

Chapter 6

Nataša Náprstková¹, Jaromír Cais², Jaroslava Svobodová³

INFLUENCE OF AlSi7Mg0,3 MODIFICATION BY Sr TO ITS MACHINING PROCESS QUALITY

Abstract: Al-Si Alloys are a leading casting alloys based on aluminum. Machining of aluminum alloys is currently frequently used and it is an important area of production. The paper deals with an experiment, that was realized at the Faculty of Production Technology and Management, University of Jan Evangelista Purkyně in Ústí nad Labem, where was machined alloy AlSi7Mg0.3. Samples were made for machining because of the master alloys of AlSi7Mg0.3, where part of the castings was left in its original condition and part of the castings was modified by strontium. This paper describes the evaluation of surface roughness and tool wear obtained after machining of these castings in terms of how the modification by strontium can affect this.

Key words: modification, machining, tool wear, roughness, cutting insert

6.1. Introduction

Machining of aluminum alloys is now often used technological process. This also applies to bellow eutectic silumins. Al-Si alloys (silumins) are among the most important casting alloys based on aluminum. They are intended for the production of shaped castings cast in sand, cast in metal mold or pressure cast. Silumins have high corrosion resistance, low coefficient of linear shrinkage and satisfactory mechanical properties. The system Al-Si is characterized by equilibrium

¹ MSc., PhD., Jan Evangelista Purkyně University in Ústí nad Labem, Faculty of Production Technology and Management, naprstkova@fvtm.ujep.cz

² MSc., Jan Evangelista Purkyně University in Ústí nad Labem, Faculty of Production Technology and Management, cais@fvtm.ujep.cz

³ MSc., Jan Evangelista Purkyně University in Ústí nad Labem, Faculty of Production Technology and Management, svobodova@fvtm.ujep.cz

diagram of eutectic type with unlimited solubility in the liquid state and the limited solubility of the aluminum and full insolubility of the silicon in the solid state. To improve their properties silumins alloyed, inoculate and modify. The experiment at FPTM was conducted with the alloy AlSi7Mg0,3, when this alloy was modified of strontium. (BOLIBRUCHOVÁ D. 2005, MICHNA Š. 2005 a)

AlSi7Mg0.3 alloy is widely used in the automotive industry as casting wheels for passenger cars or parts of engines. Another area where we can meet with this alloy is aerospace industry. Due to the presence of Si, namely the phase Mg_2Si is this alloy suitable for curing. Modification of aluminum alloys in the current production has a great importance, because the use of aluminum alloys is constantly growing and modification improves their utility properties. (MICHNA Š. 2008 b, VAJSOVÁ V. 2009).

Tool wear and quality of the machined surface is an indicator that can provide information about both of the antecedent machining process and so about the material and its properties, which has been machined. (CZÁN A. 2006, NOVAK M. 2011)

The aim of the experiment was to analyze the possible effect of modification by strontium on the surface roughness after machining of the examined alloy and on tool wear because these are the important elements for the machining process quality evaluation.

6.2. Experiment

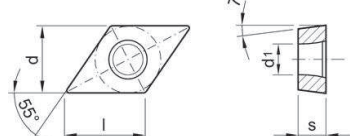
For the experiment with machining was produced 6 casting pieces from master alloy AlSi7Mg0,3. Three of them were made only from master alloy without further modifications and three were modified of strontium. Mass amount of Sr for subsequent modification was determined as 0,04%.

Castings were necessary to adjust for processing. The input sample size for the machining was 220 mm for length and 60 mm for diameter.

Test samples were machined on a lathe Emco Mat - 14 S, which is on the FVTM available. Lathe has a maximum speed of 4000 min^{-1} with

smooth control and drive power 7.5 kW. [7]. Set cutting conditions were based primarily from the type of machine and tool. Used cutting tool were plates (inserts) PRAMET DCMT 070202 E - UR, their characteristic is summarized in Tab. 6.1. Based on the material to be machined and used machine and tool was set depth of cut $a_p=1\text{ mm}$ and feed per revolution $f=0,12\text{mm}\cdot\text{rev}^{-1}$. Cutting speed v_c was necessary to adapt the options of used lathe Emco Mat - 14 S, particularly its maximum rotation speed n . Cutting plate was clamped at the outer bracket SDJCR 12 12 F 07 KT 016.

