INFLUENCE OF ADDITIONAL CHEMICAL COMPONENTS ON MACHINING PROPERTIES OF SELECTED ALUMINIUM-SILICON ALLOY

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Abstract. Al-Si alloys are the leading casting alloys based on aluminium. Machining of aluminium alloys is currently frequently used and it is an important area of production. The paper deals with an experiment that was conducted at the Faculty of Production Technology and Management, University of Jan Evangelista Purkyně in Ústí nad Labem, where alloy AlSi7Mg0.3 was machined. The samples were made for processing from the master alloy AlSi7Mg0.3, subsequently unmodified and modified by Sr, Ca and Sb and inoculated by Ti. This paper describes the evaluation of tool wear and chip formation after machining of the prepared cast in the terms how modification by Sr, Ca and Sb and inoculation by Ti may affect these values.

Keywords: Al-Si Alloy, modification, machining, evaluation, analyses.

Introduction

Machining of aluminum alloys is now an 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 production of shaped casting cast in sand, cast in metal mold or pressure cast. Silumins have high corrosion resistance, low coefficient of linear shrinkage and satisfactory mechanical properties. To improve their properties silumins are alloyed, inoculated and modified. The experiment at FPTM JEPU was conducted with the alloy AlSi7Mg0.3, when this alloy was modified by Sr, Sb and Ca and inoculated by Ti [1-4].

The composition of AlSiMg0.3 according to the standard ČSN EN 1706 is summarized in Table 1.

Table 1

Chemical composition of alloy AlSi7Mg0.3

Element	Si	Fe	Cu	Mn	Mg	Zn	Ti	Al
Amount, %	6.50-7.50	0.19	0.05	0.10	0.25	0.07	0.08-0.25	Rest to 100

The aim of the experiment was to analyze the possible effect of modification by strontium, calcium and antimony and inoculation amount of Ti on the resulting tool wear and chip formation, because both also signal a change of technological and use properties of the alloy, and tool life of the cutting tool is one of the important indicators of economic production [3; 5].

Conditions of the experiment

As noted above, the experiment was used for alloy AlSi7Mg0, 3, when for inoculation different amounts of AlTi5B1 were used and for modification Ca, Sr and Sb were used.

For each experiment three to four castings of each alloy were made, which was an experiment carried out and subsequently analyzed.

It was therefore master alloy AlSi7Mg0.3 without modification, further master alloy AlSi7Mg0.3 subsequently modified with 0.04 % Sr of the cast wt. proportion, master alloy AlSi7Mg0.3 subsequently modified with 0.05 % Ca of the cast wt. proportion and master alloy AlSi7Mg0.3 subsequently modified with 0.05 % Sn of the cast wt. proportion (ČSN EN 1769), and it was made of five kinds of alloys AlSi7Mg0.3, where the individual casts have different resultant percentage titanium content (by weight of Ti – 0 % Ti, 0.05 % Ti, 0.1 % Ti, 0.15 % Ti, 0.2 % Ti).

The casts of these alloys were subsequently cut, then the tool wear was evaluated and microscopic evaluation of the structure of individual samples was performed, and the hardness of the resulting alloys measured. The input sample for machining dimensions was of 220 mm length and 60 mm diameter.

The test samples were machined on a lathe Emco Mat – 14 S, which is on the FPTM available. The lathe has a maximum speed of 4000 min^{-1} with smooth control and drive power 7.5 kW.

The set cutting conditions were based primarily on the type of the machine and tool. The used cutting tool were plates (inserts) PRAMET DCMT 070202 E – UR and based on the material to be machined and the used machine and tool was set at the depth of cut a_p = 1 mm and feed per revolution f = 0.12 mm·rev^{-1}. The cutting speed v_c was necessary to adapt the options of the used lathe Emco Mat – 14 S, particularly its maximum rotation speed n. The cutting plate was clamped at the outer bracket SDJCR 12 12 F 07 KT 016 [7-9].

On the base of the possibilities and calculations the cutting speed for the actual machining v_c was adapted to the used lathe for resulting value v_c = 200.96 m·min^{-1}. At this speed v_c, the rotations were n = 1066 min^{-1} for diameter 60 mm and n = 4000 min^{-1} for diameter 14 mm. All the working conditions for the machining are set to achieve the maximum load inserts [9-11].

