Comparison Between Mo Addition to ZA22 Grain Refined by Ti and Ti-B Regarding its Metallurgical and Mechanical Characteristics

Adnan I. O. Zaid and Safwan M. A. Al-qawabah

Abstract— Zinc and its alloys are widely used materials in manufacturing several industrial and engineering parts especially in the automobile and aircraft industries due to their due to their good mechanical strength and hardness in addition to their inherent corrosion resistance. However, they have the disadvantage of solidifying in large grains which reduces their mechanical strength, therefore they are normally grain refined by addition of titanium or titanium plus boron to their melts prior to solidification. In this paper, comparison between molybdenum addition to ZA22 grain refined by Ti and Ti-B on its grain size and mechanical characteristics in the cast condition is investigated and the obtained results are presented and discussed.

Index Terms— Cast condition, Comparison, Grain refinement, Mechanical characteristics, Metallurgical, Molybdenum, Titanium, Titanium-boron

1 Introduction

Zinc aluminum alloys in general and ZA 22 in particular are widely used due to their useful and attractive properties. They form substitutes for cast iron and copper alloys in many structural and pressure tight applications especially whenever strength, hardness, wear and corrosion resistances or good pressure tightness are required. Since they have good wear and bearing characteristics they are used for bearing bushings and flanges replacing bronze. Other applications in which they have been successfully replaced cast iron and copper alloys include fuel-handling components, pulleys, electrical fitting and hardware articles. Zinc aluminium are ease in machining, high machinability rating and their inherent corrosion resistance give them advantages over cast iron and because the price of zinc is much less than copper give them a distinct cost advantage over copper base alloys, [1-4].

Zinc gravity casting alloys are versatile materials which are widely used in industrial applications due to their low melting and casting points, around 540 degrees Centigrade, their energy requirements are low and virtually pollution free and the gravity casting of these alloys have attractive foundry properties in addition, they can be used for manufacturing components in a wide range of sizes and weights, e.g. from 1.5 mm to 5 mm in size and from few grams up to 50 kg in weight in sand and graphite casting molds, [5]. Against these favorable advantages, they have the disadvantage of solidification in dendritic structure of large grains which tends to reduce their mechanical strength and surface quality. To overcome these describences their structures are grain refined by either Ti or Ti-B, which are normally used for this purpose in aluminum and zinc alloys foundries.

2 Experimental Procedures

The experimental work started by preparing the binary Al-Mo and the Al-Ti master alloys. The ternary Al-Ti-B was commercially available and supplied by ARAL, Arab Company of producing different aluminium article. These master alloys were used for manufacturing the different micro alloys which are used in this paper. The master and micro alloys were prepared in graphite crucibles and graphite rod was used for stirring one using graphite rods. Melting was carried out in an electrical furnace and poured to solidify in hollow thick brass rods in air. Details of the preparation of the master alloys and micro alloys are given in [8, 9]. Their chemical compositions were determined using the scanning electron microscope, (SEM) as shown in Table 1.

TABLE 1
Chemical composition of the different ZA22 micro alloys

No	Alloys	Mo%	Ti%	B%	Al%	Zn%
1	ZA	0	0	0	21.91	Ball
2	ZA-Mo	0.094	0	0	21.98	Ball
3	ZA-Ti	0.15	0	0	21.97	Ball
4	ZA-Ti-Mo	0.094	0.141	0	1.95	Ball
5	ZA-Ti-B	0	0.048	0.0096	21.99	Ball
6	ZA-Ti-B-Mo	0.047	0.047	0.0093	21.96	Ball

3 Results and Discussion

3.1 Comparison between Mo Addition to Al Grain Refined by Ti and Ti-B

Figures 1 to 4 inclusive show comparison between addition of molybdenum to ZA22 grain refined by Ti and ZA22 grain refined by Ti-B in the cast condition: the ZA22 general microstructure solidify in dendritic type with large grains which collect in cluster shape. Addition of Ti or Ti-B to ZA22 resulted in refining of its structure. Ti-B is found to be better refiner