Table 6.1. Characteristic of cutting plate (insert) DCMT 070202 E-UR

Dimensions [mm]					Feed [$\text{mm}\cdot\text{rev}^{-1}$]		Depth of cut [mm]	
l	d	d_1	s	r_e	f_{min}	f_{max}	$a_{p,min}$	$a_{p,max}$
7.8	6.350	2.8	2.38	0.2	0.05	0.12	0.2	1.0
								

The performed calculations show that for machining of the casting were needed high speed (resulting from machined material), used lathe has a maximum rotation speed $4000\cdot\text{min}^{-1}$, which was not entirely satisfactory. Therefore, the cutting speed for actual machining v_c was adapted to used lathe for resulting value $v_c=200.96\text{ m}\cdot\text{min}^{-1}$. At this speed v_c , the rotations were $n = 1066\cdot\text{min}^{-1}$ for diameter 60 mm and $n = 4000\cdot\text{min}^{-1}$ for diameter 14 mm.

6.3. Performed analysis

After machining of samples were evaluated the cutting plates wear and the roughness of the machined surfaces of the individual castings after the machining of the samples. The measurements were performed using the measuring device Hommel tester T 1000 and microscope Olympus SZX 10. (KALINCOVÁ D. 2010)

All measured values were averaged and the middle standard deviation was determined according to the equation (6.1), where:

x_i - measured value from one measurement

\bar{X} - average mean of measurements

n – number of measurements

$$\sigma = \pm \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{X})^2}{n}} \quad (6.1)$$

6.3.1. Analyses of the cutting insert wear

The experiment was evaluated by the following criteria insert plates wear:

- wear of front face VB,
- maximal wear of front face VBmax,
- wear of tip radius area VBc. (DUGIN A. 2013)

The measurement principle of tool wear is shown in Fig. 6.1. Fig. 6.2. shows wear of the insert after machining of unmodified alloys and Fig. 6.3. wear insert after machining of modified alloys.

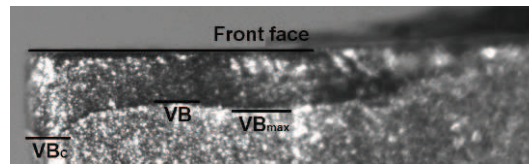


Fig. 6.1. The principle of measurement of wear values of cutting plate (insert)

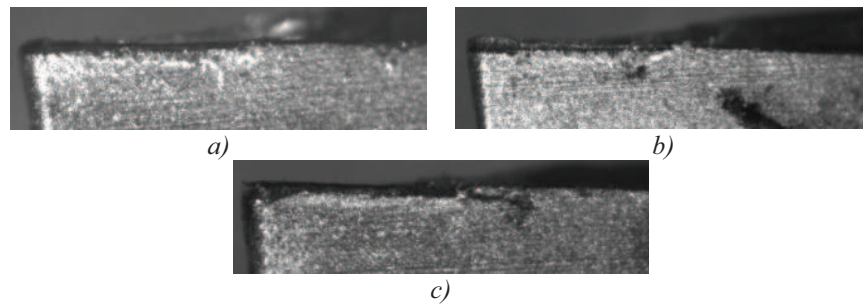


Fig. 6.2. Cutting inserts after cast machining from master alloy: a) sample 1, b) sample 2, c) sample 3

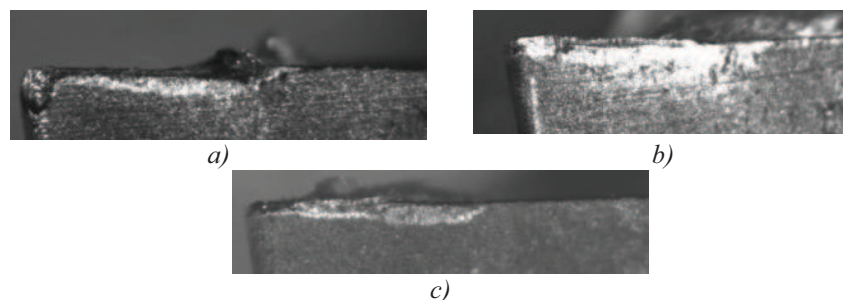


Fig.6.3 Cutting inserts after cast machining from modified alloy: a) sample 1, b) sample 2, c) sample 3

On the Fig. 6.4. is a sample of measurement.

