaws, rays passing through the flaws will get absorbed to a small extent due to the change in density and viewed black.

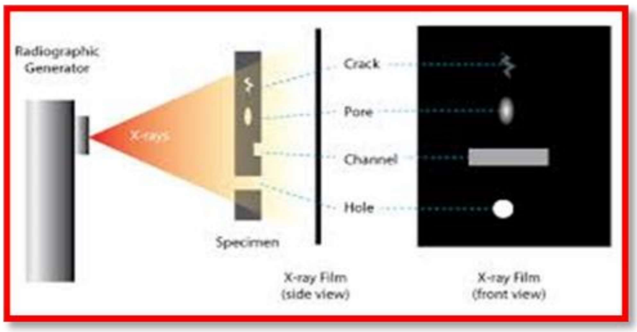

Fig.1Radiographic Process

Based on the above analysis, the results are found below:

IV. Result

The test results ofS-Casting and S-Defecting, weight loss observed in artificial seawater. Figures 2–4 showedshow that the weight loss and film weight of S-Cast and S-Defect, generally show a gradualincreasingwith corrosion time but their weight loss rates gradually decreasing with corrosion time. However the weight loss, film weight and weight loss rate of S-Defect are larger than that of S-cast.Therefore, the defects accelerate the corrosion of UNS C95810. Defects induce a discontinuous corrosionproduct film on NAB materials in seawater, which means the protective effect is very less of the film onthe substrate and corrosion rate is high.

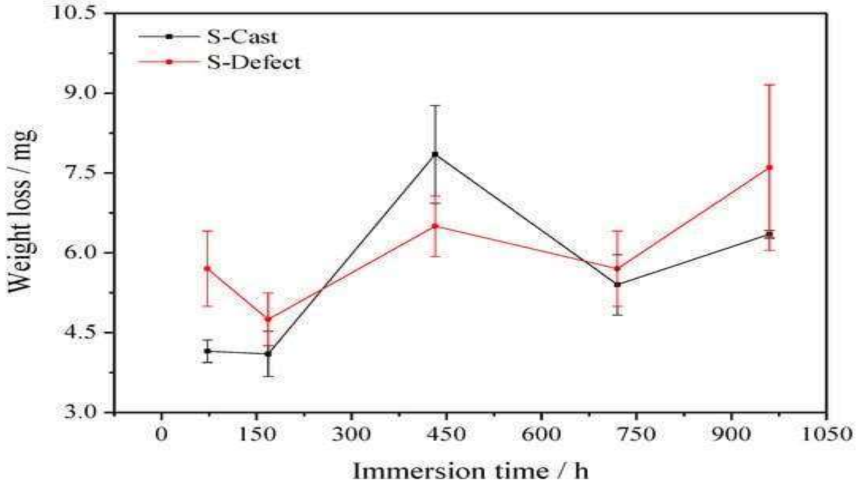

Fig 2. Weight loss of S-Cast and S-Defect immersed for different time periods in artificial seawater.

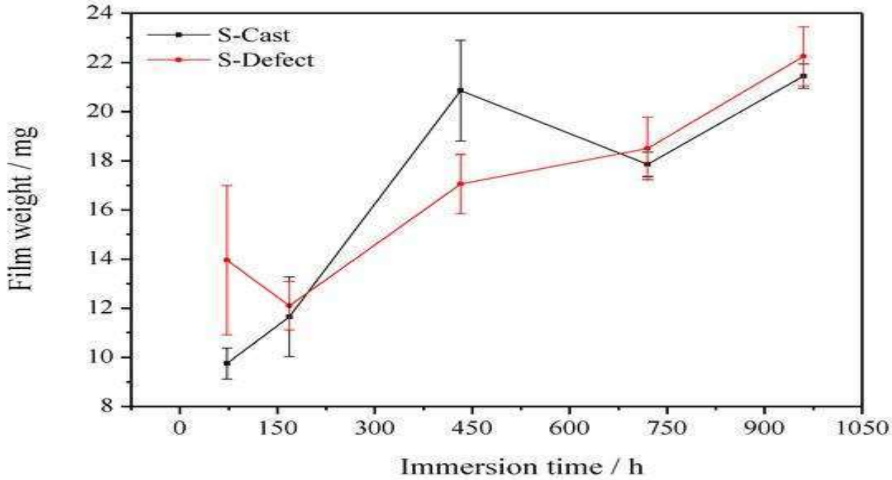

Fig 3. Film weight of S-Cast and S-Defect immersed for different time periods in artificial seawater.

