International Journal of Engineering and Technical Research (IJETR)
ISSN: 2321-0869 (O) 2454-4698 (P), Volume-5, Issue-1, May 2016

Study of Microstructures of Zn-27Al Alloy Cast at Different Casting Conditions

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Abstract— **Zinc-aluminium alloys exhibit good technological and mechanical properties. But the common problems associated with the casting process as this alloy has a high susceptibility for gassing and oxidation. At low cooling rate the solidification structures are coarse grained due to predeposition. The aim of this research project is to develop an optimal production method of zinc-aluminium-27 alloy at different casting conditions with improved properties will contribute to a better understanding of the mechanisms influencing the improvement of functional properties of the new. The ZA-27 alloy were cast at pouring temperatures 650°C, 700°C, and 750°C while the mould preheat temperature was kept fixed at 300°C The ZA-27 alloy made at various casting conditions were examined metallographically and analyzed qualitatively using optical and scanning electron microscope. The performed investigations are discussed for the reason of a possible improvement of structural properties of the alloy. The investigated material can find its use in the foundry industry; an improvement of component quality depends mainly on better control over the production parameters. Change of the cooling rate allows it to produce materials with improved properties, which are obtained by: microstructure refinement, reduction or elimination of segregation.**

Index Terms— **Casting, metallic alloys, mould, ZA-27 alloy, mirostructure, phase transformation.**

I. INTRODUCTION

Technical difficulties associated with conventional casting process, where occurs strengthening of the material related to segregation and emergence of clusters, interfacial reactions, increasing occurrence of porosity and low interfacial coherence largely limited capabilities and application of conventional methods of materials producing allowing an increase of commercial properties. The use of inductive and mechanical blending methods causes low segregation and very good mechanical properties, but there occur difficulty of obtaining reproducible properties, completely elimination of the occurrence of blowholes and porosity, as well as the presence of homogeneous structure, what is largely causes a reduction in the use of conventional production methods of metal alloy castings [1,2,12-14].

In general, fine-grained materials exhibit better toughness or resistance to shock. They are harder and stronger than coarse-grained material. In industrial casting processes, where a hot liquid is in contact with an originally cool mold, a temperature gradient will exist in the liquid. The outside is at a lower temperature than the center and therefore starts to solidify first. Thus many nuclei are formed at the mold wall and begin to grow in all directions. They soon run into the side of the mold and each other, so that the only unrestricted direction for growth is toward the center. The resulting grains are elongated columnar ones, perpendicular to the surface of the mold. Next to the mold wall where, the cooling rate is fast, the grains are small; while toward the center cooling rate is much slower, the grains are large and elongated [2,3].

Zinc-aluminium alloys are alloys with very good technological and mechanical properties. One of the main problems in the casting technology of cast zinc alloys is their high susceptibility for gassing and oxidation. Moreover they have also a predisposition to the development of coarse structures during solidification with low cooling rate. All of these issues affect the need for innovation, increasing the quality of casting technology, which after cast into the mould will eliminate metal precipitates and gas bubbles. In addition, it will help to obtain structure, which will ensure high and stable mechanical properties. Such assuming are realised in case of other alloys mainly by implemented refining and modification of the molten metal before casting operation as well as optimal heat treatment processes [1-7].

At the moment, the lack of sufficient knowledge and the lack of data, which allows to determine the effect of modifications, the cooling rate and crystallization kinetics on the alloys microstructure and properties, as well as the relationship between the properties of the Zn alloys, and the obtained results from the thermo-derivative analysis. [3,4]

Cooling of the liquid metal goes from the molten state from - the liquidus line, which is the beginning of crystallization, followed by crystallization of eutectic and intermetallic phases until the alloy reaches the stable state - the solidus line, in accordance with the phase equilibrium diagrams. Therefore on the cooling curve there are characteristic points (inflection points) derived from the exothermic reaction or endothermic transition of the crystallized eutectics and phases. On the cooling curve is difficult to determine the temperature of crystallization of different phases [8, 9, 15].

The casting temperature has a significant influence on the mechanical properties of cast zinc alloy. Influence of variation of the gradient and solidification rate on the structure of the reinforcing elements has a different character depending if the considered particle is a local heat source with the highest temperature, or if it is a resistance for the heat flow [5]. The measured changes in the temperature gradient and, above all, the gradient change itself as a function of time and location of the investigated area relative to the particle is only caused by differences in thermal properties of components. Variation of derivatives of the temperature may cause variability, which may involve changes in both amplitude and duration of the process [1, 2, 10-12].

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Based on the research there are identified two metastable phasesη's and η'E. The dissolution of Cu and Al in the Zn-rich η phase results in a change of the unit cell of the crystal structure, which affect the physical and mechanical properties, in particular the dimensional stability of the alloy [6-9]. Depending on the conditions of the casting process, the material is prepared in a variety of structures, due to solidification of liquid metal. They have impact on the microstructure, grain size, interdendritic distance and thermal conditions [13-16].

