

## **POSSIBILITIES OF RECYCLING OF MAGNESIUM AND MAGNESIUM ALLOYS**

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### **ABSTRACT**

In this paper are presented results of experimental investigation of processing of non oil-contaminated metal scrap based on magnesium and its alloys. These are the first investigations of magnesium scrap recycling in Serbia and Montenegro. Experimental investigations were conducted in laboratory scale and achieved results were verified in industrial scale (Magnesium factory "Bela Stena" in Baljevac on Ibar). Experiments included following the influence of preparation of metal scrap on metal extraction efficiency rate.

**Key words:** magnesium, magnesium alloy, separation, smelting

### **1. INTRODUCTION**

Variety of applications of magnesium alloys in automotive industry, aerospace engineering, metallurgy, chemical industry, electro-chemistry (batteries, cathode protection, etc.) contribute to rapid increasing of production of magnesium in the world (appearance of Chinese magnesium on World Trade Market-WTM) [1-5].

Magnesium is silvery-white metal that is principally used as alloying element for several non-ferrous metals [6] (Al, Zn, Pb, ...). Magnesium is among the lightest of all the metals and also the sixth most abundant on earth. Due to its light weight and with additional alloying with Al, Si, Cu, Fe, Mn, Ti, Zn superior mechanical properties could be achieved, such as: ductility, mechanical properties, high corrosion resistance, coating and castability (die-casting and pressure casting). This fact contributed increasing of the variety of applications of this metal. Production of magnesium in the world increased from 20 000 t/year in 1937 up to 400 000 t/year in 2000 year, from which only in China was produced 170 000 t of magnesium in 2000 [7]. Appearance of

China as a great world producer of magnesium in period 1995/96 caused decreasing of magnesium price on WTM.

Simultaneously with increasing of application and consumption of magnesium new significant quantities of scrap are generated, scrap from production as well as postconsumer scrap. If magnesium usage in automobile industry continuous to grow at the rapid pace that it has in past few years, than this growth could have significant immediate and long-term effects for the magnesium recycling industry worldwide. The immediate effect would be a huge increase in the quantity of new scrap generated because about 50% of the weight of input material becomes new scrap. As a result of this anticipated increase in new scrap generation, companies are planning new magnesium recycling plants or they are expanding existing capacity. The principal long-term effect is that after an automobile is junked, the magnesium-containing parts may be removed from the automobile and recycled. These additional magnesium-containing parts would result in additional quantities of old scrap as a source of supply. The projected increase in the use of magnesium in this application has prompted other developed countries such as Germany, Japan, Great Britain, USA and Canada to install additional magnesium recycling capacity [8]. In USA in 1998 the recycling efficiency rate for magnesium was estimated to be 33%. Out of total quantity of magnesium scrap 25% is postconsumer scrap.

In our country situation is quite different. Primary production of magnesium stopped in year 2000 because of low price of this metal on WTM. In the meantime in Foundry of Magnesium factory "Bela Stena" in Baljevac on Ibar preparation of magnesium scrap began, with influence from "COMESIM", France. With this aim during 2003 on Faculty of Technology and Metallurgy in Belgrade in Laboratory for Extractive Metallurgy experimental investigation of magnesium scrap preparation was conducted. Also investigation in industrial scale was done in Foundry of Magnesium Factory, but without adequate processing technology, concerning in the first place preparation of scrap.

## 2. RESULTS

New magnesium based scrap typically is categorized into one of four types. Type I is high-grad scrap, generally materials such as gates, runners and drippings from die-casting operations that is uncontaminated with oils. Types II, III and IV are lower graded materials. Type II is oil-contaminated scrap, type III is dross from magnesium-processing operations, and type IV is chips and fines.

Old magnesium-based scrap or postconsumer scrap consists of such materials as automotive parts, helicopter parts, lawnmower decks, used tools and the like. This scrap is sold to scrap processors. In addition to magnesium-based scrap, significant quantities of magnesium are contained in aluminium alloys that also can be recycled.

Most of magnesium scrap is generated in foundries of magnesium alloys. In making magnesium alloy die-casting, about 50% of the material ends up as a finished product, and the remainder as new scrap. Of the scrap generated in die-casting process, about 80% end up as trimmings; 8% as dross; 7% as chips; 4.5% as rejected parts and the remaining 0.5% as slurry, which is probably lost.

