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Research Article

Analyzing The Effect of Alloying Bronze on Cylinder Liner Hardness

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A B S T R A C T

The quality of a component material is a significant issue in today's society, where the concept of "quality for a price" is a prevalent one. This phenomenon is observed across various sectors, including official manufacturers, local factories, and even students. The objective is to consider and implement measures to enhance the quality of components, aiming for a satisfactory value. The influence of the hardness value on the ductile iron alloy with AB2 is a key factor in this study. The aim is to identify the ideal mass percentage quantity to obtain a satisfactory hardness value. This is based on the understanding that the limited quantity of gray cast iron in cast furnaces affects the value of its mixture with AB2. The process from start to finish encompasses a number of stages, during which the incorporation of AB2 into ductile iron results in a change in the quality of the molten metal, which becomes visibly more liquid. In contrast, the impact of the aluminum element is relatively modest, although the final value of the alloy, which is 37% nickel, significantly increases the hardness value. This type of iron is widely used in automotive products. It is recommended that production parties, especially those involved in the manufacture of automotive components, consider the indications that occur in the values of this test. This is because the development of material improvements has been very rapid in recent times. The hardness value achieved by the non-alloy was recorded at 372.92 HVN, the 14% AB2 alloy was 509.94 HVN, the 25% AB2 alloy had a value of 408.79, and the 37% AB2 alloy exhibited a twofold increase from the value without the alloy, namely 679.96 HVN.

1. INTRODUCTION

Metal casting is one of principal manufacturing technique in which molten metal is poured into a mold chamber vessel that resemble the geometry of desired final product [1]. For non-ferrous metalas such as aluminum, copper, lead, and other alloys, it does necessitate to use of a melting furnace. The melting furnaces technology has evolved over time, encompassing both conventional furnaces and kupola furnaces [2].

Cylinder liner is one of crucial part of internal combustion engines that is normaly produced with the die casting processes that is utilizing melting furnace. Prior to production years of 2010, there were a number of issues being identified regarding upon the quality of cylinder liners. As consequences, it results in unsatisfactory of the service life of that components.

Cylinder liners are manufactured from gray cast iron that can be upgradable by replacing it with ductile iron. Accordingly, it could improve its mechanical performances comparable to that of cast steel. Besides, one method for enhancing the strength of ferrous metals is through alloying the iron [3] with non-ferrous materials such as Bronze.

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Bronze is a type of copper alloy comprising the main elements of copper and tin [4]. However, the prevailing material distributor currently offers leaded gunmetal (LG2), aluminum bronze (AB2), and phosphor bronze (PB2) as copper alloy options. Copper alloys have advantages as engineering materials [5] including 1) exhibiting good mechanical properties, high electrical conductivity and wear resistance; 2) effortlessly to form at hot and cold working so that it could be pressed or forged at temperature below its mother materials; 3) having high machinability; 4) joining accessibility by soldering, brazing and welding; and 5) enabling to get polished as well as plated for those requiring a smooth surfaces. Therefore, it is suitable for alloying main ingredient of cylinder liner's materials.

The main cylinder liner materials had to be high temperature resistance, wear resistance, high strength at high temperature, low coefficient of expansion, and low coefficient of friction[6]. It is due to require to be able to withstand high heat and also pressure, and have the coefficient of friction that is directly related to the quality of manufacturing results [7]. Subsequently, it is notable that bronze exhibits favorable machin-ability, repairability, and weldability, which collectively facilitate the production, maintenance, and repair process [8]. Eventually, alloying gray cast iron with bronze would be an interesting area that could improve the mechanical performance of cylinder liner's material especially in context of its hardness.

2. METHODOLOGY

2.1. Material Preparations

In this study, the cylinder liner made from gray cast iron was alloyed with different concentration of Bronze that are 0%, 14%, 25%, and 37%. Beforehand, a Ferro Casting Ductile (FCD) as a type of cast iron was melted down at a temperature of 1,200 °C, then is lowered to 1,000 °C to allow addition of varying concentration of the bronze. Whilst the type of bronze employed was AB2 for all prepared specimens except for 0% of variations. The concentration of the bronze is added gradually to the molten FCD using a small factory ladle. Once the two metals have been melted, it was are casted into the dies that have geometry corresponding to the shape of the test specimen as depicted in Fig. 1. The specimens have dimension of 30 mm in diameter and 17 mm - 34 mm length.

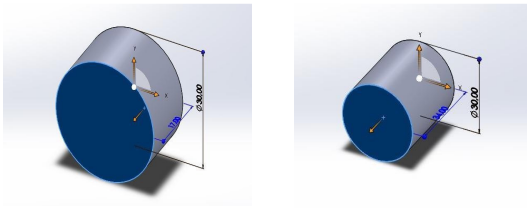


Figure 1. Geomety and dimensions of the specimens

2.2 Methods

In achieving the objective of this study, two distinct analytical approaches were employed which are qualitative s and quantitative analysis. Qualitative analysis involves the identification of the chemical compositions of the ingredient of the alloys owing to varying percentage of alloying elements.

To analyze the chemical composition of the new alloy of the cylinder liner's substance, the Eq. 1 was used.

$$\%\ Component\ Mass = \frac{Component\ Mass}{Mass\ of\ substance} \times 100\% \quad (1)$$

Furthermore, the hardness testing was carried out for quantitative approach. Micro-Vickers Hardness testing machine was utilized to obtain the hardness of new alloy. A 100 gf was selected as indenter.

