MECHANICAL AND WEAR CHARACTERISTICS OF ALUMINIUM BRASS

***Esezobor D.E.[1], Agbeleye A.A.[2], Onovo H.O.[3], Bodude M.A.[4]**
Department of Metallurgical and Materials Engineering, University of Lagos, Nigeria
E-mail: esezobordave@yahoo.com[1], agbeleye@yahoo.com[2], harrinov@yahoo.com[3], muideenbodude@yahoo.com[4]
**Corresponding Author: esezobordave@yahoo.com, +2348023082598*

ABSTRACT

In this paper, the influence of the processing parameters on the wear and mechanical properties of 5 – 12 % aluminum red brass (Al-brass) was studied. The wear characteristics of developed Al brass in dry sliding conditions were exposed through a series of pin-on-disc sliding wear tests. Three load levels of 2, 7 and 12N, sliding speeds of 125 and 250 rpm and two sliding distances of 392.7 and 785.4m were investigated. The mechanical properties of the Al brass were determined using standard techniques. The results showed an increase in tensile strength from 225 MPa at 5 % aluminum addition to a maximum of 248 MPa at 10% Al and then a decline to 240 MPa at 12 % Al. The peak stress value increases as the weight percentage composition of Al increases until at 11%Al when it reduces. The impact energy and the hardness values of the as-cast Al brass rose from 54.2 Joules and 81HRC to 122 Joules and 92.4 HRC respectively at 12 % aluminum addition. At lower load of 2N, the addition of 5 % of Al brought a drastic improvement (65 %) to the wear resistance at 125 rpm and 250rpm, but the improvement became consistent thereafter. The same trends occurred at load of 7 N, but with lower degree of improvement (approximately 40 %). In contrast, under higher load of 12 N, the addition of Al brought slight and consistent improvement (10 -15 %) to the wear resistance.

Keyword: Copper**,** Mass-loss, Strength, Wear.

1. INTRODUCTION

Copper (Cu)-based alloys are most frequently used in saline water systems, e.g. heat exchangers and distillation type desalination plants. Among the numerous Cu-based alloys, the brass and aluminum brass (Al-brass) are used as gears for pumps, valves, control rods, impellers, turbine and compressor blades, and shafts for seawater applications. They are resistant to corrosion, oxidation and have superior resistance to cavitation erosion and impingement attack. They also show relative high thermal and electrical conductivity and low cost. Specifically, brass is widely used as industrial material due to its excellent characteristics such as high corrosion resistance in non-acidic environments (Loto and Loto, 2012), nonmagnetism, good fabricability and low cost (Jordan and Powell, 1998). In contrast to standard bronze (90 % Cu and 10 % Zn) or brass (Cu and Zn),red brass which consists of 85 % Cu and 15 % Zn is characterized with excellent cold workability, good hot formability and is extensively used in automobile, electronic, energy, construction and marine industries. However, red brass requires a considerable improvement in mechanical property and wear resistance to meet the continuously growing demands on standard components and machine elements with respect to efficiency and durability. These needs arise in order to avoid premature failure that may occur due to wear.

Conventionally, the strengthening mechanisms such as cold working and precipitation hardening are ineffective due to the effect of recrystallization, and particle coarsening and dissolution respectively at high temperature (Rajaram and Rao, 2010). Major improvements can be obtained through solid solution strengthening (alloying with certain elements) to alter the proportion of phases present (Odabas and Su, 1997).

Some researchers (Arunkumar et al., 2012; Tiwariet al., 2012; Aziz-Ameen et al., 2011; Anasayida, 2009; Astakhov and Davin, 2008 and Torabian et al, 1994) have also found that there is a close correlation between the wear rate and the processing parameters such as normal load (Tiwari et al., 2012 and Aziz-Ameen et al., 2011), sliding speed (Anasayida, 2009 and Aziz-Ameen et al., 2011), geometry (Astakhov and Davin, 2008), relative surface motion (Torabian et al 1994).

Despite the aforementioned studies, the combined effects of normal load, sliding speed and distance and alloying are yet to be clearly understood. Therefore, in this paper, attempt is made to investigate the simultaneous effect of normal load, sliding speed and sliding distance on the mechanical properties and wear rate of red brass against different percentage of additions of aluminum.

2. METHODOLOGY

2.1 Materials and Preparation

The materials used in the study were aluminum 6063 alloy and copper C2300 alloy (also known as red brass) with chemical composition as shown in Table 1 were obtained respectively from NIGALEX Extrusion Company and Owode-Onirin market, both in Lagos, Nigeria.