For experiments deoiled scrap was used, which was provided by Magnesium Factory through "COMESIM", France, apropos their regional office in Belgrade. As average sample for experiments cca 60kg were taken from so called "Big-Bags", in which scrap was brought to Baljevac. Deoiled scrap was classified into three classes: massive "good" parts, massive "bad" parts and light fractions. Dimensions of massive "good" parts extends from 20 to 200 mm, thickness of 15-90 mm. Dimensions of massive "bad" parts extends from 30 to 100 mm, thickness of 20-30 mm. Dimensions of light fractions extends from 10 to 20 mm, thickness of 0.5-1 mm. All three classes are scrap from from automobile parts industry, mostly from foundries. Usually they are magnesium alloys with 4-6% Al.

In purpose of preceding of optimal solution for valorization of metal from scrap investigation we conducted concerning preparation and smelting.

Operation of preparation consists of:

- mechanical treatment in drum and separation from dust,
- chemical treatment in sulphuric acid solution,
- drying.

Smelting was conducted in induction furnace, 25kVA with graphite crucible of 1dm<sup>3</sup>.

Metal extraction efficiency rate was tracked down. Results are presented in Tables 1 and 2.

*Table 1 - Results of experimental investigation of preparations and smelting of massive "good" parts*

No.	preparation mechanical chemical	smelting salt, g	mass of sample, g	mass of metal, g	smelting loss, %	metal extraction efficiency rate, %
1	without preparation, direct smelting	-	1000	950	9.0	91.0
2	drum treatment 1h and screening	50	1257	1180	4.8	93.8
3	mechanical treatment 1h, treatment 5% H <sub>2</sub> SO <sub>4</sub> drying 100°C	-	2000	1824	4.7	91.2
4	chemical treatment 5% H <sub>2</sub> SO <sub>4</sub> drying 100°C	-	1605	1140	5.1	71

*Table 2 - Results of experimental investigation of preparations and smelting of massive "bad" parts*

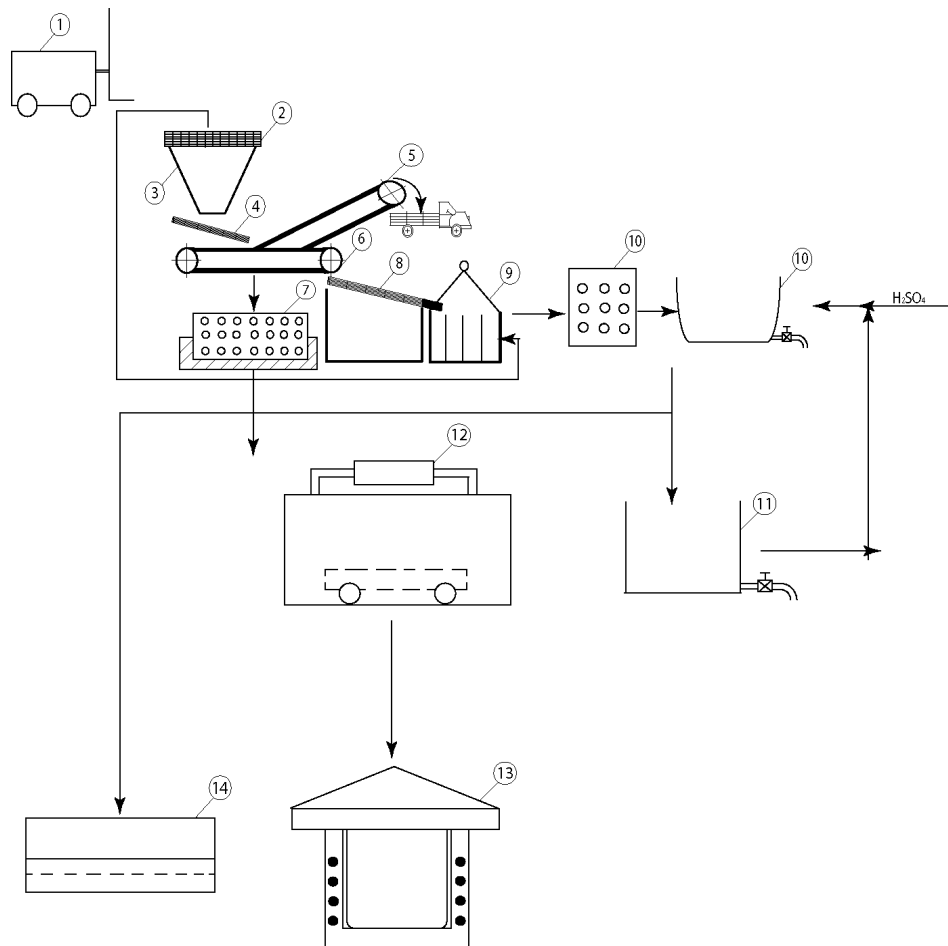
No.	preparation mechanical chemical	Smelting salt, g	mass of sample, g	mass of metal, g	Smelting loss, %	metal extraction efficiency rate, %
1	mechanical treatment 1h	-	2000	850	52.9	47.1
2	mechanical treatment 1h	100	2080	820	56.0	44.0
3	chemical treatment 5% H <sub>2</sub> SO <sub>4</sub> washing drying 100°C	-	1820	740	54.0	46

