Analysis of Machinability of New AlSi7Mg0.3 Alloys with Different Calcium Content

Elena Střihavková
Faculty of Mechanical Engineering, J. E. Purkyne University in Usti nad Labem. Pasteurova 3334/7, 400 01 Usti nad Labem. Czech Republic. E-mail: elena.strihavkova@ujep.cz

The field of application of aluminium alloys is very wide and the future use of aluminium alloys is related to the further development of new alloys. Recently, the use of alloys in aluminium alloys is a trend in achieving changes in chemical, mechanical and technological properties. This paper deals with the investigation of the area of calcium influence, especially on the machinability of the alloy. The analysis was performed by alloying AlSi7Mg0.3 with master alloy AlCa10. Four types of samples with different calcium content, from at least 0.1% Ca, up to 1% Ca maximum, were produced. In the case of such samples, research was carried out on the technological properties and especially the workability.

Keywords: Aluminium Alloy AlSi7Mg0.3, Master Alloy AlCa10, Machinability, Cutting Inserts

1 Introduction

The choice of aluminium alloys for casting is based on a number of basic criteria such as strength, shape, dimensional accuracy, surface, quality, weight, corrosion resistance, etc. The structure, and in particular the mechanical, technological and chemical properties of aluminium alloy type Al-Si can be influenced primarily by modification and addition of the valine. Modification is a process in which the melt is treated with various elements or thein alloys in order to influence the eutectic stiffening mechanism. Another type of liquid metal treatment by adding a small amount of suitably chosen substance which influences the crystallization process is a vaccination that affects the number of crystalline embryos and results, in the refining of the casting grain. Part of the authors consider calcium as a modifier, the second part precisely because, calcium has a certain modifying effect is considered to a deleterious element because the calcium-modified structure is of inferior quality as in the case of modification by another element. At a higher calcium content (above 0.14 wt. %), the intermetallic phase of $CaSi_2$ and another, yet undetected composition are formed. These phases disrupt the homogeneity of the structure and reduce the mechanical properties [1]. At the same time, creating this phase negates the harmful effect of Si. Without the addition of Ca, it would also be impossible to produce thin-walled and moped castings, because Ca improves the foundry properties, especially the boxing. The presence of Ca further reduces corrosion resistance in foundry aluminium alloys, increases the solubility of hydrogen in the melt, which causes the presence of pores in the castings [2]. At present, this topic is very timely given the high demands of both qualitative and quantitative parameters, especially in the automotive industry.

The modifying effect of calcium is not yet fully explored. Opinions about modifying Al-Si with calcium are basically different. Part of the authors consider calcium as a modifier, the second part precisely because calcium has a certain modifying effect, considers it an element harmful, because the calcium-modified structure is of inferior quality as in the case of sodium modification [3] [8].

2 Preparation of the sample AlSi7Mg0.3 alloy with different Ca content

For experimental purposes, an aluminium alloy from the group of the hypoeutectic silumin AlSi7Mg0.3 was used. This is a ternary alloy with the input chemical composition show in Tab 1. Alloying took place using calcium in the form of AlCa10 master alloy. A total of 4 melts were cast. The first without the addition of AlCa10 master alloy and the other tree with graded calcium, namely 0.1%, 0.5% and 1% Ca [4].

Tab. 1 *Input chemical composition of alloy AlSi7Mg0.3*

Alloy	Chemical composition in % by weight								
	Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti
Alloy AlSi7Mg0.3	7.09	0.105	0.001	0.017	0.230	0.001	0.001	0.003	0.118
	Chemical composition in % by weight								
	B	Be	Ca	Cd	Ga	Li	Na	V	Aluminium
	<0.0001	<0.0000	<0.0002	0.0036	0.0131	<0.0000	0.0004	0.0031	<92.41

Castings were round bars with a diameter of 20 mm and a length of 200 mm. The individual melting, refining and alloying processes were performed in an oven at 720°C, the temperature was scanner with a digital thermometer with an accuracy of ± 2°C. At each melt, the melt was treated with the refining salt and wipe was removed from the melt surface. The melt was gravitationally cast into a metal chill preheated to 220°C. After the casting, the test specimen were modified and the turning took place in several steps:

- Drilling the centring pits at both ends of the bars and turning the circumferential surface for further clamping.
- Extrude the test sticks along the length to a diameter of 15 mm where the sample was clamped between the chuck and the point fixed in the lathe´s tail.
- Turn the test rods to the final shape, removing the centre of the 12 mm rod sections.

