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The Influence of Home Scrap on Porosity of MgAl9Zn1 Alloy Pressure Castings

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Abstract

The work presents the results of examinations concerning the influence of various amounts of home scrap additions on the porosity of castings made of MgAl9Zn1 alloy. The fraction of home scrap in the metal charge ranged from 0 to 100%. Castings were pressure cast by means of the hot-chamber pressure die casting machine under the industrial conditions in one of the domestic foundries. Additionally, for the purpose of comparison, the porosity of specimens cut out directly of the MgAl9Zn1 ingot alloy was also determined. The examinations consisted in the qualitative assessment of porosity by means of the optical microscopy and its quantitative determination by the method of weighting specimens in air and in water. It was found during the examination that the porosity of castings decreases with an increase in the home scrap fraction in the metal charge. The qualitative examinations confirmed the beneficial influence of the increased home scrap fraction on the porosity of castings. It was concluded that the reusing of home scrap in a foundry can be a good way of reduction of costs related to the production of pressure castings.

Keywords: Innovative foundry technologies and materials, Automation and robotics in foundry, Environmental protection, Porosity, Magnesium alloys

1. Introduction

Magnesium cast alloys are more and more willingly used by engineers designing machines and other industrial devices, as well as home appliances. It is due to many advantageous properties of the material, e.g. its high strength at the relatively low density. Nowadays three types of magnesium alloys are preferably used in high pressure die casting (HPDC) technology [1-4]. They are magnesium-aluminium-zinc (AZ), magnesium-aluminium-manganese (AM), or magnesium-aluminium-silicon (AS) alloys [5,6]. Diversity of applications of magnesium and its alloys demands for multi-directional improvement of their properties, therefore the new types of alloys are developed, being diversified as to chemical composition, microstructure, hardness, creep resistance, tensile strength, plastic behaviour, corrosion resistance etc. [7].

The most popular alloy for high pressure die casting is MgAl9Zn1 alloy. It is characterised by excellent mechanical and casting properties, and particularly very good castability. This alloy is applied e.g. in production of cases of portable computers and mobile phones, camera bodies, etc. [2-4,8] The alloys of AM50A (MgAl5Mn) and AM60B (MgAl6Mn) series exhibit better plasticity and impact energy absorbing capacity. They have also good casting properties. The AM-type alloys are used for elements which require increased plastic properties and should be impact-resistant or would be subjected to the dynamic load. These alloys are extremely important for the automotive industry. The AM20 alloy is intended for casting with increased plastic properties, however its casting properties are not very high [8,9]. The silicon-containing alloys such as AS21 or AS41B are characterised by significantly better creep resistance than the alloys of AZ or AM series. This is caused by the presence of rare earth elements in their chemical composition. On the other hand, these elements deteriorate to a certain extent their casting properties [10].

Magnesium pressure castings are characterised by good cavity reproduction and high surface smoothness. Their most common defect is, like in other pressure castings, their internal porosity. However, this phenomenon is caused by the specific nature of the HPDC technology, and not by the alloy properties themselves. The value of specific heat and latent heat of crystallization for magnesium and its alloys is lower than for aluminium and its alloys, i.e. magnesium castings solidify in shorter time than their aluminium equivalents. Therefore, some problems can arise while producing the thin-wall castings or the large-surface ones [11]. To avoid these, the higher velocities are applied in the HPDC process with respect to magnesium castings. On the other hand, if either the rate of cavity filling or the temperature of metal and the die is too high, excessive blowholes can occur in castings. The die cavity filling process in HPDC technology is of strongly turbulent character, so that gases present in the die cavity or injection system are being entrapped in castings in the form of blowholes. Modern HPDC machines are equipped with multipliers also called cylinder intensifiers which increase the cavity pressure even by several times within miliseconds from the end of filling to exert high hydraulic pressure on the solidifying metal, thus reducing the volume of blowholes and gas porosity [12, 13].

Magnesium recycling covers not only the reuse of machine elements and appliance parts made of this material, but also the reuse of scrap generated in the production process (trial injections, gating systems, overflows, and also the dross arising at the surface of the molten metal). It often happens that these materials are intensely contaminated with grease, oil or refrigerants, and their surfaces are oxidised to varying degrees. In such cases, specialised companies are to be engaged for the recycling process. But it also frequently happens that foundries produce scrap in less contaminated form . Its recycling in a foundry could be a good way of reducing costs of production of magnesium castings. Unfortunately, this solution is not popular in foundries. They rather sell the scrap to the recycling companies and in that place get ingots of certainly good quality, but of respectively high price [14,15].

