ARCHIVES
of
FOUNDRY ENGINEERING
Published quarterly as the organ of the Foundry Commission of the Polish Academy of Sciences
ISSN (1897-3310)
Volume 9
Issue 2/2009
5-8
1/2

Registration of melting and crystallization process of MCMgLi8Ca5 alloy with use of ATND method

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Received 26.02.2009; accepted in revised form: 30.03.2009

Abstract

Among lightweight metal alloys, magnesium is the lightest structural material with density of 1.74 g/cm^3, having many attractive physical and mechanical properties combined with processing advantages. Therefore, it represents very attractive material for large amount of applications starting from automotive industry as the main user, up to other industry fields like sports, robotic electronics, armaments, and textile ones, or production of audio-video equipment. Furthermore, addition of lithium, that has density of 0,53 g/cm^3, reduces density of the resulting Mg-Li alloys to the same level as polymeric materials. On metallic matrix of magnesium alloys with lithium are also manufactured composites reinforced with e.g. ceramic fiber, which are used as a lightweight and resistant structure materials. Therefore, Mg-Li alloys become an alternative material assuring low density, improved ductility and corrosion resistance.
The paper presents an attempt of implementation of the ATND method to monitoring of crystallization process of MCMgLi8Ca5 alloys. Investigated magnesium alloys were produced in the Foundry Research Institute. Registration of melting and crystallization processes was made with use of the ATND method. Results of the preliminary tests are shown in a graphical form.

Keywords: Magnesium alloys, crystallization, Mg-Li alloy, ATND

1. Introduction

Contemporary requirements, which face machinery components and structures effect in necessity of searching after, and implementation of a new materials having significant effect on improvement of product's quality, minimization of its dimensions and mass, as well as assuring reliability in operational condition.

Magnesium alloys belong to the lightest metallic structural materials, and hence, are very attractive in such applications as automotive and aerospace industries, among others. They represent an excellent alternative for a lightweight constructions [1, 2].

Due to low density, high damping properties and good machinability magnesium alloys have gained increasing attention as environmental friendly material. Low weight is an essential factor for practical application of Mg alloys in transportation vehicles and portable IT products, whereas in view of safety - with respect to crashworthiness and comfortableness of such vehicles. High dumping capacity related to suppressing of unwanted noise, irregular vibrations and resulting structural instabilities are also very important [3].

Standards and other environmental legislation concerning environment protection cause that majority of car producers is going to use in future models 40-100 kg of magnesium alloys [4-6]. For instance, usage of 72 kg of magnesium alloys for components like engine block, four road wheel rims, gearbox housing, engine cradle and oil pan can reduce 48,5 kg in case of substituting for aluminum. In terms of CO_2 emission, it means that replacement of steel in this example will result in fuel saving of 0,25 l per 100 km, and in case of substituting for aluminum fuel saving will be about 0,1 l per 100 km [3]. Nowadays, vehicle body and drive system magnesium parts are already successfully used in Europe. Some examples are dash panels (Fiat, Audi), seat framing, tanks, filters, doors (Mercedes Benz), roof frames for convertible roofs (Porsche), steering wheels (Volkswagen), components of steering columns (Audi, Ford, Fiat), gearbox housings (Volkswagen, Audi), cylinder head covers, inlet systems (Mercedes Benz) [1, 7].

Components from magnesium alloy are usually produced in various casting processes. The most applicable methods are high-pressure die casting and gravity casting, particularly sand and permanent mould casting. Other implemented production technologies are: Squeeze Casting, Thixocasting and Thixomolding [8-10].

Magnesium with purities exceeding 99.8% is readily available commercially, but it is rarely used for engineering applications without being alloyed with other metals [11].

The Mg-Li alloys are the ultra-lightweight constructional metallic materials having density of 1.35-1.65 g/cm^{-3}, that is 1.5-2.0 times less than that of aluminum alloys. Such values of density mean they are similar to constructional plastic density [12]. The resulting Mg–Li alloys are therefore among the lightest possible metallic alloys [13, 14].

The second principal advantage of the Mg-Li alloys is the fact that they feature high ductility. It is caused by the isotropic body-centered cubic (bcc) lattice, instead of hardly deformed at ambient temperatures and anisotropy hexagonal close-packed (hcp) lattice of traditional magnesium alloys [6, 12].

The Mg-Li alloys were first produced in 1960s by NASA for utilization in aerospace fields [2]. Several parts on Apollo aerospace plane are also made from LA141 alloy [15, 16].

