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A Review of Tribological and Mechanical Investigation of Aluminum Bronze C95500 cast by Horizontal Centrifugal Casting

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Abstract - *Aluminum bronze C95500 contains 10-11% Al, 4-5%Fe, 4-5%Ni and max 1.5%Mn which is used in applications such as heavy-duty sleeve bearings, bushings, shafts and valve components for handling seawater. It offers wide range of properties likes wear resistance, low friction and anti-seizing properties. Aerospace, defense, commercial marine and the petrochemical industrial sectors continue to remain the major outlets for aluminum bronze. Cylindrical castings are prepared by centrifugal casting where molten metal is poured in rotating mold. The quality of casting is affected by the pouring temperature, mold rotation speed, mold temperature, pouring speed and melt treatment. The aim of the present study was to investigate the microstructure, wear behaviour, hardness and tensile behaviour of aluminum Bronze C95500 cast by horizontal centrifugal casting. Cover flux, degasser, Deoxidant were used in melt treatment as per standardized practice. In this study, samples were prepared at different pouring temperature at different mold rotation speed and melt treatment with or without degassing tablet and deoxidizing tubes. For Experimental design, Taguchi method (L9) orthogonal array was used to find out number of conditions for various parameter. The wear tests were carried out using pin-on-disc wear tester at load of 30 N, disc rotation of 600 rpm, track radius of 45mm and time duration of 5min. Hardness was investigated on B scale Rockwell hardness tester and tensile tests were performed on tensometer. A correlation of microstructure with hardness, tensile strength and wear rate were established for the investigated the centrifugal cast specimens.*

Key Words: Copper alloy, aluminum bronze, horizontal centrifugal casting, wear behaviour, rockwell hardness, tensile strength, pin on disc test, degassing, deoxidising tube

1. INTRODUCTION

Aluminum bronzes are the copper alloys containing 9-12% aluminum as a primary alloying element with addition of iron and nickel. Other alloying elements are mostly used for specific function. iron enhances tensile strength and acts as a grain refiner, nickel improves grain structure and corrosion resistance while manganese also performs a stabilizing function [1]. The bearings, bushing, gear blanks and valve parts are manufactured by centrifugal casting which give better density with inclusion free castings.

1.1 Horizontal Centrifugal Casting

The mold is rotated about its own axis in true centrifugal casting process. This method is used for plain cylinders or tubes. The shape is produced by centrifugal force and the thickness of cylinder depends on the volume of the molten metal poured. No core is placed inside the mold. Horizontal centrifugal casting is used with mold placement in horizontal and rotation about its own axis. Desired shape and wall thickness can be achieved by the centrifugal force produced by a rotational mold [2].

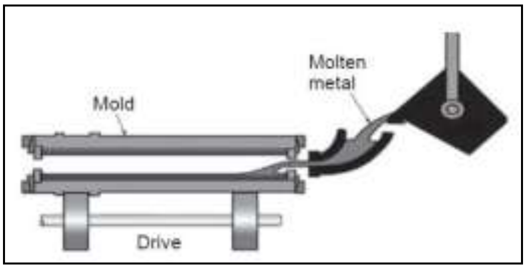

Fig -1: Schematic of horizontal centrifugal casting[2]

Solidification starts from outside surface of mold, a form of directional solidification happens which makes porosity and impurities in the metal last to freeze near the core of the cylinder. Machining of the bore removes this unwanted solidified part. Centrifugal castings, may have a little greater density than other normal castings. Higher speed of rotation is required for aluminium bronze than for tin bronzes and gun metals, but high rates of chilling cause surface cracking, therefore it should be avoided with aluminium bronze.

Fig -2: Horizontal centrifugal casting machine setup

The quality of casting produced by centrifugal casting is affected various process variables. The main process variables are speed of rotation, pouring temperature, pouring speed and mold temperature. The melt treatment used during melting the charge is also affecting the quality of casting [3]. The horizontal centrifugal casting machine was made by past researcher at workshop in U. V. Patel College of Engineering shown in figure 2. The mold is made of mild steel having outer diameter of 140mm, inner diameter of 100mm and length of 170mm.

1.2 Material Selection

In the experimental practice, the goal was to cast hollow cylinder of aluminum bronze C95500 by horizontal centrifugal casting process. Aluminum bronze C95500 material is selected as per UNS standard and material having this specific composition was purchased in the form of ingots. Table 1 shows the composition of material procured.

Table -1: Aluminum Bronze C95500 composition

Element	Cu	Al	Ni	Fe	Mn
wt%	79.04	10.74	5.13	3.72	1.07

1.3 Melt Treatment

The melt treatment covers three methods: Covering fluxes, Degassing Tablet and Deoxidising tubes. The fluxes are used for purpose of cleaning, covering, shielding the metal from the oxygen, and slag thickening. ALBRAL is mostly used for aluminum bronzes. Degassing is usually required to remove dissolved hydrogen from the molten metal at elevated temperature.

