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Effect of Preheat Temperature of the Mould on the Mechanical Properties of ZA-27 Alloy

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***Abstract*— ZA-27 alloy contains zinc and 27% aluminum with minor amount of copper and magnesium. Various researchers evaluate its properties. The aim of this study is to produce commercially available ZA-27 alloy cast in metal mould and to study its mechanical properties at different casting conditions and to compare them with other conventional foundry alloys like bass, bronze and cast iron etc. General melting practices were reported. A brief outlined of the various engineering applications in which the foundry alloy is finding increased usage were included to underlined their technical and economic advantages. A cast iron metal mould was prepared and ZA-27 alloy was cast at different conditions. The casting variables were preheat temperatures of the mould. Casting was conducted at mould temperatures 300°C, 350°C and 400°C where the melt temperature was fixed at 700°C. To determine the mechanical properties tensile test was performed. The best combination of mechanical properties for the alloy ZA-27 cast in metal mould was obtained at melt pouring temperature 700°C when the preheat temperature of the mould was 300°C.**

***Index Terms*— Casting, metal, mould, ZA-27 alloy, tensile strength, pouring temperature, preheat temperature, percentage elongation, ductility**

I. Introduction

The Al-Zn binary system has been investigated extensively over the last century. The Al-Zn system is eutectic involving a miscibility gap in the solid state. There is considerable disagreement in the literature considering the shape of the miscibility gap. The gap is important to the current study as one of the compositions under study, the ZA-27 alloy, falls into this range [1].

The phase that occur the zinc-aluminum alloys comprises α (alpha) and η(eta). Where α is a solid solution phase with face centre cubic structure which is rich in Al. It contains 31.6% Zn at 275°C and 4% Zn at 100°C. η is a solid solution phase with compact hexagonal structure which is rich in Zn. It contains 1% Al at 300°C and 0.6% Al at 275°C [2]. The system shows no intermetallic alloy formation and displays unlimited liquid solubility [3]. The intervals of solidification are quite large for a significant range of zinc composition. This wide range is an important factor in alloy preparation and the gravity casting of the prepared alloys since there is a great difference in density between liquid aluminum and liquid zinc [4].

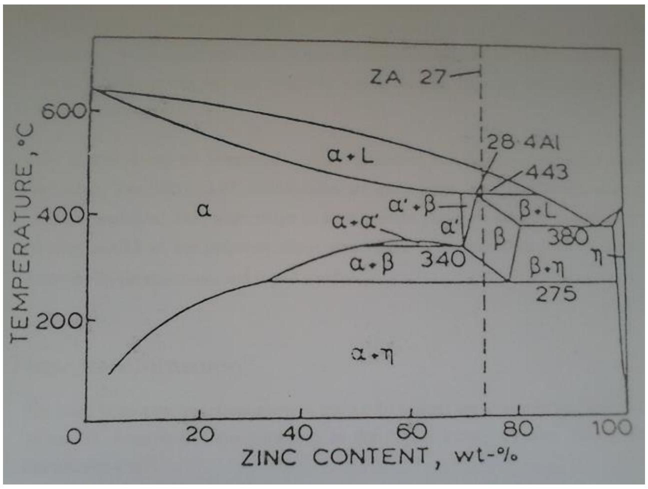

Fig. 1. Thermal Equilibrium Diagram of Zn-Al System

The Zn-Al system permits manipulation of the mechanical properties of castings by suitable heat treatment or by varying the cooling rates upon solidification [5]. The most important solid state reactions which take place are: solution hardening, where the primary Al rich phase may contain as much as 30% super saturation of zinc in substitutional site and precipitation and aging of the phase due to decreasing solute solubility with decreasing temperature [6]. The phase diagram implies that it is possible to develop heat treatments for some alloys and that a variety of hardening mechanism will be operative, depending on the cooling rate upon casting or after heat treatment [7].

Aluminum alloys are normally strengthened and hardened with copper and magnesium additions; both are known to form intermetallic compound particles and to affect the solid state reactions [8]. Magnesium is effective in small concentrations and also assures that intergranular corrosion will not take place in atmosphere of high humidity when impurities such as lead, tin and cadmium are accidentally high [9]. Copper addition is also made to increase creep strength and to improve corrosion resistance. However the addition of too much copper to zinc aluminum alloys influences the ageing characteristic [10]. The mechanical properties will decrease by a greater extent and undesirable dimensional growth will occur with time. Zinc alloys are susceptible to ageing because all phases are not in equilibrium in the as cast condition [11].

The size of grains in a casting is determined by the relation between the growth and the rate of nucleation. If the number of nuclei formed is high, a fine grained material will be produced [12]. The rate of cooling is the most important factor in determining the rate of nucleation and therefore the grain size. Rapid cooling (Chill cast) will result in a large

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number of nuclei formed and fine grain size, whereas in slow cooling (sand cast or hot mold) only a few nuclei are formed and they will have a chance to grow, depleting the liquid before more nuclei can form. Other factors that increase the rate of nucleation, thus promoting the formation of fine grain are: insoluble impurities and stirring the melt during solidification which tends to break up the crystals before they have a chance to grow very large [13].