The magnesium-lithium alloys are interesting both from theoretical and technical aspect. From the equilibrium diagram (Fig 1.), it can be seen that magnesium-lithium alloys exhibit two phase structures, the (hcp) up to 5 wt.% Li and (bcc) above 11 wt.% Li. Between 5 and 11 wt% the Li alloys are composed of two phases [17, 18]. The phases exhibit a moderate strength and low formability, the phase has better ductility, but lower creep resistance. The two phase structure exhibits an interesting compromise of their properties because the both phases combine the moderate strength of the first phase and excellent ductility of the second phase [18].

On metallic matrix of magnesium alloys with lithium are produced also a composites reinforced with e.g. ceramic fibre, which find more and more wide implementation as a lightweight and robust structural materials [13, 9, 20].

Alloy additions which increase their resistance for higher temperatures and improve their plastic properties and resistance for oxidation are: beryllium, calcium, cerium, cadmium, titanium, whereas iron, silicon and nickel reduce mechanical properties of the alloys and their corrosion resistance.

The lithium effects advantageously on deformability of magnesium alloys due to substitution of undeformable hexagonal lattice with regular lattice, what simultaneously effects in reduction of mechanical properties (due to appearance of β phase). Optimal combination of the properties is present in range of diphase $\alpha+\beta$ alloys with contents above 10 wt.% of lithium. Alloys from that range of Li contents in cast condition have elongation of about 60% [21].

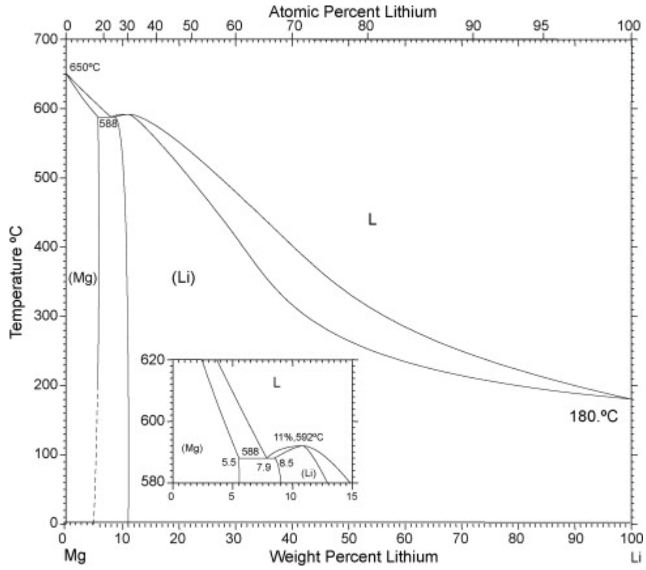

Fig. 1. Mg-Li phase system [19]

Obtaining the best material structure for specific requirements becomes possible with making use of theories on crystallization to control technological processes [22, 23]. Registration of a phenomena arisen in result of solidification process of alloys in order to determine their properties is enabled by a methods based on analysis of temperature changes run (thermal methods - ATD), of electric conductivity (electric methods - AED) and the method of the Thermal-Voltage Derivative Analysis (ATND) [24, 25].

2. Methodology of the research

In course of the tests one used the MgLi8Ca5 (8,2% Li, 4,7% Ca) alloy. Investigated alloy was produced from pure constituents and cast on experimental stand serving to melting and pouring of ultra-lightweight alloys, which is located in Krakow Foundry Research Institute [24]. Microscopy testing with use of the Olympus GX71 microscope was also performed in the Foundry Research Institute.

Suitably prepared specimens of the alloy we melted in tubular silit furnace with CO_2 protective atmosphere.

In course of melting and crystallization of the alloys there occurred permanent, simultaneous registration of specimen's temperature and potential's difference on measuring probes. The testing stand comprised, except the silit furnace, two millivoltmeters and PC computer with software [25]. The ATND (thermal-voltage- derivative analysis) used in course of the testing consists in permanent measurement of the temperature and electric voltage generated on probes during crystallization and phase transformations of solidified alloy. In course of the measurement there were measured generated voltage and temperature of the specimen. Run of the crystallization is shown in form of diagram created during solidification of the alloy.

3. Description of achieved results of own researches

In the Fig. 2 is shown a structure of the investigated alloy observed on the microscope.

