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RESEARCH ON IMPROVING THE QUALITY OF ALUMINUM ALLOYS

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Abstract: The paper presents a part of research performed out on aluminum alloys used in the manufacture of car rims. It shows the importance of evolution used to produce alloys rims and manufacturing technologies. Replacing steel with aluminum alloy has a series of advantages of which are as follows: aluminum has a much lower density than steel, is easily processed, is characterized by good physical and mechanical characteristics, relative to density and high resistance to corrosion. Auto aluminum alloy rims can be obtained by casting or plastic deformation. In the experiments aimed to improve the characteristics of 6082 alloy for obtaining forged rims. Experiments were carried out in the Faculty of Engineering of Hunedoara, the metal melts labs and strength of materials. Elaboration of the alloy was carried out in the induction furnace capacity 3 kg of molten aluminum (new crucible volume = 1.4 dm ^{3}). Casting was performed for ingot form, from which are obtained by forging bars of 20 mm diameter. From these bars were prepared test specimens for determining the mechanical characteristics and samples for chemical composition. Based on the characteristics values obtained, has been carried out technological analysis of the alloy experienced and quality improvement measures.

Keywords: aluminum alloy, rims, mechanical characteristics, forged rims

1. INTRODUCTION

Technical pure metals are used in practice because of the special properties such as thermal and electrical conductivity, good corrosion resistance, high temperature stability, such as copper, aluminum and silver for their thermal conductivity and high electrical, tin, molybdenum or tungsten for the stability at high temperatures. In practice, most metal are useful as alloys, ie metallic materials resulting from the melting together of some metals with metals or metals with non-metals (metalloids). Referring to manufacture parts for the automotive industry noted that parts are obtained both ferrous and non-ferrous alloys [1].

In the '70s, with the fuel crisis, car manufacturers began to seek ways to reduce fuel consumption, and the best way was to reduce vehicle weight. Calculations have shown that by reducing average passenger car weight of 100 kg will result in a saving of 0.6 liters of fuel per 100 km, ie, about 700 liters of fuel over the life of the car and also reduce emissions released into the atmosphere. Thus, for every 10% reduction in the weight of the vehicle, there is a fuel saving of 5-7%. Car manufacturers began to replace many parts of the machine with some made of aluminum, reducing the weight of the vehicle. Today, an average of 110-145 kg of aluminum is used for the production of a car, which quantity continues to grow each year [2].

Alcoa Aluminum offers great benefits in vehicles with advanced engines, improving fuel economy by 13.5% as compared to a hybrid vehicle equivalent composed of steel. The use of aluminum has reached a record high, with a rate of 8.6% by weight of new cars produced in 2009, compared to just 2% in 1970 and 5.1% in 1990 [3].

Aluminum has about one-third of the density (7.86 / 2.7 = 2.91) and stiffness of steel. It is easily machined, cast, pulled and extruded. Aluminum is characterized by high plasticity, low mechanical resistance, high thermal and electrical conductivity and high resistance to corrosion in air, water and organic acids. Aluminum is theoretically 100% recyclable without any loss of its natural qualities [4].

Car manufacturers have set high targets regarding the fuel consumption of the vehicle, so that, in a short period of time, decreased the CO2 emissions (with 29.41%) from 170 g / km in 2003 to 120 g / km in 2012.

In the automotive industry, aluminum alloys are used in the form of castings or forgings, semi-finished obtained by forging, plates, profiles, rods, etc., as shown in figure 1. Among the many pieces of aluminum alloy products mentioned: inlets or exhaust tubes, air or oil coolers, air conditioning installation, pistons, body parts, suspension parts, brake cylinders, aluminum wheels, brake pistons, engine blocks, etc.

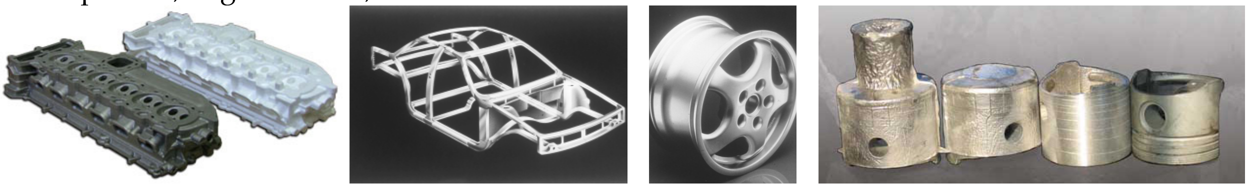

Figure 1. Various pieces of aluminum alloys in the automotive industry

2. EXPERIMENTAL RESEARCH

The wheels used on equipping road vehicle can be made of steel, aluminum alloys, magnesium alloys, or titanium.

