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A Study on the Corrosion and Hardness Properties after Addition of Chromium to the Nickel Aluminum Bronze Alloy

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***Abstract*—Corrosion is a major reason for equipment failure. Materials used in marine environments have to withstand corrosion. Nickel–Aluminum bronze (NAB) alloys show better corrosion resistance under marine conditions. Cost effectiveness also considered an important parameter for the usage of material. Many authors studied the corrosion resistance of NAB alloys in sea water or 3.5M NaCl solution. To enhance the properties of NAB alloy, chromium is added additionally after excluding iron, manganese and bronze of the NAB alloy. This paper will focus on the influence of chromium addition to the aluminum nickel alloy to the corrosion resistance properties and hardness. Chromium is added in 4%, 8% and 12% using powder metallurgy route. The chromium addition is observed in the microstructure of the extruded specimens. The electro-chemical corrosion test was carried out to find out the corrosion properties of the alloys. 3.5M NaCl is the electrolyte that is used during the electro-chemical corrosion test. The corrosion properties are increased than the available alloy composition as per ASTM B505M – 14. It also indicates that the micro-hardness also has got increased due to the addition of chromium.**

Keywords*—NAB alloys, Hot-Extrusion, Electro-chemical corrosion, ASTM B505M-14.

1. INTRODUCTION

The aluminum bronzes comprise a wide range of compositions, and alloys can bechosen with a correspondingly wide range of properties to suit many types of duty. Infact, the mix of properties available is so varied that alloy selection needs to be carefullyconsidered, and expert advice is always useful.Nickel-aluminum bronze known as NAB is a series of copper-based alloy with additions of 9% - 12% Al and 6% Ni and Fe. High corrosion resistance of this alloy has made it one of the most practical alloys in marine applications e.g. ship propellers [1,2]. Recently, a vast range of investigation have been carried out to study the corrosion behavior of the cast nickel-aluminum alloy [3,4] and it has been found that optimum corrosion resistant of the alloy in seawater can be obtained by controlling the mictro-structure [5].Meighet al. [6] declared crevice corrosion occurs in the nickel-aluminum bronze when it is not cathodically protected. It has been reported that the rate of crevice corrosion of the alloy in seawater is about 0.7 - 1.0 mm y-1 [7,8]. The optimum mix of tested mechanical proper- ties with ultimate tensile strength in the range of 325 MPa, elongation of around 60% and Rockwell hardness values of 46.5 - 63.7 HRc, making this alloy suitable as alternatives to steel in low/medium strength structural applications [9].Structural applications are mostly based on ferrous materials, steels in particular. Findings have shown that aluminium bronzes are fast replacing contemporary steel materials for some specific applica- tions especially in components for marine/sub-sea applications. The consumption of aluminium bronzes have increased sharply in the USA. And other countries due to their property of being non-rusting in marine environment as well as also their resistance to corrosion in highly aggressive environments. Aluminium bronze alloy construction for basic oxygen and electric arc furnace hoods, roofs and side vents was identified as a viable alternative for carbon steel construction for these equipments. The use of aluminium alloy was found to be as much as five times the life of comparable carbon steel. In propeller material stainless steel have been also used and it also has high corrosion resistance due to the presence of chromium. Thus, the chromium is added to the NAB alloy to improve its mechanical and corrosion resistance properties.

2. EXPERIMENTAL DETAILS

The metal powders are mixed in the ratio of 4%, 8% and 12% chromium keeping the other metal proportions constant which are 9.5% aluminium, 4% nickel. Copper is the base metal and its proportion are changed in accordance with chromium addition. The powders have the size of 44 microns and 325 mesh and have 99.98% pure. The three different compositions are ball-milled, compacted in UTM with 1:1 L/D ratio. The three specimens are then treated in muffle furnace at 850°C and the ageing time was 90 minutes. Further, the specimens are cooled in the furnace itself in order to get high strength. The hot – extrusion was done by the hydraulic press with the use and punch and die of 10mm diameter. The extruded specimens are made to have 10mm diameter and 5mm thickness. The specimens were polished using the grade sheets of different scale from coarse to fine and etched with ferric chloride solution. The micro-vickers hardness(1Kg) and Rockwell hardness (1Kgf) are taken in separate specimens.A daheng software driven optical microscope was used to analyze the microstructures of the developed alloy. Prior to this, the specimen for the microscopy were mounted, grinded using a series of emery paper of grits

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sizes ranging from 60 µm - 2400 µm, it was further polished using an ultrafine polishing cloth, its effectiveness was enhanced using polycrystalline diamond suspension of particle size 3 µm with ethanol solvent. The specimen was chemically etched by swabbing using acidified ferric chloride composing of 8 g of Ferric (II) Chloride, 50mil of HCl and 100 mil of water for 60seconds before micro- structural examination was performed using optical microscope.

