ANALYSIS OF ALSI7MG0.3 ALLOYS WITH CALCIUM FOR SURFACE ROUGHNESS

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Abstract. Machining of aluminum alloys is a frequently used technology for further processing of aluminum alloys into final products. Roughness and surface profile are among the basic indicators of surface quality. The infeed and cutting speed can also have a further influence on the roughness parameters, which significantly influence the direction of the primary plastic deformation region and thus affect the usable surface properties. The article deals with an experiment with machined alloy AlSi7Mg0.3 and other new alloys of the type AlSI7Mg0.3 with different calcium content. For experimental purposes, an aluminum alloy from the group of hypoeutectic silumin AlSi7Mg0.3 was used. The alloying was carried out using calcium in the form AlCa10 master alloy. A total of melts were cast. The first without the addition of AlCa10 master alloy and the other three with graded amounts of calcium, namely 0.1, 0.5 % and 1 % Ca. The paper describes the evaluation of the roughness of the obtained surface after machining these castings in the base alloy and in the alloys with calcium. The values of the parameters Ra, Rz and Rt were measured, where the parameter Ra is the most commonly used in common engineering practice, Rz is used mainly for the evaluation of the surface quality in the automotive industry and Rt is directly related to the material share, when the significance of this parameter for the surface evaluation increases. The experiment and measurements are part of more extensive research conducted at FSI UJEP.

Keywords: aluminium alloys AlSi7Mg0.3, master alloy AlCa10, roughness, machinability, surface quality.

Introduction

Machining of aluminium alloys is a technological process that is often used. However, it is associated with considerable problems due to the material softness and toughness. In terms of machining technology, machinability is one of the most important properties of materials. Machinability can include a number of properties and parameters. In addition to the requirement for the workpiece dimension accuracy, these are tool life, cutting forces, surface quality and the desired chip shape for a given machining method [1].

The quality of the machined surface is an indicator that can provide information about both the machining process that has taken place and the material and its properties that have been machined. The aim of the experiment was to analyse the possible effect of calcium modification on the surface roughness after machining of the investigated alloy, because this indicator is one of the important elements in evaluating the quality of the machining process [2].

In the previous publications of the author, it was stated that a long chip is entering during machining of aluminium alloys. This also applies to hypoeutectic silicones, which include the alloy studied in the experiment. The experiment was realized on AlSi7Mg0.3 alloy. The structure of this alloy consists of primary dendrites of α (Al) phase and eutectic. As silicon content increases, so does the occurrence of eutectics [3].

Aluminum alloys with silicon have a very fast development due to the wide range of applications, they are among the most widely used foundry alloys and in terms of volume most produced aluminium alloys in the nonferrous metal foundry industry. AlSi7Mg0.3 alloy has a wide and highly up-to-date range of applications in various industries, especially for castings of passenger car wheels, as well as for engine parts and, last but not the least, in the aerospace industry.

Improvement of machinability of aluminium alloys can be improved by adding some elements in the form of modification or inoculation. By increasing the content of these elements in the solid solution, the machinability of the material is improved. Modification is a process, in which the melt is treated with various elements, or their alloys, to influence the mechanism of solidification of the eutectic. The modifying effect of calcium has not yet been fully investigated.

The opinions on Al-Si calcium modification are essentially different. Part of the authors consider calcium to be a modifier, the other part – calcium has a modifying effect as a harmful element, because the calcium modified structure is inferior to that of another element. At a higher calcium content (above 0.14 wt. %), the intermetallic phase of CaSi2 and another, yet undetected composition is formed. These phases disrupt the homogeneity of the structure and reduce the mechanical properties

[1]. At the same time, the formation of this phase negates the harmful effect of Si. Without the addition of Ca, it would also not be possible to produce thin walled and complicated castings, since Ca improves casting properties, and in particular, curves. The presence of Ca further reduces the corrosion resistance of foundry aluminum alloys, increasing the solubility of hydrogen in the melt causing the presence of pores in castings [3]. At present, this topic is very topical in view of the high demands of both qualitative and quantitative parameters, especially in the automotive industry.