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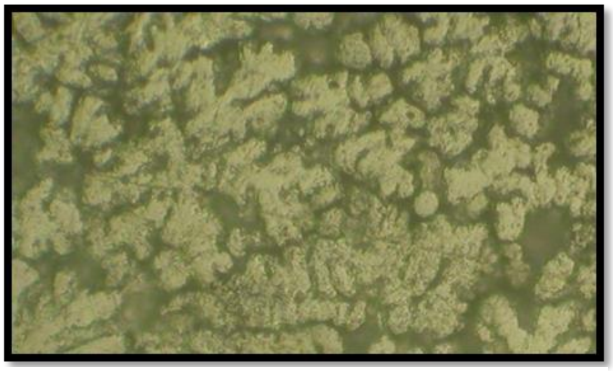
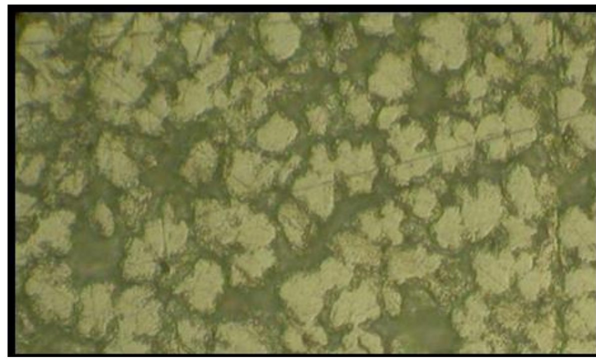
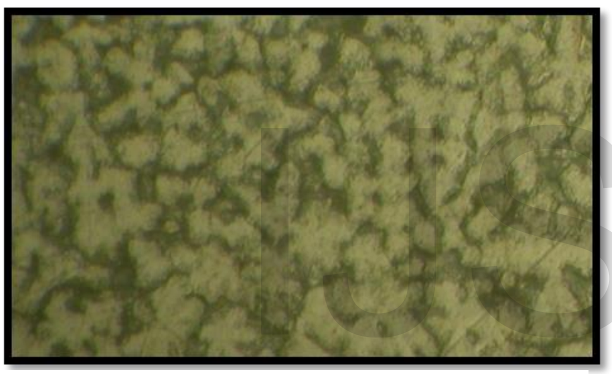
than Ti although the Ti percentage in Ti-B addition is smaller than percentage in case of Ti addition, although boron is not a refiner itself. However, in the case of Mo addition the structure in completely different from the ZA22 or ZA22-Ti or the ZA22-Ti-B micro alloys as the grains collected in a columnar type structure with little or no distance between the grains. Addition of Mo to ZA22 grain refined by Ti resulted in further refinement with small distance between the grains. However in case of Mo addition to the ZA22, it changed the Metallurgical structure into petal-like type.



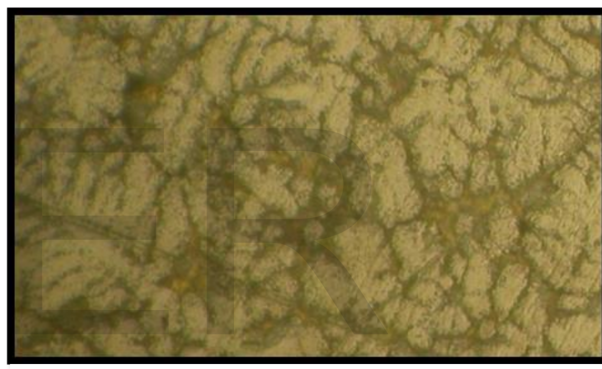
a) ZA22: the grains gather in colonies or cluster.



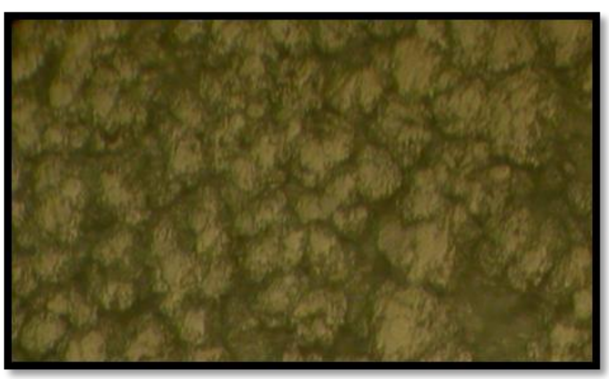
b) ZA22-Ti: the grains are smaller in size and distance between grains is larger than the other micro alloys.



