Effects of Combined Addition of Aluminum Oxide, Fly Ash, Carbon and Yttrium on Density and Hardness of ZA27 Zinc Alloy

A. K. Birru[a*], R. Manohar Reddy[a], B. Srinivas[a], K. Balachandan Reddy[a] and K. Nithin[a]

[a]Department of Mechanical Engineering, Christu Jyothi Institute Of Technology & Science, Jangaon, Warangal, India

Abstract: ZA-27 alloy plays a vital role in ZA family of alloys with a high strength and pinnacle applications in manufacturing. The research papers emphasized to enhance hardness and minimize the density of the aforesaid alloy with combined addition of Al_2o_3, fly ash, carbon and yttrium as reinforcements. Hence we observed that with density was gradually decreased at 7% with 5% Al_2O_3, 0.15% carbon and 0.01% Yttrium addition. Similarly, further decreased density at 10% with 7.5% Al2O3, 0.25% carbon and 0.05% Yttrium. However, hardness was initial increased more than 11% with 5% Al_2O_3, 0.15% carbon and 0.01% Yttrium. Conversely, hardness was slightly decreased at 5% with 7.5% Al_2O_3, 0.25% carbon and 0.05% Yttrium.

Keywords: Aluminum oxide; Flyash; Carbon; Yttrium; Density; Hardness.

1. Introduction

Zinc alloys with higher aluminium content (25-27 wt. %) obtained by conventional processes of melting and casting, are applied in various fields, particularly in automobile industry, because of their good mechanical, technological and economical properties. Lim Ying Pio et al. [1] conducted the experimentation of LM6 Al-Si alloy on a sand casting of different modulus, the addition level of Al5Ti1B into the melt ranges from 0 wt. % to 1 wt. % with the increment of 0.25 wt. %. The experimental results shown that the mechanical properties of LM6 sand casting can be optimally improved by grain refinement of 0.5 wt. % AL5Ti1B. Christian et al. [2] The effects of various heat treatments upon the microstructure and mechanical properties of a rolled 5754 aluminium alloy modified with 0.23 wt.% Sc and 0.22 wt.% Zr were investigated. Found that large incoherent precipitates formed during solidification and hot-rolling, and fine coherent precipitates formed from secondary precipitation, which improved alloy strength, as shown by hardness. Rajakumar et al. [3] studied the AA6061-T6 aluminium alloy (Al–Mg–Si) alloy hardness along with the welded joints. It was observed that parameters like rotational speed, welding speed, axial force, shoulder diameter, pin diameter and tool hardness was influenced the hardness. Among them tool rotational speed between 1155 and 1157 rpm is an optimum input to obtain an excellent welded component produced from aforesaid aluminium alloy. Li Hui-zhong [4] studied that effects of yttrium (Y) content on precipitation hardening, elevated temperature mechanical properties and morphologies of 2519 aluminium alloy were investigated by means of micro hardness test, The results shown that the by increased Y content from 0 to 0.10% (mass fraction) at room temperature, and from 155 MPa to 205 MPa by increasing Y content from 0 to 0.20% at 300 ^{O}C. The high strength of 2519 aluminium alloy is attributed to the high density of fine precipitates and intermetallic compound AlCuY with high thermal stability was obtained.

Mahmudi et al. [5] studied the effects of 0.15 wt. % Zr addition on mechanical properties and wear resistance of A319 aluminium casting alloy were investigated. The cast alloys were given a solutionizing treatment followed by artificial aging in the temperature range 175 to 235 °C for different period of times. It was found that the minor addition of Zr results in the precipitation of Al_3Zr particles in the aluminium matrix. These particles are stable upon heating due to the low solubility of zirconium in aluminium matrix. The main effects of such particles are an increase in hardness, strength, quality index and wear resistance. This is very promising where these aluminium cast alloys are to be used at relatively high temperatures. Sanjib Banerjee [6] the work is aimed at investigating the influence of trace additions of Tin (Sn) on the microstructure, mechanical properties and age-hardening behaviour of Al–6.2%Cu–0.6%Mg alloy system.

Al–6.2%Cu– 0.6%Mg alloys containing varying weight percentages (from 0 to 0.1 wt. %) of Sn were prepared by casting technique. The mechanical properties and microstructure of these alloys were investigated in the as-cast as well as different heat treated conditions. The hardness and strength of the alloy increased but the ductility reduced with increase in Sn content up to 0.06 wt. %. precipitation hardening behaviour of the alloys was investigated by analyzing the aging time required to attain the peak hardness value. Addition of trace percentage of Sn was observed to have no significant influence on the peak ageing time of the investigated alloy system.

