AlSi7Mg ALLOY CAR RIMS MANUFACTURING TECHNOLOGY

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Abstract

Aluminum alloy rims can be produced by the following methods: forging, twisting, gravity casting and low-pressure casting. Irrespective of the advantages and disadvantages of each of these technologies, by far the most common way of producing Al-Si alloy rims is low-pressure casting (up to 0.2 MPa). This process provides good quality products with the required performance properties and customer-imposed shapes at comparatively low production costs. Low-pressure rim casting can be conventionally divided into main and auxiliary processes. The former refer to the place where the rims are made: melting shop (foundry), heat and mechanical processing, diamond cutting, painting shop. Auxiliary processes include inter-operational inspections, visual evaluation of the finished rim, preparation of casting molds (dies), raw material management and in-plant logistics. Article comes courtesy of Superior Industries Production Poland sp. z o.o. authorities.

Keywords: Foundry, Al-Si alloys, rims, silumin melting, refining, modification

1. INTRODUCTION

Cast Al-Si alloys (the so-called silumines), due to their silicon content, can be divided into three groups: subeutectic alloys with a content of 4 to 10 wt% Si, eutectic alloys (10 to 12 wt% Si) and alloys with a supereutectic composition of about 17 to 30 wt% Si [1-4]. These alloys have good mechanical properties, as measured by, among other things, specific stiffness (the ratio of Yang's modulus to density) or specific strength (the ratio of tensile strength to density). These parameters are often a criterion for the selection of materials in terms of weight reduction, making it possible to reduce energy consumption during operation [5-8].

For the production of aluminum alloy rims, the most commonly used silumins are: AlSi7Mg, AlSi9Mg and AlSi11. The latter is characterized by good casting properties, i.e. good flowability, low linear shrinkage and low propensity to hot cracking.

2. THE PROCESS OF PREPARATION AND MELTING OF ALUMINUM ALLOYS

AlSi7Mg, AlSi9Mg and AlSi11 alloys were supplied in the form of metallurgical ingots. Deliveries are inspected for conformity of type and elemental content according to the supplier's certificate. At specified intervals, for a given alloy type, a sample is taken for chemical composition analysis and verification with the supplier's certificate. If the chemical composition meets the requirements specified by the customer, the material is transferred to production, where it is melted in gas melting furnaces. The approximate chemical composition of AlSi7Mg alloy for rim castings at Superior Industries is shown in **Table 1**.

Table 1 Chemical composition results of AlSi7Mg alloy used for rims (wt%)

	Si	Fe	Cu	Mn	Mg	Zn	Ti	Ca	Sr	Other

Min.	6.80	-	-	-	0.26	-	0.10	-	0.02	separate	total
Max.	7.40	0.13	0.01	0.03	0.32	0.03	0.15	0.002	0.03	0.03	0.10

After a temperature of about 740 °C is reached, the alloy is transferred from the melting furnaces to a ladle, where modification and refining are carried out. These processes are designed to improve the properties of the alloy by grinding the grains of the α(Al) solid solution and changing their shape. **Figure 1a** shows the microstructure of AlSi7Mg alloy before modification, and **Figure 1b** shows the microstructure of AlTi5B1 alloy after modification with AlTi5B1 mortar, after refining with nitrogen and a nitrogen-hydrogen mixture.

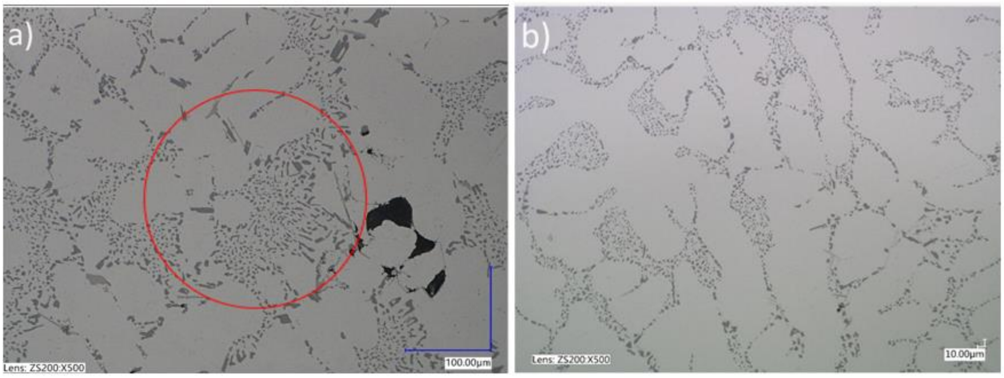


Figure 1 Microstructure of AlSi7Mg alloy: a) before; b) after the modification and refining process