Solidification of the ZA27 alloy starts with the α′ phase dendrites, and then by peritectic reaction of the Zn-β reach phases around the edge of the α′ phase. The increase in the cooling rate during solidification reduces the range of occurrence of peritectic reaction in order to enrich the liquid with Zn and stop the solidification of the eutectic β and phase η. The rapid cooling causes - through the β phase transition in eutectoid temperature some irregular particles α and η. Most of the α′ phases generally consist of a mixture of Zn-rich phase and Al matrix. These structures are formed by the rapid super cooling of the alloy [13]. The disintegration of the metastable phase is limited by the addition of Cu during the eutectic transformation. After solidification the copper-rich phase forms with the Zn-η the CuZn4 phase in interdendritic areas, most of the remaining copper is dissolved in the η phase [9].

The size of grains in a casting is determined by the relation between the rate of growth G and the rate of nucleation N. If the number of nuclei formed is high, a fine grained material will be produced, and if only a few nuclei are formed, a coarse grained material will be produced [7]. 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 number of nuclei formed and fine grain size, whereas in slow cooling (sand cast or hot mould) 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 [11, 12].

II. EXPERIMENTAL PROCEDURE

A. *Casting Condition*

Mould used: Permanent mould of cast iron
Alloy used: ZA-27
Furnace used for casting: Pit furnace
Heating system used to preheat the mould: Gas flame
Additives used: Copper 1% and Magnesium 0.02%
Preheat temperature of the mould: 300°C
Pouring temperatures of the melt:

1. 650°C
2. 700°C
3. 750°C

B. *Metallography*

Metallographic section of a cylindrical shape which had the dimension of 8mm diameter and 10mm height was prepared by lathe machine. Then grinding was done on the surface of the sample. The specimen was polished on a series of emery papers containing successively finer abrasives. The first paper was no.3, then 2, 1, 1/0, 2/0, 3/0 and finally 4/0. The final approximation to a flat scratch-free surface was obtained by the use of a wet rotating wheel covered with a special cloth that was charged with alumina powder of size 0.04µm.
Then etching solution of sodium sulphate and chromic acid in water mixture was used to etch the sample. Then the sample is mounted in the microscope. Various phases were revealed. The microstructures were observed and images were taken. Then the etched and unetched samples were observed in the scanning electron microscope. The backscattered and secondary electron (SE & BSE) images were taken.