3. RESULTS AND DISCUSSION

The already using NAB alloy is having corrosion properties i.e. it has the value of 65µm as per [11]. This NAB alloy is used almost in every propellers of the ship which have been used in marine environments. The newly prepared combination with the addition of chromium has increased the corrosion resistance.

3.1. *Density*

The both theoretical and actual density of the samples was found. The calculated volume of the compacted specimens is 12.271cm3(L/D = 1). The density of the extruded samples were found to be higher than the sintered specimens and are listed in table.

3.2. *Mechanical properties*

For Rockwell hardness, it is measured in B-scale intender with load of 100Kgf, 1/16 inch steel ball intender. Micro-hardness reveals that the obtained hardness is much more than the existing NAB alloys. Thus, the chromium influences increase the hardness of the alloys.

Table 1.Powder Composition

No	COMPOSITIONS (weight %)			
	COPPER	ALUMINIUM	NICKEL	CHROMIUM
Specimen 1	82.5	9.5	4	4
Specimen 2	78.5	9.5	4	8
Specimen 3	74.5	9.5	4	12

Table 2.Density attained at various process stage

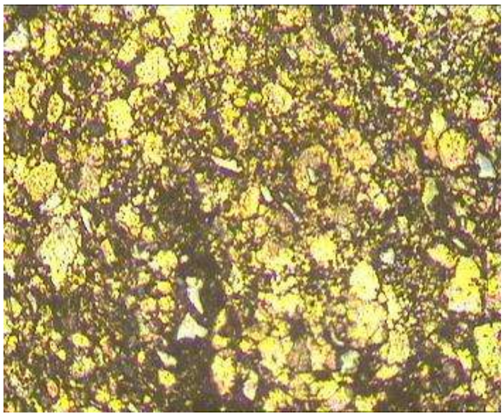
No	DENSITY (g/cm3)			
	SINTERING		EXTRUSION	
	THEORITICAL	ACTUAL	THEORITICAL	ACTUAL
Specimen 1	7.2834	5.4038	7.2834	6.850
Specimen 2	7.2257	5.5466	7.2257	7.10
Specimen 3	7.1690	5.6195	7.1690	7.10

Table 3.Microhardenss test results

No	HARDNESS			
	ROCKWELL		MICRO-VICKER'S	
	SINTERING	EXTRUSION	SINTERING	EXTRUSION
Specimen 1	67	76	98	128
Specimen 2	77	88	167	265
Specimen 3	89	97	240	318

3.3. *Microstructures*

The microstructure of the 3 different compositions shows that the chromium content increases as percentage of chromium addition increases. The micro structures are taken after the hot extrusion process.



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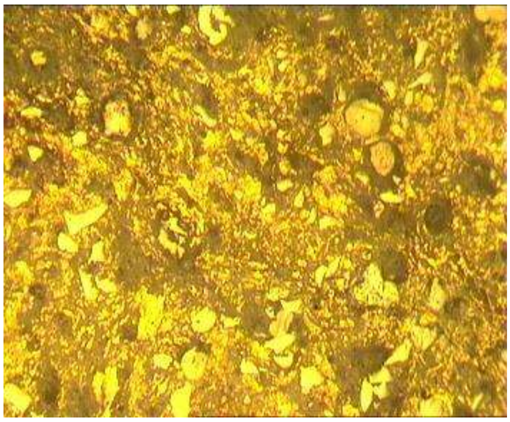

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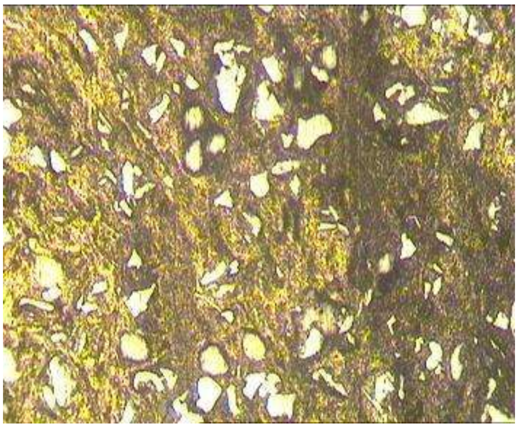

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Fig. 1. Microstructure of (a) 4% Cr (b) 8% Cr(c) 12% Cr.