Because with mechanical treatment in drum and screening all metal oxide could not be disposed, chemical treatment was conducted with solution of H<sub>2</sub>SO<sub>4</sub>. Also solution concentration and time of chemical treatment were investigated, and conclusion is that optimal concentration is 5-8 wt.% and time 1-5 min. Temperature of solution became from the exothermal reaction 45-50°C.

For verification of presented laboratory results tests in industrial scale were performed in Foundry of Magnesium Factory.

Sample for preparation (classification, screening, chemical treatment and drying) was take from 36 "Big-Bags" in amount of 43 235kg. After preparation, manual classification into three classes: massive "good" and massive "bad" parts was conducted. Separated massive "bad" parts were layed aside. Rest was screened on screen 10×10 mm. Fraction +10 mm was merged with massive "good" parts for further processing. Light fraction, -10 mm, wasn't processed any further. In this way quantity of 5 582 kg from 13% of separated scrap was separated. Quantity of 1 544 kg of so called "rods" was added. For chemical treatment total amount of scrap was 7 126 kg. Chemical treatment of prepared scrap was performed by usage of steel scuttle with sifter 10×10 mm. The scuttle with scrap was immersed by crane in tub with 5% H<sub>2</sub>SO<sub>4</sub>, and pulled through the tub with water running during washing. After washing 6 597 kg was gained, meaning the mass loss was 7.43%. Prepared scrap was dried 6-8h in containers above opened furnace. After scrap was put in the crucible and additionally dried for 6-8 h on 200°C. Afterwards furnace temperature was settled on 800°C, and casting was conducted on 750°C. During smelting mixture of smelting and refining salt was added in quantity of 420 kg. When total quantity of scrap was smelted molten metal was poured into crucible in order to separate the metal from slag. Metal without slag was then heated on

750-800°C, refined and casted in ingots. Process-technological scheme of preparation and processing of non oil contaminated magnesium scrap is presented in Fig. 1.



- 1.Forklift, 2.Bunker, 3.Screen (300×300), 4.Vibro-screen (10×10), 5.Conveyer,  
6.Sorting conveyer, 7.Drum, 8. Vibro-screen, (10×10) 9.Plastic basket 10.Tab  
11.Chemical treatment 12.Drying 13.Smelting furnace 14.Neutralization

*Fig.1 - Process-technological scheme of preparation and processing of non oil contaminated magnesium scrap*

Total mass of gained metal in this way was 5 592 kg. Quantity of metal which was inputet in furnace was 6 372 kg, which means that metal extraction efficiency rate was:

$$\eta = \frac{5592}{6372} \cdot 100 = 88.4\% \quad (I)$$

### 3. CONCLUSION

Experimental investigations of recycling of magnesium scrap conducted on Faculty of Technology and Metallurgy and Foundry of Magnesium factory "Bela Stena" show that:

- processing of this kind of scrap is possible with metal extraction efficiency rate in range 45-90 %, depending on quality of scrap,
- in purpose of achieving satisfying techno-economical effects it is necessary to have suitable processing technology, which includes preparation, metallurgical processing, smelting and refining.

Basing on the experimental results it is possible to project processing technology and in dependence on location and conditions suitable different main projects.

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