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 their 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 sodium modification [1] [8].

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 AlSi7Mg0.3 | Chemical composition in % by weight |
|-----------------|------------------------------------|
|                 | Si   | Fe   | Cu   | Mn   | Mg   | Cr   | Ni   | Zn   | Ti   |
|                 | 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 \( n_{\text{max}} \) [min\(^{-1}\)], used Emcomat – 14s.

![Cutting insert DCMT070202E-UR](image)

| Dimensions [mm] | Feed [mm] | Depth of cut [mm] |
|-----------------|-----------|-------------------|
| l | d | dl | 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 \( n_{\text{max}} = 3998.585 \) 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.

![Worn area of the flank](image)

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              | Replaceable cutting insert wear [µm] |
|--------------------|-------------------------------------|
| AlSi7Mg0.3 s 0 wt. % Ca | VB | VB<sub>max</sub> | VB<sub>c</sub> |
|                    | 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              | Replaceable cutting insert wear [µm] |
|--------------------|-------------------------------------|
| AlSi7Mg0.3 s 0.1 wt. % Ca | VB | VB<sub>max</sub> | VB<sub>c</sub> |
|                    | 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 | VBc  |
|                                 | 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 Al-

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 | VBc  |
|                                 | 82.4 | 51 | 76.4 |

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 alloy without added calcium and alloy AlSi7Mg0.3 with calcium added 1 wt. % Ca

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. Taking 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.

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 due 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.
References

[1] BOLIBRUCHOVÁ, D., TILLOVÁ, E. (2005). Zlievarenské zliatiny Al-Si, ŽU v Žiline – EDIS, Slovak republic

[2] WANG, L., MAKHLOUF, M. (1995). Aluminium die casting alloys: alloy composition microstructure and properties – performance relationships. In: International Materials Reviews, Vol. 40, No. 6, pp. 221 - 238

[3] CAIS, J., SVOBODOVÁ, J., STANČEKOVÁ, D. (2017). Modification of the AlSi7Mg0.3 Alloy Using Antimony. In: Manufacturing Technology, Vol. 17, No. 5, pp. 685 – 690, Czech republic

[4] MAV. Výroba řezných nástrojů a měřidel, [online] [cit. 2014.05.29] Available on the Internet: https://katalog.mav.cz/detail.php?id=86936

[5] MICHNA, Š., NÁPRSTKOVÁ, N. (2011). The Mechanical Properties Optimizing of Al –Si Alloys Precipitation Hardening and the Effect on the Character of the Chip, In: Acta Metallurgica Slovaca, No.3, Slovak republic

[6] STŘIHAVKOVÁ, E. (2017) Analysis of the new type Al-Si-Mg alloy structures with different contents of Ca due to chemical properties. In: Engineering for Rural Development, pp 521 – 527, Jelgava, Latvia

[7] NÁPRSTKOVÁ, N., CAIS, J., SVOBODOVÁ, J. (2013), Vliv modifikace strociem slitiny AlSi7Mg0,3 na tvorbu třísky. In: Strojirenská technologie, Vol. 18, No.4, pp 265 – 269, Czech republic

[8] FOUSOVA, M., DVORSKY, D., VOJTECH, D., (2017), Additively Manufactured Aluminium AlSi10Mg Alloy. In: Manufacturing Technology, Vol. 17, No. 4, pp. 446 – 451, Czech republic

[9] HRONEK, O., ZETEK, M., BAKŠA, T., ADÁMEK, P., (2017), Quality of the Cutting Tool Microgeometry for Machining Aluminium Alloy, In: Manufacturing Technology, Vol. 17, No. 4, pp. 463 – 469, Czech republic

10.21062/ujep/160.2018/a/1213-2489/MT/18/4/679
Copyright © 2018. Published by Manufacturing Technology. All rights reserved.