3.4. Corrosion Test

Corrosion test was carried out in potentiostat from which tafel graph is obtained and shown. A 3.5 wt% NaCl solution was prepared by analytical grade NaCl and distilled water to be used as test medium to simulate seawater in lab.

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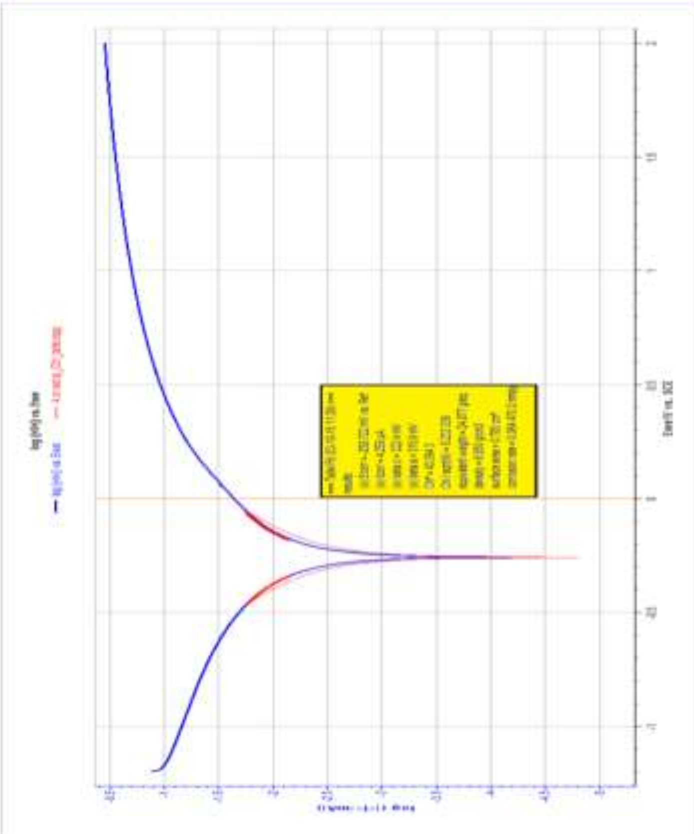

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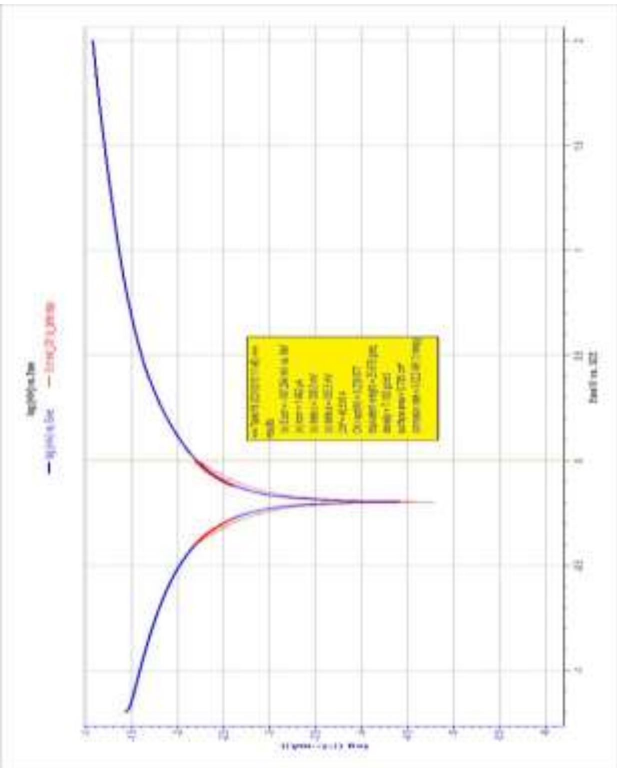

