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Influence of Solution Heat Treatment on Toughness of Zinc-Aluminum (ZA5) Solder Alloy

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ABSTRACT

Background: Zinc-Aluminum (ZA) alloys are important industrial alloys which are gaining widespread use for many industrial applications due to their excellent castability and cutting machinability. Since they were introduced in the early 1970s, various investigations have been carried out on this family of engineering materials to broaden the scope of areas where they can be usefully applied. While many investigations have been carried out on many of the ZA alloy materials, only a few studies have reported investigations on ZA5.

Objective: Therefore, this study investigated the toughness properties of ZA5 alloy. Toughness properties of ZA5 solution heat-treated were investigated.

Methods: ZA5 alloy material was prepared in the laboratory and cast into rods of 15 mm diameter and 200 mm length. A sample of the cast rods was solution heat-treated at 100ºC for 6 hours, while another untreated sample which served as control was also prepared. The samples were evaluated for toughness and modulus of toughness on the Universal testing machine.

Results: Results showed that ZA5 alloy material exhibits superplastic behavior at low flow stress. Solution heat treatment performed on the alloy significantly modified the structure of the alloy, and increased the toughness and modulus of the toughness of the alloy.

Conclusion: Solution heat treatment at 100ºC for 6 hours, the toughness of the ZA5 alloy can be used to improve the toughness of ZA5 alloy. In general, solution heat treatment of ZA5 alloy for 6 hours at 100C influenced the properties of the alloy material.

Keywords: Solutionizing, Toughness, Modulus of toughness, ZA5

Introduction

Zinc-Aluminum (ZA) alloys are important industrial alloys available for various engineering applications. Distinctiveness, antifriction capability, corrosion resistance, and technological properties, mainly relating to their excellent castability and cutting machinability, make ZA alloys promising material for industrial applications[1,2].

Since they were introduced in the early 1970s, various investigations have been carried out on this family of engineering materials to broaden the scope of areas where they can be usefully applied. Particularly, research efforts have been made to understand the phenomenon of dendritic segregation in these alloys[2]; the effects of casting/processing techniques of structural formations in the ZA alloys[3-5]. Efforts were also made to investigate mechanical properties [3,6,7], however mostly, tensile properties of these alloys were more studied. Only a few studies have reported research efforts on ZA5, one of the important materials in this family of alloys. No research efforts have reported investigations on the toughness of ZA5 alloy. To meet the growing demands for the application of these alloys in industry, extensive studies on microstructural changes and phase transformations which occur during various thermal and thermo-mechanical processes are required [8]. Generally, understanding the mechanical properties of materials is very important [9-12] to provide knowledge which is vital and useful for design and many other important engineering applications.

Therefore, in this present study, the investigation into the toughness property of ZA5 is made. The influence of solution heat treatment at 100ºC for 6 hours on the toughness of the alloy is investigated.

Materials and Experimental Procedure

The material used for the study is zinc-aluminum alloy (ZA5). This material was produced by melting together and casting zinc and aluminum metals. About 9Kg of Zinc metal scrap was melted in a lift-out crucible furnace, after which about 0.5Kg of Aluminum was dissolved in the molten zinc metal. The molten metal alloy mixture produced was cast into rods of 15mm diameter and 200mm length in sand molds. The quantitative elemental chemical analysis of the cast rods was carried out with an optical emission spectrometer. The result of the chemical analysis test is presented in Table 1. Produced cast rods were machined into ASTM standard tensile and impact test pieces on a lathe machine for evaluating fracture energy and toughness of the test pieces. Two test pieces each were produced from the cast rods for each test, fracture energy, and toughness. One test piece served as a control specimen, while the other test piece was heat-treated at a temperature of 100ºC for 6 hours, after which the sample was removed and quickly quenched in water maintained at a temperature of 10ºC. Both rods were then evaluated for fracture energy on Universal Testing Machine and toughness on the Hounsfield impact testing machine.

The stress-strain curve of the samples from testing on the universal testing machine was equally obtained for further analysis.

Results and Discussion

The results of the study are presented in Tables 1 and 2 and Figures 1 to 5. Table 1 presents the results of the elemental chemical analysis of the produced ZA5 alloy. Table 2 and Figure 1 show the result of the toughness test and fracture energy evaluation by the Hounsfield Impact testing machine and Universal Testing Machine. Figures 2 and 4 show the stress-strain curves for the untreated (control) sample and the solutionized sample respectively. The microstructures of the control and the treated samples are presented in Figures 3 and 5 respectively.