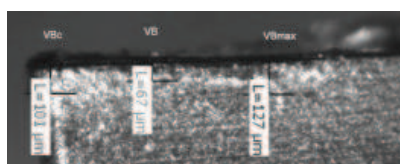


Fig.6.4. Measurement demonstration of insert wear in frame of experiment

The measured averaged values of wear plates are summarized in Tab.6.2.

Table 6.2. The measured values of the used inserts wear

Cast No.	Modif.	Tool No	The parameters of tool wear					
			\overline{VB} [μm]	$\pm\sigma_{VB}$ [μm]	\overline{VBmax} [μm]	$\pm\sigma_{VBmax}$ [μm]	\overline{VBc} [μm]	$\pm\sigma_{VBc}$ [μm]
1	no	1a	52,33	10.65624	98.33	21.2968	90,33	18.811
2		1b						
3		2a						
4	yes	2b	47	14,7648	70,33	12,2957	117	71.9073
5		3a						
6		3b						

In Fig. 6.5 is a comparison of the average tool wear VB, VBmax and VBc for the modified and unmodified alloy. From this graph it is seen that the average wear of the insert is smaller in the case of modified castings, only in case VBc (wear of the tool tip) it is the opposite. But this

deviation caused the value 217 μm on one plate 2b (Fig. 6.3. a). This could be most probably due to the highly irregular shape of casting No. 4 where after the preparation of casting for the experiment was in the sample at the bottom of the visible groove (shrinkage) which caused during machining with diameter 60 mm to 56 mm strong sound effects and vibration of the whole system. It is therefore likely that this is due the tip wear on the tool 2b is so significant. For the other two modified casting this wear is again noticeably lower. It can therefore be concluded that the modification of AlSi7Mg0,3 alloy by Sr has the expected positive effect on tool wear.

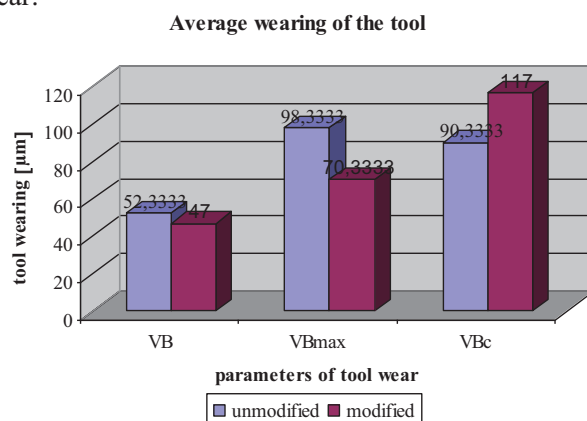


Fig. 6.5. Comparison of the average tool wear

Before starting of machining, there was also an assumption with regard to the type of material that will be on the tool heavily built-up form, and this suspicion was well filled. Built-up was formed on all cutting plates. On the Fig. 6.6. is the example of it.

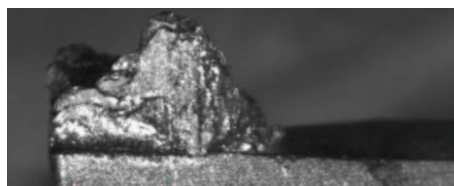


Fig. 6.6. Sample of created up edge (built-up) on the insert

This phenomenon was probably caused especially by cutting conditions, but which have been set to their maximum in order to insert showed wear.

6.3.2. Analysis of the roughness of the machined surface

The surface roughness is defined according to the standard EN ISO 4287 and in the field of the experiment the attention was focused at the parameters Ra, Rz and Rt. Data output of this device is in the form of the protocol. (VALÍČEK J. 2008) The measurement was performed always in the upper, middle and bottom part of the casting and every five measurement. The measured wear values of the cutting plates are summarized in the tab. 6.3. till tab. 6.5.