Wen-tao Wang [7] investigated the precipitation hardening response, microstructures and mechanical properties of 2519A aluminum alloy plates with additions of 0, 0.2 and 0.4 wt.% Ce were investigated. The results shown that 0.2 wt. % Ce promotes the precipitation of denser and finer phase, which improves the tensile strength of the alloy at both room and elevated temperatures. High melting point Al_8Cu_4Ce phase particles are found in alloys with additions of Ce up to 0.4 wt. %, which contributes to the mechanical properties at elevated temperature. Wang Feng [8] studied the series of die casting heat-resistant magnesium alloys based on Mg-Al system were developed for automotive application by adding Y and various amounts of Ca. The mechanical properties and microstructures of die casting AZ91 alloy with combined addition of Y and Ca were investigated. It was found that for AZ91-1Y-*x*Ca alloy, the hardness and the elevated temperature tensile strength increase, while the elongation decreases with increasing the addition of Ca. The mechanism of mechanical properties improvement caused by the combined addition of Y and Ca was also discussed. Karthikeyan [9] studied the effects of FSP (Friction Stir process) on microstructure and mechanical properties of cast aluminium alloy of 2285 grade at three different feed rates viz. 10 mm/min, 12 mm/min and 15 mm/min under two different speeds 1400 and 1800 rpm. The observations have been elaborated in detail along with the microstructures of parent and processed specimens. Wuhua Yuan [10] The effects of Zr addition on mechanical property in the aged Al–Mg–Si alloy exposed to thermal-resistant treatment (180 to 250 ^{O}C) have been studied by using both Brinell Hardness tests and tensile tests. The softening process at 180 ^{O}C and 250 ^{O}C has been investigated. The results shown that with improved addition of Zr the Brinell hardness could maintain no *less* than 90% of their initial values when the alloy is exposed to heat treatment at 180 ^{O}C for 400 h and 230 ^{O}C for 2 h. Yet, no work was found in ZA27 Zinc alloys particularly in combined addition of Alumina, Flyash, Carbon and Yttrium addition. Hence present work emphasised to find the density and hardness of aforesaid alloys.

2. Experimental Procedure

The investigations were carried out on ZA27 alloys using die casting, present investigations was aimed to enhance the hardness and evaluate the density respectively, with combined addition Aluminum oxide, Fly ash, Carbon and Yttrium as shown in the Table 1. The metallic moulds were used for preparing metal casting is of rectangular cross-section of dimensions 30 x 4 cm, as shown in Figure 1. For all the alloys molten metal was poured manually from the ladle in to the metal moulds before the molten metal was poured metallic moulds was preheated at 200 ^{O}C for all the aforesaid alloys.

Table 1 Composition of ZA 27 alloy with addition of reinforcement elements

Alloy	Aluminum oxide %	Fly ash %	Carbon %	Yttrium %
ZA 27	0.0	0.0	0.0	0.0
Modified -1 ZA 27	5.0	2.0	0.15	0.01
Modified -2 ZA 27	7.5	2.0	0.25	0.05

Figure 1 Shows Metallic mould with ZA27 Casted alloy.

2.1 Density Test

In present investigation density of specimen is calculated using Archimedes principle. It states that, for practical purposes water is incompressible, so the submerged body would displace an amount of water equal to its own volume. By dividing the mass of the body by the volume of water displaced, the density of the submerged body was obtained for the said principal as shown in the Figure 2. The density of the specimen is calculated and depicted in the Table 2.

Table 2 Density of unmodified and modified alloys using Archimedes principle

Alloy	Mass (kg)	Volume displaced (m^3)	Density (kg/m^3)
ZA-27 base alloy	0.315	62×10^{-6}	5081
Modified -1 ZA-27	0.380	80×10^{-6}	4750
Modified -2 ZA-27	0.690	150×10^{-6}	4600

Figure 2 shows ZA27 Alloy dipped in the water beaker.