For cutting machining cutting conditions were determined to determine the effect of structural change by adding calcium to tool wear and chip shape. For machining all castings, the same cutting conditions and one type of cutting inserts [9].

Cutting conditions were determined primarily with respect to the type of machine and tool used. The tool used was cutting inserts Pramet DCMT070202E-UR, which is shown in Fig. 1 and Tab. 2. The following conditions were determined based on the machine material and the machine and tool used. 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 machine. The cutting speed was adjusted to the maximum speed of n_{max} [min^{-1}], used Emcomat – 14s.

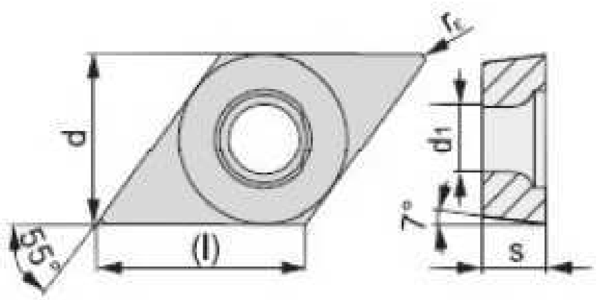


Fig. 1 *Cutting insert DCMT070202E-UR [5]*

Tab. 2 *Characteristics of cutting inserts DCMT070202E-UR [5]*

Dimensions [mm]					Feed [mm]		Depth of cut [mm]	
l	d	d1	s	rε	fmin	fmax	amin	amax
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 made which were calculated with respect to the optimum tool life. The calculation of the cutting conditions was based on the type of cutting inserts chosen, the maximum conditions of use were chosen to show signs of wear relative to the material to be machine and the quantity of workpiece material to be machined [6].

Using the maximum speed of the machine, the cutting speeds were adjusted to a cutting speed v_c = 226 m.min^{-1}, at this speed, the maximum speed was n_{max} = 3998.585 min^{-1}. The adjustment of the values was due to the maximum load in order to show the wear.

3 Replaceable cutting insert wear

After the machining of the samples, the state of replaceable inserts was evaluated and the wear of the insert was evaluated using the Olympus SZX 10 light microscope. All samples were machined with the same type of cutting inserts and under the same cutting conditions.

Tab. 3 *Overview of recommended and used cutting parameters*

Parameter	Recommended	Cutting parame-
Cutting	630 – 180	226 m.min^{-1}
Depth of cut	0.2 – 1 mm	1 mm
Feed f	0.05 – 0.12 mm	0.12 mm

Generally wear on all machine parts that are in contact with each other and relative movement. During machining, the tool – workpiece and tool – splinters occurs during the cutting process. Due to multiple factors such as the influence of mechanical, chemical, thermal and abrasive factors, wear of a replaceable insert occurs. The areas where wear is greatest are the parts of the cutting insert that are in direct contact with the workpiece and perform the cutting operation. These areas include the forehead, the main and the minor ridge and the radius of the tip [5] [9].

In Tab. 3 the recommended ranges of cutting parameters and values used in practice for machined material (aluminium alloy) are summarized.

The following parameters were measured for the wear of the replaceable inserts:

- Wear of spine VB,
- Wear of the maximum VB_{max} spine,
- VB_c peak wear.

The individual areas for measuring the wear of the ridge are shown in Fig. 2. For each cutting inserts, the shape and size of the chips was also measured.

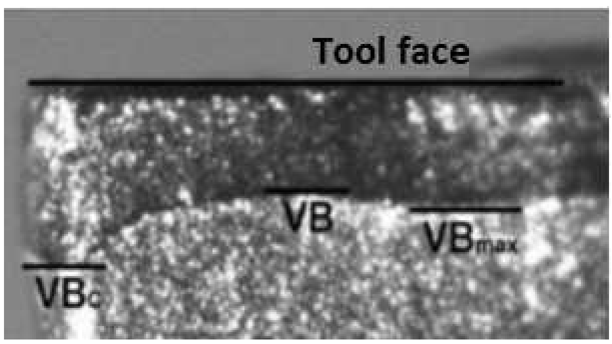


Fig. 2 *Worn area of the flank*

3.1 Wear of AlSi7Mg0.3 alloy without addend calcium 0 wt.% Ca

The first measurement was performed on the cutting insert after machining the AlSi7Mg0.3 alloy without the addition of calcium (0 wt. % Ca). Ten castings were made from this alloy. For the machining of a set of ten castings, one new insert was always used. Measured values for the

AlSi7Mg0.3 alloy without the addition of calcium (0 wt. % Ca) are shown in Tab. 4. In Fig. 3, the cutting insert is used after machining the AlSi7Mg0.3 alloy without the addition of calcium.