Calcium has been used for binding impurities in aluminium alloys in the past, but the results were not stable. Calcium was also designed to improve electrical conductivity in commercial aluminium.

The paper deals with the influence of added AlCa10 master alloy into the hypoeutectic silicon AlSi7Mg0.3 mainly due to the technological properties of the new AlSi7Mg0.3Ca alloy. Calcium causes a significant change in the structure in the original AlSi7Mg0.3 alloy by eliminating eutectic silicon in the form of rods to fibres that appear as round grains in the metallographic section. A machinability test was performed on the investigated alloys.

From the binary diagram of Al-Ca (Fig. 1) the solubility of calcium in aluminium is readable to some extent, it is a hypereutectic alloy. AlCa10 alloy contains eutectic (α + AlCa4) and coarse plates of Ca Al4 phase. Metallurgical defects and large pores are also evident in the structure. It can also be stated that the AlCa10 master alloy exhibits considerable structural heterogeneity in the CaAl4 phase plate distribution [4; 5].

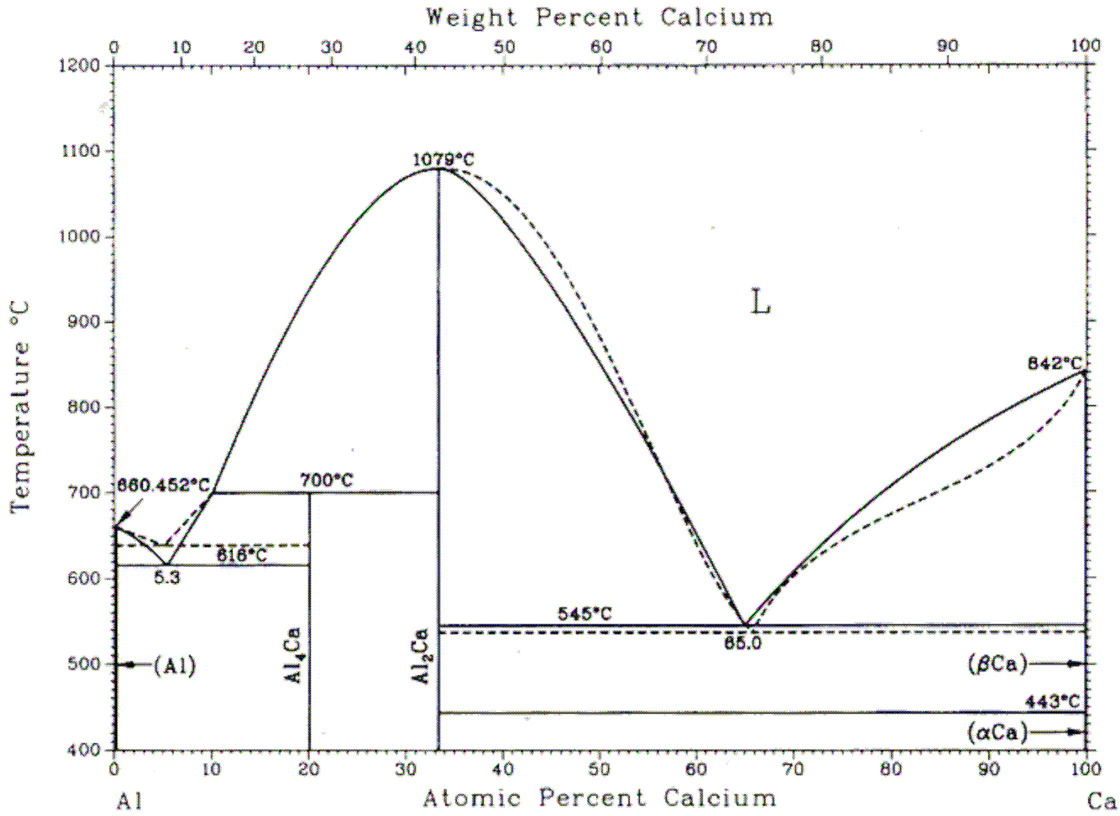

Fig. 1. **Binary diagram aluminium – calcium [6]**

Preparation of AlSi7Mg0.3 alloy samples with different Ca content

For experimental purposes, an aluminium alloy from the group of hypoeutectic silumines AlSi7Mg0.3 with the chemical input composition is given in

Table 1. The alloying was carried out using calcium in the form of AlCa10 master alloy. A total of 4 heats were cast. The first without addition of AlCa10 master alloy and three others with graded calcium 0.1 %, 0.5 % and 1 % Ca [7].