3. RESULTS AND DISCUSSION

3.1. Chemical Composition

The results shown in Table 1 presents the variation of ingredient elements of cylinder liner's material. Table 1 points out that bronze addition as cast iron alloying elements would shift its natural chemical compositions. chemical testing on each sample yielded a chemical content result value, with the percentage quantity varying. These results

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significantly influenced the final result, which was the hardness value achieved by reading on a hardness test instrument, one of which was the Micro-Vickers hardness test, which was employed in this research. The following is a display of the chemical quantity content and the chemical percentage quantity of the castings in each sample, as listed in Table 1.

Table 1. The chemical composition of alloy due to varying percentage of bronze concentration

Chem. El.	AB2 Alloy			
	0%(%)	14%(%)	25%(%)	37%(%)
C	**4,132**	**3,998**	**3,636**	**3,995**
Si	**2,979**	**2,945**	**3,043**	**2,982**
Mn	**0,239**	**0,177**	**0,248**	**0,176**
P	**0,03**	**0,036**	**0,034**	**0,035**
Si	**0,015**	**0,014**	**0,014**	**0,014**
Cr	0,029	0,031	0,03	0,031
Mo	0,012	0,02	0,025	0,023
Ni	***<0,004***	***0,0095***	***0,0066***	***0,012***
Cu	0,037	0,890	0,411	0,720
Al	***<0,002***	***<0,002***	***<0,002***	***<0,002***
Co	***<0,003***	***0,0036***	***<0,0030***	***0,0038***
Mg	0,028	0,007	0,015	0,011
Nb	0,0096	0,0062	0,0066	0,0076
Ti	0,024	0,24	0,023	0,025
V	<0,003	<0,003	<0,003	<0,0030
W	<0,02	<0,02	0,02	<0,02
B	<0,001	<0,001	<0,001	<0,001
Sn	***<0,002***	***0,061***	***0,29***	***0,056***
Fe	***92,46***	***91,77***	***92,47***	***91,91***

The preceding results indicate that the various percentage addition of AB2 would induce fluctuation the chemical composition of the cylinder liner's material. The primary element of AB2, copper, exhibits fluctuations, while the element that contributes to the addition of aluminum, which is limited in quantity, decreases. This is due to the fact that a small portion of aluminum is added during the casting process, which will result in a reduction of the quantity of aluminum in the final product. Moreover, Another constituent element of bronze, namely tin, is also fluctuating. The peak value of tin is attained at 25% percentage of AB2 addition. This figure had to be taken into account since it would affect the hardness of the new alloy. Similar phenomena also reveal for nickel. Nickel plays a significant role in the process of mixing the castings, particularly in the highest alloy. Its presence would also affect the hardness value. However, the addition of AB2 only slightly influence chemical compositions of the iron.

3.2. Hardness

The addition of AB2 in grey cast iron was assumed to be improved the cylinder liner's material mechanical properties. This assumption is affirmatively true. However, the improvement fails to be proportional as evident from Table 2 and Fig. 2. It tends to be fluctuated as its chemical compositions.

Table 2. The hardness value due to AB2 variation

Alloy AB2 (%wt)	Sample	HVN	Average	Description
0	1	372,93	372,93	The indenter load was set at 100 gf.
14	1	540,30	502,94	
	2	465,58		
25	1	395	408,79	
	2	422,59		
37	1	826,57	679,96	
	2	533,35		

The highest hardness is gained at addition of 37% percentage of AB2. Nickel and tin is considered to contribute for the magnitude of the hardness. But, overlooking to results exhibited in Fig. 2, The role of nickel is significant. As composition of nickel increases then the hardness value of the alloy also soars. Therefore, it inferred that nickel as strength enhancement agent is evident.

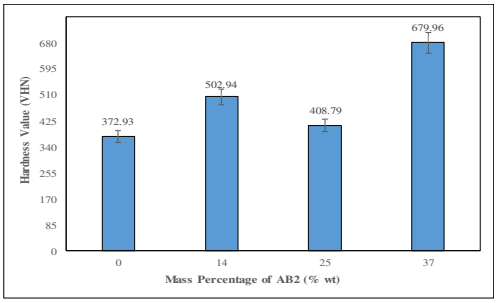


Figure 2. Influence of AB2 addition on the hardness values

However, there are certain conditions where the nickel content only contribute slightly. In this case, adding 25 % of aluminium bronze into grey cast iron at hot phase could influence the hardness when it was undergoing annealing processes prior to approaching solid phase. In other words, at convinced case, the effect of nickel elements tends to be trigging imperfection of cooling processes.

4. CONCLUSION

Cylinder liner made of grey cast iron that was alloying with aluminum bronze (AB2) could improve its mechanical properties especially its hardness.

However, AB2 alloying to grey cast iron fail to effect proportionally its hardness. At 14% of AB2 addition, the hardness of cylinder liner's material increase from its original state. But, casting more percentage of AB2 up to 25% would decline the hardness. Even tough, at 37% of AB2 inclusion into grey cast iron would be beneficial on the hardness slump.

Eventually, the high magnitude of hardness attained at 37% of AB2 addition is dominated by the presence of nickel. Nickel element could in advanced cause annealing effect if it is improper added into the grey cast iron.

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