Tab. 4 *Values measured for cutting inserts after machining AlSi7Mg0.3 alloy with 0 wt. % Ca*

Alloy AlSi7Mg0.3 s 0 wt. % Ca	Replaceable cutting insert wear [µm]		
	VB	**VB_{max}**	**VB_c**
	55.6	85	87.4

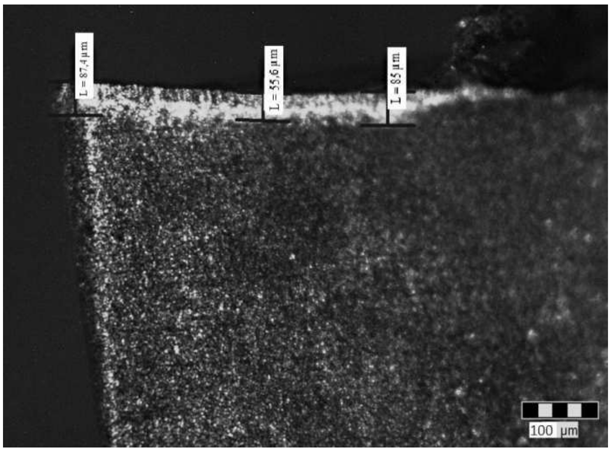


Fig. 3 *Worn cutting insert after machining AlSi7Mg0.3 alloy without added Ca (0 wt. % Ca) vol. 3.2x*

3.2 Wear on alloy AlSi7Mg0.3 without added calcium 0.1 wt. % Ca

Other machined castings were cast AlSi7Mg0.3 alloys with addend calcium (0.1 wt. % Ca). From this alloy, 10 castings were made for further testing. The AlSi7Mg0.3 altered values for the alloy with the addend amount of calcium (0.1.wt. % Ca) are shown in Tab. 5. In Fig. 4, cutting insert is used after machining an AlSi7Mg0.3 alloy with an added amount of calcium (0.1 wt. % Ca).

Tab. 5 *Values measured for cutting insert after machining AlSi7Mg0.3 alloy with 0.1 wt. % Ca*

Alloy AlSi7Mg0.3 s 0.1 wt. % Ca	Replaceable cutting insert wear [µm]		
	VB	**VB_{max}**	**VB_c**
	49.6	57.4	60.6