Table 1: Chemical composition of the ZA5 alloy

	Mn	**Si**	**Cu**	**P**	**Cr**	**Ni**	**V**	**B**	**Al**	**Mg**	**Na**
Mean (Conc. %)	0.13	0.12	1.47	<0.0005	0.005	0.12	0.002	0.0135	15.4104	0.0005	<0.0001
	Ca	**Ti**	**Zr**	**Fe**	**Ag**	**Zn**	**Sn**	**Sb**	**Pb**	**Co**	
Mean (Conc. %)	0.0003	0.003	0.001	0.036	0.035	>79.0	0.002	-	3.74	0.004	

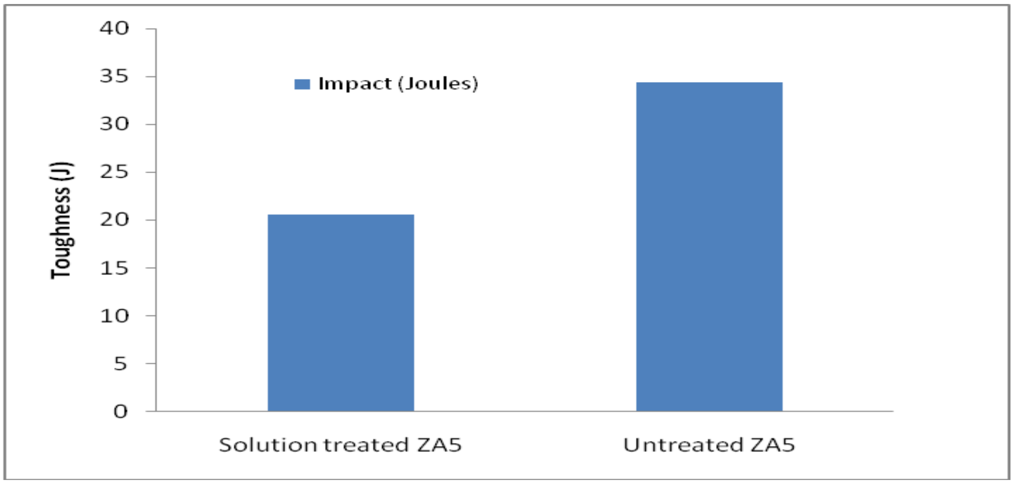

Figure 1: Toughness values of the tested samples of ZA5 alloy

Table 2: Toughness values of the tested samples of ZA5 alloy

Sample	Toughness (Joules)	Fracture Energy (Joules)
Solution treated ZA5	20.54	1.24
Untreated ZA5	34.41	0.56