2. Methods of investigation

The purpose of the work was to investigate the influence of the home scrap fraction in the metal charge on the porosity of castings made of AZ91 alloy by the high pressure die casting method using the hot chamber die casting machine. The re-using of home scrap from the same foundry is an important example of recycling, which is significant from the technological point of view. It should be also considered in respect of the quality of castings, the productivity, and the production economy. The fact that the work discusses the AZ91 alloy, the most popular one in pressure casting, is of particular economic importance. Five series of handle castings were produced by HPDC method under the industrial conditions to determine the relationship between porosity and home scrap percentage in the charge. Each charge was composed of AZ91 alloy, but the series differed in proportion between the ingot metal and the home scrap metal as follows: A1 charge consisted of 100% re-melted ingot alloy but after one re-melting cycles, A2 charge was prepared of 70% ingot alloy and 30% home scrap, A3 was 50% ingot alloy and 50% home scrap, A4 – 30% ingot alloy and 70% home scrap, A5 consisted of 100% home scrap. The home scrap added to all of the prepared charges was of the same chemical composition, taken after a single re-melting cycle. For the purpose of comparison, castings were produced also of 100% AZ91 home scrap after five re-melting cycles (A6), and specimens were taken directly from the AZ91 ingot alloy (A0 series).

The metal injection temperature (mould filling temperature) was equal to 630°C and was constant for all examined series of castings. The liquid metal surface was kept under the protective gas mixture (0.5% SO_2 + 99.5% dry air). The casting process parameters were set as follows: plunger velocity during the 1st stage of injection V_1 = 0.15 m/s, plunger velocity during the 2nd stage of injection V_2 = 2.5 m/s, the intensification pressure holding time t_{dop} = 1.5 s.

Porosity was determined qualitatively by optical microscopy and quantitatively by weighting in air and in water. The porosity assessment was done according to the BN-75/4051-10 standard. The examinations were performed for 20 trimmed handle castings of each series, the specimens being randomly selected from the whole population of the respective series. All specimens were weighted in air and in water, and their densities were determined from the relationship:

$$\rho_P = \frac{m_1}{m_1 - m_2} \cdot \rho_W \qquad (1)$$

where: ρ_P – specimen density, m_1 – specimen weight in air; m_2 - specimen weight in water; ρ_W – water density.
Next the porosity values for the examined specimens were calculated from the formula:

$$P = (1 - LG) \cdot 100\% \qquad (2)$$

where: $LG = \rho_P/\rho_{WZ}$; ρ_{WZ} – true (absolute) density, for AZ91 alloy equal to 1810 kg/m^3.

3. Results of investigation

Photographs of porosity occurring in the examined castings taken during microscopic observations are shown in Figs. 1-6. Fig. 1 presents the microstructure of a specimen cut out of the AZ91 alloy ingot. This specimen is characterised, as expected, by the lowest porosity. The castings coming from A1 and A2 series exhibited much larger porosity, but as the home scrap content in the charge increased, porosity definitely decreased.

The results of porosity examinations are presented in Table 1 and graphically in Fig. 7.

The presented results of examination of porosity indicate the decreasing number and volume of pores accompanying the growing fraction of home scrap in the metal charge. The visible voids of irregular shape arranged in the intercrystalline spaces can be the shrinkage defects or gas blowholes deformed while applying pressure to a casting in the semi-solid state. Further exploration should be carried out in order to determine definitively the type of porosity, but gas porosity should be considered as the most probable one. The significant reduction of porosity with an increase in home scrap percentage can be explained by the possible rise of liquid metal viscosity due to the greater amount of fine solid particles. The process can be considered as metal suspension casting. Such an operation proceeds at the lower cavity filling rate, which is beneficial with respect to the possibility of air removal from within the die cavity and contributes to the reduced porosity.

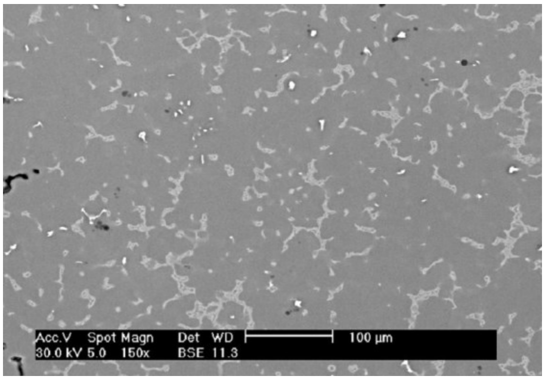

Fig. 1. Shrinkage and gas porosity in AZ91 alloy castings (A0 series)