VBD measurement of inserts wear

After cutting the samples were evaluated for inserts wear and these measurements were taken using a microscope Olympus SZX.

Wearing occurs in all machine components that are in contact with each other and in relative motion. In machining during the cutting process relative movement of the tool - workpiece and tool – chip occur. Due to the mechanical, thermal, chemical and abrasive factors it leads to the cutting plate wearing. The areas where there is wearing are the forehead, the major and minor back and radius area of the tip [10; 12-14].

The following criteria of the cutting plate wearing were evaluated (Fig. 1, according with the standard ISO 3685):

- back wear VB,
- back wear maximal VB_{max},
- wear in the tip area VB_c [8; 9; 15].

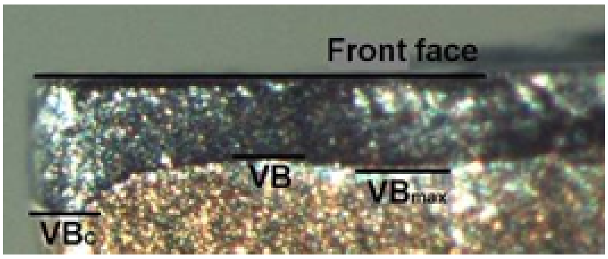

Fig. 1. **Principle of measurement of wear values of cutting plate (insert)**

For measurement the software QuickPHOTO CAMERA 3.2 was used. Fig. 2 shows a sample of measurement implementation.

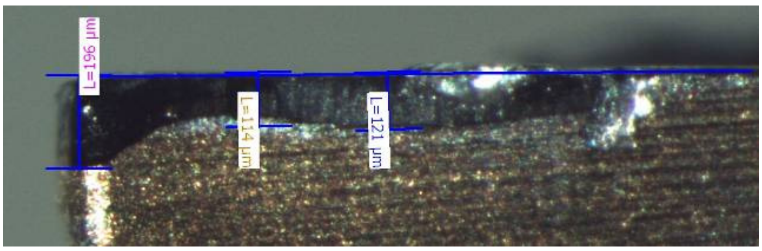

Fig. 2. **Measurement of insert wear in frame of experiment with software QuickPHOTO CAMERA**

Fig. 3-5 show a comparison of the average tool wear parameters within all modifications of AlSi7Mg0.3 alloy, which were produced in the experiment. From these, it is evident that the subsequent modification has some small impact on the tool wear down (change of Si morphology) and alloy inoculation turns upwards (increasing the number of hard parts, e.g., TiB_2, $(TiV)B_2$ AlB_2, AlB_{12}). This is quite true for all parameters.