Table 6.3. Measured surface roughness after the machining of the unmodified and modified casting – upper part

Casting number	Modification	Upper part of the casting				
		Ra [μm]	$\pm\sigma_{Ra}$ [μm]	Rz [μm]	$\pm\sigma_{Rz}$ [μm]	Rt [μm]
1	yes	8.84	1.1932	40.297	5.7607	60.722
2		7.118	0.9305	32.62	2.1397	45.744
3		9.426	0.5678	42.33	3.8931	50.504
4	no	9.606	0.6478	43.14	3.3430	53.454
5		9.432	0.8282	41.666	3.0824	53.38
6		9.428	1.2774	40.984	6.1808	60.298

Table 6.4. Measured surface roughness after the machining of the unmodified and modified casting – middle part

Casting number	Modification	Middle part of the casting					
		Ra [μm]	$\pm\sigma_{Ra}$ [μm]	Rz [μm]	$\pm\sigma_{Rz}$ [μm]	Rt [μm]	$\pm\sigma_{Rt}$ [μm]
1	yes	5.992	0.1692	28.628	1.0173	36.154	1.944
2		4.814	0.4902	23.942	2.4505	32.09	5.8504
3		5.934	0.3003	27.2	3.4203	38.2	3.8346
4	no	4.686	0.6656	23.96	2.3375	33.44	3.9491
5		6.06	0.4148	30.508	2.3624	42.234	4.5491
6		5.566	0.5011	27.444	1.2828	40.718	4.4962

Table 6.5. Measured surface roughness after the machining of the unmodified and modified casting – bottom part

Casting number	Modification	Bottom part of the sample					
		Ra [μm]	$\pm\sigma_{Ra}$ [μm]	Rz [μm]	$\pm\sigma_{Rz}$ [μm]	Rt [μm]	$\pm\sigma_{Rt}$ [μm]
1	yes	3.698	0.4137	20.928	2.2068	28.732	3.9918
2		4.92	0.4315	26.746	2.9937	39.504	12.0912
3		4.432	0.5279	23.602	3.1711	35.64	5.7427
4	no	4.442	0.6485	25.074	3.3989	35.756	7.7960
5		5.12	0.9540	25.342	2.9405	33.416	4.8425
6		3.902	0.59	23.074	3.37	33.704	8.3548

The average achieved values of the measured roughness for modified and unmodified castings in the upper, middle and bottom part of the casting are on the Fig. 6.7. till 6.9.

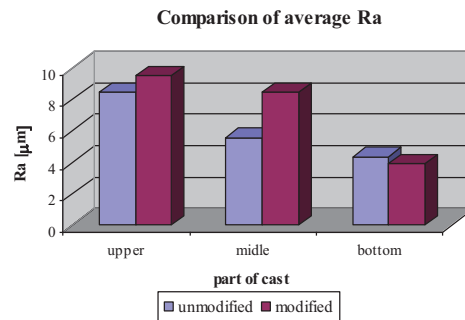


Fig. 6.7 Comparison of the average Ra for unmodified and modified alloy

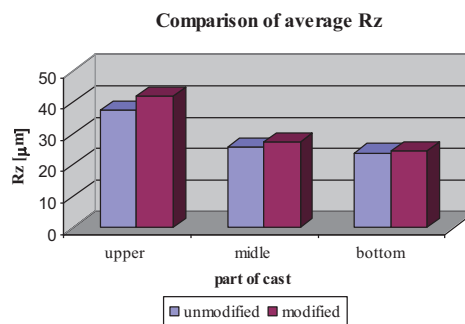


Fig. 6.8 Comparison of the average Rz for unmodified and modified alloy

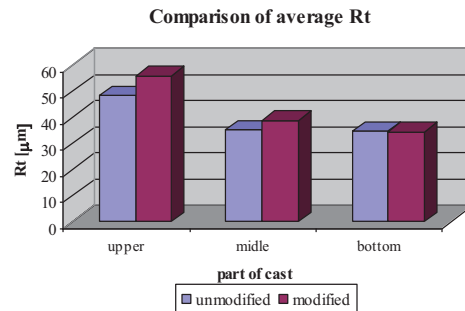


Fig. 6.9. Comparison of the average Rt for unmodified and modified alloy

From the data above it is apparent that the modification Sr had not a great influence at the surface roughness. Its values were almost identical with the values of the unmodified alloys. There is a little different to the disadvantage of the modified castings. Only by the roughness Ra in the middle part of the casting it is a noticeable different but because the way of the casting (gravity casting) it can only mean irregularity in the casting structure. Furthermore, it is possible to conclude, that the values of all the types of the roughness were always the greatest in the upper part of the sample and downward decreased with that in the middle and bottom part of the workpiece they were at a similar level. It can be attributed to the method of the castings and to their cooling again. This is also supported by the microstructural analysis (Fig. 6.10. and 6.11.), where it is possible to see the finer structure in the bottom part of the casting than in the upper part of the casting and this by the modified and unmodified casting.