The parts produced by casting are virtually endless shape, size and mass. Obtain them through other technological processes whether it is possible or that would result in overgrowth of price. The choice of technology is in most cases determined with the election of material. In addition to a remarkable aesthetic role that profoundly changes the whole picture of the car, alloy wheels are composed of aluminum and magnesium, which gives increased rigidity compared to steel wheels, thus providing additional stability, especially on twisty roads. Also, the thermodynamic qualities of the alloy, allows better cooling of the brake system of the car, while maintaining its effectiveness. These rims have a weight equal to or less than that of steel, a higher dimensional accuracy, and the ability to recycle, due to the aluminum alloy used for forming the rim [5].

With the continuous development of the production process for rims and wheel hubs, production costs have been significantly reduced, so that a light aluminum alloy was produced in large numbers for the BMW 5 Series in 1995.

Using aluminum wheels for cars started with the upper class or emblematic models in order to give them a distinct personal touch. In the 1970s it began to be mass produced cars equipped with alloy wheels from the factory [2].

There are three types of manufacturing processes used in the manufacture of aluminum rims.

1. Forging is an excellent technique to make aluminum rims and involves compressing a solid piece of aluminum or a block to achieve the desired design of the rim. Rim obtained by this process is strong and durable [6, 7].
2. Another method of obtaining the rim is rolled forging plates and the aluminum sheets are rolled through some heavy wheels press which printing or pressing aluminum in order to obtain the desired design of the rim. This process uses a small amount of aluminum than the normal forging.
3. The third manufacturing process is the casting of molten aluminum in the forms called molds.

The forging is a combination of strength, light weight and ductility. Physical and mechanical strength characteristic of forged rims is distributed to the whole rim at the level of grains. The result is a stress or impact resistance far higher than the equivalent rim obtained by casting [8].

Advantages of forged wheels:

- ✓ A forged wheel is far lighter than the equivalent cast. Reducing weight that benefit forged wheels help improve vehicle performance by reducing unsprung mass of the vehicle and increase performance suspension, which ultimately leads to a better attire on the road and safety cornering.

✓ The low weight of forged wheels means that the couple will have a lower angle. In practical terms this means driving dynamics improved by a low power during acceleration and braking more efficient [9].

The purpose of research carried out, whose results are presented in the paper was to improve the quality of aluminum alloys for the manufacture of rims for road vehicles, of wrought / forged. Among the aluminum alloys for obtaining forged aluminum rims, note aluminum alloys 6082 and 6061.

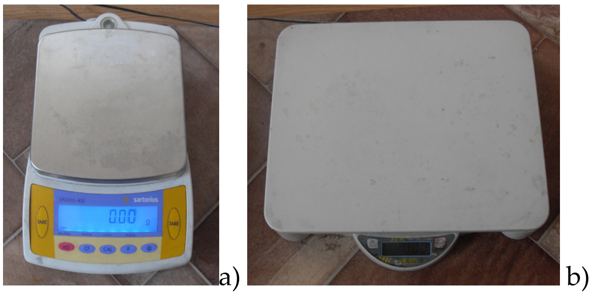

Figure 2. Scales - a) balance SARTORIUS CP2202S-OCE; b) balance KERN ECE 50K50

For phase laboratory experiments have used the following equipment:

a) Electronic scales for weighing load components:

- CP2202S-OCE-Sartorius balance (figure 2.a) with features: the minimum amount of measurement: 0.5 grams; measuring the maximum amount of 2200 grams; precision: 0.01 grams.
- Balance KERN ECE 50K50 (figure 2.b) with features: the minimum amount of measurement: 50 grams; measuring the maximum amount: 50 kg; precision: 50 grams.

b) Induction furnace (figure 3), with the following characteristics: capacity 10 kg (iron / steel); 3.5 kg (aluminum alloy); crucible diameter of 97 mm; crucible height 220 mm; useful volume 1.4 dm3; current frequency of 100 KHz; 150 KVA power transformer; primary voltage 500 V; the secondary voltage 167 V; variable voltage 100/83/50V; high-frequency power of 50 kW; duration of the melting of 50 -60 min; lining basic – magnesite.

c) Melting furnaces

- melting furnace (calcination) Nabertherm L15/12/B180 model (figure 4.a) with the following characteristics: power: 3.6 kW; maximum temperature: 1200°C; volume: $10dm^3$.
- melting furnace (calcination) Nabertherm model LHT 02/17 (figure 4.b) with the following characteristics: power: 3kW; maximum temperature: 1700°C; volume: 5 dm^3..