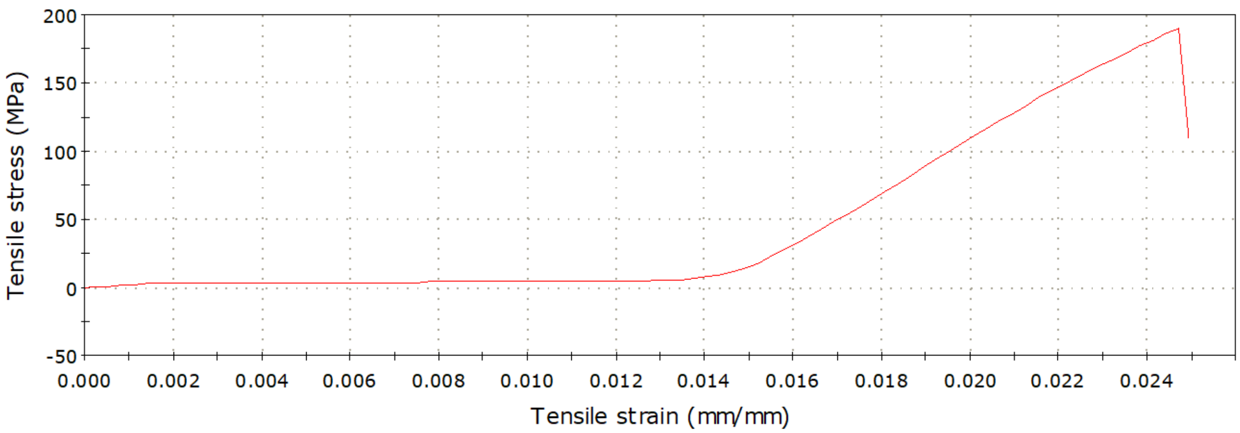

Figure 2: Stress-Strain curve for control sample

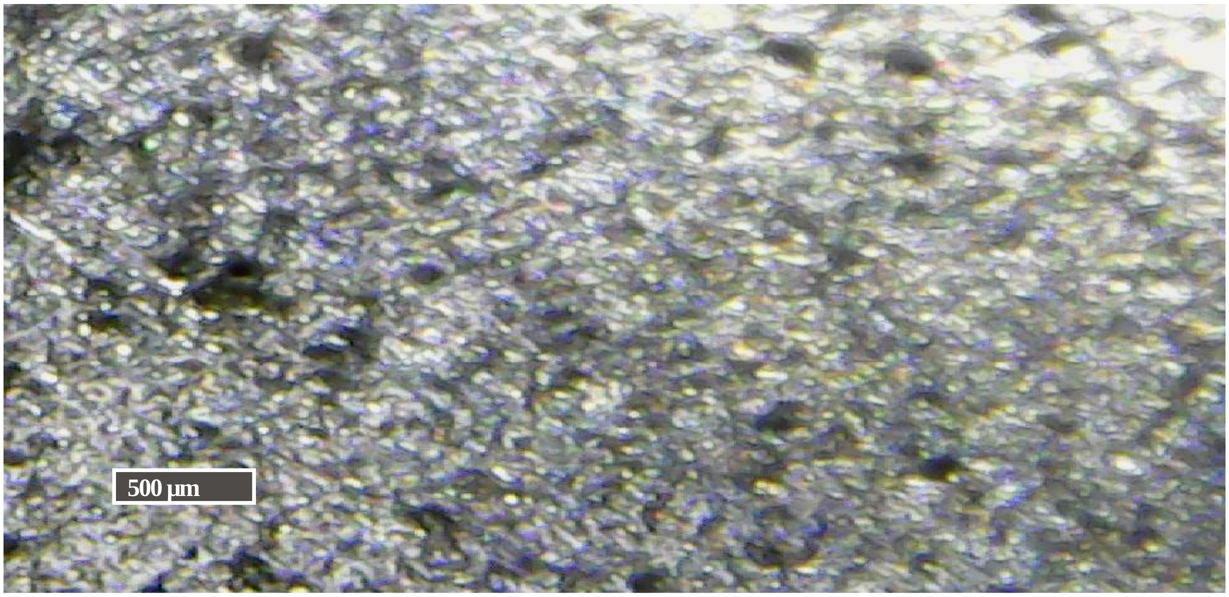

Figure 3: Microstructure of control sample

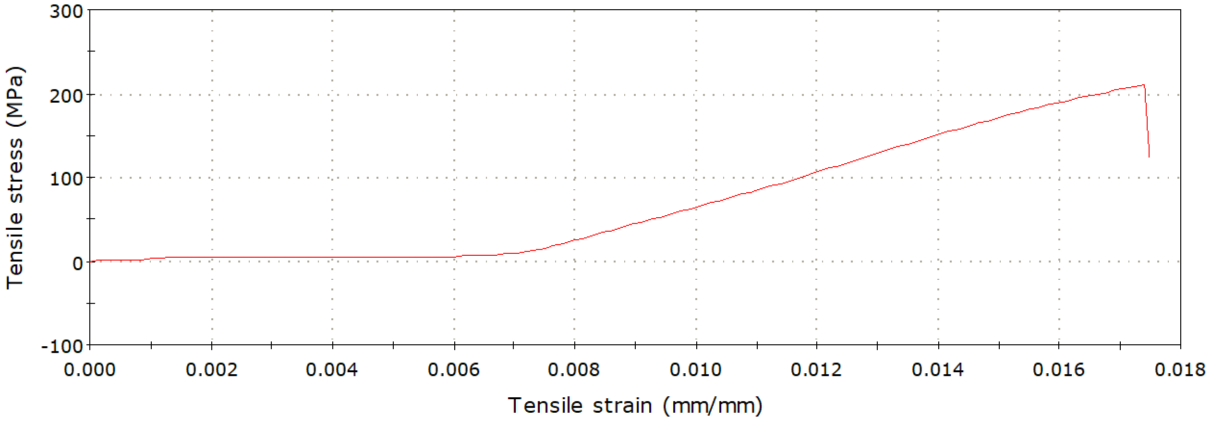

Figure 4: Stress-Strain curve for the solutionized sample

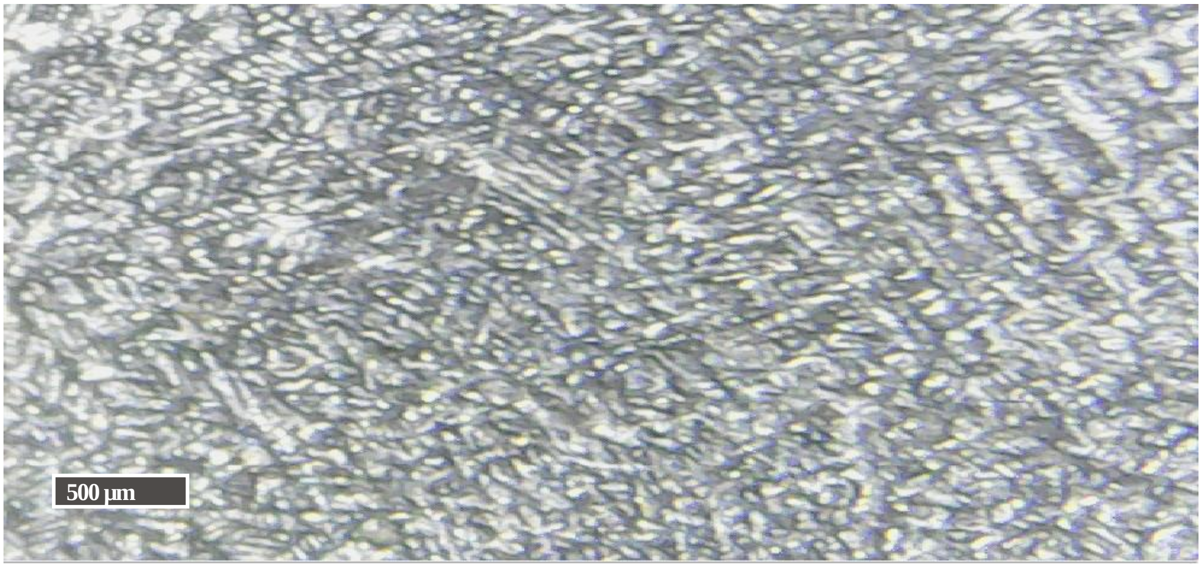

Figure 5: Microstructure of solutionized sample

Table 2 and Figures 2 and 4 present toughness and fracture energy test results measured by the Hounsfield Impact testing machine and Universal testing machine respectively. The result shows that the untreated (control) sample had a higher toughness value of 34.41J, while the solution heat-treated sample had a lower toughness value of 20.54J. The untreated (control) sample had fracture energy of 0.56J while the solution heat-treated sample had a higher fracture energy value of 1.24J. The fracture energy values are rather low and indicative of the concave-up (J-type) stress-strain curve [9,10] observed for the samples. J-type stress-strain curves normally exhibit low area under the stress-strain graphs, indicating low energy absorption during the deformation of samples by tensile tests [10]. Materials exhibiting J-shaped stress-strain curves can be extremely tough, even though the fracture energy for the material is not particularly high [10]. This toughness arises for the fact that the lower part of the J-shaped curve gives a very large extension for low applied stress, so the shear modulus in this region is very low and so there is no mechanism whereby the released strain energy on fracture can be transmitted to the fracture zone. Areas of large extensions for low applied stresses are seen in Figures 2 and 4. The material gets stiffer as the failure point approaches ensuring that very large extensions require large