Specimens of Al-brass were prepared by varying the weight percentages (5 – 12wt. %) of aluminum alloy and red brass through liquid metallurgy stir casting route. Specimens of Al-brass were melted in a crucible furnace at 1084^oC, sand cast and thoroughly cleansed by sand blasting. The specimens were dimensioned into different sizes and shapes for the various mechanical properties tests and microstructural analysis. The chemical analysis of the specimens was conducted using optical emission spectrometer (model ARL 3460). The specimens were solutionised at 850˚C for 2 hours in a muffle resistance furnace and normalized in air. Hardness, tensile and Charpy impact and wear test specimens were prepared in accordance with ASTM B927 / B927M (2013) standards.

2.2 Experimental Design

The hardness values of the cast Al-brass specimens were obtained through the Rockwell hardness tester on C-scale using a steel ball indenter. Four indentations were made at random locations for each specimen's surface by applying a preliminary minor load of 10 Kg and major load of 150 Kg for duration of 10 seconds. The tensile property of tests were conducted in an Instron electro-mechanical testing system 3369 at a nominal strain rate of $10^{-3}s^{-1}$, while the notch toughness of the specimen was evaluated through impact energy with the aid of a Charpy tester model 6703 at a striking force of 300 Joules.

The abrasive wear resistance of the test specimens was determined using a pin-on-disc wear testing machine under dry sliding conditions at room temperature (25^oC) with varied (at a time one parameter while keeping others constant) composition (5 – 12wt % of Al) of Al-brass. Three load levels of 2, 7, 12 N, sliding speed of 125 and 250 rpm and two sliding distances of 392.7 and 785.4 m at constant sliding radius of 0.1 m and time of 5 minutes were investigated. The specimens were constantly cleared with woolen cloth in order to avoid entrapment of wear debris. The wear rate, W, (g/m) which relates to the mass loss (Δm), g and sliding distance (L), m was calculated using expression in equation 1:

$$W = {}^{\Delta m}/_{L} \tag{1}$$

The specimens were carefully prepared for micro-structural characterization studies using standard metallographic techniques. The ground and mechanically polished specimens were etched with 50 ml hydrochloric acid in 100 ml distilled water for 20 seconds. The micro-structure was examined under a digital metallographic optical microscope at 200 microns magnification.

3. RESULTS AND DISCUSSION

The results of the chemical analysis, hardness, impact, tensile and wear tests are presented in Table 1 and Figures 1 - 4, while the microstructures are displayed in Plates 1-2.

Table 1: Composition Analysis of red brass, aluminum alloy and Al-brass

	Composition, wt %						
Materials	**Cu**	**Al**	**Si**	**Fe**	**Mn**	**Mg**	**Zn**
Copper alloy C2300 (Red brass)	85.00	-	-	-	-	-	15.00
Aluminum alloy (AA6063)	0.076	98.90	0.479	0.024	0.053	0.481	0.068
Brass-5% Al	80.75	4.980	0.02	0.001	0.002	0.02	14.22
Brass-6% Al	79.88	6.006	0.03	0.001	0.003	0.03	14.05
Brass-8% Al	78.30	8.01	0.04	0.002	0.004	0.04	13.60
Brass-11% Al	75.66	10.90	0.05	0.004	0.006	0.05	13.33
Brass-12% Al	74.80	11.88	0.06	0.004	0.006	0.05	13.20

The weight percentage of brass – 5% Al, brass – 6% Al, and brass – 8% Al, are found to be 4.980%, 6.006% and 8.01% very close to 5%, 6% and 8% respectively. This suggests that the cast structure made is very sound and appropriate and that the processing parameter such as pouring temperature is also adequate.

Mechanical Properties

The tensile strength of the Al-brass increases as the weight percentage of aluminum increases in brass up to 10% and decreases on further rise in proportion of aluminum. The results showed an increase in tensile strength from 225 MPa at 5 wt.% aluminum addition to a maximum of 248 MPa at 10wt.% Al and then a decline to 240 MPa at 12 wt.% Al. From the graph (Figure 1), it is observed that the peak stress value increases as the weight percentage composition of Al increases until at 11wt.% Al when it reduces. The Rockwell hardness values increases as the weight percentage of Al increases from 5 to 12 wt.% Al due to increase in the β' martensites phase.

