ARCHIVES
of
FOUNDRY ENGINEERING

Published quarterly as the organ of the Foundry Commission of the Polish Academy of Sciences

ISSN (1897-3310)
Volume 10
Issue Special1/2010
431-434

85/1

Development of environmentally friendly cast alloys and composites. High zinc Al-base cast alloys

(The paper was prepared on the basis of the presentation during the conference Euromat 2009, Glasgow UK, 4-9 Sept. 2009, [1 – 2])

W.K. Krajewski[a,]*, J. Buras[a], H. Haberl[b], P. Schumacher[b]
[a] Faculty of Foundry Engineering. AGH University of Science and Technology. Reymonta 23, 30-059 Krakow, Poland
[b] Chair of Foundry Research. University of Leoben, Franz-Josef-Strasse 18, A8700 Leoben, Austria
*Corresponding author. E-mail address: krajwit@agh.edu.pl

Received: 26.02.2010; accepted in revised form: 30.03.2010

Abstract

This work is devoted to grain refinement of the foundry Al-20 wt% Zn (AlZn20) alloy, aiming at improving ductility of the sand-cast alloy The melted alloy was inoculated using traditional AlTi5B1 (TiBAl) and AlTi3C0.15 (TiCAl) master alloys and newly introduced (Zn,Al)-Ti3 one. The performed structural examinations showed out significant increasing of the grain population of the inoculated alloy and plasticity increase represented by elongation. The high damping properties of the initial alloy, measured using an ultrasonic Olympus Epoch XT device, are basicly preserved after inoculation. Also tensile strength preserves its good values, while elongation shows an increase – which are beneficials of the employed grain-refining process.

Keywords: High-Zinc Al Alloy; Nucleation; Grain Refinement; Strength and Damping Properties

1. Introduction

The castings production in Poland from Mg-based and AlZn-based alloys is still very small as compared to the Fe ones, though Poland produces significant amount of pure zinc – Fig. 1, [3 – 7]. Recent efforts of the European Community are aimed, among others, at energy saving and improving environmental protection at the same time. From this point of view, foundry industry production should be focused on wider application of the alloys, which are less energy consumable during their melting process. Replacing some amount of Fe-based castings with the AlZn-based ones is very important for environmental protection, because they are relatively cheaper according to lower melting temperatures – Fig. 2, which allows saving energetic expenses.

The, so called, high-zinc aluminium cast alloys are a good example of these alloys, of good strenght and high damping properties, which could replace other, more energy consumable ones. However, wider implementation of the high-zinc aluminium cast alloys requires improving their plastic properties.

As it appears from Fig. 3, the AlZn20 alloy, selected here as the representative of the high-zinc aluminium alloys, requires increasing its plastic properties, which should be achieved after its grain-refinement. On the other hand, it is well known from literature, that Al-Zn alloys are numbered into the group of increased damping properties [10].

Thus, the presented work is focused on obtaining data concerning relationship between strength and damping properties versus structure finenes. The next aim of this publication is spreading to Polish Foundrymen community information about the Marie Curie European project CastModel, in frame of which the research is carried on.

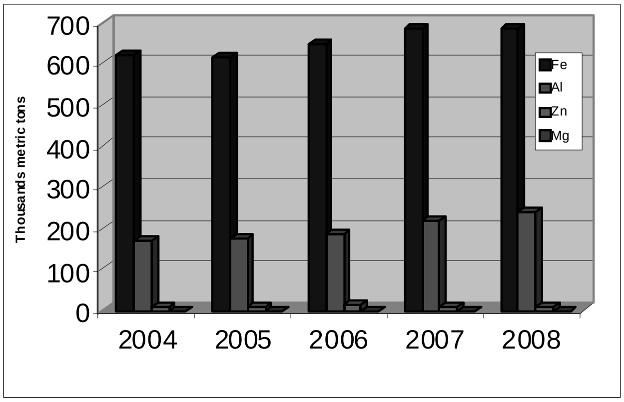

Fig. 1. Structure of casting production in Poland. (Diagrams based on data published in [3] to [7])

