

The Influence of Home Scrap on Mechanical Properties of MgAl9Zn1 Alloy Castings

Z. Konopka *, A.C. Chojnacki, M. Lagiewka, A. Zyska

Department of Foundry, Czestochowa University of technology
Al. Armii Krajowej 19, 42-200 Czestochowa, Poland

* Corresponding author. E-mail address: konopka@wip.pcz.pl

Received 27.06.2016; accepted in revised form 03.11.2016

Abstract

The work presents the results of examinations concerning the influence of various amounts of home scrap additions on the properties 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. The examinations consisted in the determination of the following properties: tensile strength R_m , yield strength $R_{p0.2}$, and the unit elongation A_5 , all being measured during the static tensile test. Also the hardness measurements were taken by the Brinell method. It was found that the mechanical properties (mainly the strength properties) are being improved up to the home scrap fraction of 50%. Their values were increased by about 30% over this range. Further rise in the home scrap content, however, brought a definite decrease in these properties. The unit elongation A_5 exhibited continual decrease with an increase in the home scrap fraction in the metal charge. A large growth of hardness was noticed for the home scrap fraction increasing up to the value of 50%. Further increasing the home scrap percentage, however, did not result in a significant rise of the hardness value any more.

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

1. Introduction

Magnesium cast alloys become more and more popular as a structural material, first of all due to their advantageous functional properties combined with their low density. Magnesium alloys exhibit good casting properties, high corrosion resistance, and high mechanical properties even at the increased temperature values [1-5]. The largest group of magnesium castings comprises castings for the automotive industry, such as steering columns, gearboxes, car seat frames. A great deal of them is used also in electronics: cases of portable computers and mobile phones, camera and telescope bodies, etc. Magnesium alloys are used wherever the reduction of weight of a product with

simultaneous maintaining high strength properties is a crucial factor [3,6].

An increasing production of non-ferrous castings results in the necessary recirculation of many materials, mainly metals. Thus home scrap recycling becomes one of basic tasks in contemporary foundries [7].

The most popular material applied in pressure die casting is MgAl9Zn1 alloy. It is characterised by excellent mechanical and casting properties, and most of all, it exhibits very good castability [8,9]. The ever-increasing requirements concerning the quality of castings force the development of new, advanced magnesium alloys. They should have better properties, and first of all they should maintain good creep strength at increased temperature values [4,5]. The treatment applied to improve properties of cast alloys significantly increases costs of production

by the high pressure die casting process [10,11]. If the newly developed alloys are both to meet the above mentioned demands and to be price-competitive as compared with the magnesium alloys already present on the market, the basic alloying elements such as Al or Zn should be at least partially replaced with elements which would improve the required parameters, i.e. with Mn, Si, Ca [12,13].

Nowadays more attention is paid to the utilisation of the produced items while their service life is over. The fact that magnesium to the larger and larger extent replaces plastic elements is beneficial with respect to the recycling of the applied material, because magnesium is much easier recyclable than plastics. All magnesium products can be recycled, therefore magnesium can be counted as the environment-friendly material, so that both the manufacturers and the customers should not be afraid of problems with respect to the utilization of these products, so useful in everyday life [7, 8, 14-16].

2. Methods of investigation

The purpose of the work was to examine the influence of the home scrap content in metal charge on the properties of castings made of MgAl9Zn1 alloy produced by high pressure die casting (HPDC) method. Five series of specimens, each of a melt produced of a charge containing a different fraction of metal scrap, were cast under the industrial conditions (A1-A5 series). Additionally, for the purpose of comparison, there were produced castings of the melt prepared solely of MgAl9Zn1 home scrap after five remelting cycles (A6 series), and some specimens were cut out of the MgAl9Zn1 ingots without remelting or casting (A0 series). All castings (A1-A6 series) were produced by means of the hot-chamber pressure die casting machine. The home scrap added to all of the prepared charges was of the same chemical composition, taken after a single re-melting cycle. The detailed data for each series of specimens are presented in Table 1.