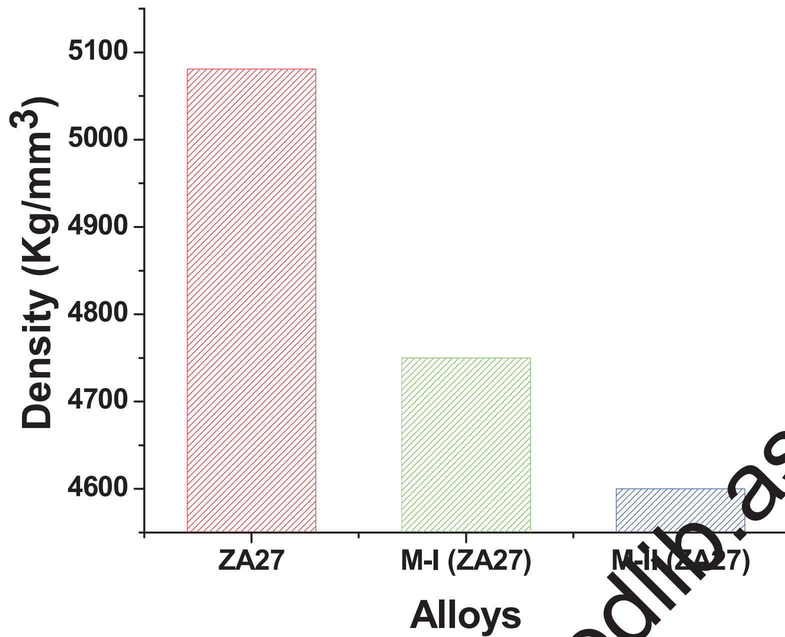

Figure 3 shows density of unmodified and modified ZA-27 alloys.

2.2 Hardness Test

In present investigation Brinell hardness test was investigated with carbide ball indenter. The indenter is pressed into the specimen by an accurately controlled test force. The force is maintained for a specific dwell time, normally 10-15 seconds. After the dwell time is complete, the indenter is removed leaving a round indent in the sample. The size of the indent is determined optically by measuring two diagonals of the round indent using a portable microscope. The Brinell hardness number is function of the test force divided by the curved surface area of the indent. The indentation is considered to be spherical with radius equal to half the diameter of the ball. The average of the two diagonals is used in the following formula to calculate the Brinell hardness and is depicted in the Table 3, 4 and 5 respectively.

$$HB = \frac{2P}{\pi D\left(D - \sqrt{D^2 - d^2}\right)}$$

Table- 3 Hardness test for ZA 27 alloy by Brinell hardness test

Load P (N/mm^2)	**Indenter diameter D (mm)**	**Indentation diameter d (mm)**	**Brinell hardness number (HB)**
500	5	2.2	125
750	5	2.6	131
1000	5	3.1	118
1000	10	3.3	114
1500	10	3.7	135
2000	10	4.2	138
2500	10	5.0	119
3000	10	5.2	131

Table 4 Hardness test for Modified -1 ZA 27 alloy by Brinell hardness test

Load P (N/mm^2)	Indenter diameter D (mm)	Indentation diameter d (mm)	Brinell hardness number (HB)
500	5	2.1	138
750	5	2.5	143
1000	5	3.1	119
1000	10	3.5	134
1500	10	3.5	151
2000	10	4.1	145
2500	10	4.5	149
3000	10	5.0	143

Table 5 Hardness test for Modified -2 ZA 27 alloy by Brinell hardness test

Load P (N/mm^2)	Indenter diameter D (mm)	Indentation diameter d (mm)	Brinell hardness number (HB)
500	5	2.1	138
750	5	2.8	111
1000	5	3.3	102
1000	10	3.3	114
1500	10	3.75	131
2000	10	4.2	138
2500	10	5.0	119
3000	10	5.5	116