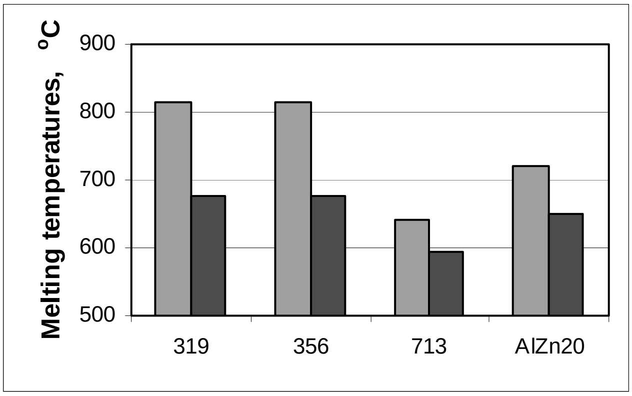

Fig. 2. Melting temperatures of typical foundry sand-cast alloys 319 (AlSi6Cu4), 356 (AlSi7Mg0.3), 713 (AlZn8Cu1Mg) and the high-zinc AlZn20 aluminium alloy. (Diagrams based on data published in [8] and [9])

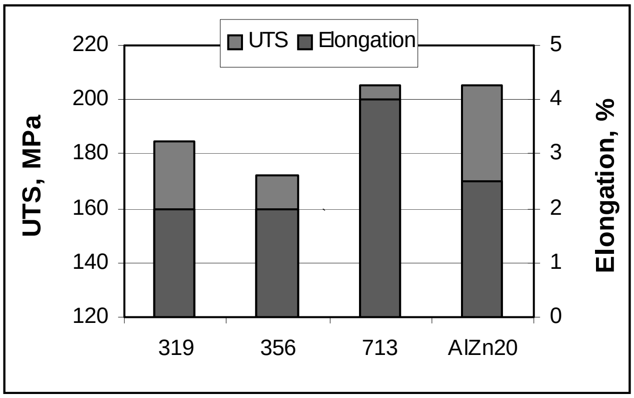

Fig. 3. Ultimate tensile strength UTS and elongation of typical foundry sand-cast alloys 319 (AlSi6Cu4), 356 (AlSi7Mg0.3), 713 (AlZn8Cu1Mg) and the high-zinc AlZn20 aluminium alloy. (Diagrams based on data published in [8] and [9])

2. Experimental

The examined alloy AlZn20 and the master alloy AlZn-Ti3 were laboratory melted from electrolytic aluminium (minimum purity 99.96%); electrolytic zinc (99.995%) and titanium sponge (98-99.8%, from Johnson Matthey Alfa). The melting was performed in an electric resistance furnace, in an Salamander clay-bounded graphite crucible, of 1.5 litre capacity. The AlZn20 melt was superheated to ~740^{o}C and purified by flashing with pure Argon for 10 min. Then a master alloy was added and the melt was held for 2 minutes to ensure complete dissolution of the master alloys added. Then the melt was stirred for next 2 minutes with an quartz-glass tube, and finally the alloy was cast into a dried sand moulds to obtain dog-bone shape samples (working part ∅12x60 mm) for tensile tests and ∅32x50 mm samples for damping tests. To monitor the melting process thermocouples NiCr-NiAl0.5 ∅0.20 mm were used. Temperatures (accuracy ± 1^{o}C) were recorded using a multi-channel recorder Agilent 34970A (Agilent Technologies Inc., USA). Microsections for LM examinations were ground on abrasive paper (grit 200-1000) and then were polished using sub-microscopic aluminium oxide in water-alcohol suspension. The AlZn20 samples, used in macrostructure examinations, were etched chemically with Keller's or electrochemically with Barker’s reagent. LM observations of microstructures were performed using Leica-DM IRM and Zeiss Axio Imager A1m light microscopes. The grain size was determined by measuring the real grains with the software NIS Elements Br 3.0, Nikon. Meaurements of the attenuation coefficient were performed using the Olympus testing device Epoch XT, connected with a normal probe PF2R10 with a frequency of 2MHz. The examinations were carried out using oil as lubricant. The tensile tests were performed using an Instron 3308 device.

3. Results

Al-Zn foundry alloys solidify naturally with coarse primary dendrites of the α(Al) solid solution [11-16], which is clearly seen in Fig. 4. The ductility of these alloys can be increased by refinement of the α(Al) dendrites, which is common practice in casting technology of Al alloys. In industry, Al-Ti-B (TiBAl) and Al-Ti-C (TiCAl) master alloys are used to refine the α(Al) dendrites. A new alternative — a master alloy based on the Zn-Ti-Al system ((Al,Zn)-Ti3) has its density very close to the AlZn20 melt and introduces (Al,Zn)3Ti particles, of L12 crystal structure and lattice parameter nearly the same as that of the α(Al) phase [14 – 16]. These features characterize the master alloys of good grain-refining performance.