Table 1. Material proportion and the way of specimen preparation

Series designation	Components, mass %		Manner of specimen preparation
	Ingots	Home scrap	
A0	100	0	Material being cut out of ingots without remelting
A1	100	0	Charge melting and casting according to the procedure
A2	70	30	Charge melting and casting according to the procedure
A3	50	50	Charge melting and casting according to the procedure
A4	30	70	Charge melting and casting according to the procedure
A5	0	100	Charge melting and casting according to the procedure
A6	0	100	Multiple remelting and casting

A four-cavity die was prepared to cast tensile test specimens in order to examine mechanical properties of each type of the alloy. The casting process was performed by means of HPDC machine of clamping force equal to 300 metric tons. The metal injection temperature was 630°C and was constant for all the examined melts. The charge was melted in the resistance furnace of 100 kW power rating. The liquid metal surface was protected with gas mixture consisting of SO₂ and dry air in proportion of 0.5% SO₂ + 99.5% dry air. The casting process parameters were set as follows: plunger velocity during the 1st stage of injection V₁ = 0.15 m/s, plunger velocity during the 2nd stage of injection V₂ = 2.5 m/s.

Microstructural examinations of selected castings from each of the series were done and then mechanical properties were tested on 100 tensile test specimens randomly selected from the total number of 2000 castings obtained from each of the melts. The tests were performed according to the standard in effect, i.e. PN-EN-10002-1:2002 by means of ZWICK 1488 universal testing machine. The performed tensile tests allow for determining the tensile strength R_m, the yield strength R_{p0.2}, and the unit elongation A. Hardness of castings was measured by Brinell method. A steel ball of 10 mm diameter was used for indentation, being pushed with a force of 1000 N for 30 seconds.

3. Results of investigation

The basic mechanical properties of pressure castings from individual melts are presented in Table 2. The given values are averages of 100 measured values, and the standard deviation S for each average value is calculated. The results presented in Table 2 are also shown in graphic form in Figs. 1-4 beneath.

Table 2. Measurement results with respect to mechanical properties of castings

Series designation	R _m MPa	S _{Rm} MPa	R _{p0.2} MPa	S _{Rp0.2} MPa	A [%]	S _A [%]	HB	S _{HB}
A0	180	9.3	110	7.6	3.52	0.29	65	5.9
A1	214	11.8	122	9.6	3.21	0.25	68	5.1
A2	245	18.8	151	15.0	2.74	0.33	73	6.1
A3	251	21.1	163	17.7	2.38	0.27	81	7.4
A4	238	22.0	135	16.9	2.19	0.26	84	9.3
A5	212	26.4	115	14.2	2.07	0.22	87	10.9
A6	210	24.7	107	16.6	1.75	0.24	97	12.1

The obtained results show that the tensile strength and the yield strength grow considerably while the home scrap content in the charge is increased up to the level of about 50%. The tensile strength rises by about 20% (from 214 MPa for castings made of pure ingot alloy to 251 MPa for castings prepared of the charge containing 50% of home scrap, see Fig. 1). Further increasing of the home scrap percentage in the charge results in the decrease of the tensile strength to the value of 210 MPa, i.e. this achieved in castings without home scrap addition.

The change in the yield strength due to the change in the home scrap content in the charge is of similar character. The maximum increase of 30% is observed at the 50% home scrap content in the charge (Fig. 2). Larger fractions of home scrap in the charge result in the distinct drop of the yield strength value.

In turn, the standard deviation values calculated for the above discussed properties indicate that their uniformity diminishes with the growing content of home scrap in the charge.

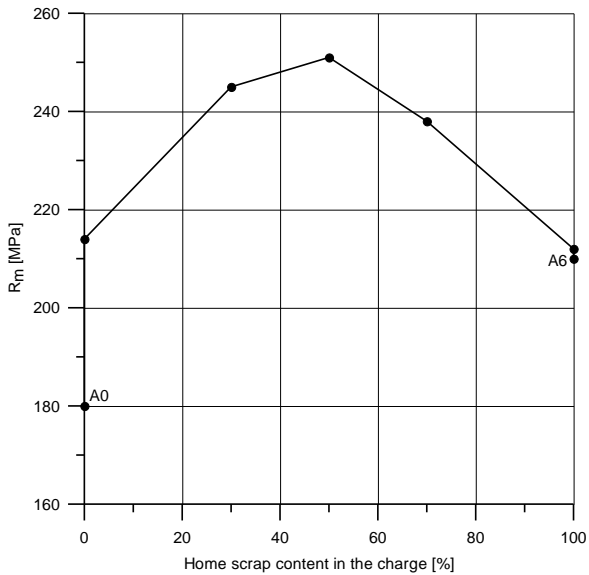


Fig. 1. The influence of the home scrap content in the charge on the tensile strength of MgAl9Zn1 alloy castings