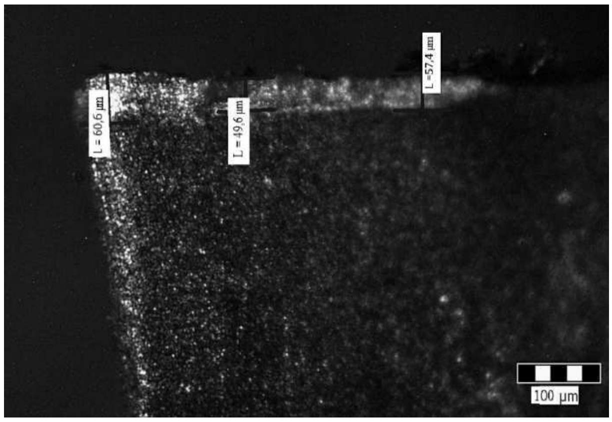
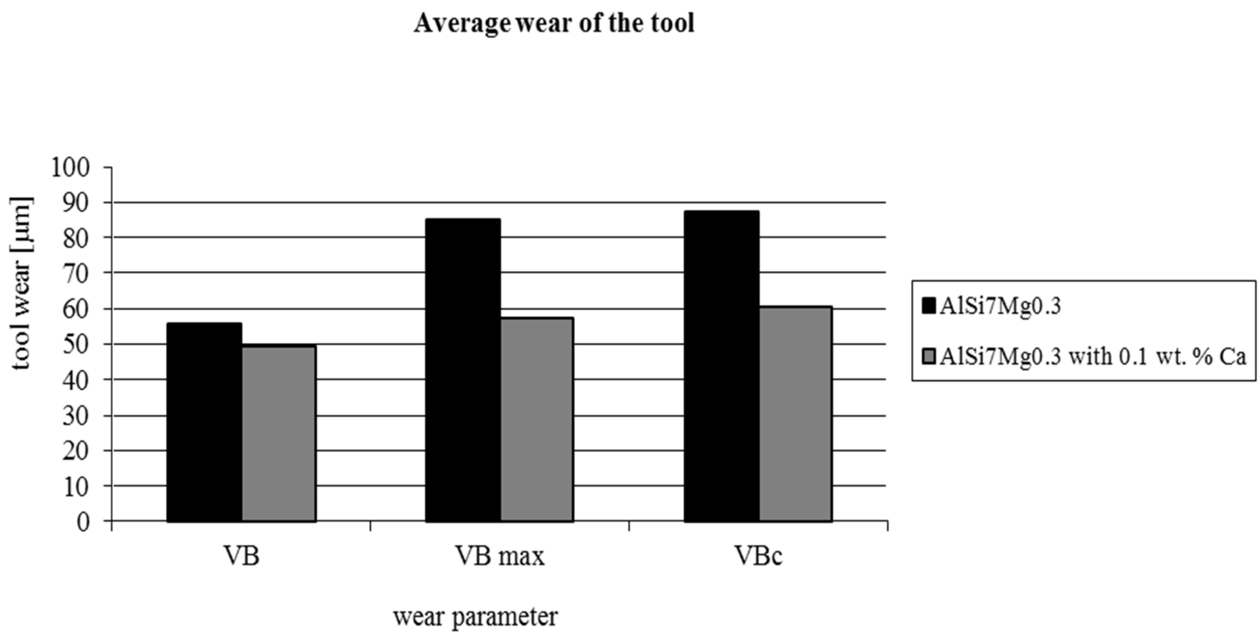


Fig. 4 *Worn cutting insert after machining AlSi7Mg0.3 alloy without added Ca (0.1 wt. % Ca) vol. 3.2x*

The Graph 1 is a comparison of the average AlSi7Mg0.3 alloy wear values without addend calcium and aluminium samples AlSi7Mg0.3 with an added amount of calcium of 0.1 wt. % Ca. The values initiates that the wear of the cutting insert is higher than the alloy insert with 0.1 wt. % Ca. According to primary results, the effect of calcium on the wear of the instrument should be positive.



Graph 1 *Average tool wear for AlSi7Mg0.3 alloy without added calcium and alloy AlSi7Mg0.3 with calcium added 0.1 wt. % Ca*

3.3 Wear of alloy AlSI7Mg0.3 with added calcium 0.5 wt. % Ca

Tab. 6 *Values measured for cutting insert after machining AlSi7Mg0.3 alloy with 0.5 wt. % Ca*

Alloy AlSi7Mg0.3 s 0.5 wt. % Ca	Replaceable cutting insert wear [µm]		
	VB	VB_{max}	VB_c
	53.6	57.8	76.8

Subsequently, alloy castings AlSi7Mg0.3 were added, with an added amount of calcium of 0.5 wt. % Ca, a new insert was again used. From this alloy, 10 castings were made for further testing. Measured values for the insert after machining the AlSi7Mg0.3 alloy with an added amount of calcium 0.5 wt. % Ca are in Tab. 6. In Fig. 5 cutting insert after is used after machining the AlSi7Mg0.3 alloy with an added amount of calcium of 0.5 wt. % Ca.

Graph 2 compares the average wear values of the AlSiMg0.3 starting aluminium without the addition of calcium and aluminium samples AlSi7Mg0.3 with an added amount of calcium of 0.5 wt. % Ca. The values confirm the previous claim and this is the positive effect of calcium on tool wear.