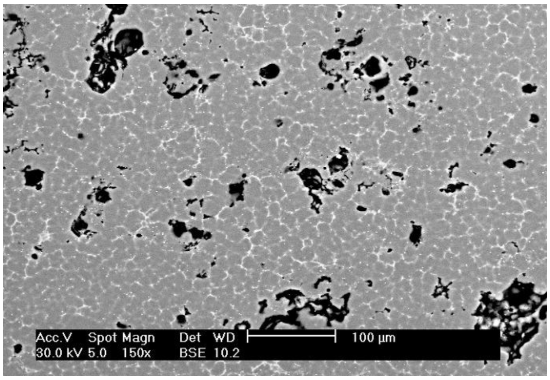

Fig. 2. Shrinkage and gas porosity in AZ91 alloy castings (A1 series)

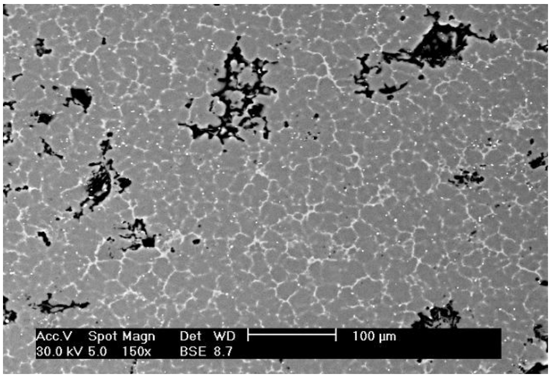

Fig. 3. Shrinkage and gas porosity in AZ91 alloy castings (A2 series)

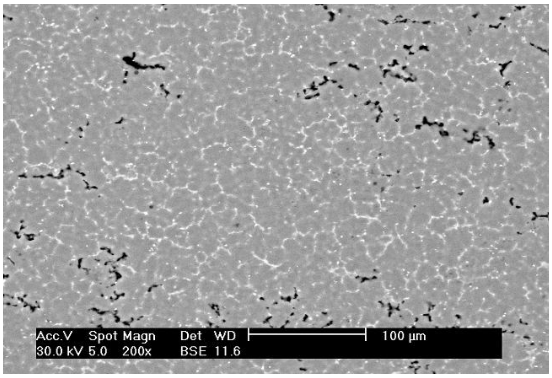

Fig. 4. Shrinkage and gas porosity in AZ91 alloy castings (A3 series)

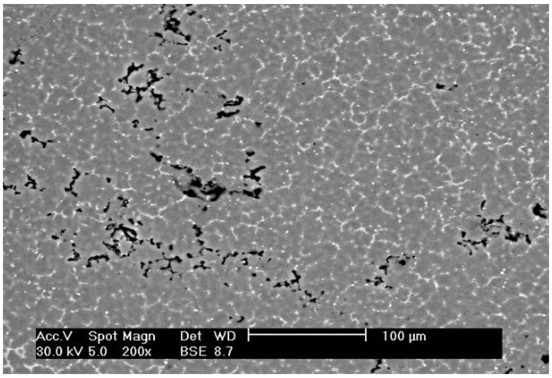

Fig. 5. Shrinkage and gas porosity in AZ91 alloy castings (A4 series)

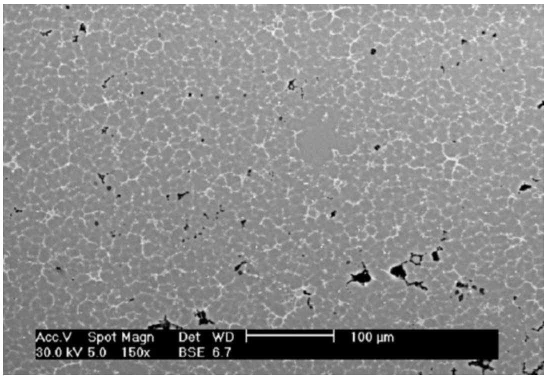

Fig. 6. Shrinkage and gas porosity in AZ91 alloy castings (A5 series)

Table 1
The results of porosity examinations

Specimen series	Specimen density kg/m^3	Standard deviation S_ρ kg/m^3	LG (ρ_P/ρ_{WZ}) –	Porosity %
A0	1747.74	149.19	0.9656	3.44
A1	1732.35	124.88	0.9571	4.29
A2	1734.34	117.45	0.9582	4.18
A3	1736.51	114.58	0.9594	3.76
A4	1753.71	122.31	0.9689	3.11
A5	1755.16	144.76	0.9697	3.03
A6	1740.86	211.04	0.9618	3.82