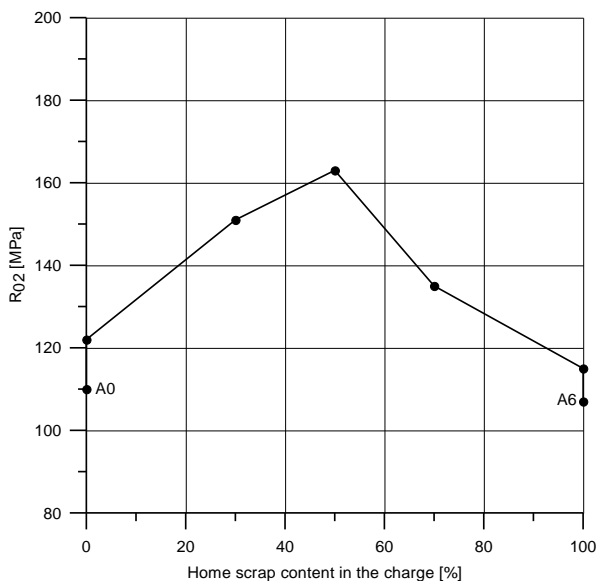


Fig. 2. The influence of the home scrap content in the charge on the yield strength of MgAl9Zn1 alloy castings

The results of unit elongation (A) measurements concerning the examined castings reveal the continual drop in its value with an increase in the content of home scrap in the charge (Fig. 3),

however the values retain their rather uniform distribution over the population of specimens (see standard deviation values in Table 2).

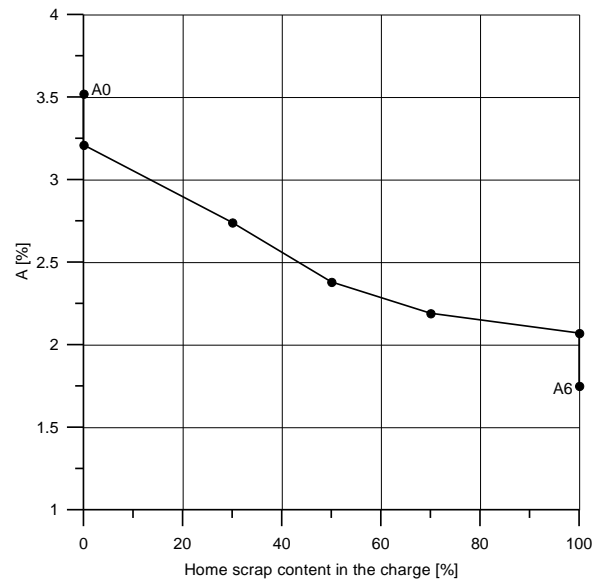


Fig. 3. The influence of the home scrap content in the charge on the unit elongation of MgAl9Zn1 alloy castings

The representative course of change in hardness versus the home scrap content in the charge is illustrated in Fig. 4. The relatively large increase in hardness (about 30%) occurs when the home scrap percentage approaches 50%. Further increase in home scrap fraction does not rise the hardness value to a notable degree.

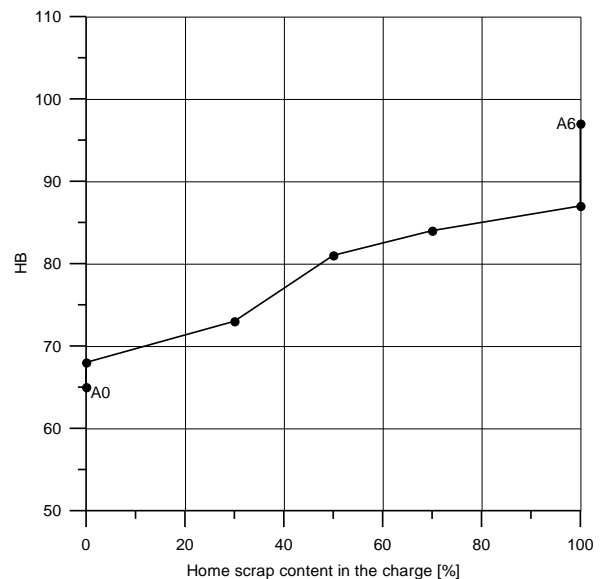


Fig. 4. The influence of the home scrap content in the charge on the hardness of MgAl9Zn1 alloy castings

4. Conclusion

An increasing share of magnesium alloys in the world foundry market is caused by their excellent properties. Good castability, low shrinkage, low density, high dimensional stability, and high damping capacity along with high strength make engineers replace other previously used materials with magnesium. The next important feature of magnesium alloys is the ease of their recycling, what is also the advantage of their industrial application. It is related to the environmental protection and can bring savings in material costs by using the scrap metal.