Figure 3. Induction furnace

a) melting furnace (calcination) Nabertherm model L15/12/B180;

b) melting furnace (calcination) Nabertherm model LHT 02/17

Figure 4. Melting furnace

Furnace load consisted of over 99% purity aluminum, coming from quashing of electrical transformer stations. To obtain the alloy 6082 were used the following materials: Si metal pre-alloy of Mg and Mn80%. For finishing the grain size we used microcoolers of aluminum alloy wire AlTi5 (table 1). For the protection of the bath we used flow protection and for degassing the bath, KCl, NaCl and $CaCl_2$. The material for the protection of the bath were added when the metal bath was formed to a depth of about 50 mm, and the refining, about 5 minutes prior to casting, the metal bath being intensively stirred with a steel rod. In table 2 shows the chemical composition of the cast alloy 6082 and batches.

Table 1. Addition materials during the development of casting

Butch number	Further alloying element (g)			Further forming slag and refining (g)		Further wire Al/AlTi5 for finishing structure (g)	
	Si	Mn	Mg	Flow forming slag	Further $NaCl+KCl+CaCl_2$	Al	AlTi5
1.	17	16	19	80	15	10	14
2.	21	16	20	80	15	15	10
3.	18	15	19	80	15	10	12
4.	17	17	18	80	15	10	12
5.	18	18	18	80	15	10	10
6.	19	18	20	80	15	15	10

Table 2. Chemical composition, %

	%	Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Al
6082	min.	0,70	-	-	0,40	0,60	-	-	-	-	Bal
	max.	1,30	0,50	0,10	1,00	1,20	0,25	0,01	0,20	0,10	Bal
Batch 1		1,30	0,39	0,018	0,431	0,724	0,03	0,002	0,05	0,06	Bal
Batch 2		1,10	0,49	0,02	0,42	0,718	0,03	0,003	0,05	0,05	Bal
Batch 3		1, 28	0,50	0,02	0, 43	0,97	0,09	0,01	0,048	0,051	Bal
Batch 4		0, 76	0,42	0,03	0,61	0,82	0,08	0,003	0,04	0,05	Bal
Batch 5		1,12	0,44	0,04	0,72	0,85	0,07	0,01	0,03	0,06	Bal
Batch 6		1,15	0,41	0,04	0,75	0,82	0,08	0,008	0,03	0,08	Bal

Figure 5. Aspects of drafting and casting aluminum alloy

Table 3. Properties of aluminum alloys

	ISO: $AlSi_1MgMn$ (EN AW- 6082)
Mechanical properties	
Tensile strength Rm (N / mm^2) 0/T4/T6	130/260/340
Yield strength $Rp_{0,2}$ (N / mm^2) 0/T4/T6	60/170/310
Shear strength τ (N / mm^2) - 0/T4/T6	85/170/210
Elongation A_{50} (%) - 0/T4/T6	26/19/11
Brinell hardness, HB - 0/T4/T6	35/70/95
Vickers hardness, HV - 0/T4/T6	35/75/100
Thermal properties	
Electrical conductivity (%IACS) 0/T4/T6	55,5/42/44
Thermal conductivity (W/m-K) 0/T4/T6	216/167/172
Physical properties	
Density (kg / m^3)	2700
Solidification temperature (°C)	570
The liquidus temperature (°C)	650
Longitudinal modulus of elasticity E (GPa)	70
Stiffness modulus (GPa)	26,4
Poisson coefficient	0,33
Resistivity (nΩ-m) 0/T4/T6	31/41/39

The alloy was cast as an ingot of circular cross section of diameter 80 mm and height 160 mm. After removal from the ingot mold ingots were subjected to homogenization treatment at a temperature of 480°C (470-510°C) with hold time of 12 h and cooled under a stream of air (Figure 5). In table 3 shows the mechanical, thermal and physical characteristics of the alloy studied [10].

For mechanical testing, the samples were processed by forging, these being heated to 400 °C (360-510 °C). Additions of alloying elements were made on average 8 minutes prior to discharge, and the addition of wire AlTi5 with 5 minutes. The addition of aluminum wire granules (diameter = 2 mm, length = 2mm) was added during the evacuation and casting the aluminum in ingot mold (diameter = 85mm, height = 180mm). As noted above, the ingot obtained was forged bars with diameter 18-20 mm, of which, by machining the samples were made to determine the physical-mechanical characteristics, as shown in Figure 6. The values of the physical-mechanical characteristics are shown in table 4.