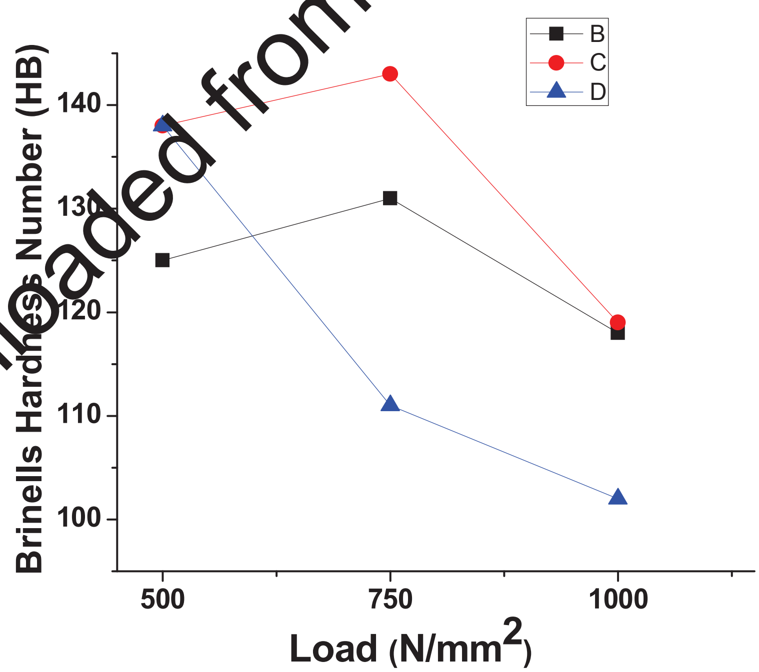

Figure 4 shows Brinell hardness number for 5mm carbide ball indenter.

ISBN : 978-81-925233-3-0

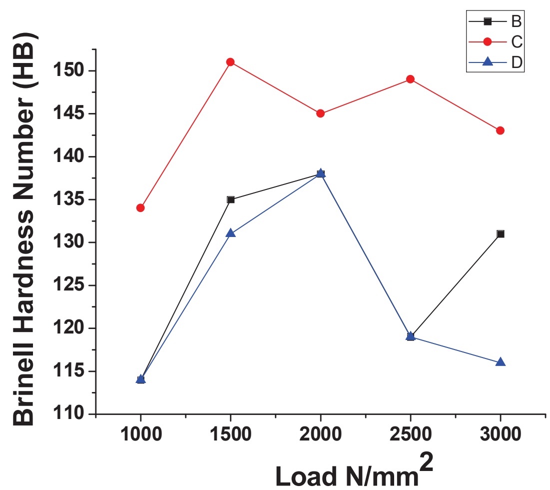

Figure 5 shows Brinell hardness number for 10mm carbide ball indenter.

3. Results and Discussion

The results of density and hardness of ZA-27 alloy for both Un-Modified and Modified alloys were discussed below

3.1 Influence of density on Un-modified and Modified of ZA-27 alloy

Density of both Modified -1 ZA-27 and Modified -2 ZA-27 was compared with ZA-27 base alloy. It clearly shows that the amount of mass occupied per unit volume are lower for both modified alloys as shown in the Figure 6.

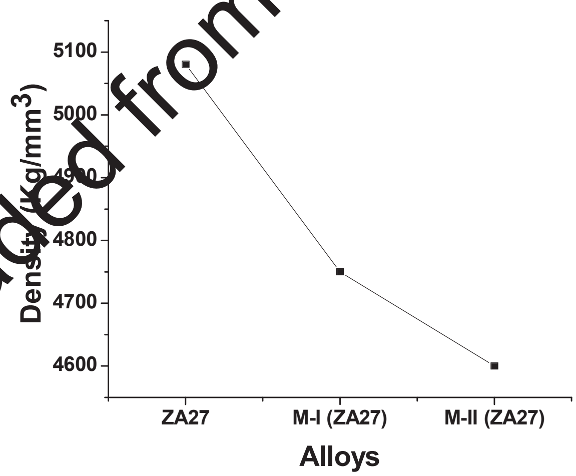

Figure 6 shows density of unmodified and modified ZA-27 alloys.

3.2 Influence of hardness on Un-modified and modified ZA 27 alloy

Hardness of both Modified -1 ZA-27 and Modified -2 ZA-27 was compared with ZA-27 base alloy. Hardness of investigated alloys is obtained by considering average of Brinell hardness numbers at different loads. It is clearly observed the increment hardness for Modified -2 ZA-27 it might be optimum addition of Aluminium oxide and carbon which is shown in the Figure 7.