stresses. Since the J-shaped curve is concave, the area under the curve up to a given extension is far lower than that for the equivalent Hookean curve meaning that the energy released in the fracture of a material with a J-shaped stress-strain curve is far lower than the energy released when an equivalent Hookean material fails. Since the release of energy drives crack propagation, a material that releases less energy on fracture is tougher.

The improved fracture energy values of the solutionized specimen can be due to the fine and stable grain size of the aluminum-rich (α-phase) and zinc-rich (β-phase) terminal solid solutions superplastic microstructure formed during solution treatment of the alloy at 100ºC [5], which has improved the energy release during fracture. Normally, smaller plastic zone size in-plane strain results from the triaxiality of the stress state, which restricts plastic yielding. Superplastic states have been reported to improve elongation [3,5]. Improvement of the material property leads to improved fracture energy observed for the solution heat-treated ZA5 alloy. The presence of superplastic structure is confirmed in the micrograph of solution heat-treated sample presented in Figure 5

Conclusion

The result of the investigation showed that ZA5 alloy has low toughness values for both treated and untreated samples. This alloy in the as-cast and solution heat-treated states; exhibits superplastic conditions, where low flow stresses bring about high elongation in the material. Solution heat treatment at 100ºC for 6 hours, the toughness of the ZA5 alloy can be used to improve the toughness of ZA5 alloy. In general, solution heat treatment of ZA5 alloy for 6 hours at 100C influenced the properties of the alloy material.

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