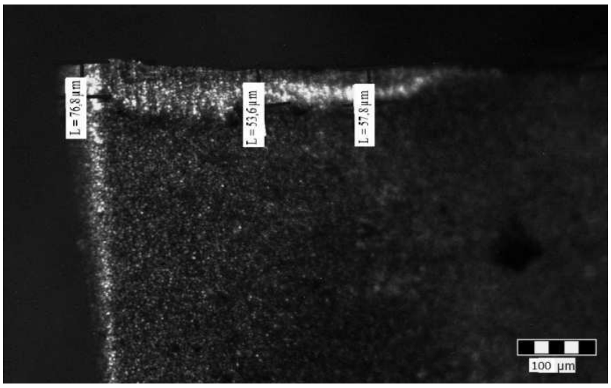
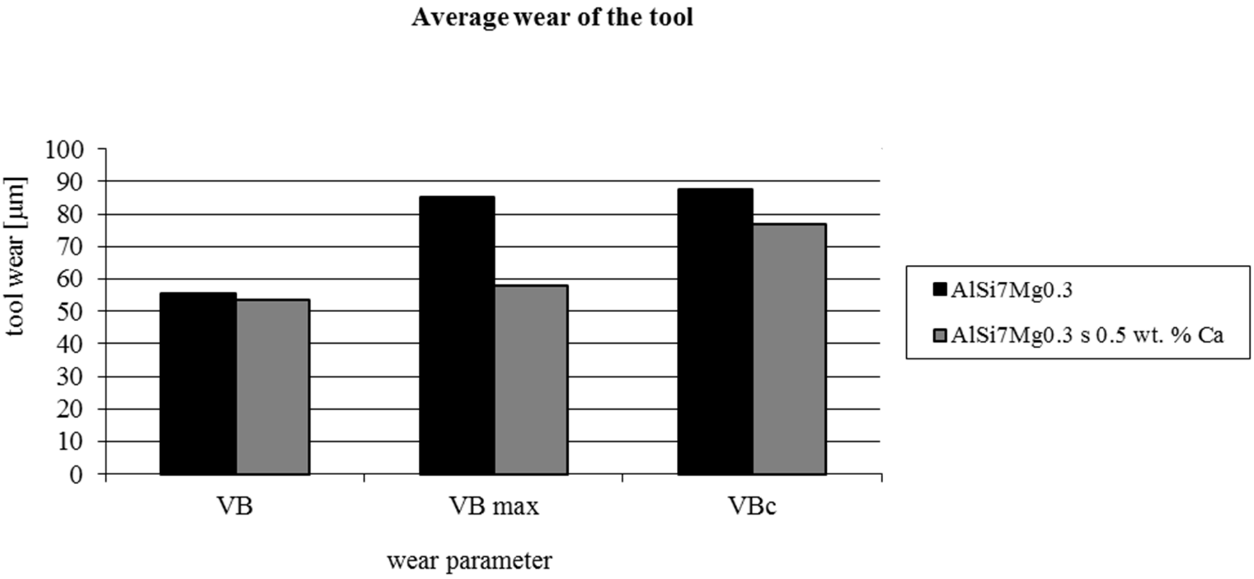


Fig. 5 *Worn cutting insert after machining AlSi7Mg0.3 alloy without added Ca (0.5 wt. % Ca) vol. 3.2x*



Graph 2 *Average tool wear for AlSi7Mg0.3 alloy without added calcium and alloy AlSi7Mg0.3 with calcium added 0.5 wt. % Ca*

3.4 Wear of AlSI7Mg0.3 alloy with added calcium of 1 wt. % Ca

The last measurement was carried out on alloys AlSi7Mg0.3 with an added amount of calcium of 1 wt. % Ca, a new cutting insert was again used. From this alloy, 10 castings were made for further testing. Measured values for the insert after machining AlSi7Mg0.3 alloy with an added amount of calcium 1 wt. % Ca are in Tab. 7. In Fig. 6 the cutting insert is used after machining the AlSi7Mg0.3 alloy with added amount of calcium 1 wt. % Ca.

Tab. 7 *Values measured for cutting insert after machining AlSi7Mg0.3 alloy with 1 wt. % Ca*

Alloy AlSi7Mg0.3 s 1 hm. % Ca	Replaceable cutting insert wear [µm]		
	VB	VB_{max}	VB_c
	82.4	51	76.4