The rate of growth relative to the rate of nucleation is greatest at or just under the freezing point. If the liquid is kept accurately at the freezing temperature and the surface is touched by a tiny crystal (seed), the crystal will grow downward into the liquid. If it is withdrawn slowly, a single crystal can be produced [14].

In general fine grained materials exhibit better toughness or resistance to shock. They are harder and stronger than coarse-grain material. In industrial casting processes, where a hot liquid is in contact with an originally cold mould, a temperature gradient will exist in the liquid. The outside is at lower temperature than the center and therefore starts to solidify first. Thus many nuclei are formed at the mould wall and begin to grow in all directions. They soon run into the side of the mould and each other, so that the only unrestricted direction for growth is toward the center. The resulting grains are elongated columnar ones to the surface of the mould. Next to the mould wall where, the cooling rate is fast, the grains are small; while toward the center, where the cooling rate is much slower, the grains are larger and elongated [15].

Zinc-Aluminum foundry alloys are readily melted in refractory-lined crucible furnaces similar to those used for other non-ferrous foundry alloys. It can also be melted easily in pit furnace. In this study, pit furnace was used to melt the alloy. In general, it is recommended that a separate crucible be reserved for melting because of low impurity limits specified for the alloys. Crucibles which have previously held aluminum alloys can be used if thoroughly cleaned, those that have held lead or tin containing copper alloys must be avoided. The zinc alloys melt in less time and do not require fluxing or degassing as is common with aluminum alloys [16]. Melting the alloys produces no fumes and the relatively low casting temperatures, 450-600°C help to extend the service life of foundry equipment. The normal foundry practice of blending foundry returns with fresh ingots is recommended [17].

The zinc alloys have excellent mould filling characteristics and low casting temperatures compared to most other foundry alloys. These inherent properties account for fewer casting rejects, reduced metal losses, and the casting versatility of the alloys. They can be cast using all the traditional processes including sand, permanent mould, pressure die, shell and investment casting [18].

II. EXPERIMENTAL PROCEDURE

A. Mould making

Cast iron was chosen for mould making. The mould block was sand cast and grinding was done. Extra feeder part was removed by hacksaw from the proposed block. After sand casting the blocks were given proper dimension by machining. Then two cope parts were joined together with screws. Sprue cavity and specimen cavities were made by thorough drilling. The drag part was machined to obtain the runner and sprue base cavity. In this case milling was done by the milling machine and the material was removed from the block forming the desired shape.

B. Casting Condition

Mould used: Permanent mould of cast iron

Alloy used: ZA-27

Additives used: Copper 1% and Magnesium 0.02%

Casting variables: Preheat temperatures of the mould

Pouring temperature of the melt: 700°C

Preheat temperatures of the mould:

1. 300°C
2. 350°C
3. 400°C

C. Melt Practice

Experimental zinc-aluminum alloys were prepared using special high grade zinc (99.99% min), commercial purity aluminum (99.95%min), electrolytic tough pitch copper (99.99%min), and commercial purity magnesium (99.8% min). In this experiment the alloy was melted in a pit furnace. Since aluminum does not dissolve readily in molten zinc, the aluminum was melted first, along with any copper addition. Zinc was added to aluminum and magnesium was preferably introduced just before casting.

The alloyed bath was stirred vigorously to ensure batch homogeneity and allowed to rest prior to skimming. The alloy was transferred to the mould using suitable ladles and pouring was done to prevent skimming from being entrained. The experimental alloy was cast in to standard test pieces using well established casting patterns.

Before preheating the mould, a coating was applied in to the mould. In this experiment calcium carbonate was used as a coating material. After coating the mould was used with a gas flame. The mould was heated as it got uniform temperature over the entire mould. To obtain the desired preheat temperature the surface temperatures were measured at various locations and average temperature was taken as the preheat temperature.

The ladle was removed from the furnace and melt temperature was measured with a thermocouple. When the melt temperature reached to the desired pouring temperature the melt was poured into the mould. The pouring was done carefully so that mould cavity was filled with the liquid metal. Then the casting was allowed to cool. Then the solidified casting was removed from the mould.

II. DETERMINATION OF PROPERTIES

The samples of all the three casting conditions were subjected to tensile test. The %elongation was also measured. All the results of tensile test were tabulated in Table1, and Table2.

A. Tensile test

Tensile strength and ductility of the samples were measured by using a Universal Testing Machine.