Fig -2: Albral 2 flux, Degassing Tablet & Deoxidising tubes

For the aluminum bronze material, LOGAS 50 tablets are used for degassing purpose. Before pouring, DEOXIDISING TUBES are used to take away residual oxygen from molten alloy by the addition of deoxidising agent to make a stable oxide which comes out on surface of the molten metal [4].

Preparation of aluminum bronze casting includes following steps:

a. Charge Metal into the crucible of furnace
b. Melt Treatment with cover flux, Degassing tablet and Deoxident tube
c. Dross Removal
d. Mold rotation at desired speed
e. Metal Pouring
f. Solidification

2. Literature Survey

Literature review is an assessed report of information found from the literatures associated to particular area of study. This survey covers the centrifugal casting, its process parameters, melting of aluminum bronzes, analysis of experiment data and performance of casting during various tests.

Uyime Donatus had investigated locally produced sand cast aluminum bronze alloy. Aluminum bronze rods of composition of 89Cu-10.8Al-0.02Fe have been produced. He produced Al bronze with composition of 89Cu-10.8Al-0.02Fe and performed tensile and hardness tests. He got 230Mpa tensile strength and 38HRC hardness. It is found that the close distribution of α precipitates in β matrix in microstructure which cause high strength and hardness of aluminum bronze. He also applied heat treatment process to compare the effect on casting. After normalizing and ageing, the optimum tensile strength was 325MPa and hardness of 46-63 HRC is improved [5].

Madhusudhan had worked to find out properties of centrifugal cast Tin at different die rotation speeds. he found that the rate of solidification affects most on the micro-structure and mechanical properties of the casting. Also rate of solidification is dependent of mold wall temperature, pouring speed and temperature and mold rotation speed. At three different speeds, it is clearly seen that the rate of cooling increases with increase of mold rotation speed. Microstructure, hardness & wear behaviour were analysed. The heat transfer rate between the molten metal and the die affects more on the rate of cooling. From results, it can be seen that the slow solidification rate gives coarse shape grains whereas faster rate of solidification gives fine, dense and equiaxed grains. At around 800 RPM for Tin, the refined structure is achieved due to higher solidification rate. Also, hardness was increased and hence wear also decreased [6].

S. ILANGOVAN had examined the effect of ageing on microstructure, wear and hardness behaviour of sand cast Cu-4Ni-6Sn bronze alloy. The cast parts were solution heat-treated and aged for the different periods. It was found that the aging process increases the hardness of the alloy expressively due to the change in the microstructure of the alloy. Lower wear found because of higher hardness of the alloy but coefficient of friction was not affected by the aging process. The hardness of alloy with heat treatment was improved by 1.5 times than non-heat-treated alloy. It is noted that microstructure improves throughout the aging process contribute to the rise in the hardness of the alloy [7].

Shatrudhan Pandey produced the bimetallic pipe by vertical centrifugal casting process and examined the quality by changing the mold rotation speed in centrifugal machine. Three mold rotation speeds were selected as 800rpm, 1320rpm and 1980rpm. First of all, the molten Copper is poured into the rotating mold and then after solidification, the molten Aluminum is poured. SEM and EDS were used to analyse the bond quality and the chemical composition of the bond respectively. From the results, it is found that quality of casting improves with increase in mold rotation speed. From the SEM examination, it can be concluded that the bonding. Also, from the studies, it is seen that If the temperature should select high enough to create intermetallic bonds between two metals [8].

M. Moradlou et. al. investigated tribological properties of cast aluminum bronzes. In this research, the effects of 0, 2, 4, 6, 8 & 10% magnesium and nickel on wear behaviour of cast aluminum bronzes have been investigated. After the casting, all the specimens were heated at 870°C for 20 min, and then quenched in water and tempering treatment was conducted at 600°C for 2 hours. The wear test was conducted by pin-on-disc machine. It was found that addition of magnesium and nickel reduces the size of α and β′ phases in microstructure. Increasing the amount of magnesium and nickel up to 10%, it enhances the tribological and mechanical properties of the alloys. When the alloying elements are low, the wear mechanisms are delamination and abrasive while increasing the alloying elements decrease these wear mechanisms [9].

Mustafa Yasar examined the wear behaviour, hardness and microstructure of aluminum bronzes C95200 and C95300 alloy. The wear test was performed on pin-on-disk wear tester. From the examination of microstructure of alloy C95200, it is noted that black regions in the SEM represents primary-α structure and white grain boundaries are β phase. By examining microstructure of C95300 alloy, white regions found at the grain boundaries along with primary α phase are β phase. C95300 has β structure at room temperature and two phases. Experimental results showed that C95300 has a higher wear resistance due to smaller grain size and harder phase structure. Hardness value of C95200 and C95300 alloys were found to be 103 BHN and 138 BHN, respectively. Grain sizes of C95200 and C95300 alloys are about 77.7 and 27.9mm, respectively [10].