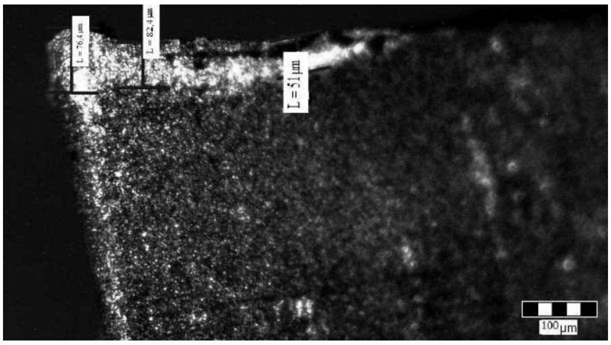
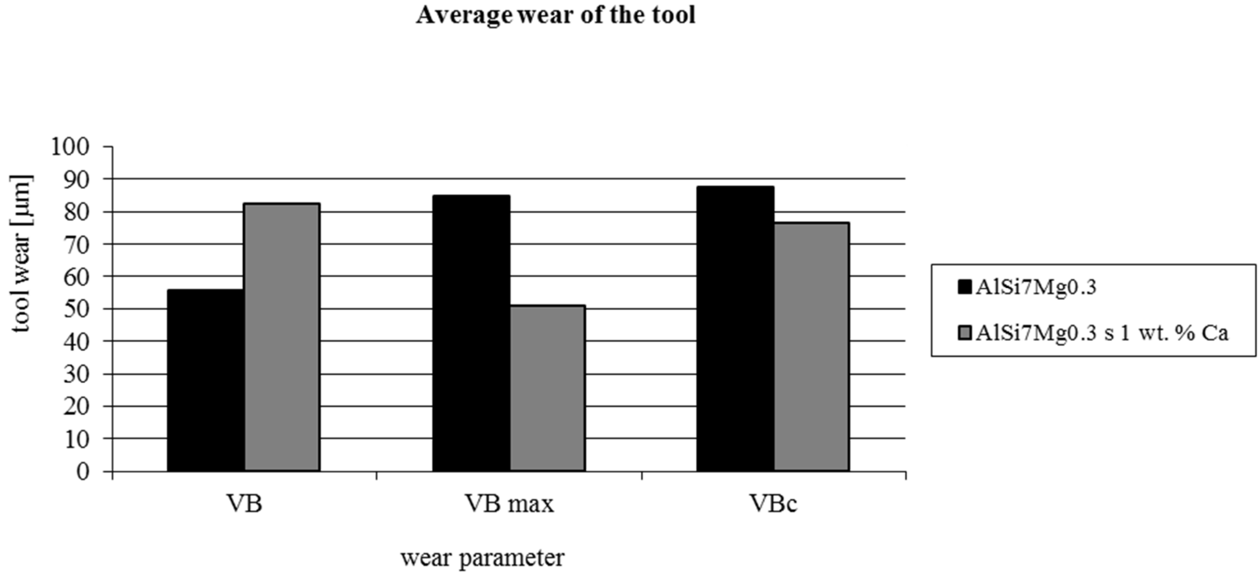


Fig. 6 *Worn cutting insert after machining AlSi7Mg0.3 alloy without added Ca (1 wt. % Ca) vol. 3.2x*

Graph 3 is a comparison of the average wear value of the AlSi7Mg0.3 starting alumina alloy without the added amount of calcium and alumina alloy samples

AlSi7Mg0.3 with an added amount of calcium of 1 wt. % Ca. Values again confirm the reduced wear of the cutting insert to VB (wear on the back) where the wear value is higher. This is due to defects that occur on castings with a calcium content of 1 wt. % Ca showed the highest level. Machining at the defect sites was manifested by loud sound effects and oscillation of the system.