Table 1: Measured Tensile Strength of all samples cast at different mould preheat temperatures at fixed melt pouring temperature 700°C

Mould Preheat Temperature(°C)	**Sample No.**	**UTS (MPa)**	**Average UTS (MPa)**
300	1	302.1	297.08
	2	300.8	
	3	295.3	
	4	293.3	
	5	298.2	
	6	292.8	
350	1	222.6	221.06
	2	228.8	
	3	209.9	
	4	230.8	
	5	215.5	
	6	218.8	
400	1	189.9	182.85
	2	183.6	
	3	178.6	
	4	190.2	
	5	174.5	
	6	180.3	

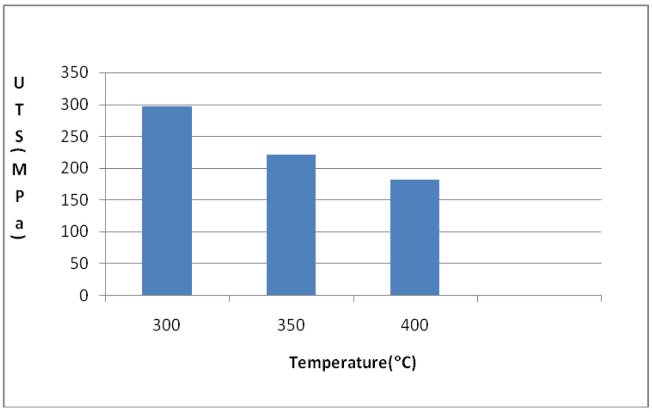

Fig. 2. Tensile strength of ZA-27 alloy cast at different mould preheat temperatures

Fig.2 shows as mould preheat temperature increases ultimate tensile strength (UTS) decreases. Then further increase in mould preheat temperature causes decrease in UTS to a value of 174.5 MPa at mould preheat temperature 400°C. From Table1 maximum tensile strength 302.1 MPa was obtained with the specimen cast at mould preheat temperature 300°C

Table 2: Measured %elongation of ZA-27 alloy cast at different mould preheat temperatures at fixed melt pouring temperature 700°C

Mould Preheat Temperature(°C)	**Sample No.**	**Elongation (mm)**	**Average % Elongation**
300	1	1.0	1.7
	2	0.7	
350	1	0.05	0.8
	2	0.75	
400	1	0.55	1.3
	2	0.75	

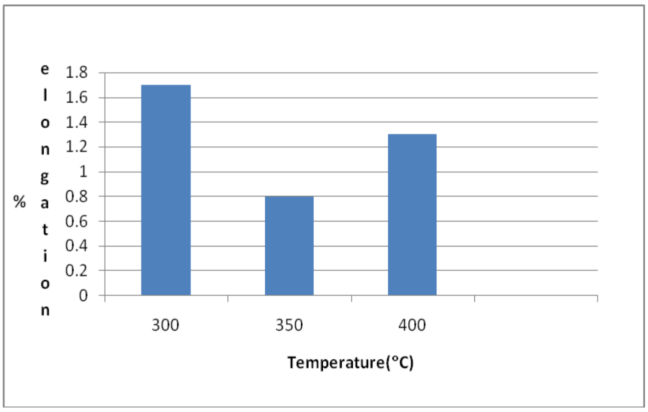

Fig. 3. % Elongation of ZA-27 alloy cast at different mould preheat temperatures

Fig.3 states that as preheat temperature of the mould increases percentage elongation decreases. Further increase in preheat temperature of the mould increases % elongation. Maximum ductility was observed with the specimen cast at mould preheat temperature 300°C.

Table 2: Comparison of Tensile Strength of various alloys

Material	**Tensile Strength (MPa)**
ZA-27 (experimental)	297
ZA-27(from papers)	400
Gray Cast Iron (grade G1800 as cast)	124
Gray Cast Iron (grade G3000 as cast)	207
Gray Cast Iron (grade G4000 as cast)	276
Brass (grade C26000)	300-365
Brass (grade C36000)	340
Bronze grade (C93200)	240

III. Conclusion

From the present experiment the following conclusions can be drawn

- As mould preheat temperature increases tensile strength decreases. As the preheat temperature of the mould increases at a fixed melt pouring temperature the cooling rate slows down. Hence, when preheat temperature of the mould increases grain size become coarser as it gets more time to grow which reduces the strength of the structure and a lower tensile strength was obtained. Moreover, high temperature also promotes the oxidation rate which ultimately reduces the tensile strength of the cast alloy.
- Maximum tensile strength 302.1MPa was obtained with the specimen cast at pouring temperature 700°C when the preheat temperature of the mould was 300°C.
- With the increase in preheat temperature of the mould percentage elongation decreases. But at 400°C of the mould preheat temperature the cast alloy shows more ductility than at 350°C. As preheat temperature of the mould increases solidification rate decreases and grain size becomes larger. So % elongation decreases. Hence, ductility of the cast alloy decreases.
- Maximum ductility was observed with the specimen cast at pouring temperature 700°C when the preheat temperature of the mould was 300°C.
- While comparing the experimental cast ZA-27 alloy shows more tensile strength than different grades of gray cast iron and some bronze grades.
- The experimental alloy ZA-27 exhibits lower strength than different brass grades and ZA-27 alloy from papers.
- The best combination of mechanical properties for the alloy ZA-27 cast in metal mould was obtained at melt pouring temperature 700°C and mould preheat temperature 300°C. This type of cast alloy can best be used as an alternative for Gray Cast Iron (grade G1800 as cast), Gray Cast Iron (grade G3000 as cast), Gray Cast Iron (grade G4000 as cast) and Bronze (grade C93200).

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