As it appears from Fig. 5, all of the master alloys which were used cause significat increase of grain population in the examined alloy. Namely, the initial, non refined alloy has its mean grain size of about 4500 µm, while the same alloy - inoculated with addition of 0.04 wt % Ti, introduced into the AlZn20 melt with the mentioned above master alloys – has its grain size only 300 – 550 µm [18].

It is clear that grain refinement should be performed to an extent which allows improving plastic properties as well as improving or preserving other properties. As relates the high-zinc aluminium alloys, attention should be focused on preserving tensile strength and high damping properties. The dependence strength properties vs. grain size is presented in Fig. 6. Surprisingly, the TiBAl master alloy showed rather weak influence on the examined alloy elongation, while TiCAl and (Al,Zn)-Ti3 master alloy caused the increase of elongation by about 30%. On the other hand, all the master alloys used caused slight increase of tensile strength, which is beneficial. Fig. 7 shows dependence between grain size and damping properties, represented by attenuation coefficient. From Fig. 7 it can be seen, that performed grain refinement only slightly influences the attenuation coefficient. However, one can observe the slight increase or sligth decrease of attenuation coefficient of the refined samples in comparison to the initial, non refined alloy, which is unclear. Elucidation of this requires additional, more detailed examinations [20].

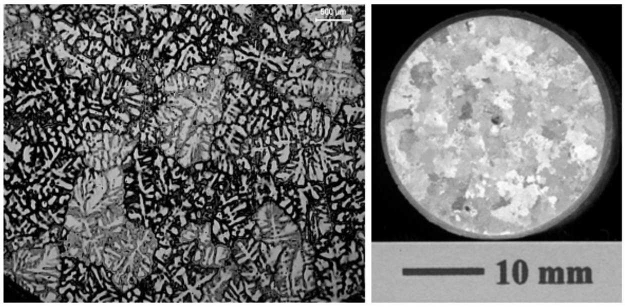

Fig. 4. Microstructure and macrostructure of the initial sand-cast AlZn20 alloy

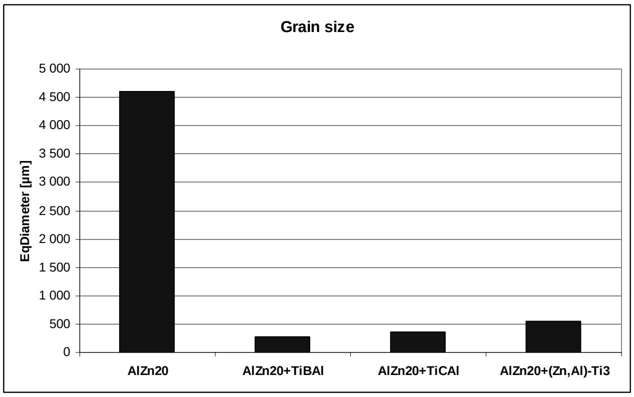

Fig. 5. Grain size of the sand-cast AlZn20 alloy and its inoculated alternatives. Ti addition 0.04 wt. % [18]

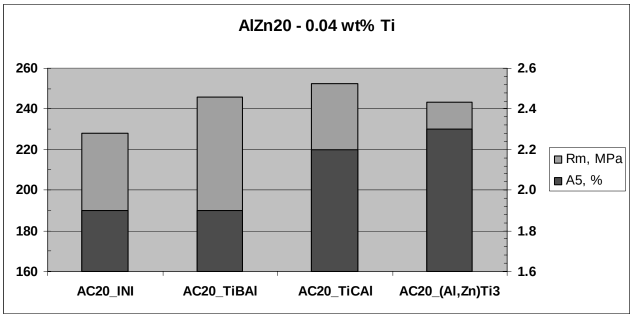

Fig. 6. Tensile strength and elongation of the examined alloy

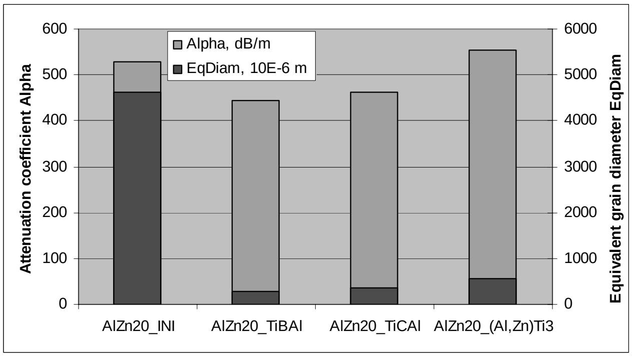

Fig. 7. Changes of attenuation coefficient vs. grain size of the examined alloy [19]

4. Conclusions

On the basis of the presented in the paper examinations the following conclusions can be formulated:

1. The used master alloys TiBAl, TiCAl and AlZn-Ti3 show good efficiency as the grain refiners of the examined sand-cast AlZn20 alloy – Fig. 5.
2. The AlZn-Ti3 master alloy has its density very close to the AlZn20 melt which allows to avoid difficulties connected with significant differencies in densities between inoculated melt and a refiner.
3. The refined α(Al) phase allows improving elongation while ultimate tensile strength and attenuation coefficient remain basically preserved – – Figs 6 - 7, which are advantages of the performed grain-refinement process.