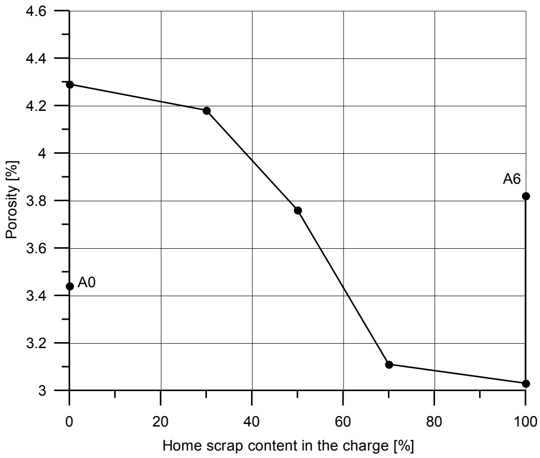

Fig. 7. The influence of home scrap content in the metal charge on porosity of AZ91 alloy castings

4. Conclusion

Magnesium recycling in the foundry is a good way to reduce costs of production of magnesium castings. This solution, however, demands both for preparation of storage space (storage rooms), containers, and for arrangement of suitable transport. The recycling of home scrap can include re-melting and production of ingots of suitable chemical composition, or re-melting in the melting furnace and transferring the molten magnesium to the casting furnace of the pressure die casting machine, or else direct re-melting in the casting furnace of the machine (the closed circuit). The last solution demands for only small alterations with respect to the standard production process.

The examinations revealed a decrease in porosity with an increase of home scrap fraction in the metal charge. It can be explained by two probable mechanisms. One is the strong correlation to the refinement of structure and the tendency to simultaneous crystallization, which creates beneficial conditions for occurrence of tiny and dispersed (i.e. advantageous) shrinkage porosity. The second mechanism is related to the die cavity filling. Increased fraction of home scrap in metal charge results in the greater amount of the solid particles (oxide fraction) in the melt, and leads in turn to the generation of suspension of solid particles in metal, which exhibits obviously greater viscosity than the liquid metal itself. This brings about the reduction in die filling rate and facilitates the gas escape from the die cavity. Therefore, the decrease in gas porosity is observed.

References

[1] Cashion, S.P., Ricketts, N.J. (2001). The Metallurgical Society of CIM. Replacing SF6 with the hydrofluorocarbon gas HFC-134a for magnesium melt protection. The Conference of Metallurgists. Toronto. Canada.

[2] ASM handbook (1994). ASM international. Third printing. vol.15 Casting.

[3] PN-EN 1753. (2001). *Magnesium and magnesium alloys - Magnesium alloy ingots and castings*. Ed. Polish Committee for Standardization. (in Polish).

[4] Eliezer, A., Abramov, E., Gutman, E.M. (1997). Mechano-chemical behavior and plasticity of Mg-Al alloys. In Magnesium 97. Dead Sea, Israel. (pp. 192-201).

[5] Avedesian, M.M., Baker, H. (1999). Magnesium and Magnesium Alloys. ASM International.

[6] Dobrzański, L.A. (1998). *Physical Metallurgy*. Warsaw: Ed. WNT. (in Polish).

[7] Dahle A.K., StJohn D.N. (1999) The Origin of Banded Defects in High Pressure Die Cast Magnesium Alloys. In Proceedings of 20th International Die Casting Congress, World of Die Casting. Cleveland T99-062.

[8] Oniszczuk, A., Rzadkosz, S. (2005). Analysis of quality of magnesium alloy castings. In 19th Scientific Conference of the Faculty of Foundry Engineering of AGH UST, November 2005 (pp.193-198). Cracow. (in Polish).

[9] Street, A.C. (1986). *The die casting book*. (Second edition). Redhill: Portcullis Press.

[10] Fitze, R. (2003). Improve the competitiveness of magnesium die casting by inline recycling of ten runner system. In 11th Magnesium Automotive and End User Seminar, 25-26 September 2003, Aalen.

[11] Kainer, K.U. (2000). Magnesium Alloys and their Application. In Sb. Int. Congress Magnesium Alloys and their Application. Mnichov. (pp. 534-608).

[12] Moscovitch, N., Gertsberg, G., Nagar, N., Gur, D., Bronfin, B., Aghion, E. (2000). The use of die casting technology in the process of developing new magnesium alloys. 9th Magnesium and User Seminar. Aallen. Germany.

[13] Sannes, S., Gjestland, H., Westengen, H., Laukli, H.I. (2003). Magnesium alloys and applic. DGM, Wolfsburg. Germany. 725-731.

[14] Chojnacki, A., Konopka, Z. (2010). Casting of the AZ91 alloy below atmospheric pressure. In 11th International Scientific Conference 'New technologies and achievements in metallurgy and material science', 20-21 May 2010 (pp. 563-566). Częstochowa: Ed. WIPMiFS. (in Polish).

[15] Konopka, Z. & Chojnacki, A. (2011). Structure of the AZ91 alloy pressure castings fabricated of home-scrap containing charge. *Archives of Foundry Engineering*. 11(2), 61-64.