T. Kimura had studied the sliding wear behaviour analysis of copper alloys used for bearing applications. He experimented on lead bronze, phosphor bronze and aluminum bronze under the high pressure using sliding abrasion tester. The contact loading varies from 0 to 20MPa by adjusting the air pressure, and the sliding speed from 0 to 180 rpm. Wear resistance of aluminum bronze casting is superior to lead bronze casting and Phosphor bronze casting because hardness of (220 HV) is better than lead bronze (118 HV) and phosphor bronze (121 HV). It has been understood to show an excellent sliding wear characteristic in the material that improves the hardness after the work hardening from initial hardness in the sliding wear. Hardness has increased remarkably by the plastic flow. Hardness values of Lead bronze increase from 118 to 229HV, 220 to 424HV in aluminum bronze and 121 to 321HV in phosphor bronze [11].

Dr. Sami A. Ajeel had performed and improved the casting conditions in AB1 (Cu10Al5Fe) & AB2 (Cu10Al5Fe5Ni) aluminum bronzes using proper procedures of melting and casting with or without treating materials with Albral 2 flux, Logas 50 degasser and deoxidizing tube E3. These conditions are applied for sand casting mold and metal mold where mold dimensions are Ø100×250 mm. Microstructure examinations, hardness test and tensile test were performed. It is seen that the structure of alloy without treating in metal mold has large size of alpha phases (α) with white color and small amount of γ_2 within β phase. This is due to absence of nickel content and increase in the cooling rate in metal mold. In addition, the structure involves some inclusions and oxides due to absence of the melt treatment. Preheating of mold minimizes the shrinkage cavity and also refines grain size. Melt treatment reduces the casting defects and improves the mechanical properties [12].

M. Kaplan had examined the microstructures and mechanical properties of an aluminum bronze Cu9Al4Fe4Ni and comparing between sand casting and die casting. Sand cast specimen showed a dendritic structure which contains grain α Cu and α + β phase. Die mold cast specimen has thin rounded grains appeared along outer section of casting and the long column grains and big rounded grains appeared at inner section of casting. The microstructure of the casting contains β phases which are distributed finely at the grain boundaries and in α -Cu main matrix as it occurred in the sand mold casting. Dendritic structure variation that is formed due to the effect of different solidification speed. Hardness range of sand mold casting is 178-185HB and in die mold casting is 178-200HB. It has been observed that the structure of the sand mold casting contains fine rounded grains along outermost cross section and lengthwise inclined column grains towards inside and big grains innermost. It is possible to obtain fine proper grains with the scientific techniques such as implant techniques, solidification homogenous by means of cooling speed and the direction control [13].

3. Experimental procedure

The literature survey shows that many researchers have successfully investigated the centrifugal casting with process parameters on microstructural examination, tribological and mechanical properties. From this survey, the pouring temperature, mold rotation speed and melting treatment was selected as process parameters for aluminum bronze C95500. The aim of this study is to find the effect of parameters on microstructure, wear, hardness and tensile strength and to establish the relationship between microstructure and mechanical properties.

Table -2: Input parameter with different levels

Factors	Parameter Name	Levels		
A	Pouring Temp.	1100	1200	1300
B	Rotating Speed	1050	1150	1250
C	Melting Practice	1	2	3

Where, 1 = Cover flux, 2 = Cover flux + Degassing and 3= cover flux + degassing + Deoxidant tubes

There are three factors namely, pouring temperature, mold rotation speed and melting practice. All these factors have three levels. Minitab (version 18.1) gave the L9 orthogonal array for given parameters which is shown in table 3.

Table -3: Experiment setup (L9 Orthogonal Array)

Sr. no.	Sample ID	Pouring Temp.	Mold Rotating Speed	Melt Treatment
1	P01	1100	1050	1
2	P02	1100	1150	2
3	P03	1100	1250	3
4	P04	1200	1050	2
5	P05	1200	1150	3
6	P06	1200	1250	1
7	P07	1300	1050	3
8	P08	1300	1150	1
9	P09	1300	1250	2

This table shows the possible experiments and then various tests were performed on all specimens.

3. CONCLUSIONS

From, this literature study, it is concluded that limited work was done on the aluminum bronze (C95500) cast by horizontal centrifugal casting process. Aluminum Bronze finds wide range of applications in heavy duty bearing, bushing, marine casting, pump parts etc. The quality of casting is mainly dependent on the selected parameters from which the most significant factor can be found by experiments and testing.

Wear test will be performed on pin on disc wear tester by varying applied load, track radius, disc rotation. The hardness will be measured by rockwell hardness tester with 1/16” ball indenter (B Scale) and the tensile test will be performed on tensometer. These tests will be performed on all specimens and we can find the most affecting parameter on wear, microstructure and, mechanical properties. The effect of melt treatment with degassing and deoxidising tubes can be seen on output parameters. The work will continue to find out the optimum process parameters which gives good quality casting.

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