Acknowledgements

The authors acknowledge The European Community for financial support under Marie Curie Transfer of Knowledge project No. MTKD-CT-2006-042468, entitled: Development of enironmentally friendly cast alloys and composites. One ot the authors, WKK, thanks Clare Hall Cambridge for accomodation and access to Internet when preparing the Euromat2009 presentation. The authors acknowledge the provision of laboratory facilities in the Department of Materials Science and Metallurgy - University of Cambridge, Chair of Foundry Research – University of Leoben and Austrian Foundry Institute.

References

[1] W. K. Krajewski, A. L. Greer, J. Buras, M. N. Mancheva, M. Zurakowski, Development of Environmentally Friendly Cast Alloys. High-Zinc Al Alloys. European Congress on Advanced Materials and Processes Euromat 2009. Glasgow 6-10 Sept. 2009. Symposium C11 (unpublished)

[2] W. K. Krajewski, J. Buras, M. Zurakowski, A. L. Greer, M. N. Mancheva, K. Haberl, P. Schumacher, Development of Environmentally Friendly Cast Alloys. High-Zinc Al Alloys (submitted to Fonderie in 2010)

[3] 39th Cenzus of World Foundry Production. Modern Casting, Dec. 2005

[4] 40th Cenzus of World Foundry Production. Modern Casting, Dec. 2006

[5] 41st Cenzus of World Foundry Production. Modern Casting, Dec .2007

[6] 42nd Cenzus of World Foundry Production. Modern Casting, Dec. 2008

[7] 43rd Cenzus of World Foundry Production. Modern Casting, Dec. 2009

[8] AMS Handbook, AMS International, 2003.

[9] A.E. Wol, Strojenije i swojstwa metalliczeskich sistem. Fizmatgiz, Moskwa, 1959.

[10] I.G. Ritchie, Z-L. Pan, High-damping metals and alloys. Metallurgical Transactions A, 22A (1991) pp. 607-616

[11] W. Krajewski, Archives of Metallurgy 44 (1999), pp. 51-61.

[12] W. Krajewski, DTA Examinations of the Solidification Course of Medium-Aluminium Zinc Alloys Modified with Ti. Metallurgy and Foundry Engineering **26** (2000), pp. 143-147

[13] W. K. Krajewski, A. L. Greer, T. E. Quested, W. Wolczynski, Solidification and Crystallization, ch. 16 (pp.137-149). Euromat 2003 papers. Viley-VCH, 2004, Ed. D.M. Herlach

[14] W. K. Krajewski, A. L. Greer, J. Buras, Grain Refinement of Al-Zn Alloys by Melt Inoculation with Zn-Ti Based Refiner. Euromat 2005, Prague, Czech Republic.

[15] W.K. Krajewski, A.L. Greer, J. Zych J, J. Buras, Effectiveness of Zn-Ti Based Refiner of Al and Zn Foundry Alloys. Proceedings of the 67th World Foundry Congress, Harrogate UK, 2006 (on CD)

[16] W. K. Krajewski, A. L. Greer, J. Zych, M. Zurakowski, Influence of Grain Refinement on Damping Properties of the Al-Zn Cast Alloys. Euromat 2007, Nuremberg, Germany

[17] W. K. Krajewski, J. Buras, M. Zurakowski, A. L. Greer, Structure and Properties of Grain-Refined Al - 20 wt% Zn Sand Cast Alloy. Archives of Metallurgy and Materials 54 (2009), pp. 329-334

[18] K. Haberl, Examination of the influence of various grain refiners on an AlZn20-alloy. Report 1, Marie Curie Host Fellowship, June 2009 (unpublished)

[19] K. Haberl, Examination of AlZn20 alloyed with various grain refiners. Report 2, Marie Curie Host Fellowship, July 2009 (unpublished)

[20] K. Haberl, W.K. Krajewski, P. Schumacher, Microstructural Features of the Grain-refined Sand Cast Alloy AlZn20. Archives of Metallurgy and Materials 55 (2010) Issue 3 (to be published)