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Analysis of chromium presence and Corrosion Behaviour of Nickel Aluminium Bronze Alloy

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Abstract: *The issue of corrosion is a major problem on equipments failure and damage in industrial that would affect the safety and efficiency of the equipments. Especially, materials used in marine environments have to withstand corrosion and need more hardness to withstand corrosion. Nickel–aluminium bronze (NAB) alloys show good corrosion resistance under marineconditions.Thereforematerialrequirementstowithstand such a high corrosive environment are most important. Along with these, cost effectiveness also considered in the usage of material. Many papers gives the corrosion resistance of behavior of NAB alloys in sea water or 3.5M NaCl solution in detail manner. But the alternate material to NAB is not studied as copperisthematerialshowsveryhighcorrosionresistanceinsea water. In order to enhance the properties of NAB alloy, chromium is added additionally and excluding iron, manganese and bronze of the NAB alloy. This paper will be focusing on the influence of chromium addition to the aluminium nickel alloy in the corrosion resistance properties and hardness. Chromium is added in 4%, 8% and 12% through powder metallurgy route. The specimen prepared for the corrosion testing by sinteringand hot – extrusion. The chromium addition can be seen in the microstructure of the extruded specimens. The electro-chemical corrosion test was carried out in potentiostat in order to find out the corrosion properties of the alloys. 3.5M NaCl is used as the electrolyte during the electro-chemical corrosion test. The corrosion properties were increased than the available alloy composition as per ASTM B505M – 14. Further, the micro- vicker's is done which shows that the micro-hardness also has got increased due to the addition ofchromium.*
Keywords: *NAB ALLOYS, HOT-EXTRUSION, ELECTRO-CHEMICAL CORROSION, ASTM B505M-14.*

I. INTRODUCTION

The aluminum bronzes comprise a wide range of compositions,andalloyscanbechosenwithacorrespondingly widerangeofpropertiestosuitmanytypesofduty.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 andFe.Highcorrosionresistanceofthisalloyhasmadeitone 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 obtainedbycontrollingthemictro-structure[5].Meighetal.[6] declared crevice corrosion occurs in the nickel-aluminum bronze when it is not cathodically protected. It hasbeen 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 tensilestrength 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 improveitsmechanicalandcorrosionresistanceproperties.

II. EXPERIMENTALDETAILS

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- vickershardness(1Kg) and Rockwell hardness (1Kgf) are taken in separate specimens.Adaheng software driven optical microscope was used to analyze the microstructures of the developedalloy.Priortothis,thespecimenforthemicroscopy weremounted,grindedusingaseriesofemerypaperofgrits sizes ranging from 60 μm - 2400 μm, it was further polished using an ultrafine polishing cloth, its effectiveness was enhancedusingpolycrystallinediamondsuspensionofparticle 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 opticalmicroscope.

III. RESULTS ANDDISCUSSION

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

Theboththeoreticalandactualdensityofthesampleswas 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 intable.

3.2. Mechanicalproperties

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 thealloys.