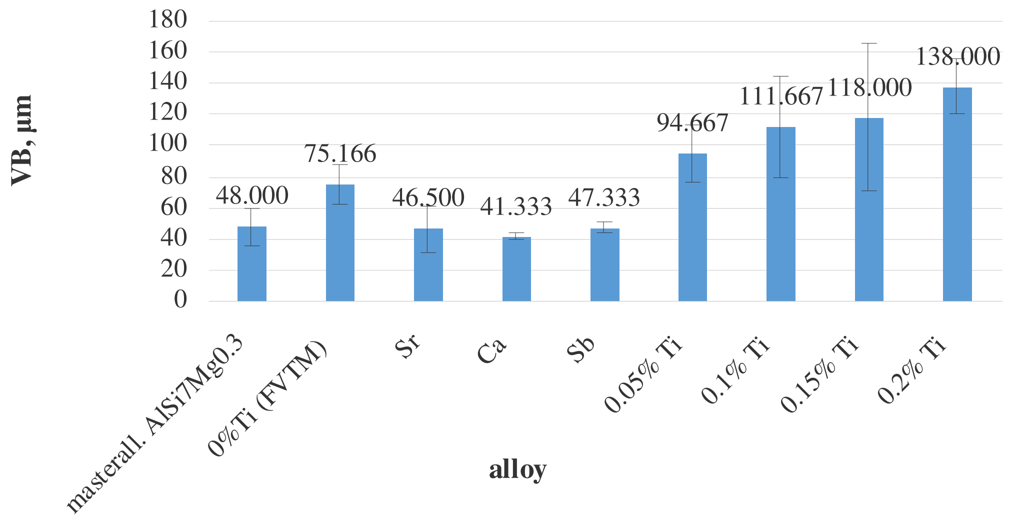

Fig. 3. **Average wear VB for each alloy**

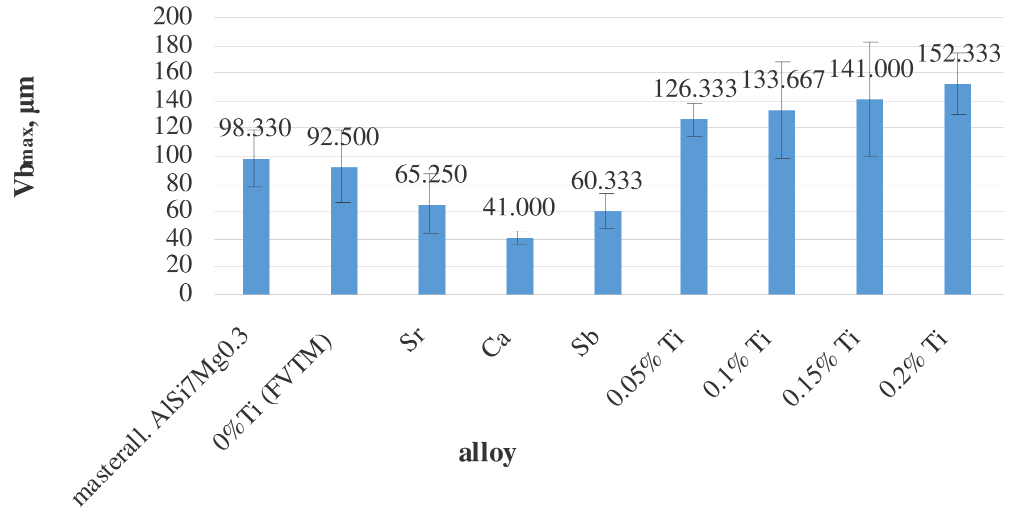

Fig. 4. **Average wear VBmax for each alloy**

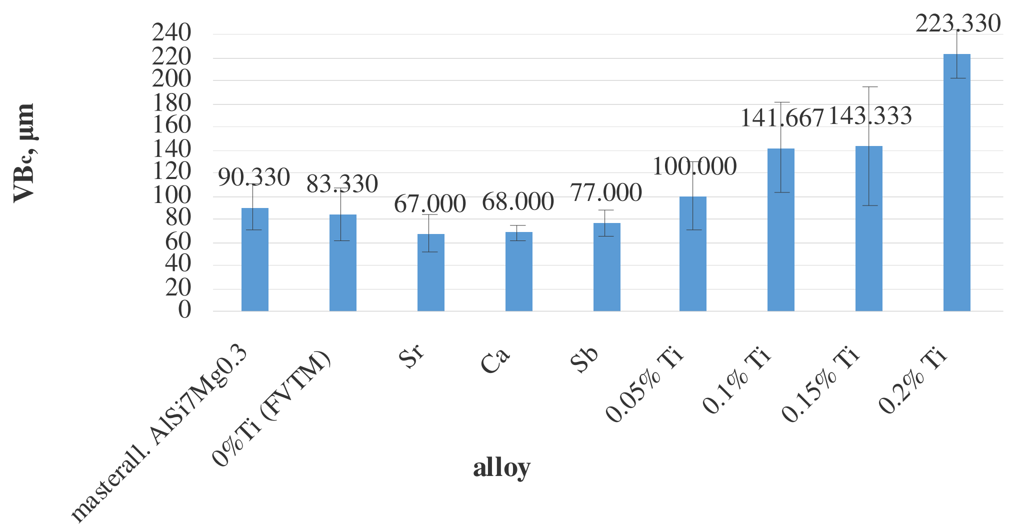

Fig. 5. **Average wear VBc for each alloy**

After investigation it is possible to say that the cause of the cutting insert wear on the back after machining of the test samples was mainly abrasive wear. The obtained values, when comparing, confirmed the premise that modification has a positive, albeit not significant influence on the tool wear, on the contrary, how it was assumed, a higher proportion of hard particles, e.g., TiB_2 or $(VTi)B_2$, which originated in the alloy during inoculation affect tool wear negatively [13; 14].

From the images of some used inserts it is also evident that during machining quite intensively built-up formed (Fig. 6), which was due to the fact that Al alloys have this tendency of behavior and unfortunately could not be achieved favorable cutting conditions due to the possibilities at FPTM and the needs of the experiment [13; 14].