The quantitative results obtained from the impact test which is the energy required to fracture the test samples helps to determine the value of the toughness of the specimens which in turn tells whether the specimens are ductile or brittle. Generally, all the specimens were tough i.e. ductile but the alloy with the highest weight percentage of Al showed the highest ductile property by physically not fracturing even with the highest impact energy. The impact energy and the hardness values of the as-cast Al brass rose from 54.2 Joules and 81 HRC to 122

Joules and 92.4 HRC respectively at 12wt. % aluminum addition. The results of wear tests on all specimens with varying loads (2.0, 7.0, 12.0 N) presented in Figures 2 and 3 indicate that the mass loss due to wear decreases when the percentage of Al increases. The decrease in mass loss with increasing percentage of Al can be attributed to the increasing presence of hard β' martensites phase particles adhered to the alloy (Khan and Singh, 2013).

Variation of sliding speed with wear is shown in Figures 4 (a) and 4 (c). With increasing sliding speed, the interface temperature of the sample increases, although with negligible effect on the mass loss and invariably the wear rate, making it softer and thus increases the weight loss. With the increase in time, weight loss increases due to increase in sliding distance in wearing. At lower load of 2N, the addition of 5 wt. % of Al brought a drastic improvement (65 %) to the wear resistance at 125 rpm and 250rpm, but the improvement became consistent thereafter. The same trends occurred at load of 7 N, but with lower degree of improvement (approximately 40 %). In contrast, under higher load of 12 N, the addition of Al brought slight and consistent improvement (10 – 15wt.%) to the wear resistance.

Microstructure analysis

The microstructures of as-cast specimens viewed under the microscope with alloy compositions of 5 % Al – 95 % brass, 6 % Al – 94 % brass, 8 % Al – 92 % brass, 11 % Al – 89 % brass, and 12 % Al – 82 % brass, are shown in plates 1 and 2.

An optical micrograph of 5 % Al – 95 % Cu alloy shown in Plate 1 (a), revealed rounded crystallized particles of Al surrounded by fine eutectic α-copper (brighter parts) and β' martensite which later decompose to pearlite ($\alpha+\gamma_2$) (Khan and Singh, 2013). Copper has networked structure. It is evident that the degree of refinement of the eutectic copper decreased as the copper content of the alloy decreases beyond the eutectic composition (Plate 2).