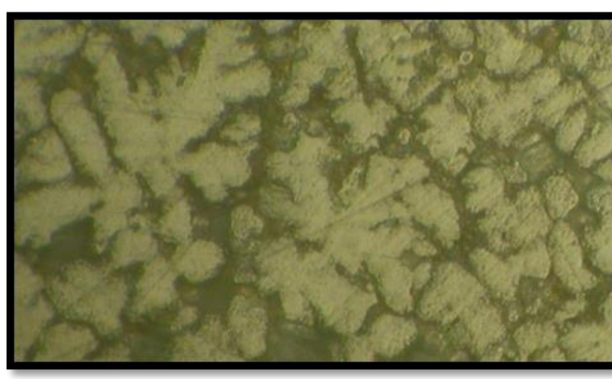
c) ZA22-Ti-B: in this case the grains are smaller than case Ti addition.



d) ZA22-Mo: the grains are in columnar structure type.



e) ZA22-Ti-Mo: the grain is smaller than In case of Ti or Ti+B



f) ZA22-Ti-B-Mo: the grains are in petal-like structure

Fig. 1. Photomicrographs of ZA22 and its Micro Alloys: (a) ZA22, (b) ZA22-Ti, (c) ZA22-Ti-B, (d) ZA22-Mo, (e) ZA22-Ti-Mo, (f) ZA22-Ti-B-Mo, cast condition X 500.

Addition of Mo to either ZA22 grain refined by Ti or Ti-B resulted in enhancement of its hardness giving better enhance-

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ment in case of ZA22 grain refined by Ti-B and Ti-B-Mo, as shown in the histogram of figure 2.

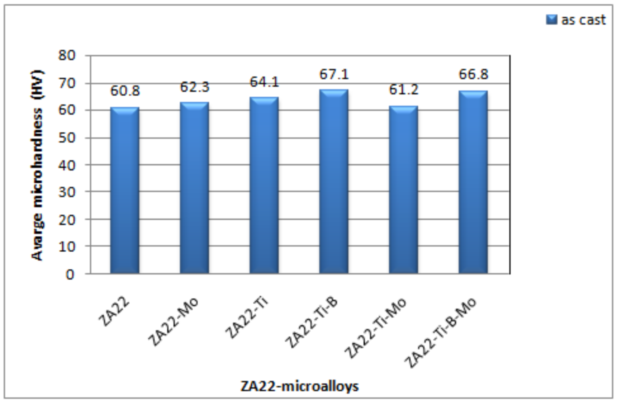

Fig. 2. Effect of molybdenum addition on the micro hardness of ZA22 and ZA22 grain refined by Ti, Ti-B in the as cast condition.

Regarding the effect addition of Mo on the mechanical behavior of ZA22, it can be seen that addition of Mo alone or in the presence of Ti or Ti+B resulted in deteriorating of its mechanical behavior, i.e. reduction of its flow stress and. On the other hand addition of Ti alone to ZA22 resulted in achievement of its mechanical behavior. In case of addition Mo to ZA22 grain refined by either Ti or Ti-B there is a circuital point at 0.2 strain as indicated by figures 3, and 4

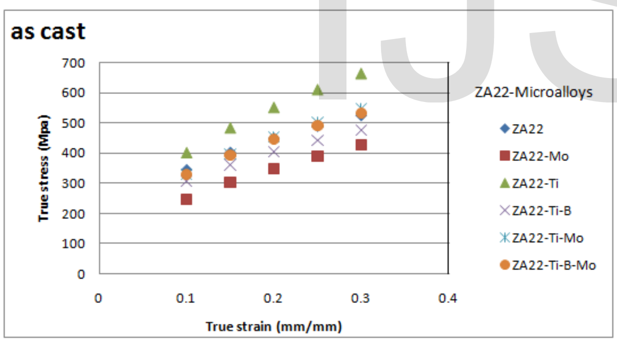

Fig. 3. True. Stress True. Strain of ZA22 and ZA22 grain refined by Ti and Ti-B in the as cast condition.