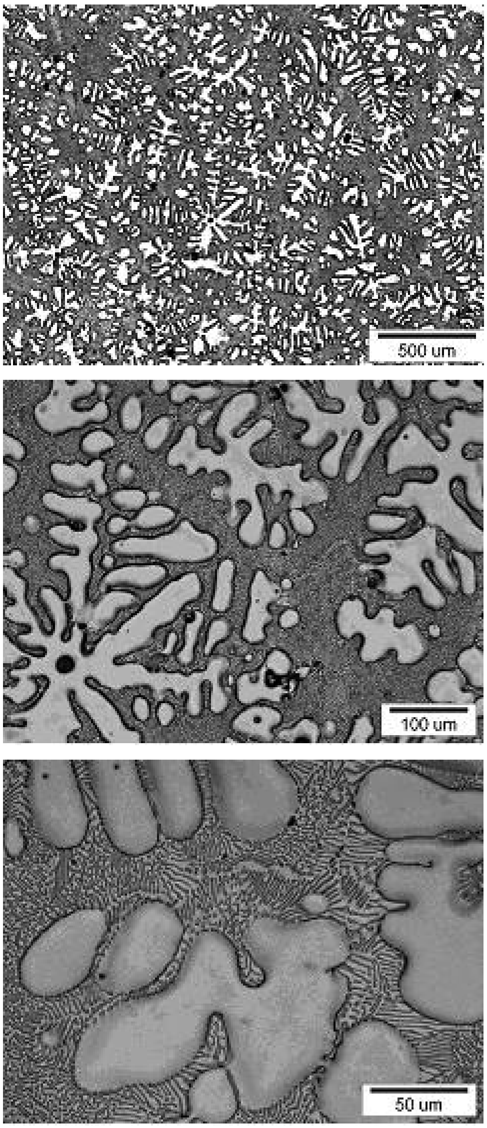

Fig. 2. Structure of the MCMgLi8Ca5 alloy

In structure of the investigated alloy are present two structural constituents: solid solution of magnesium with lithium (β phase) and eutectic mixture ($CaMg_2$ phase and Mg) .

In the Fig. 3 is shown a course of heating (melting) process of the investigated alloy.

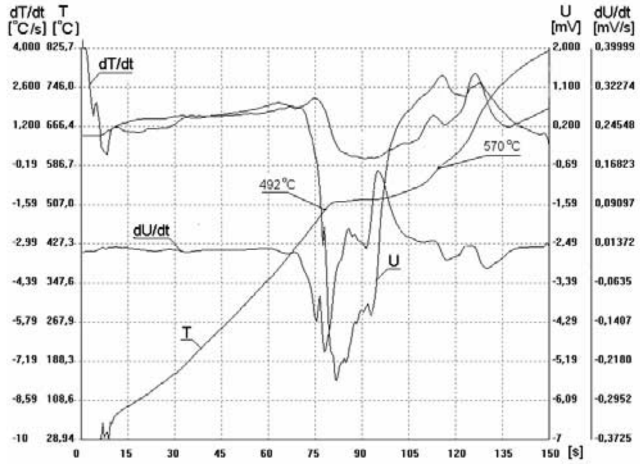

Fig. 3. Curves of the ATND method showing heating (melting) of the MCMgLi8Ca5 alloy

In the Fig. 4 is shown a run of crystallization of the investigated alloy.

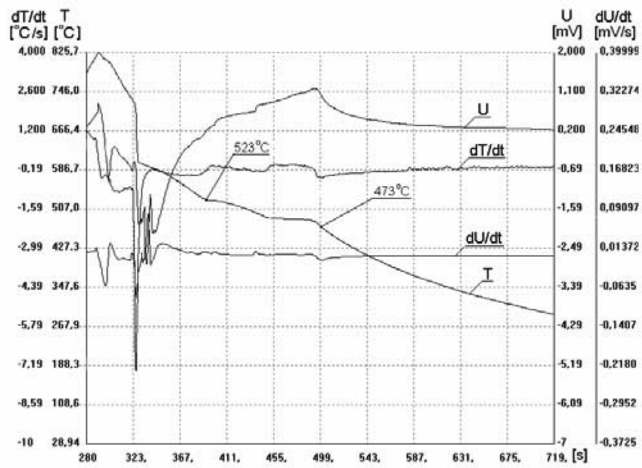

Fig. 4. Curves of the ATND method showing crystallization of the MCMgLi8Ca5 alloy

From the diagrams (Fig. 3, 4) one has read temperature of beginning of the melting, which amounted to 492°C and final temperature of the melting amounted to 570°C, as well as temperature of beginning of crystallization of the alloy (523°C) and temperature of completion of the crystallization (473°C).

4. Conclusions

Preliminary testing has confirmed feasibility of implementation of the ATND method (Thermal-Voltage-Derivative Analysis) to registration of crystallization of ultra-lightweight Mg-Li alloys.

In the ATND method, thermal and voltage curves show at physical-chemical phenomena occurring during melting and crystallization of the alloy.

On base of the obtained diagrams (Fig. 3, 4) one has determined temperatures of melting and crystallization of the MCMgLi8Ca5 alloy.