Castings were round bars with a diameter of 20 mm and a length of 200 mm, total of 40 specimens. Five measurements were made for each type of alloy, and average values were calculated from all measured values. The test specimens were machined on the Emcomat – 14s. For machining of castings, cutting conditions have been established to determine the effect of structure change by adding calcium on the chip shape, tool wear and roughness. The same cutting conditions and one type of indexable inserts were determined for machining all castings.

Table 1

Input chemical composition of alloy AlSi7Mg0.3

Alloy	Chemical composition in % by weight								
Alloy AlSi7 Mg0.3	Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti
	7.09	0.105	0.001	0.017	0.23	0.001	0.001	0.003	0.118
	Chemical composition in % by weight								
	B	Be	Ca	Cd	Ga	Li	Na	V	Al
	< 0.0001	< 0.0000	< 0.0002	0.0036	0.0131	< 0.0000	0.0004	0.0031	< 92.41

Cutting conditions were determined primarily with respect to the type of the machine and tool used. The tool used was cutting inserts Pramet DCMT070202E-UR, which is shown in Fig. 2 and Table 2. The following conditions were determined based on the machine material and the machine and tool used. The depth of cut a_p = 1 mm and feed rate per revolution f = 0.12 mm, these conditions were chosen in order to ensure that the plate was fully loaded and the wear was made with respect to the material to be machined. The cutting speed was adjusted to the maximum speed of n_{max} (min^{-1}), used Emcomat – 14s.

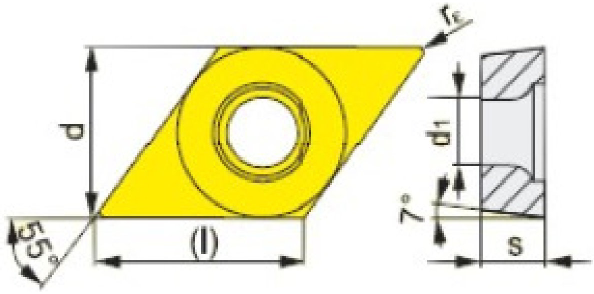

Fig. 2. **Cutting insert DCMT070202E-UR [8]**

Table 2

Characteristics of cutting insert DCMT070202E-UR [8]

Dimensions, mm					Feed, mm		Depth of cut, mm	
l	d	$d1$	s	$r\varepsilon$	f_{min}	f_{max}	a_{min}	a_{max}
7.8	6.350	2.8	2.38	0.2	0.05	0.12	0.2	1.0

To determine the final cutting conditions, calculations were performed that were calculated with respect to the optimum tool life. The calculation of the cutting conditions was based on the selected type of indexable inserts, the maximum conditions of use were chosen to show signs of wear with respect to the material being machined and the amount of the material being machined.

Due to the use of maximum machine speed values, the cutting speed was adjusted to a cutting speed value of $v_c = 226$ m·min^{-1}, at this speed, the maximum standing speed is $n_{max} = 3998.585$ min^{-1}. The values have been adjusted for maximum wear to show the wear [8].

After casting and machining, the sample set was heat treated. The set consisted of a total of 20 samples of 5 castings from each type of alloy, without added calcium, with a calcium content of 0.1 wt. %, 0.5 wt. %, 1.0 wt. %.

The thermal regime had the following stages.

1. Dissolve heating at 530 ºC for 6 hours.
2. Turbidity of samples 30 seconds after being removed from the furnace into water at 30 ºC.
3. Cure (aging) samples at 170 ºC for 2 hours. The samples were placed in a preheated oven.
4. Removing the samples from the furnace and cooling them in air (ambient temperature 22 ºC).