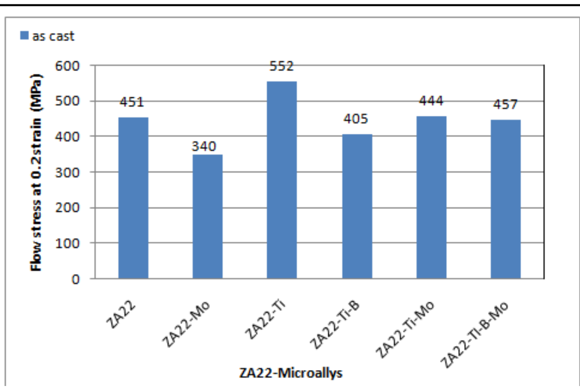

Fig. 4. Effect of molybdenum addition on the flow stress at 20 % strain of ZA22 and ZA22 grain refined by Ti and Ti-B in the as cast condition.

It can be seen from the summary of the resultants of the mechanical behavior and the mechanical characteristic of ZA22 and its five micro alloys in the as cast condition and after the pressing by the ECAP process presented in Table 8 that the mechanical behavior is decreased by the addition of all grain refiners except Ti addition in as cast condition where the strength coefficient, K, in the as cast condition is increased by addition of Ti by (37.6%) followed by Ti-Mo addition being (14%) and by Ti-B-Mo addition, but it is decreased by Ti-B and Mo addition. However, the only parameter which was increased by all the additions is the work hardening index, n, as clearly demonstrated in Table 2.

TABLE 2
MECHANICAL CHARACTERISTICS OF ZA22 AND ITS MICRO ALLOYS IN THE CAST CONDITION

Micro Alloys	Flow stress (MPa)at strain=20%	Strain hardening index (n)	Strength coefficient (K) MPa	General equation of mechanical behavior
ZA22	451	0.384	836.4	$\bar{\sigma}=836.4\bar{\varepsilon}^{0.384}$
ZA22-Mo	349	0.495	774.5	$\bar{\sigma}=774.5\bar{\varepsilon}^{0.495}$
ZA22-Ti	552	0.456	1150.8	$\bar{\sigma}=1150.8\bar{\varepsilon}^{0.456}$
ZA22-Ti-B	405	0.394	763.84	$\bar{\sigma}=763.84\bar{\varepsilon}^{0.394}$
ZA22-Ti-Mo	456	0.458	953	$\bar{\sigma}=953\bar{\varepsilon}^{0.458}$
ZA22-Ti-B-Mo	447	0.432	895.4	$\bar{\sigma}=895.4\bar{\varepsilon}^{0.432}$

Conclusion

From the previous investigation the following points are concluded:

i) Addition of molybdenum, Mo, to the ZA22 alloy, resulted in reduction of its grains i.e. refining them.

ii) Addition of Mo to ZA22 grain refined by Ti or Ti-B resulted in increase of its micro hardness in the cast condition.

iii) Addition of Mo to ZA22 grain refined by Ti or Ti-B in as cast condition resulted in deterioration of its mechanical behavior i.e. its reduced the true stress-true strain (σ-ε) curve, flow stress where decreased by 22.6% at 20% strain was achieved in Mo addition, whereas it improved its work hardening index, n, and its ductility, i.e. improves formability and hence reduces the number of stages required for forming the alloy at large process strains in excess of the plastic instability strain.

iv) Addition of Ti to ZA22 resulted in improvement of its mechanical behavior i.e. its true stress-true strain (σ-ε) curve, increase of flow stress by 22.4 % at 20% strain was achieved, increase of work hardening index, n, by 18.75%.

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REFERENCES

[1] Budinsk, K.G. (1992), Engineering Materials Selection, Fourth Edition, Prentice-Hall, Inc., New JERSY.

[2] Callister, W.D. (1994), Materials Science and Engineering and Engineering: an Introduction, Third Edition, John Wiley and Sons Inc., New York.

[3] Nevison, D.C.H. (1998), Zinc and Zinc Alloys, American Society of Metals, ASM Handbook, Fourth Edition.

[4] Kalpakjian, S. Schmid, S.R., (2003). Manufacturing processes for engineering materials, 4th edition, prentice Hall.