After the refining process, the metal mirror was purified in a melting-pot. The collected impurities constitute secondary material, which was remelted into full-grade raw material. A refining process that is too short can result in low alloy density and deterioration of strength properties. So-called "outgassing", oxides and inclusions (visible after the refining process) may be visible on castings, deteriorating the strength of the alloy. An example of such defects in AlSi7Mg alloy is shown in **Figure 2.**

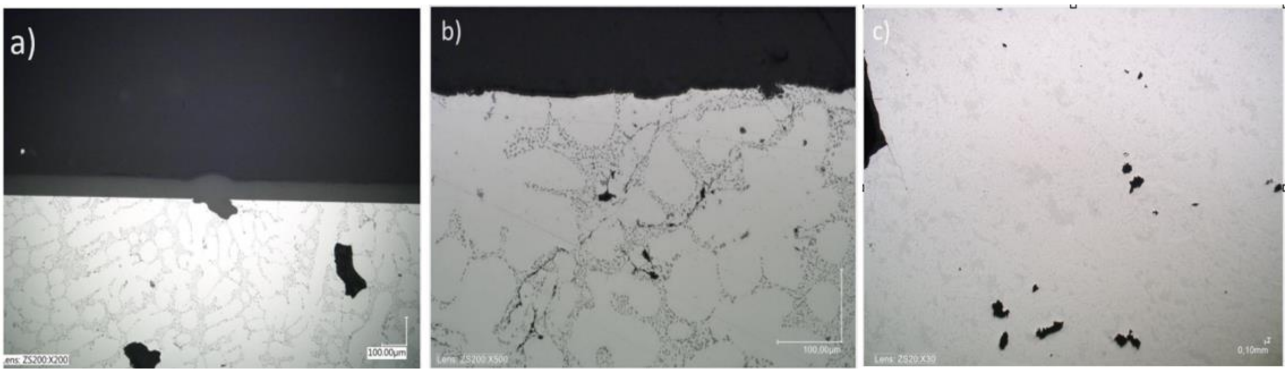


Figure 2 The most common defects in the microstructure of AlSi7Mg alloy: (a) so-called "outgassing"; (b) oxides; (c) inclusions, such as electrocorundum or lubricant

The melting-pot with AlSi7Mg alloy was then transported to casting machines equipped with electric furnaces of a certain capacity. The quality of the cast alloy was tested by measuring the density and checking the chemical composition on a spectrometer. Samples for testing the chemical composition were taken from each transport melting-pot. If the chemical composition was out of specification, the rims cast from this metal were retained to determine the further handling process.

3. RIM CASTING PROCESS

Casting aluminum rims is a low-pressure casting process. The first stage is the filling of the die, which is carried out by exerting a small air pressure (phase I about 20 kPa) in the preheating furnace on the surface of the liquid alloy. Under the pressure, the inside of the die (placed on a special plate above the preheating furnace), is filled with the melt (phase II about 50 kPa and phase III about 80 kPa). The next stage is cooling (solidification) of the casting. It takes place under pressure, and volumetric shrinkage is compensated by liquid alloy from the preheating furnace fed through a pouring tube. To speed up the solidification process, the jaws (side cores) and cores of the die are cooled with compressed air. Once the casting has solidified, pressure is no longer applied to the surface of the liquid metal in the preheating furnace, and the metal that remains in the tube flows back into the furnace (**Figure 3**). The cycle ends with the removal of the casting from the die.