The samples for each type of alloy were wire-bonded, for ease of handling, were placed in the furnace for 6 hours, after being removed from the furnace, quenched in a ceramic vessel in 30 ºC water. They were then put back in a preheated oven at 170 ºC for 2 hours and cooled in air at 22 ºC.

Surface roughness analysis

After machining of samples, the roughness of the machined surfaces of individual castings was determined. Surface roughness and surface profile are described by the standard ČSN EN ISO 4287. The standard defines parameters of surface roughness, profile and material content including calculations, classification of permissible inequalities, labelling and methods of their evaluation. At present, the most commonly used parameter is *Ra* – average arithmetic deviation of the assessed profile, further the highest profile height *Rz* and the total profile height *Rt*, which were also evaluated within the experiment.

The roughness measurement was performed on the Hommel Tester T1000, which evaluates the surface profile based on the movement of the probe tip over the measured surface and displays the data in the evaluation program. The measurements were performed on cast samples after machining. One part of the measurements was carried out on samples of all types of alloys without heat treatment and the other part was carried out on samples of all types of alloys after heat treatment. The values are displayed on Table 3.

Table 3

Average roughness values for all types of alloys without heat treatment

Measured parameter		**AlSi7Mg0.3 with 0 wt. % Ca**	**AlSi7Mg0.3 with 0.1 wt. % Ca**	**AlSi7Mg0.3 with 0.5 wt. % Ca**	**AlSi7Mg0.3 with 1 wt. % Ca**
***Ra*, μm**	Ø, μm	0.178	0.346	0.196	0.228
	± σ	0.009	0.189	0.028	0.097
***Rz*, μm**	Ø, μm	1.28	2.618	1.234	2.398
	± σ	0.073	1.509	0.131	1.552
***Rt*, μm**	Ø, μm	1.518	7.796	1.664	5.692
	± σ	0.143	7.294	0.125	5.277

According to the graph, for *Ra*, *Rz* and *Rt*, it is clear that the calcium modification has a negative effect on the surface roughness after machining. The highest values are achieved with a calcium content of 0.1 wt. % Ca. As the calcium content increases further, the Ra value decreases, the other roughness values (*Rz* and *Rt*) remain slightly elevated, but do not reach the same values as for the alloy containing 0.1 wt % Ca.

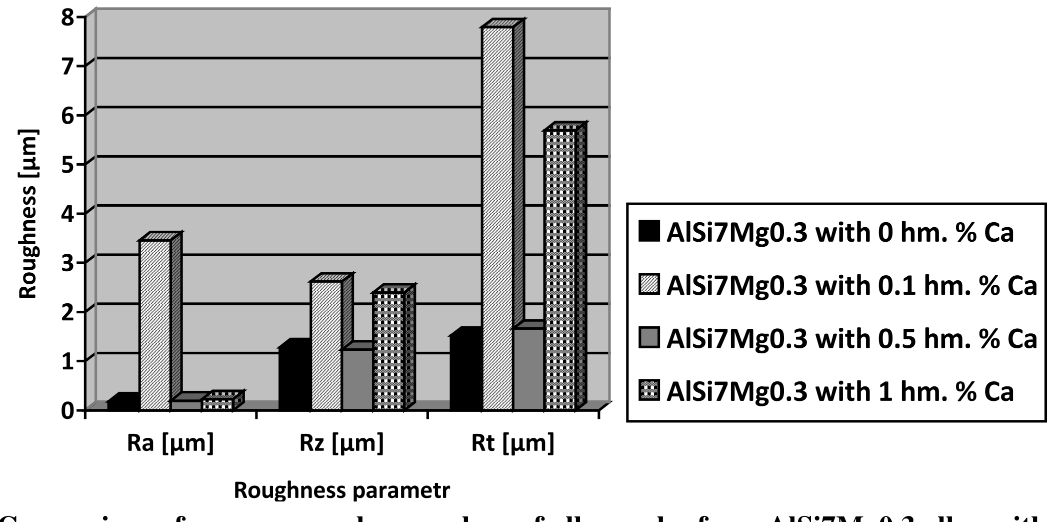

Fig. 3. **Comparison of average roughness values of all samples from AlSi7Mg0.3 alloy with different calcium content without heat treatment**

The second part of the samples was after heat treatment. The heat treatment was carried out according to the conditions described above. Five measurements were made for each alloy type (0 wt. % Ca, 0.1 wt. % Ca, 0.5 wt. % Ca and 1.0 wt. % Ca) and average values were calculated from all measured values, Table 4.