'Figure 6. Forging and machining the samples

Table 4. Physical-mechanical characteristics of batches

Batch number	Physical-mechanical characteristics				
	$Rp_{0,2}$ (N/mm^2)	R_m(N/mm^2)	A (%)	Z (%)	Hardness (HB)
1.	177	275	21	22	80
2.	172	268	20	22	85
3.	168	272	20	19	87
4.	167	262	22	19	84
5.	175	280	23	20	88
6.	184	285	24	21	92

We considered that is interest a comparison of the values obtained for the mechanical characteristics for the 6 batches, with values obtained on samples of a forged wheel made of the same alloy and decommissioned. We have taken samples of the spoke of the rim and the inside disc thereof, as shown in figure 7 and samples were made for tensile stresses and bending shock (figure 8).

Figure 7. Elements taken from forged wheels

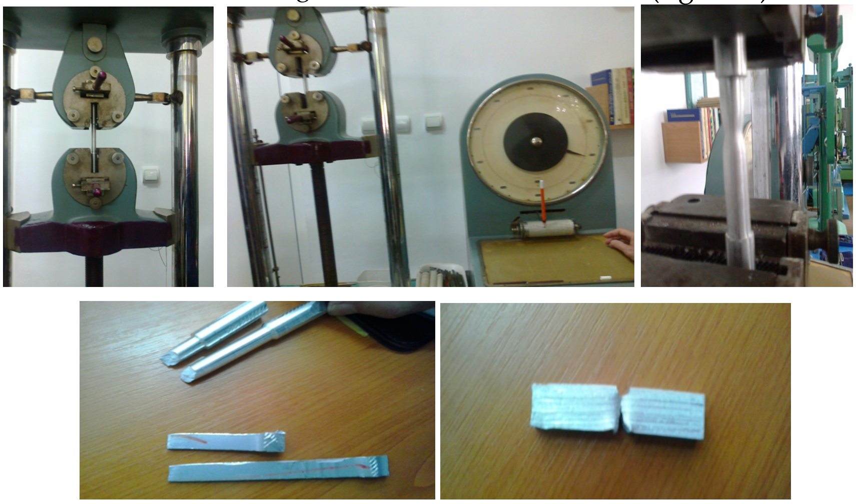

Figure 8. Specimens used for tensile testing and impact bend

Sample taken from the spoke rim, tensile strength Rm was 365.42 N/mm^2 and yield strength $Rp_{0,2}$ was 222 N/mm^2. Higher values compared to those obtained in the 6 batches, is explained by the finishing the structure (fine grains and precipitation of Mg_2Si globular form).

It was also realized shock resistance test, given that the wheels are subjected to collisions during operation. Resistance value was KCU = 2 J/cm².

3. TECHNOLOGICAL ANALYSIS

Based on data concerning the chemical composition and physico-mechanical, was performed a technological analysis of the results obtained:

- ✓ in terms of chemical composition, all 6 batches were within the limits set in the standard. Regarding the Mg, it has been well controlled due to the fact that has been introduced into the metal bath by immersion (introduced in a metal perforated), to reduce burning losses, on the one hand, and on the other hand, measures labor protection. Alloying element Si, with one exception was in the range 1-1.3. Regarding the Mg concentration did not exceed 1%. Also, Mn was in the first part of the standard set;
- ✓ using as the main component of the cargo, Al with very high purity (over 99%), the Fe content has not exceeded the maximum set by the standard. Regarding the trace elements Cr and Zn content of its well below the limit set by the standard. Regarding the Ti, due to the addition of Ti wire, there is an increase of the content of Ti, particularly for batches 5 and 6 but without exceeding the limit imposed;
- ✓ mechanical characteristics are superior to those provided by the standard, with their increasing trend with increasing content of Ti, Mn, Mg and Si. Good mechanical characteristics can be influenced mainly by controlling the content of Ti and Fe, by this element preventing the formation of fragile components, as well as the Mg content, in view of formation of Mg_2Si compound.

4. CONCLUSIONS

From the research, experimentation and technological analysis carried out, results the following conclusions:

- ✓ for development of the aluminum alloy 6082 is necessary to use waste as high purity aluminum desirably at least 99%, which provides a rigorous control of alloying process;
- ✓ when used aluminum waste with alloying elements, should be required to know the chemical composition of the waste, or to take samples for chemical analysis, after the melting and, if appropriate, dilution of the melt with primary aluminum;
- ✓ after the addition of primary aluminum melting mandatory sampled for chemical composition, which is necessary for proper alloying;
- ✓ by respecting the chemical composition and homogenization treatment ensures the mechanical characteristics of the values provided in the standard;
- ✓ research will be extended to establish a number of mathematical correlations between the qualitative characteristics and the main elements of the chemical composition and their influence on grain size.

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