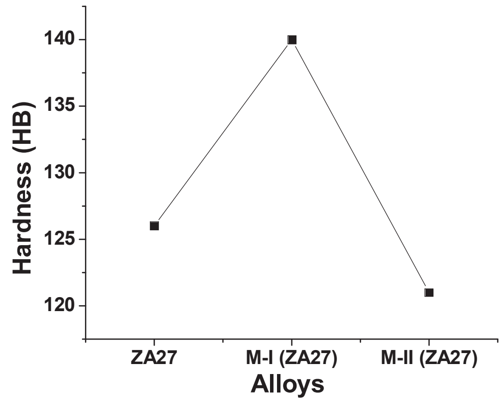

Figure 7 Hardness of unmodified and modified ZA-27 alloys

Case I: Density and hardness for modified -1 ZA-27 alloy and ZA-27 base alloy

From the present investigations it is observed that the density is lower and hardness is higher for modified -1 ZA-27 than ZA-27 base alloy, it might be due to influence of reinforcement of Al_2O_3 5%, Fly ash 2%, Carbon 0.15%,Yttrium 0.01% mass share in Modified -1 ZA-27 alloy.

Case II: Density and hardness for modified -2 ZA-27 alloy and ZA-27 base alloy

From the present investigation it is observed that both the density and hardness is lower for modified -2 ZA-27 alloy when compared with ZA-27 base alloy, it might be due to influence of reinforcement of Al_2O_3 7.5%, Fly ash 2%, Carbon 0.25%,Yttrium 0.05% mass share in Modified -2 ZA-27 alloy.

4. Conclusions

Based on experimental investigations following conclusion were drawn:

- All modified alloys have significantly lower density compared to ZA-27 base alloy.
- Density of aforesaid alloys was decreased from 7% to10% from Modified -1 ZA-27 alloy and Modified -2 ZA-27 alloys when compared with ZA-27 base alloy.
- Hardness of aforesaid alloys was increased by 11% and 16% for Modified -1 ZA-27 alloy and Modified -2 respectively in comparison with ZA-27 base alloy

References

1. Lim Ying Pio, Shamsuddin Sulaiman, Abdel Majid Hamouda, Megat Mohamad and Hamdan Megat Ahmad, "Grain refinement of LM6 Al–Si alloy sand castings to enhance mechanical properties", *J of Mat Pro. Tech* 2005; 163: 435–441.
2. Christian B. Fuller, Albert R. Krause, David C. Dunand, David N. Seidman, "Microstructure and mechanical properties of a 5754 aluminum alloy modified by Sc and Zr additions", *Mat Sci and Eng* 2002; A338: 8-16.
3. Rajakumar S, Muralidharan C, Balasubramanian V, "Predicting tensile strength, hardness and corrosion rate of friction stir welded AA6061-T6 aluminium alloy joints" , *Mat and Des* 2011; 32: 2878–2890.
4. Li Hui-zhong, Liang Xiao-peng, Fang-fang LI, Guo Fei-fei, Zhou LI, Zhang Xin-ming, "Effect of Y content on microstructure and mechanical properties of 2519 aluminum alloy", *Tran. of Nonfer Met Soc of Chi* 2007; 1194-1198 .

5. R. Mahmudi, P. Sepehrband, H.M. Ghasemi, "Improved properties of A319 aluminum casting alloy modified with Zr", *Mat Lett* 2006; 60: 2606–2610.
6. Sanjib Banerjee, P.S. Robi, A. Srinivasan, Praveen Kumar Lakavath, "Effect of trace additions of Sn on microstructure and mechanical properties of Al–Cu–Mg alloys", *Mat and Des* 2010; 31: 4007–4015.
7. Wen-tao Wang, Xin-ming Zhang, Zhi-guo Gao, Yu-zhen Jia, Ling-ying Ye, Da-wei Zheng, Ling Liu, "Influences of Ce addition on the microstructures and mechanical properties of 2519A aluminum alloy plate", *J of All and Comp* 2010; 491: 366–371.
8. Wang Feng, Wang Yue, Mao Ping-li, Yu Bao-yi, Guo Quan-ying, "Effects of combined addition of Y and Ca on microstructure and mechanical properties of die casting AZ91 alloy", *Trans of Nonferr Met Soc of Chi*, 2010; 20: 311-317.
9. Karthikeyan L, Senthilkumar V.S, Balasubramanian V, Natarajan S, "Mechanical property and microstructural changes during friction stir processing of cast aluminum 2285 alloy", *Mat and Des* 2009; 30: 2237–2242.
10. Wuhua Yuan, Zhenyu Liang, "Effect of Zr addition on properties of Al–Mg–Si aluminum alloy used for all aluminum alloy conductor", *Mat and Des* 2011; 32: 4195–4200.