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Mechanical Properties of Magnesium Die Castings Produced Utilizing Process Scrap

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Abstract

Magnesium alloys are one of the lightest of all the structural materials. Because of their excellent physical and mechanical properties the alloys have been used more and more often in various branches of industry. They are cast mainly (over 90%) on cold and hot chamber die casting machines. One of the byproducts of casting processes is process scrap which amounts to about 40 to 60% of the total weight of a casting. The process scrap incorporates all the elements of gating systems and fault castings. Proper management of the process scrap is one of the necessities in term of economic and environmental aspects.
Most foundries use the process scrap, which involves adding it to a melting furnace, in a haphazard way, without any control of its content in the melt. It can lead to many disadvantageous effects, e.g. the formation of a hard buildup at the bottom of the crucible, which in time makes casting impossible due to the loss of the alloy rheological properties. The research was undertaken to determine the effect of an addition of the process scrap on the mechanical properties of AZ91 and AM50 alloys. It has been ascertained that the addition of a specific amount of process scrap to the melt increases the mechanical properties of the elements cast from AZ91 and AM50 alloys.
The increase in the mechanical properties is caused mainly by compounds which can work as nuclei of crystallization and are introduced into the scrap from lubricants and anti-adhesive agents. Furthermore carbon, which was detected in the process scrap by means of SEM examination, is a potent grain modifier in Mg alloys [1-3].
The optimal addition of the process scrap to the melt was determined based on the statistical analysis of the results of studies of the effect of different process scrap additions on the mean grain size and mechanical properties of the cast parts.

Keywords: Mechanical properties, Magnesium alloys, Recycling, High Pressure Die Casting (HPDC)

1. Introduction

Enormous amounts of scrap are produced as a byproduct of casting processes. Depending on the technology, scrap makes up from 40 to even 100% weight of a casting. Overflows, risers, gating systems and rejected castings all add up to that amount. Process scrap is relatively clean (type I) and should be reused in further production along with primary alloys.

Industrial experience has shown that uncontrolled addition of process scrap to a melt very often causes formation of hard conglomerates in the liquid metal. When these are present in high number, such situation can be very detrimental to rheological properties of the alloy and in consequence could disrupt the casting process. That is why the addition of process scrap should be precisely controlled [4].

High pressure die casting is a very efficient and cost effective casting technology. Die cast parts have relatively high strength but the elongation is rather poor [5].

The results of the research on the effect of an addition of the process scrap on the mechanical properties of die cast parts have shown that a controlled addition of the process scrap to a primary alloy melt can cause an increase in elongation values in respect to parts cast only from primary alloy.

2. Work methodology

Two alloy grades, i.e. MgAl9Zn1 (AZ91) and MgAl5 (AM50) with the chemical composition shown in Table 1, were chosen for tests. Both are commonly used in casting technologies.

Table 1.
Chemical composition of the tested alloys [wt. %]

Alloy	Al	Zn	Mn	Fe	Si	Cu	Ni
AZ91	10,00	0,73	0,22	0,0050	0,010	0,0009	0,0009
AM50	5,17	0,01	0,31	0,0025	0,011	0,0014	0,0005

A series of experimental melts with various content of the process scrap was carried out. The test parts were prepared using die casting technology. A schematic view of the castings is shown in fig. 1.

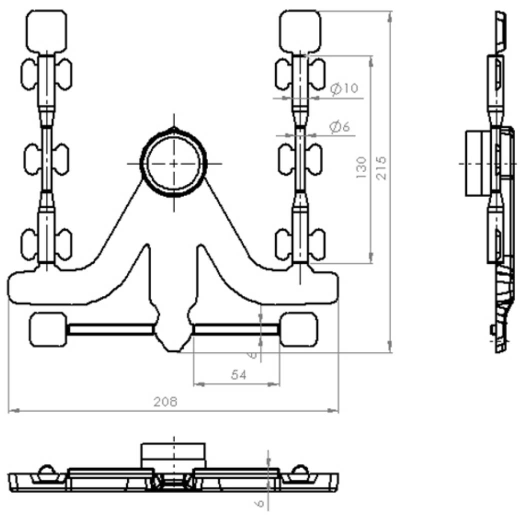

Fig. 1. Dimensions of the tested samples

The equipment involved in the production of the test parts consisted of a horizontal cold chamber die casting machine Buhler H160-BD2 with clamping force of 1600kN, a resistance furnace with a crucible capable of melting up to 15 kg of a Mg alloy, a Regloplas 200 heating-cooling device for thermal stabilization of the die and a Frech Dataprocess monitoring device used to visualize the casting parameters. The given casting parameters were used to produce the tested castings:

- plunger speed in the second phase: 2,0 m/s,
- metal velocity in the gate: ≈ 32,0 m/s;
- casting pressure (third phase): 40 MPa,
- metal temperature: 680-700°C,
- die temperature:
  - moving platen: 190 ±5 ºC,
  - fixed platen: 210±5 ºC.