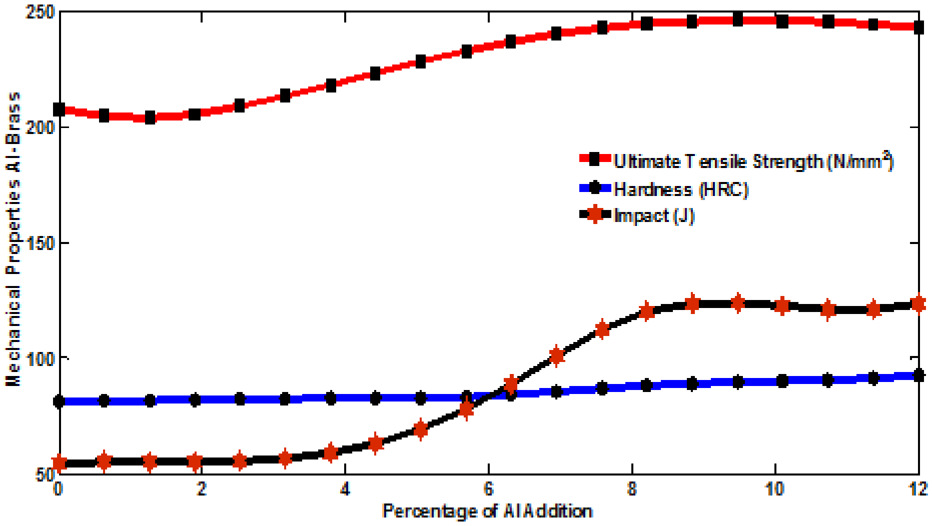

Figure 1: Effect of Al additions on the mechanical properties of Al-Brass

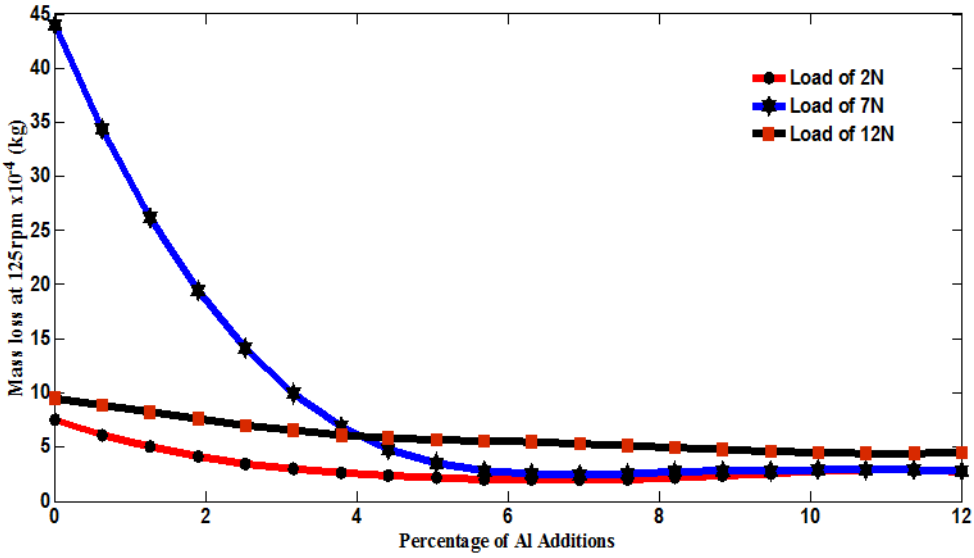

Figure 2: Variation of mass loss of Al-brass with varied loads at constant time (5min) and Speed (125rpm)

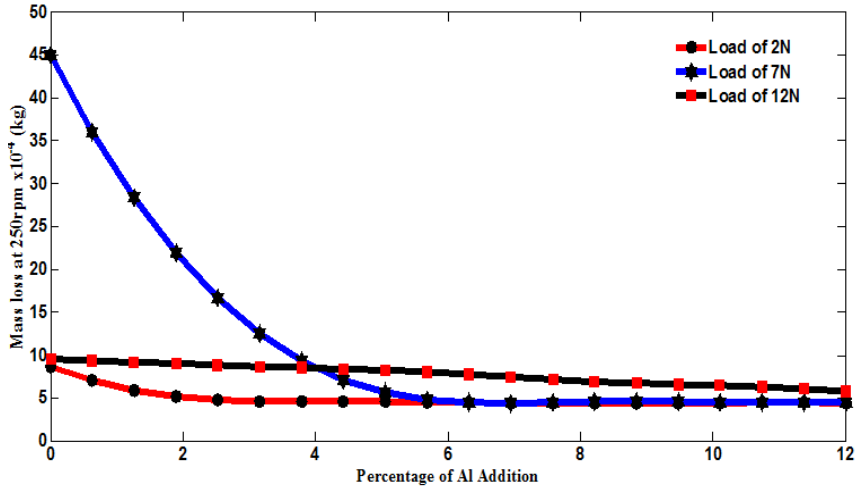

Figure 3: **Variation of mass loss of Al-brass with varied loads at constant time (5 min) and Speed (250 rpm)**