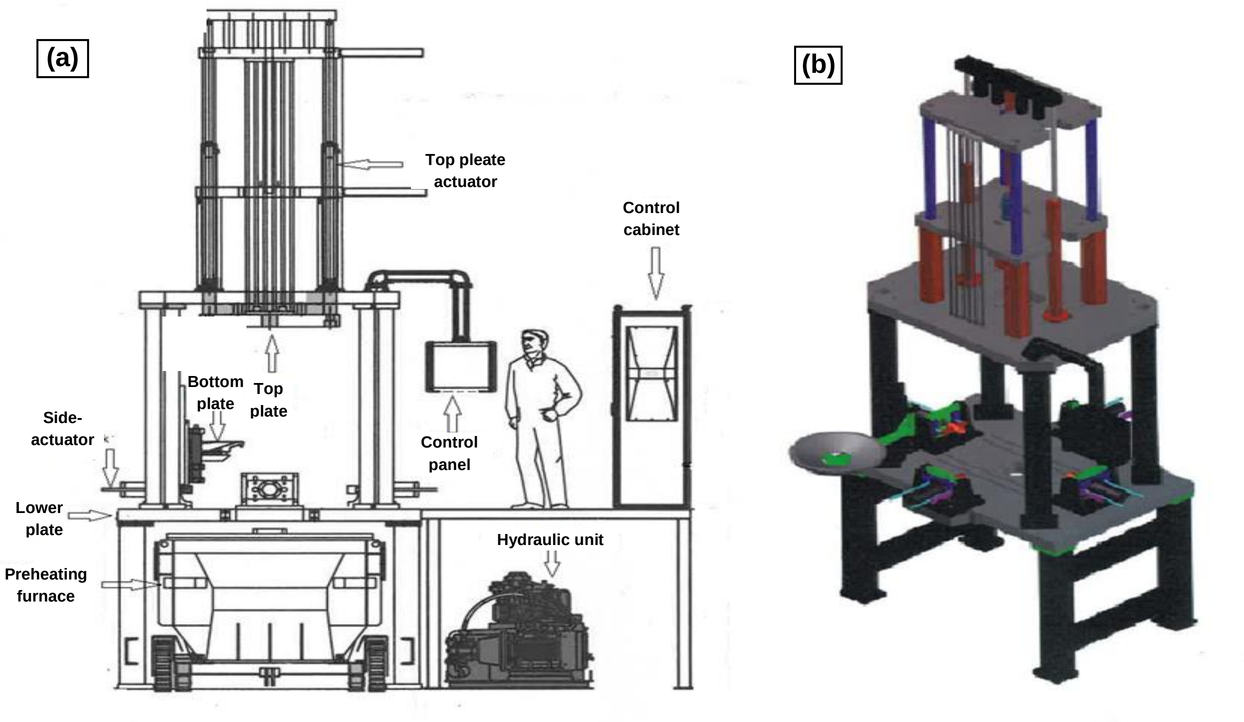


Figure 3 Rim casting stand: (a) schematic diagram; (b) computer visualization

When removed from the die, the rim castings have a temperature of about 400 °C. The foundry man visually inspects the rim for the presence of under fills or other visible surface defects, such as seizures, pitting and fogging. The rims are then cooled with water at the appropriate temperature. After cooling, removal of the trapping and automatic measurement of deformation (the so-called "diaphragm") in the rosette area (**Figure 4** - green arrow), the rims are transported by feeder to the X-ray equipment.