3. Description of achieved results

The effect of the process scrap content in the melt on the mechanical properties (UTS, YS, E) of the AZ91 and AM50 alloys was tested on samples prepared using die casting technology. Tensile tests were carried out at ambient temperature (~20^{o}C). Every result is a mean value from 5 tensile tests of cylindrical samples (diameter ~5mm) obtained from the die castings. The tensile tests were performed according to the PN-EN ISO 6892-1:2010 standard, using Instron 5582 tensile machine.

The mechanical properties of the AZ91 samples are shown in table 2 and in figures 2 and 4 (the dotted line corresponds to the alloy prepared only from primary ingots). The results of the AM50 samples are shown in table 3 and in figures 5-7.

Table 2.
Mechanical properties of the AZ91 samples

No.	Process scpap content, %	Mechanical properties		
		UTS, MPa	*YS*, MPa	*E*, %
1.	0	207	155	2,3
2.	10	209	154	2,1
3.	20	224	161	3,6
4.	**30**	**230**	**159**	**3,9**
5.	40	221	152	3,6
6.	50	214	157	2,8
7.	60	217	160	2,8
8.	70	218	163	2,8
9.	80	221	162	3,1
10.	90	207	160	2,0
11.	**100**	**234**	**167**	**3,7**

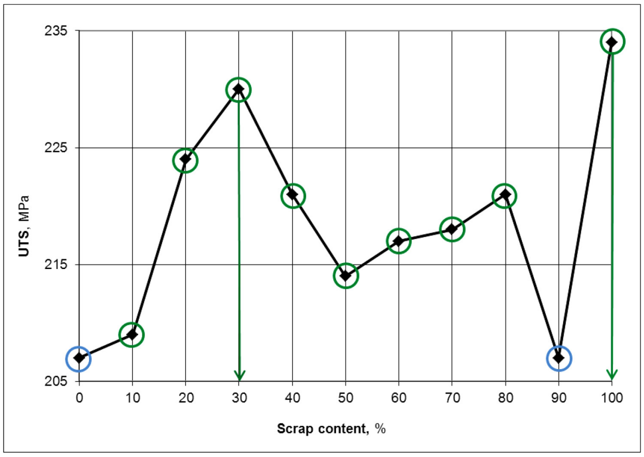

Fig. 2. Dependence of UTS on scrap content in the AZ91

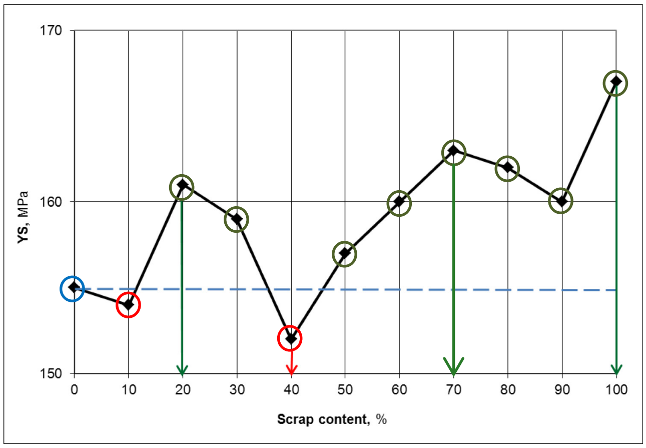

Fig. 3. Dependence of YS on scrap content in the AZ91

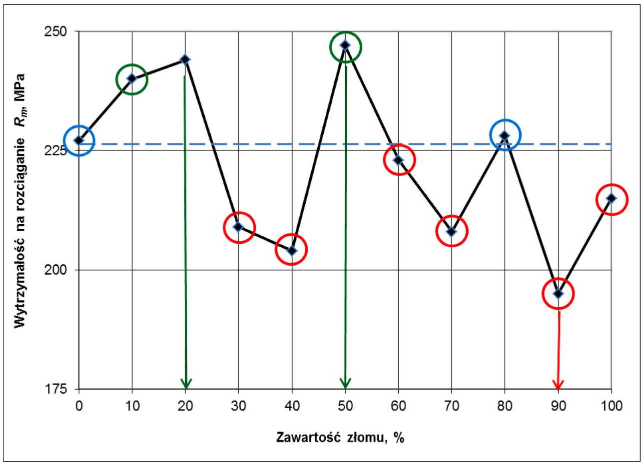