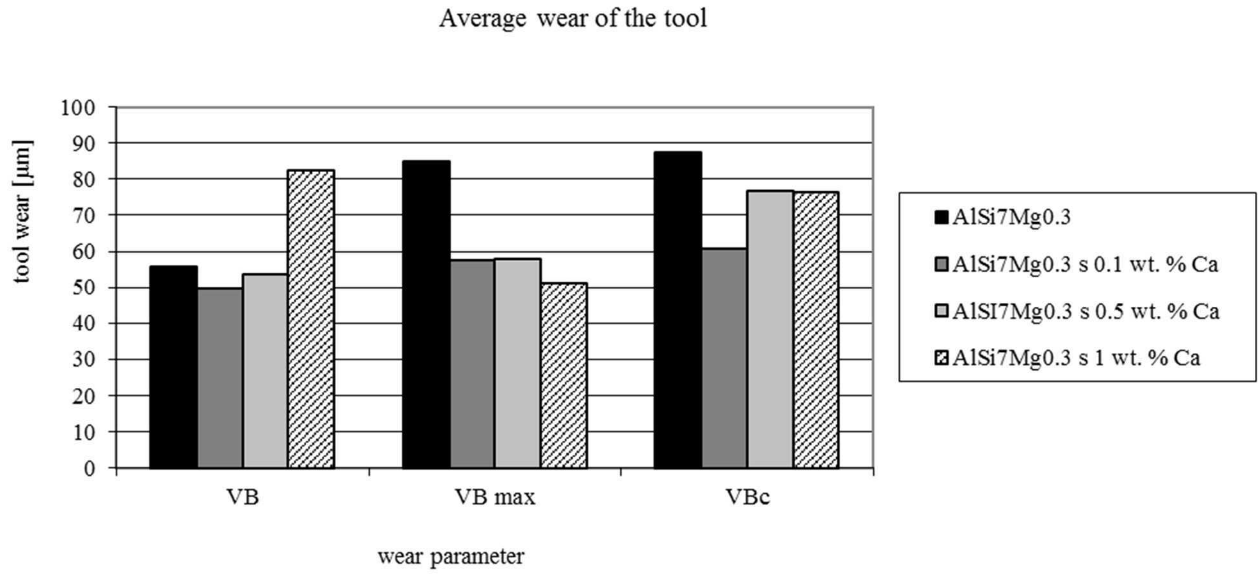
Graph 3 *Average tool wear for AlSi7Mg0.3 al loy without added calcium and alloy AlSi7Mg0.3 with calcium added 1 wt. % Ca*

4 Results and discussions

Analysing the results of the samples after machining showed that the added calcium in the AlSi7Mg0.3 alloy has a positive effect on the wear of the tool. Graph 4 compares the measured values of all cutting insert for four types of machined alloys. The graph shows differences in wear between cutting insert when machining the starting alloy without added calcium and alloys with a certain proportion of calcium. This result can be to a large extent a casting quality, where the castings show a significant amount of pores and cavities, which are mainly due to casting technology not suitable for this alloy.

The grates wear was measured at the VB_{max} tools maximum wear and at the tip of the VB_c tool for the initial alloy without added calcium. Negative addition of calcium with a content of 1 wt. % Ca mainly for VB spine wear and VB_c tool tip wear, which can largely be due to casting quality.

On the contrary, the best values of all measured parameters show a staring alloy with an added amount of calcium of 0.1 wt. % Ca. Good results also show a calcium containing alloy of 0.5 wt. % Ca, although it shows elevated values for the VB_c parameter. Talking into account previous analyses, where the calcium alloy contains 0.5 wt. % Ca best value, it can be said that even for the machining test this alloy is the best.



Graph 4 *Comparison of average tool wear values for all alloys examined*

The visual wear comparison tool for all types of alloys analysed with different calcium content is the Fig. 7. The cutting insert for calcium content 0.5 wt. % Ca (part of Figure 3) appears to be the least worn in this image. Thus, we can say that the calcium modification has a certain impact on tool wear within the tool wear. There is a change in the morphology of silicon, which appears to be positive for the machining, process and consequently for the wear of the tool.