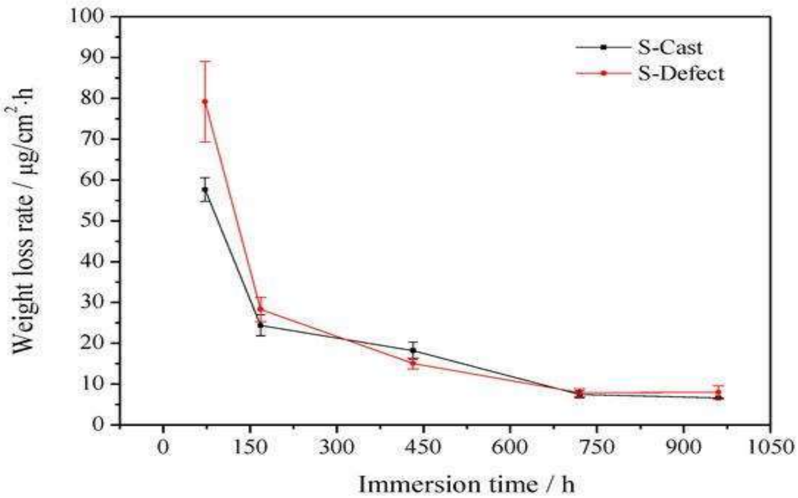

Fig 4. Weight loss rate of S-Cast and S-Defect immersed for different time periods in artificial seawater.

While immersion the NAB alloys in a 3.5% NaCl solution and exposed to a constant stress of 450 MPa (65 ksi) to 600 MPa (87 ksi) for 20 days, the corrosion cracking was observed. The micro structural characterization in Figure 5, is showing that. Preferential corrosion is observed at the α/κ interface for the samples subjected to plastic deformation, associated with high concentration of dislocations. The high residual stresses influence the susceptibility to stress corrosion cracking.

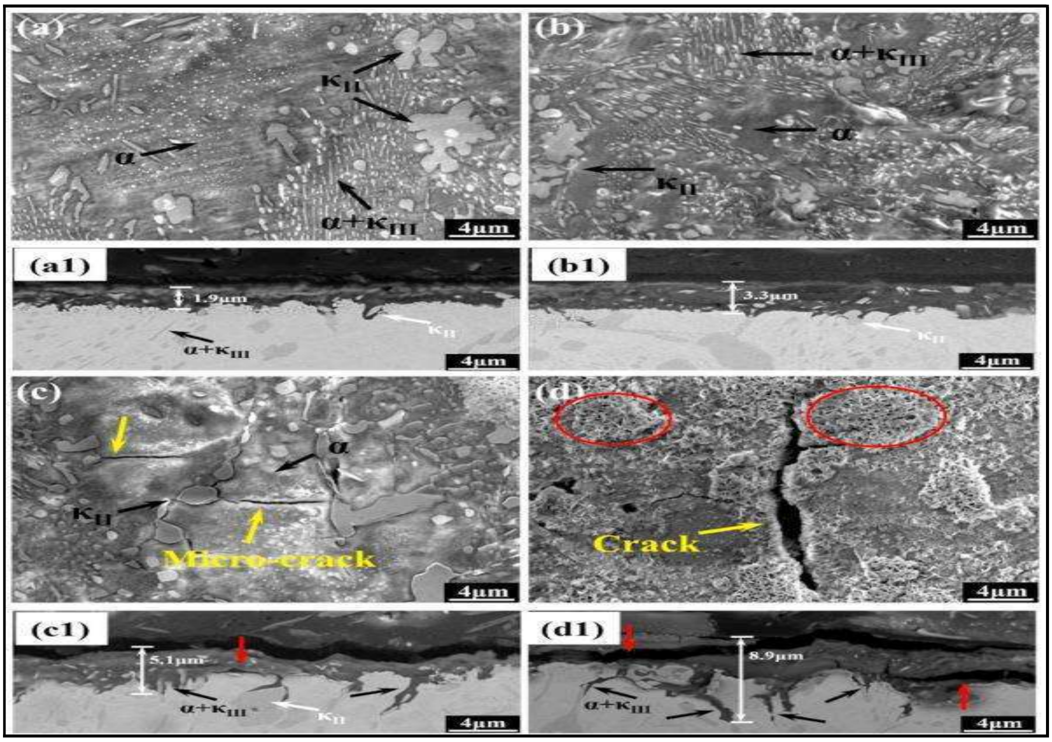

Fig.5 The micro structural characterization

V. CONCLUSION

After the analysing by Electrochemical process, Radiographic Process, or other testing, it has been observed that corrosion rate of NAB is high. To reduce the corrosion rate the materials should be protected by passivating oxide layers, like paint coatings and cathodic protection with zinc and aluminium. It's also protected by DLC coatings in terms of wear resistance. DLC coating doped by copper nano-particles, which is used to improve the mechanical and anti-corrosion properties of NAB alloys

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