Fig. 4. Dependence of UTS on scrap content in the AM50

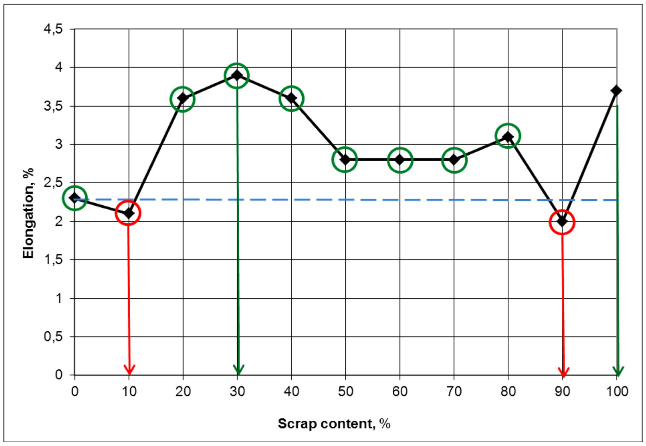

Fig. 4. Dependence of elongation on scrap content in the AZ91

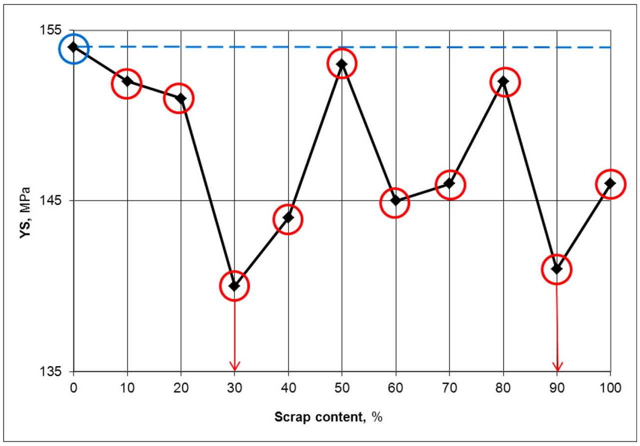

Fig. 5. Dependence of YS on scrap content in the AM50

Table 3.
Mechanical properties of the AM50 samples

No.	Process scpap content, %	Mechanical properties		
		UTS, MPa	*YS*, MPa	*E*, %
1.	0	227	154	6,0
2.	10	240	152	8,0
3.	**20**	**244**	**151**	**8,5**
4.	30	209	140	5,9
5.	40	204	144	4,8
6.	**50**	**247**	**153**	**8,7**
7.	60	223	145	6,6
8.	70	208	146	5,2
9.	80	228	152	6,6
10.	90	195	141	4,9
11.	100	215	146	6,5

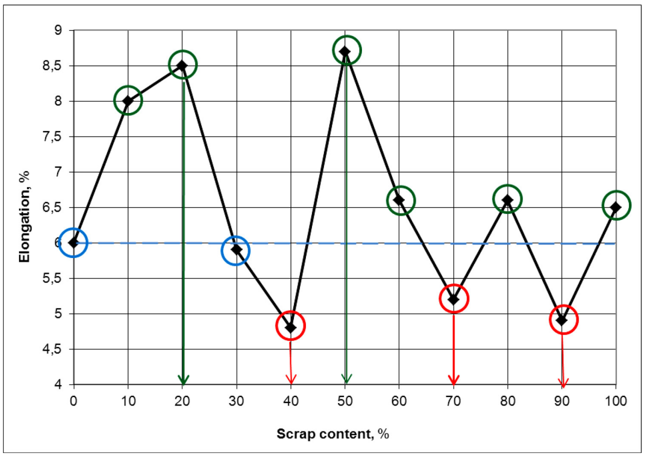

Fig. 6. Dependence of elongation on scrap content in the AM50

4. Conclusions

1. Addition of the process scrap to the primary alloy increases the mechanical properties of castings with the exception of the range between 70 to 90%;
2. The most advantageous scrap content, when taking into consideration the mechanical properties, is 30% in case of AZ91 and 20 or 50% for AM50,
3. The work has been concluded with the development of an effective method of reusing process scrap without any deleterious effects on the quality of castings that helps to maintain an economic production of Mg parts.

Acknowledgements

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