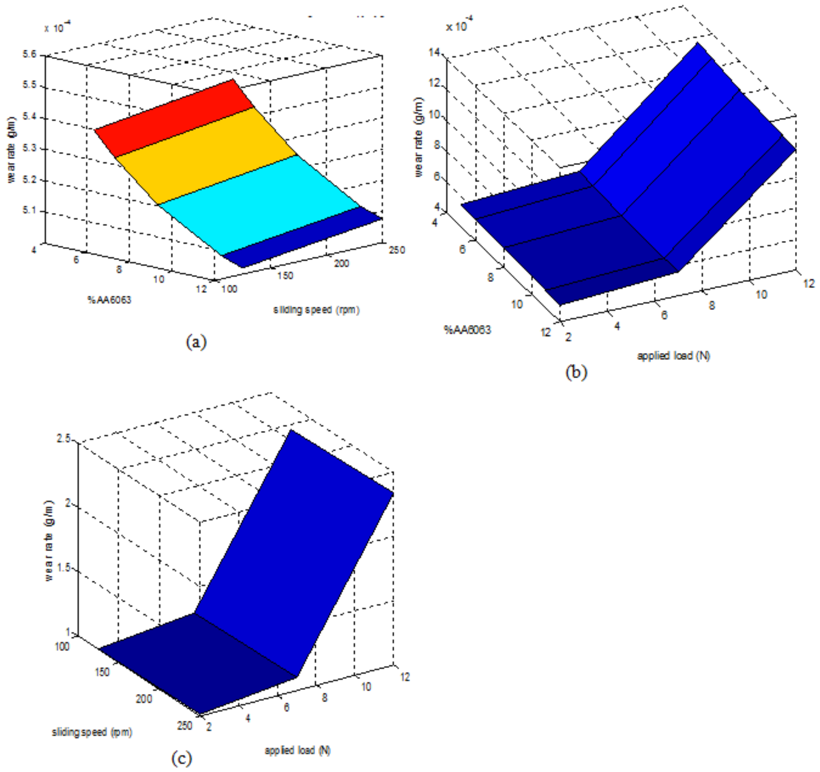

Figure 4: **Graph of wear rate of Al-brass against: sliding speeds, (a), and applied loads, (b)at varying percentage of AA6063and applied loads at varying speeds, (c).**

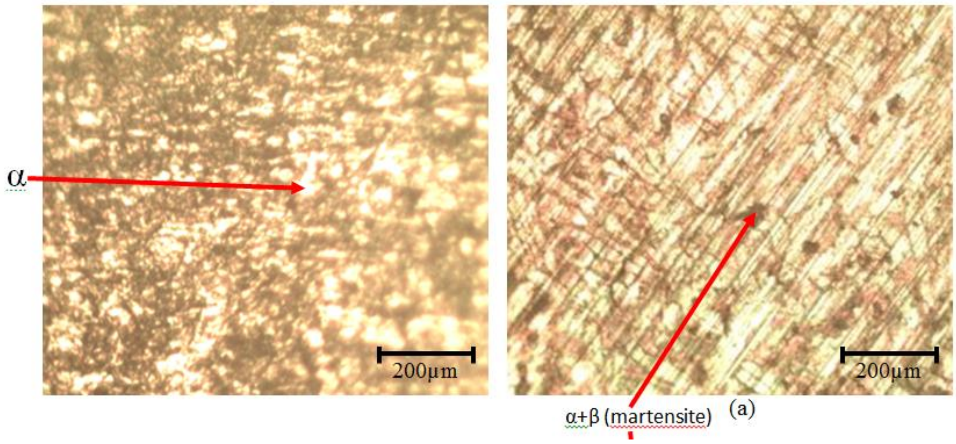

Plate 1: Microstructure of Al-brass (Control Sample)