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

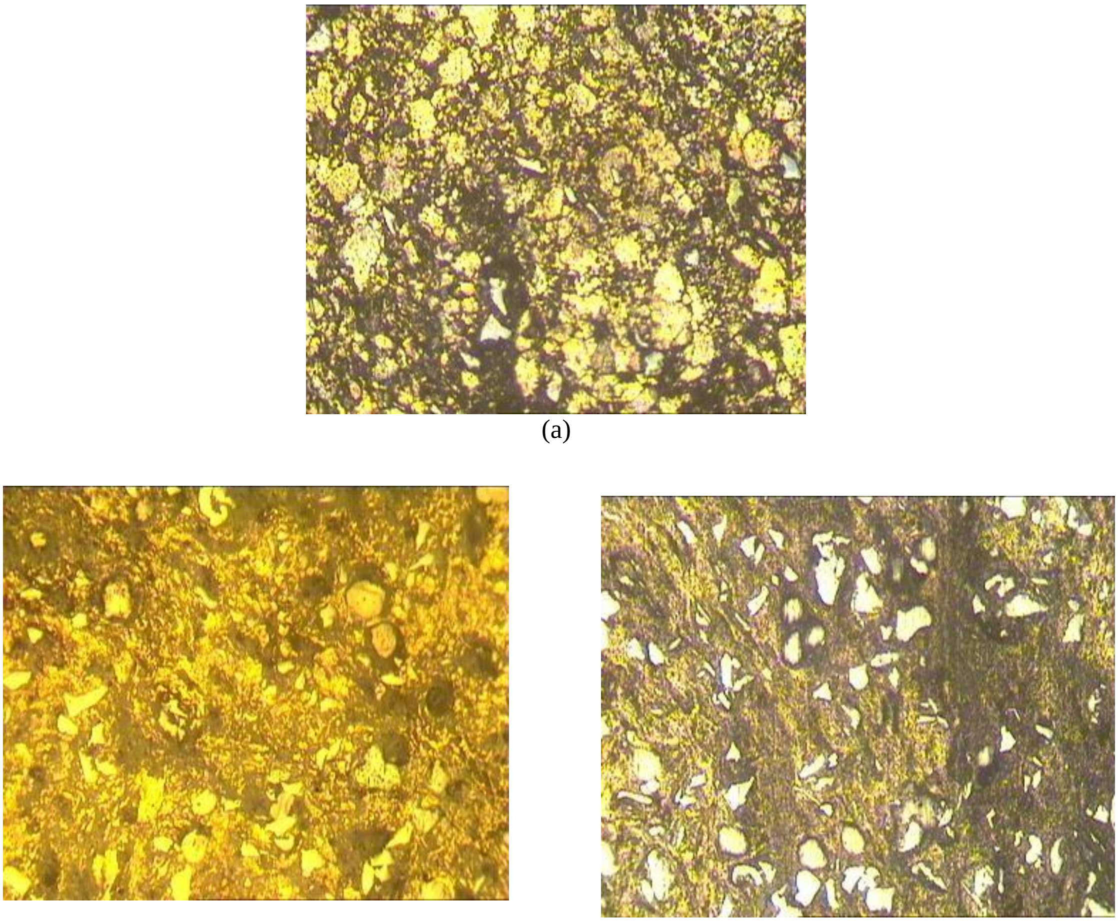
No	DENSITY (g/cm3)			
	SINTERING		EXTRUSION	
	THEORITICA L	ACTUA L	THEORITICA L	ACTUA L
Specimen 1	7.2834	5.4038	7.2834	6.850
Specimen 2	7.2257	5.5466	7.2257	7.10
Specimen 3	7.1690	5.6195	7.1690	7.10

Table 3. Microhardenss test results

No	HARDNESS			
	ROCKWELL		MICRO-VICKER'S	
	SINTERIN G	EXTRUSIO N	SINTERIN G	EXTRUSIO N
Specime n 1	67	76	98	128
Specime n 2	77	88	167	265
Specime n 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.



(a) (b) (c)

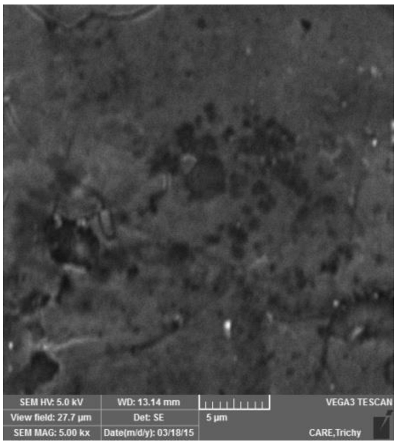
Fig. 1.Microstructure of (a) 4% Cr (b) 8% Cr(c) 12% Cr.

3.4. CorrosionTest

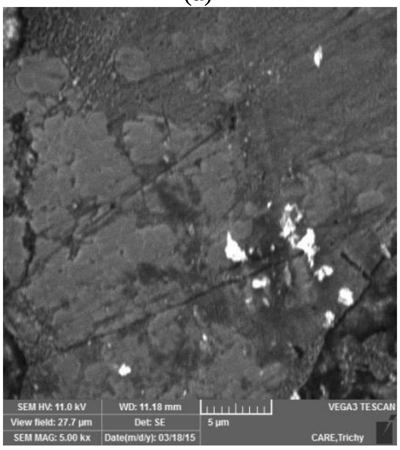
Corrosion test was carried out in potentiostat from which tafel graph is obtained and shown. A 3.5 wt% NaCl solution was prepared by analytical grade NaCl and distilled water to be used as test medium to simulate seawater in lab.

3.1. SEManalysis

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



(a)



(b)

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

IV. CONCLUSIONS

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

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