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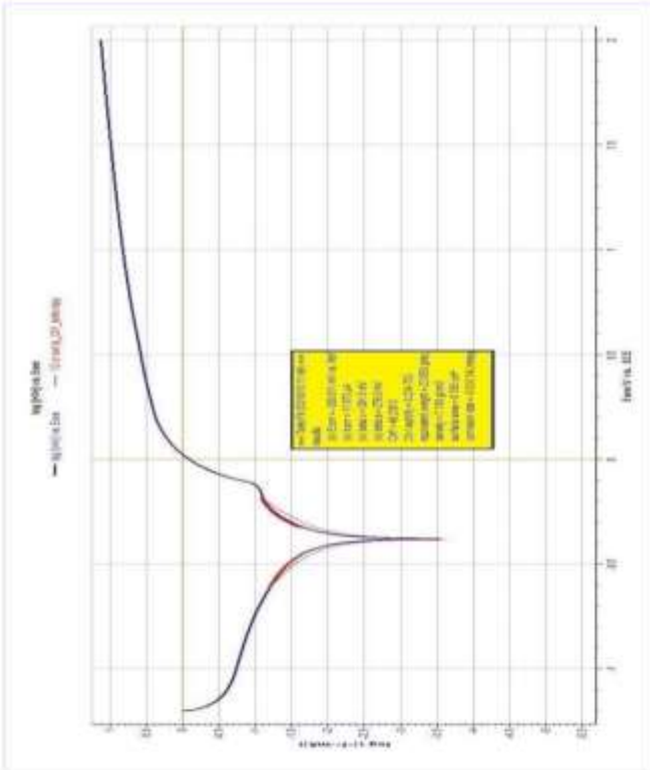

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Fig. 2 .Tafel graph (a) 4% Cr (b) 8% Cr (c) 12% Cr

Table 4. Comparison of corrosion rate with varying Cr content

SPECIMENS	CORROSION RATE(μm)
4% Cr	64.4
8% Cr	22.4
12% Cr	10.5

Table 4.The corrosion resistance for the recommended alloys is really high compared to the already existing NAB alloys. The polarization curves shows the corrosion rate by tafel graph.

3.5. *SEM analysis*

The corroded image was seen on the SEM analysis and it is noted that the corrosion happens due to the cavitations stress. The SEM images are below: that the cracks have higher entropies in comparison to pits in comparison to normal (no defect) in their images. It has been observed that with only increasing corrosion, there are visible pits in SEM images. In contrast, when the cyclic stress is increased, there are visible cracks and pits in SEM images. To provide a better illustration, a two dimensional projection of images (normal

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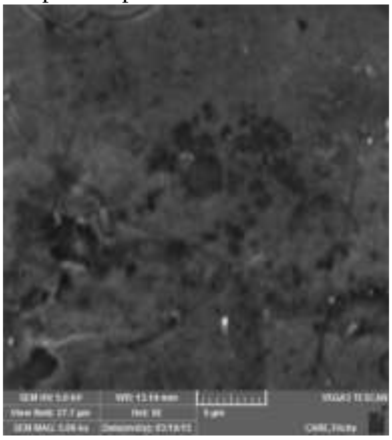
(no defects), pits, cracks, and combination of pit-crack cases into the feature space is presented.



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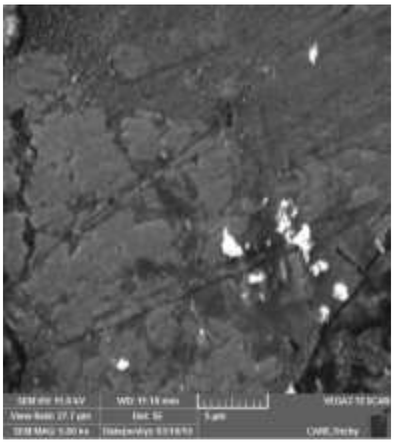

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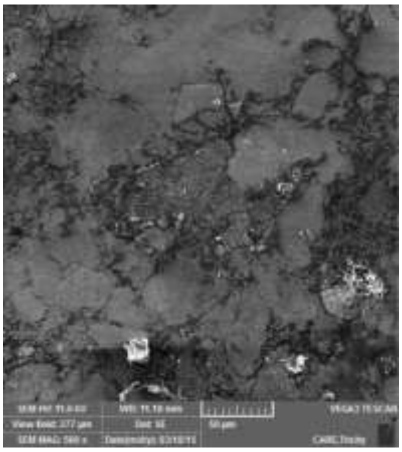

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Fig. 3 SEM image (a) Specimen 1 – 4% Cr
(b) Specimen 2 – 8% Cr (c) Specimen 1 – 12% Cr

4. CONCLUSIONS

- Microstructure of the as hot-extruded sample is composed of α grains, globular precipitates of K phases with a small fraction of retained β1martensite and lamella eutectoid products.
- Corrosion resistance increases with the increase in chromium addition.
- Thus the chromium addition improves both hardness and corrosion.

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