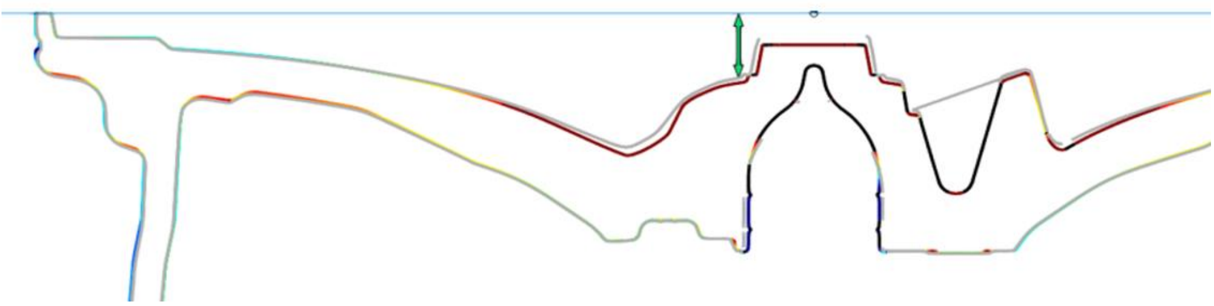
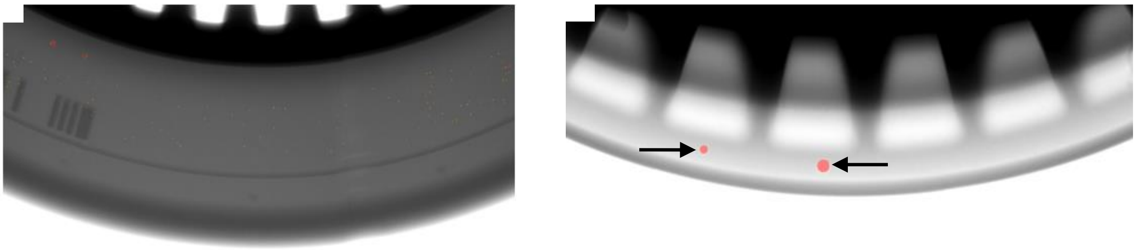


Figure 4 Measurement of deformation on the cross-section of the rim

X-ray inspection is carried out semi-automatically or automatically. Hidden defects (shrinkage cavities, gas bubbles, inclusions, cracks and overheating) are detected during its course. Defective rims are automatically destroyed, marked with the correct color for the type of alloy and transported for remelting. Rims free of latent defects are visually inspected at the inspection station (**Figure 5**).



(a) (b)

Figure 5 X-ray inspection of rims: a) without defects; b) with gas bubble defects

4. HEAT TREATING OF RIMS

The visual inspection is followed by the removal of the sprue formed from the gating system, which reduces machining time. After the sprue is drilled out, the rims are subjected to a heat treatment process to increase mechanical properties (R_m, $R_{0.2}$, A). The heat treatment line consists of two modules: supersaturation and aging, with a water pool in between. The supersaturation of Al-Si alloys is carried out at a temperature of about 535°C for a fixed period of time. The process involves heating the castings to a temperature above the solubility limit line of the alloying elements, close to the temperature of the beginning of melting, which ensures maximum dissolution of the alloying elements. After supersaturation, the rims are cooled in tanks of water and then aged at about 155°C. Aging is designed to increase strength properties. Due to changes in the morphology of silicon crystals during supersaturation annealing, it is possible to maintain good plastic properties, the required hardness and to consolidate mechanical properties.

After heat treatment, the rims are subjected to hardness tests. If the hardness is too low, the rims are automatically directed to heat treatment again. Once a day, one rim from each furnace is set aside for mechanical property testing.

Testing of hardness properties (R_m, $R_{0.2}$, A) is carried out on rim samples after heat treatment from areas, indicated by the customer. The most common is the spoke, the back/front edge, the naba and the spoke, which are shown in **Figure 6**. The basic values of the strength properties of AlSi7Mg alloy are shown in **Table 2**. After heat treatment, the rims are automatically directed to the machining department.

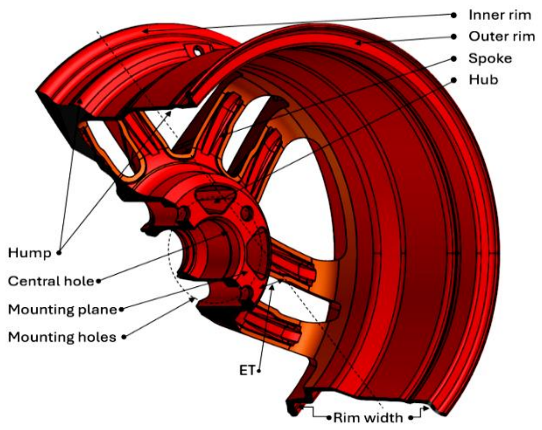


Figure 6 The most important parts of the rim

Table 2 Mechanical properties of the various parts of the rim shown in **Figure 5**