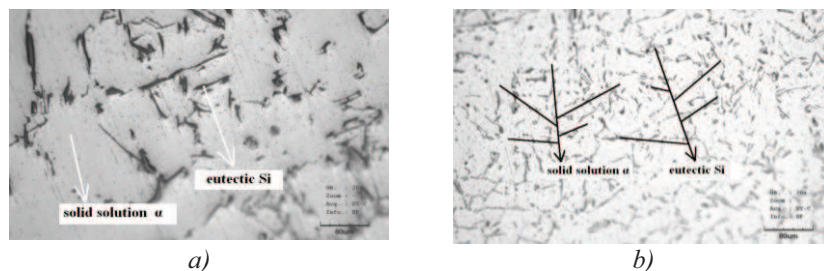


Fig. 6.10. Structure of the unmodified casting, magnified 200x, a) upper part, b) bottom part

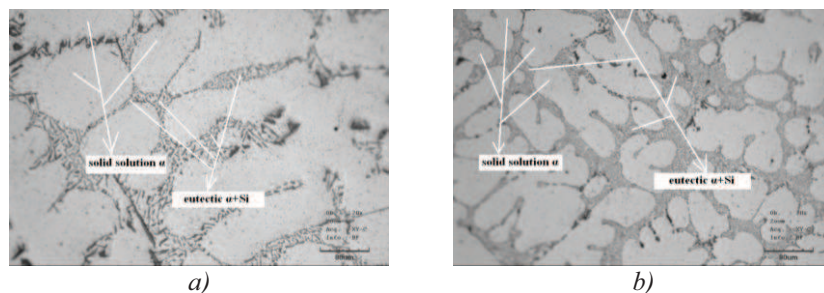


Fig. 6.11. Structure of the modified casting, magnified 200x, a) upper part, b) bottom part

6.4. Conclusion

In the frame of experiment were cast six casts pieces from master alloy AlSi7Mg0,3. Three castings were produced only from the master alloy, without other modification of the melt, the three castings were produced from the master alloy, which has been modified strontium so that the modification of strontium consisted 0.04% by weight of the melt. The castings were subsequently machined and were then evaluated the effect of modifications to the tool wear and surface roughness obtained with the use of the parameters Ra, Rz and Rt.

Based on the measured values could be stated that the average of insert wear is reduced in the case of modified castings, just in case VBc (wear of the tool tip) is the opposite, but here it is probably due to the inhomogeneity of the casting and the results of other casting has been modified again show less wear. It can therefore be concluded that the modified of alloys AlSi7Mg0,3 has the expected positive effect on tool wear (lower wear after machining of modified alloy).

By optimizing of the modification process and melting in laboratories at FPTM can be achieved a structure that would be more homogeneous and we can then assume that the measured results should be less variance.

As expected, also on the tool intensively formed built-up, which was probably caused used cutting conditions, but which cannot be changed (to

be used as possible cutting conditions to on the plates, due to the quantity and type of material to be machined, wear resulted). The experiments and measurements are part of the extensive research carried out at FPTM JEPU.

Was evaluated the roughness of machined samples with help of parameters Ra, Rz, Rt. From the above data and graphs it showed that the Sr modification had no influence on the surface roughness. Its values were almost identical to the values of the alloy without modification. Detected anomalies could be caused by the way of the casting (graphite crucible to melt, handmade blending melt, gravity casting), that caused uneven structure within the single cast. This could be solved for example by the using of the pressure casting which is usually used for the aluminium castings or also using the induction melting furnace where it would be ensured better mixing of the melt. These technologies are currently on FPTM unavailable. The performed experiment and measurements are the part of the extensive researches performed at FPTM UJEP.

By optimizing of the modification process and melting in laboratories at FPTM can be achieved a structure that would be more homogeneous and we can then assume that the measured results should be less variance.

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