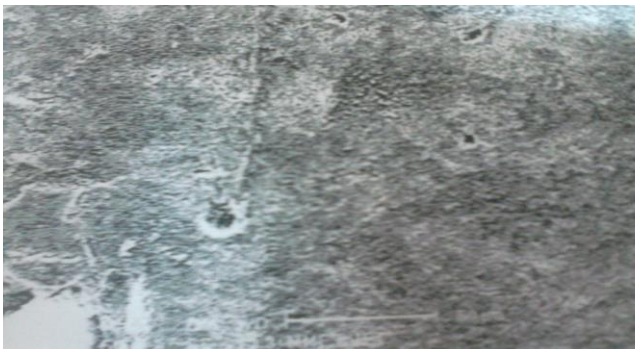

Fig. 1. SE image of sample cast at pouring temperature 650°C

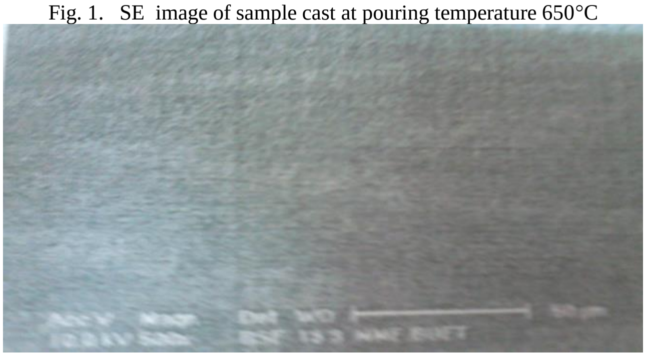

Fig. 2. BSE image of sample cast at pouring temperature 650°C

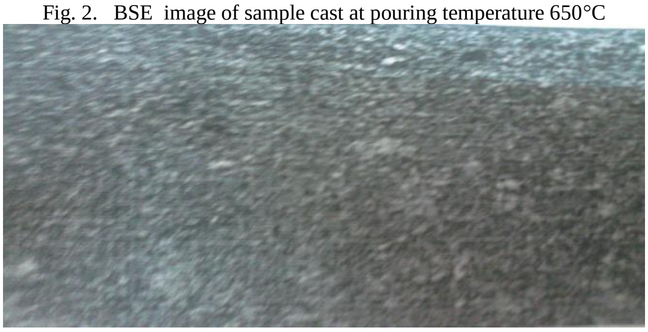

Fig. 3. Optical microscope image of sample cast at pouring temperature 650°C

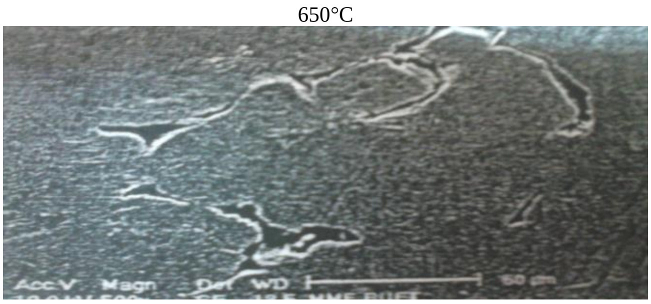

Fig. 4. SE image of sample cast at pouring temperature 700°C

Fig. 5. BSE image of sample cast at pouring temperature 700°C

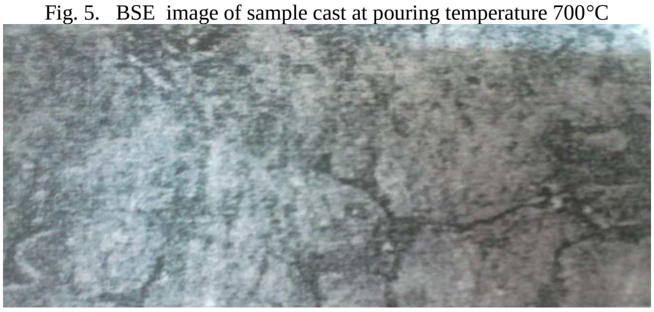

Fig. 6. Optical microscope image of sample cast at pouring temperature 650°C

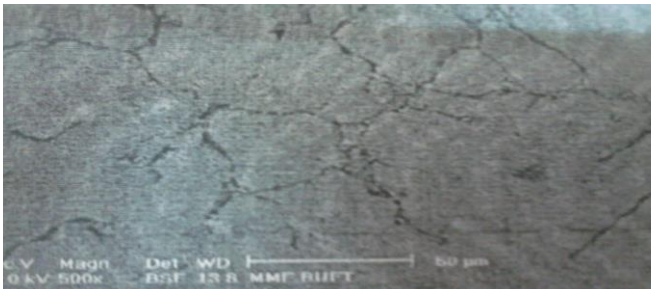

Fig. 7. SE image of sample cast at pouring temperature 750°C

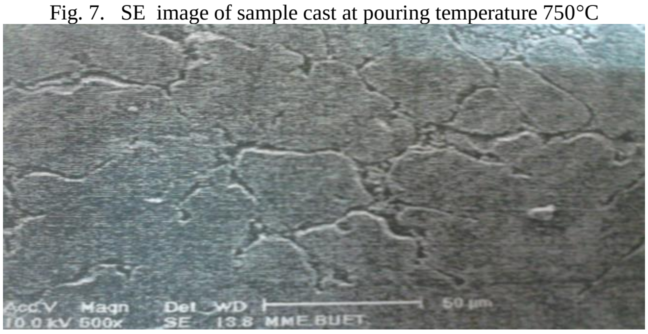

Fig. 8. BSE image of sample cast at pouring temperature 750°C

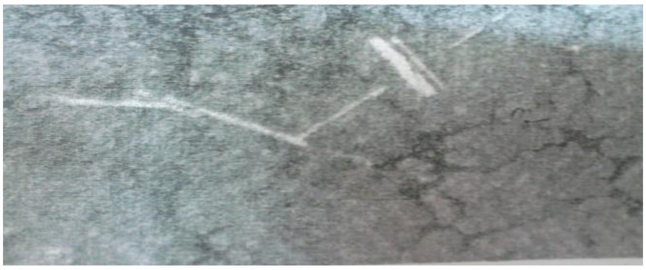

Fig. 9. Optical microscope image of sample cast at pouring temperature 750°C

III. CONCLUSION

From the present experiment the following conclusions can be drawn

- Scanning electron microscope investigations shows the Zn phases as a main phase in this alloy, responsible for mechanical properties enhancement, with the possibility to determine to size of the crystallites.
- All the microstructures represent typical cored structure, consists of small, flaky and rod like irregularly shaped intermetallic compound in the dendrites and eutectic regions.
- As the pouring temperature increases the grain size become smaller at fixed preheat temperature. As solidification rate increases the grain cannot grow much more. Sample cast at 750°C shows relatively sound structure than the samples cast at 650°C and 700°C.

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