Spoke				**Edge back/front**			
$R_{0,2}$ (MPa)	R_m (MPa)	A (%)	HB	$R_{0,2}$ (MPa)	R_m (MPa)	A (%)	HB
≥ 160	≥ 220	≥ 4	≥ 70	≥ 170	≥ 240	≥ 7	≥ 80
Naba				**Runners (flat samples)**			
≥ 160	≥ 220	≥ 2	≥ 70	≥ 160	≥ 220	≥ 3	≥ 70

5. MACHINING OF RIMS

Machining consists in obtaining the appropriate dimensions and shape of the rim in accordance with the technical drawing. This process is fully automated (CNC machining) and consists mainly of turning and drilling. All operations are performed in automated numerically controlled machining centers. After the machining process, the rims are directed to a washer, after which the critical features are automatically measured. These features are different for each customer, but the most common are, for example, the diameter of the center hole, the spacing of the mounting holes, the diameter of the lid, the width of the lid seating, etc. Static and dynamic balancing is then measured, followed by a tightness check. After the tightness check, the rims go to the manual processing stations, where the final grinding (removal of any sharp surfaces) is done.

6. PAINTING OF RIMS

The rim painting process begins with chemical treatment to prepare the surface for painting. The chemical treatment consists of a cycle of cleaning baths, i.e. degreasing, removal of any mineral and chemical deposits left over from previous processes. After the chemical baths, the rims are sent to a dryer, where they stay at 155 °C for about 45 minutes. The dried rims are directed to the powder booth, where priming powder is applied using the electrostatic method (**Figure 7**), and then placed in the furnace, where the powder is fired at 210 °C. After leaving the furnace, the rims are directed to a booth where a color-enhancing base coat is sprayed, followed by the application of clear coat. The painting time for one rim is about 5 h. The finished rim is sent to the packaging area for preparation for shipment. The triple painting of aluminum rims is what makes them resistant to all kinds of external factors.

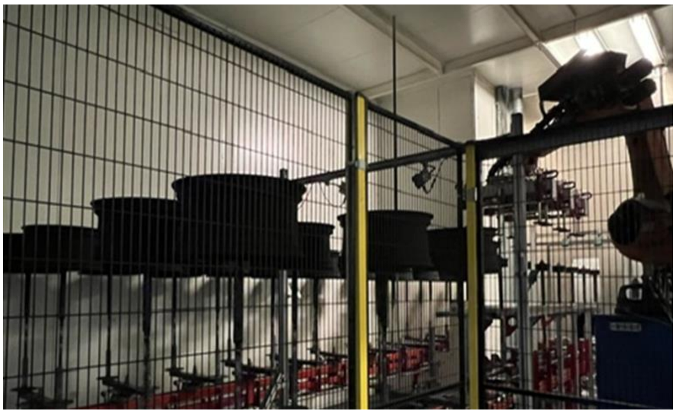


Figure 7 Painting

7. SUMMARY

Low-pressure casting is now a common process used in foundries. The molten aluminum alloy slowly fills the mold under low air pressure, which can be controlled thus reducing turbulence and obtaining very good quality casting parts (less risk of oxide formation and porosity).

In addition, thanks to the total control over the time of filling the mold, the internal structure of the material is more homogeneous and free of defects, which has its direct effect on increased strength, especially tensile strength. Low-pressure casting guarantees good density, strength and high dimensional accuracy. All this makes Al-Si alloy wheels superior to steel ones in the following aspects:

- weight - aluminum wheels are lighter than steel wheels by about 15 to 30%, which contributes to lower fuel consumption and higher car performance,
- increased ductility - aluminum wheels can withstand higher loads under varying driving dynamics, as well as during braking,
- better cooling of brake discs and pads - cool brakes work more efficiently, resulting in less deformation of brake discs,
- corrosion resistance - with the use of appropriate coatings, aluminum wheels are more resistant to corrosion, especially in harsh autumn and winter conditions,
- for larger diameters (over 18 inches), practically only aluminum variants are available, as they have greater durability than steel versions**.**

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