The results of examinations show distinctly the strong influence of home scrap percentage in the charge on the mechanical properties of castings.

The values of the examined properties considered as functions of home scrap content in the charge of furnaces of pressure die casting machines exhibit a specific course. It can be generally stated that the strength properties significantly improve up to the home scrap content of 50%. An increase even by about 30% is observed. Further rise of home scrap content in the charge results in the distinct decrease of these properties. The quantity of 50% home scrap in the charge can be regarded also as a certain limit as far as the elongation and hardness curves are considered. The rate of change of these values is obviously reduced after this limit is exceeded.

The obtained results allow to draw an important conclusion that the home scrap addition in the charge do not deteriorate the R_m value of castings made of MgAl9Zn1 alloy. On the contrary, the tensile strength grows and at the scrap metal content equal to 50% its maximum increase (by about 30%) is noticed. However, the dispersion of results is also increased, what means that the values of these properties are exposed to greater changes, resulting first of all from the structure of castings.

The values of basic mechanical properties of the examined castings are strongly correlated with the changes in microstructure which occurred after introduction of various quantities of home scrap to the charge.

The observed refinement of the structure is decisive for the increase of the tensile strength and the unit elongation, being an effect of the alloy hardening. The decrease of these values in castings produced of metal containing large fractions of home scrap (over 50%) can be explained by the increased quantity of the non-metallic inclusions in the structure of such castings. Moreover, the inclusions are not uniformly distributed within the metal matrix and form clusters. The large dimensions of such inclusions and the non-uniformity of their distribution are the essential reasons of the decrease in the discussed values. The increased values of the calculated standard deviations inform also that the dispersion of results rises with an increase in the home scrap fraction in the charge, which is another result of the structural non-uniformity.

The negative influence of the large content of non-metallic inclusions can also be noticed in unit elongation (A) and hardness (HB) curves. It should be remembered that gas porosity, characteristic for pressure castings, also contributes to the drop in plastic properties of the material.

The plastic properties of the examined castings are less sensitive to the changes in composition and microstructure, which

is a beneficial factor since the increased technological resume is not necessary.

References

- [1] Przybyłowicz, K. (1999). *Physical Metallurgy*. Warsaw: Ed. WNT. 4th edition. (in Polish).
- [2] Gross, W.H. (1959). *The Story of Magnesium*. American Society for Metal.
- [3] PN-EN 1753. (2001). *Magnesium and magnesium alloys - Magnesium alloy ingots and castings*. Ed. Polish Committee for Standardization. (in Polish).
- [4] Avedesian, M.M., Baker, H. (1999). *Magnesium and Magnesium Alloys*. ASM International.
- [5] Dobrzański, L.A. (1998). *Physical Metallurgy*. Warsaw: Ed. WNT. (in Polish).
- [6] Eliezer, D., Aghion, E., Froes, F.H. (1997). Magnesium science, technology and applications. In *Magnesium 97*. Dead Sea, Israel. (pp. 169-177).
- [7] 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*, (pp. 25-26) September 2003 Aalen.
- [8] Cashion, S.P., Ricketts N.J. (2001). The Metallurgical Society of CIM. Replacing SF₆ with the hydrofluorocarbon gas HFC-134a for magnesium melt protection, presented at The Conference of Metallurgists. Toronto. Canada.
- [9] ASM handbook (1994). ASM international, third printing. vol.15 casting.
- [10] Eliezer, A., Abramov, E., Gutman, E.M. (1997). Mechanochemical behavior and plasticity of Mg-Al alloys. In *Magnesium 97*. Dead Sea, Israel. (pp. 192-201).
- [11] Street, A.C. (1986). *The die casting book*. (Second edition). Redhill: Portcullis Press.
- [12] Kainer, K.U. (2000). Magnesium Alloys and their Application. In *Sb. Int. Congress Magnesium Alloys and their Application*. Mnichov. (pp. 534-608).
- [13] 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.
- [14] Chojnacki, A., Konopka, Z. (2010). Influence of the AZ91 alloy home scrap in charge on pressure castings structure. In *11th International Scientific Conference 'New technologies and achievements in metallurgy and material science'*, 20-21 May 2010 (pp. 559-563). Częstochowa: Ed. WIPMiFS. (in Polish).
- [15] 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)
- [16] 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.