[5] Cubberly, W. H, Properties and metal selection: none ferrous alloys and pure metals, Metals Handbook, ASM, V.2, 1994

[6] Zaid, Adnan I .O, "Effect of Addition of Tantalum and Zirconium on the Mechanical Behaviour of Aluminum Grain Refined by Ti+ B". Accepted for Presentation at the 8th International Symposium on Advanced Materials, Islamabad-Pakistan. Sept. (2003).

[7] "Effect of Addition of Zirconium on the Mechanical Strength and Fatigue Life of Zinc-Aluminum Alloy-5, AZ5, Grain Refined by Ti". Proceedings of the 8th International Symposium on Advanced Materials, Islamabad-Pakistan. Sept. (2003).

[8] Zaid, Adnan I .O. Grain Refinement of Aluminum and Its Alloys". Proceedings of the seventh International Symposium on Advanced Materials, ISAM-7. Islamabad-Pakistan. Sept. 17th – 21st (2001).

[9] Zaid, Adnan I .O. "Grain Refinement of Zn- Al Alloys", Proceedings of the Second International Conference on the Frontier of Advanced Engineering Materials, FAEM- 2006, Lahore, Pakistan, (2006).

[10] Abdel Hamid, A. A., (1985). On the mechanism of the grain refinement of aluminum by small addition of Ti and B, The Second Arab Aluminum Conference ARBAL ,85, Egypt, Oct. 1985.

[11] Abdel Hamid, A.A. (1992), Structure Modification of the α-Phase in Zn-Al Cast Alloys by Microalloying. Metalkd, V.83, pp.314-318.

[12] Abdel-Hamid, A.A. and Zaid, A.I.O. (2000), "Poisoning of Grain Refinement of Some Aluminum Alloys", Seventh, Cairo Intern. Conference, Current Advances in Mechanical Design and Production, Cairo, Feb 2000, pp.331-338.

[13] Arjuna A. Rao, Murty B.S., and Chakraborty M, (1997). Role of zirconium and impurities in the grain refinement of aluminum with Al-Ti-B, Material Science and Technology, 13, pp.769-777.

[14] Assifa, M. M., (2011), Effectiveness of Naphthalene in Grain Refinement of Commercially Pure Aluminum and Zinc Ingot Castings, Engineering & Technology Journal, V-29, Issue 8, pp 1545-1553.

[15] Azad, A. Bichler, L. and Elsayed, A. (2013), Effect of a Novel Al-SiC Grain Refiner on the Microstructure and Properties of AZ91EMagnesium Alloy, International Journal of Metal casting, V-7, Issue 4, pp 49-60.

[16] Birch, M.E.J. and Fisher, P. (1986), "Grain Refining of Commercial Aluminum Alloys with Titanium Boron Alloys" Aluminum Tech., Institute of Metals, pp.117-142.

[17] Pearson, J. and Birch, M. E. J. (1979), The Effect of the titanium Boron Concentrations on Aluminum Grain Refining Alloy. Journal of Metals, V. 31, No.11, pp.27-31.

[18] Pollard, W.A. Pickwick, K. M. Jubb, J.T., and Packwood, R. I., (1974), The Grain Refinement of Zinc-Aluminum Alloys by Titanium, Can. Metal. Soc.V.13. No 4.

[19] Cibula. A, Journal Institute of Metals, 1949-1950, V.76, pp.321-360.

[20] Cibula. A, Journal Institute of Metals, 1951-1952, V.80, pp.1-15.

[21] Elbaradie, Z.M., (1998), Grain Refining of Zn22%wt Al Superplastic Alloy. Journal of Materials Processing Technology, V.84, pp. 73-78.

[22] Tsan, C. L. Nakata, T. and Hayashi, T. (1976), Effect of Zirconium, Titanium, Manganese, and Nickel Additions on Dendrite Morphology of Zinc-Aluminum Alloys. IMONO, V. 3, pp. 167-174.

[23] Tu¨rk, A. Durman, M. and Kayali, E.S. (2007), the effect of manganese on the microstructure and mechanical properties of zinc–aluminium based ZA-8 alloy, Journal Material of Science, v-42, pp 8298–8305.