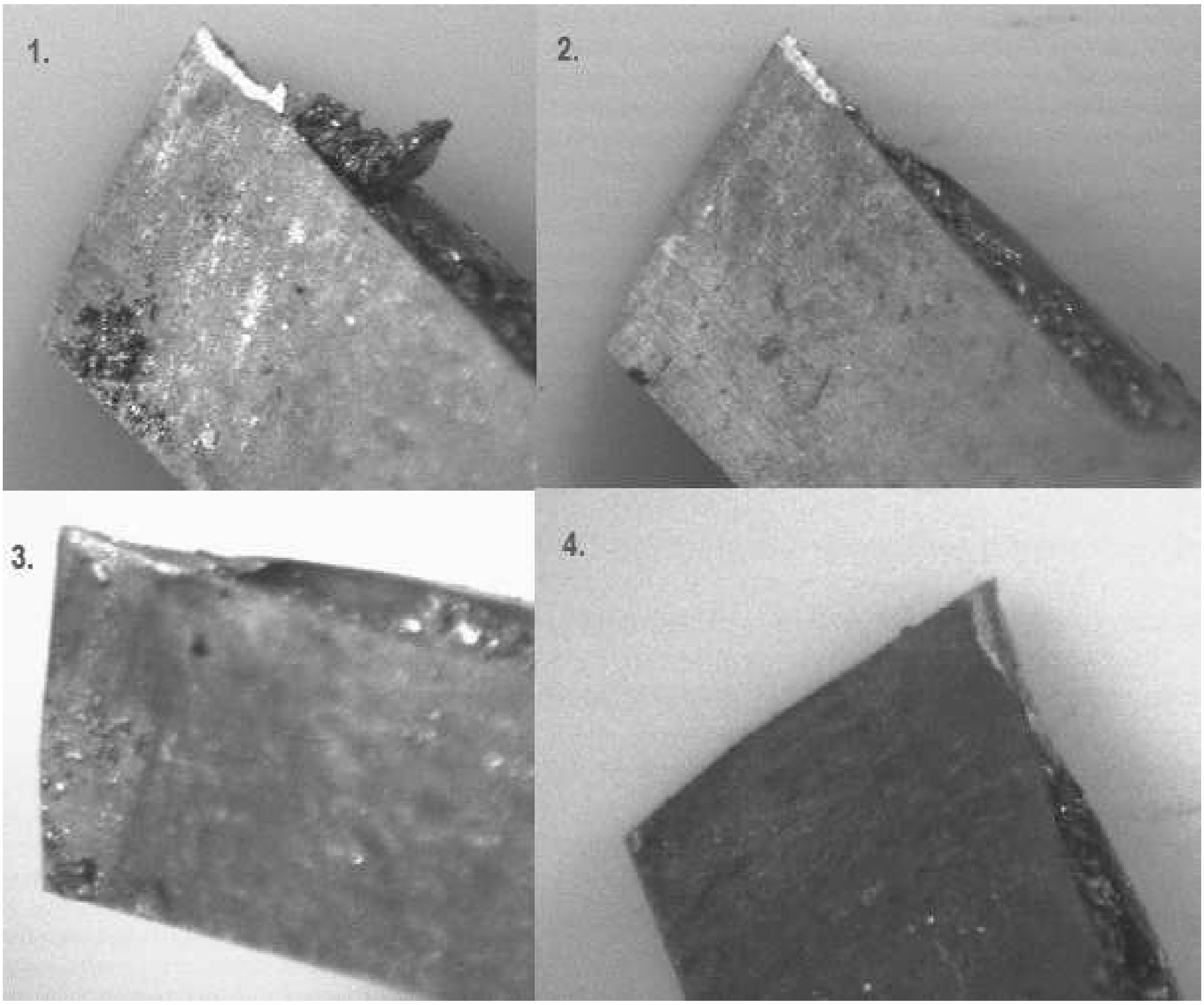


***Fig.** 7 Comparison of cutting insert used for machining alloys AlSi7Mg0.3 without Ca and with different Ca*

The increase (1. AlSi7Mg0.3 alloy, 0 wt. % Ca) which was probably due to the inclination of alumina alloys to this behaviour, is formed during the machining process, another part of the same figure (2. AlSi7Mg0.3 alloy, 0.1 wt. % Ca) still shows an increase but in noticeably less pronounced, which can be justified by the calcium content of the alloy shows Fig. 7. For other types of alloys (3. AlSi7Mg0.3 alloy, 0.5 wt. % Ca) and (4. AlSi7Mg0.3 alloy, 1 wt. % Ca), the increase does not appear. Thus, the positive effects of calcium can be attributed to a reduction to avoiding an increase.

5 Conclusion

A machinability test was performed on the alloys examined, where, inter alia, the wear of replaceable inserts was evaluated. The rest results show a positive effect of calcium on tool wear. The best values are alloys with a calcium content of 0.1 wt. % and a very good value is also found with an alloy containing 0.5 wt. % Ca. In terms of wear, calcium modification has some influence on tool wear. There are changes in the silicon morphology, which appears to be positive for the machining process and consequently for the wear of the tool. There was a positive increase in the amount of calcium depending on the calcium content of the alloy. The biggest increase was formed in the machining of the starting alloy, which is probably die to the fact that aluminium alloys are inclined to such behaviour. After adding calcium to the alloy, there was a marked decrease in the increase. Another part of the machining test was the size measurement and chip analysis. Measurement of the shape and size of the chip was performed to determine the effect of calcium on the machining process

On the basis of the measurement made so far, we can state the positive effect of calcium on the alloy, especially in the amount of 0.1 to 0.5 wt. % Ca.

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