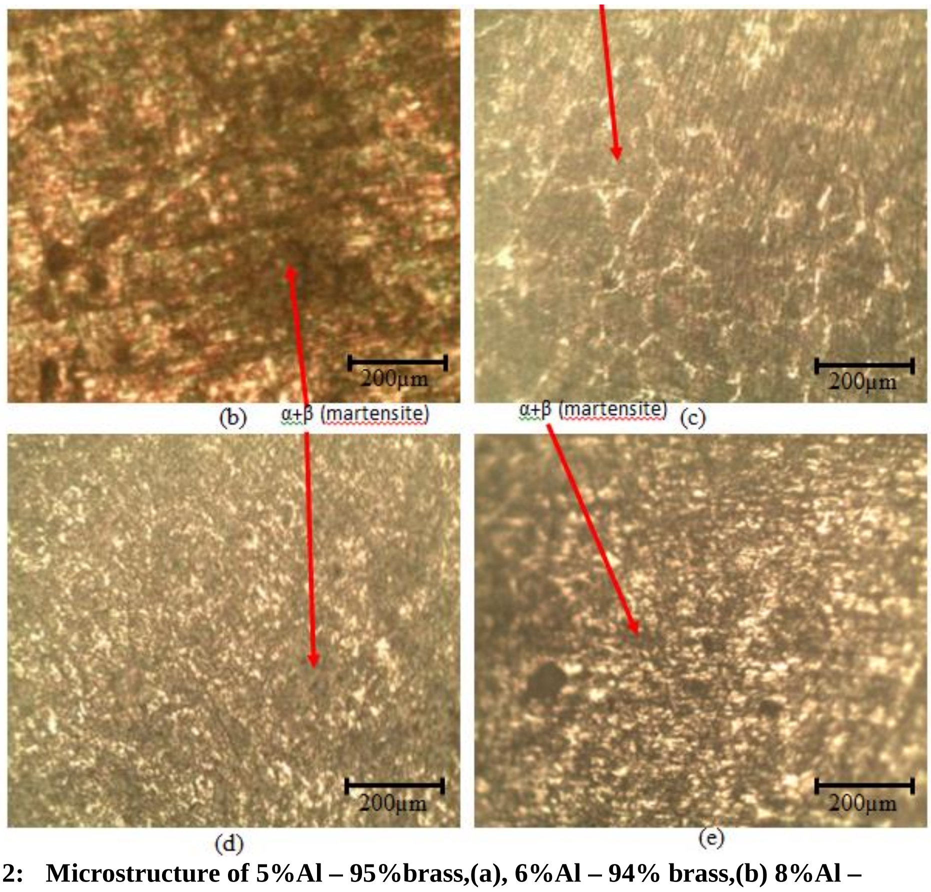

Plate 2: Microstructure of 5%Al – 95%brass,(a), 6%Al – 94% brass,(b) 8%Al – 92%Cu,(c),11%Al – 89%Cu,(d) and 12%Al – 88%Cu, (e)

4. CONCLUSION

It can be established from the experimental results that mass loss is seen to be directly proportional to the wear rate of Al – brass. The wear behavior is dependent on the applied load, and sliding speed. The ultimate tensile strength increases with increase in weight percentage of Al until about 11 wt.% Al where it declines. The mass loss was also observed to be inversely proportional to the sliding speed in agreement with the Archard's equation. Hardness and toughness of the Al – brass composite increases with the increase in the amount of Al present. Mechanical behavior of Al-brass depends primarily on the percentage addition of aluminum. Alloys with up to 8 wt.% aluminum have a ductile single phase structure that are most suitable for cold working into sheet tubes, strips and wires. Al-brass with increased in aluminum content from (8 and 10 %), the alloy is strengthened by a second harder phase which makes them more suitable for hot working and casting. Above 10% and with proper heat treatment, an even greater strength and hardness may be developed for specialized wear resistant applications.

REFERENCES

Anasayida A. S., Daud A. R. and Ghazali M. J. (2009). "Dry sliding wear behavior of al-4Si-4mg alloys by addition of cerium", *Intl. J. Mechanical and Materials Engineering*, **4**, 127-130.

Arunkumar N., Shareef AbdurRawoof H., and Vivek R. (2012). *International Journal of Engineering Research and Applications (IJERA)* ISSN: 2248-9622 www.ijera.com. **2**(4):1111-1121

Astakhov P. Victor and Davin J. Paulo (2008). Tools (Geometry and Material) and Tool Wear. Pp 29-57 in Machining Fundamentals and Recent Advances. Ed. Davim J.P., 2008, XIV, 362p ISBN: 978-1-84800-212-8 http://www.springer.com/978-1-84800-212-8

ASTM B927/B927M - 13. Standard Specification for Brass Rod, Bar, and Shapes ASTM International, West Conshohocken, PA, 2013, www.astm.org

Aziz-Ameen Hani, Hassan Salman Khairia and Mubarak Mhdi Mohamed Ethar (2011). Effect of loads, sliding speeds and times on the wear rate for different materials. *American Journal of Scientific and Industrial Research,* **2** (1): 99 – 106

CDA, (1986)Copper Development Association. Aluminium Bronze Alloys for Industry, *CDA Publication* **83**,8http://www.copper.org Assessed 20 June, 2015

Jordan D. E. and Powell C. (1998). Fabrication of copper-nickel alloys for offshore applications. *Welding in Maritime Engineering*, Croatia.

Khan A. and Singh P. K. (2013). "Influence of heat treatment on microstructure and mechanical properties of aluminum bronze", *International Journal of Metallurgical & Materials Science and Engineering (IJMMSE)*, **3** (1), 57-66

Loto C.A. and Loto R.T. (2012). Corrosion Resistance Behaviour of Duplex (α β) Brass in Nitric Acid Concentrations. *Int. J. Electrochem. Sci*., 7, 12021 – 12033.

Odabas D. and Su S. (1997). "A comparison of the reciprocating and continuous two-body abrasive wear behavior of solution-treated and age-hardened 2014 Al alloy", *Wear,* **208**, 25-35.

Rajaram G., Rao T. S., (2010). "High temperature tensile and wear behaviour of aluminum silicon alloy", *Materials Science and Engineering* (A) **528**247-253.

Tiwari, A. K., Mishra T. K., Choubey M., Ranjan R. K. (2012). Investigation of wear behaviour of Al+Cu powder preforms. IOSR *J. Engineering*. **2** (10):59-64.

Torabian H., Pathak J. P. and Tiwari S. N. (1994). "Wear characteristics of Al-Si alloys", *Wear*, **172**, 49-58.