Table 4

Average roughness values for all types of alloys after heat treatment

Measured parameter		AlSi7Mg0.3 with 0 wt. % Ca	AlSi7Mg0.3 with 0.1 wt. % Ca	AlSi7Mg0.3 with 0.5 wt. % Ca	AlSi7Mg0.3 with 1 wt. % Ca
***Ra*, µm**	Ø, µm	0.245	0.506	0.268	0.301
	± σ	0.011	0.219	0.048	0.107
***Rz*, µm**	Ø, µm	1.75	3.968	1.60	3.483
	± σ	0.104	1.856	0.184	2.018
***Rt*, µm**	Ø, µm	1.908	8.124	1.895	6.213
	± σ	0.234	7.342	0.149	5.110

Referring to Fig. 4, there is no significant change in the samples after heat treatment.

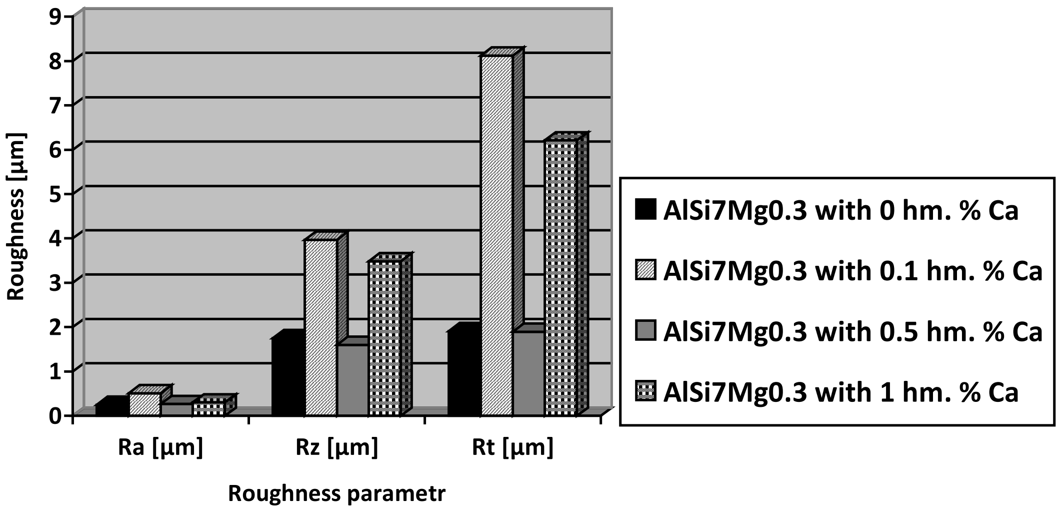

Fig. 4. **Comparison of average roughness values of all samples from AlSi7Mg0.3 alloy with different calcium content after heat treatment**

Conclusions

With the investigated alloys a machinability test was performed. According to previous analyses, the calcium containing alloy 0.5 wt. % showed better performance compared to other alloys. It can be stated that even from the roughness point of view it is an alloy with good properties, only a negligible increase in the roughness. This increase in the roughness content of the alloy has no effect on the roughness parameters.

In general, after the heat treatment, the values of all measured parameters increased slightly. Alloys with a calcium content of 0.5 wt. % show the same values slightly increased with the stating alloy. So, we can also say that heat treatment has no significant positive effect on the roughness.

The infeed and cutting speed can also have a further influence on the roughness parameters, which considerably affects the direction of the envelope of the primary plastic deformation and thus affects the properties of the useful area.

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