References

[1] H. Haferkamp, M. Niemeyer, R. Boehm, U. Holzkamp, C. Jaschik, V. Kaese, Alloy Development, Processing and Applications in Magnesium Lithium Alloys, Material Material Transaction, vol. 42, No. 7 (2001) 1160-1166

[2] G. J. Shen, B. J. Duggan, Metal Trans A 38 (2007), p. 2593

[3] Joong-Hwan Jun, Ki-Duk Seong, Jeong-Min Kim, Ki-Tae Kim and Woon-Jae Jung, Influence of Microstructural Change on Damping Capacity of Mg-X%Li Alloys, Material Science Forum, vol. 539-543 (2007) 1764-1768

[4] Aghion, B. Bronfin, D. Eliezer, The role of the magnesium industry in protecting the environment, Journal of Materials Processing Technology 117 (2001) 381-385

[5] D Hartman,in: Magnesium into the Next Millenium, International Magnesium Association, Rome, Italy, 1999, p.21

[6] S. Schumann, F.Friedrich, B. Mordike, K.Kainer, Material Alloys and their Applications, Werkstoff-Informationsgesellschaft mgH, Wolfsburg, Germany, 1998, p.3

[7] L. A. Dobrzański, T. Tański, L. Cizek, Microstructure of MCMgAl12Zn1 magnesium alloys, Archives of Foundry Engineering, vol. 7, Iss. 1 (2007) 179-182

[8] E. Aghion, B. Bronfin, Magnesium Alloys Development towards the 21st Century, Material Science Forum, vol. 350-351, Trans Tech Publications, Switzerland 2000, 19-30

[9] A. Rudajevová, P. Luká˘c, S. Kúdela, Influence of Li content on thermal strains in MgLi-Saffil fibre composites, Journal of Alloys and Compounds 378 (2004) 172–175

[10] K. U. Kainer, T. U. Benzler, Squeeze-Casting and Thixo-Casting of magnesium Alloys, Magnesium – Alloys and technology (2004) 56-71

[11] I.J. Polmear, Light Alloys (Fourth Edition) From Traditional Alloys to Nanocrystals, Elsevier Ltd. (2005) 237-297

[12] F. M. Elkin, V. G. Davydov, Russian Ultralight Constructional Mg-Li Alloys. Their Structure, Properties, Manufacturing, Applications, Magnesium: Proceedings of the 6th International Conference Magnesium Alloys and Their Applications (2005) 94-99

[13] W.A. Counts, M. Fria´k, D. Raabe, J. Neugebauer, Using ab initio calculations in designing bcc Mg–Li alloys for ultra-lightweight applications, Acta Materialia 57 (2009) 69-76

[14] R. K. Singh, Ductility troughs in Mg-Li alloys, Journal of Materials Science Letters 13 (1994) 744-745

[15] H. Haferkamp, M. Niemeyer, R. Boehm, U. Holzkkamp, C. Jaschik, V. Kaese, Development, processing and applications range of magnesium lithium alloys, Journal Materials Science Forum (2000), vol. 350/351,.31−42

[16] P. Crawford, R. Barrosa, J. Mendez, J. Foyos, O. Es-Said, On the transformation characteristics of LA141A(Mg-Li-Al) Alloy, Journal of Materials Processing Technology (1996), vol. 56, 108−118

[17] Zhang Mi-lin, Wu Rui-zhi, Wang Tao, Liu Bin, Niu Zhong-yi, Microstructure and mechanical properties of Mg-*x*Li-3Al-1Ce alloys, Transaction of Nonferrous Metal Society of China 17 (2007), 381-384

[18] A. Rudajevová, P. Lukáč, S. Kúdela Thermal Properties of Mg-Li and Mg-Li-Al Alloys, Magnesium: Proceedings of the 6th International Conference Magnesium Alloys and Their Applications (2004), 106-109

[19] T.B. Massalski, J.L. Murray, L.H. Benett and H. Baker, Binary Alloy Phase Diagrams, American Society for Metals (1990)

[20] S. Kudela Magnesium-lithium matrix composites an overview, International Journal of Materials and Product Technology, Vol. 18, No 1-2 (2003) 91-115

[21] A. Bialobrzeski, K. Hubner, K. Saja, Ultralight magnesium-lithium alloys, Archives of Foundry Engineering, vol. 7, Iss. 2/3 (2007) 11-16

[22] J. Pezda, Identification of AG10 alloy's mechanical properties on base of ATND method, Archives of Foundry Engineerring vol. 7, Iss. 1 (2007) 135-138

[23] J. Pezda, Determination of impact strengh of AK9 silumin on base of ATND method, Archives of Foundry vol. 8, Special Iss. 1 (2008) 269-272

[24] A. Białobrzeski, K. Saja, K. Hubner, Ultralight Magnesium-Lithium Alloys, Archives of Foundry Engineering Vol. 7, Issue 3/2007 11-16

[25] A. Białobrzeski, J. Pezda, T. Ciućka, Registration of crystallization process of ultra-lightweight Mg-Li alloys with use of ATND method, Archives of Foundry Engineering, vol.7, Iss.3 (2007) 17-20