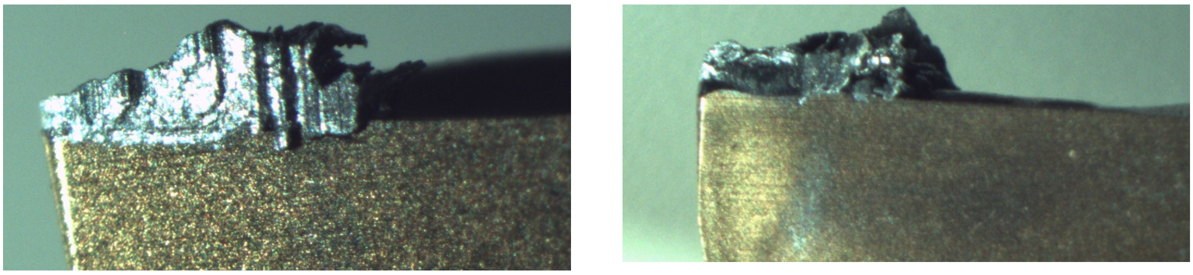

Fig. 6. **Samples of created up edge (built-up) on the insert after cutting of the mentioned alloys**

Evaluation of chip

The reason for monitoring of the chip parameters is the fact that when machining there are required only certain kinds of chips that are appropriate in terms of continuity of the cutting process. Other reasons include that the change in the chip shape during the cutting process indicates tool wear, too.

Within the experiment the chips both in terms of the shape as well as the size were also evaluated. When the machining of all samples formed a segmented arched divided chip, the chip had a tendency to spin into spirals.

The chip was evaluated for the reason that modification of the AlSi7Mg0.3 alloy structure has also a potential impact on the shape and size of this chip. For evaluation of the chip, for evaluation of its shape and dimension, from each machined casting chips were removed from the diameter of each of 60-50 mm, 48-34 mm and 32-14 mm. From each amount of the collected chips always minimum of 10 chip pieces were measured. It means that on one casting at least 30 pieces of chips were evaluated.

Fig. 7 shows an example of measurement. In the same way all measurements were carried out in the experiment [13; 15].

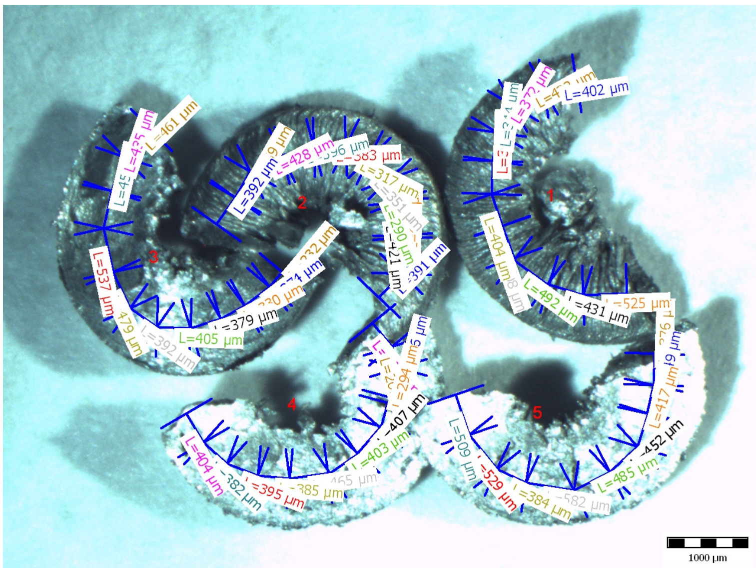

Fig. 7. **Example of chip measuring**

It can be said that the shape of the chips for all castings was similar, based on the measurement it was then shown that for some adjustments alloys differed only slightly in size. For all experiments carried out during the full course of the machining process the chips formed, which could be described as a spiral divided according to the classification of ISO 3685 [15].

Fig. 8 shows a graph that summarizes the average values of the chips for all machined castings. It clearly shows that the differences in the length of the chips for the individual alloys are small and that the modifications have little effect on the chip length. The shortest chip is for AlSi7Mg0.3 alloy inoculated by 0.1 wt. % Ti. The longest chip is for AlSi7Mg0.3 alloy without modifications made at FPTM JEPU, which was expected.

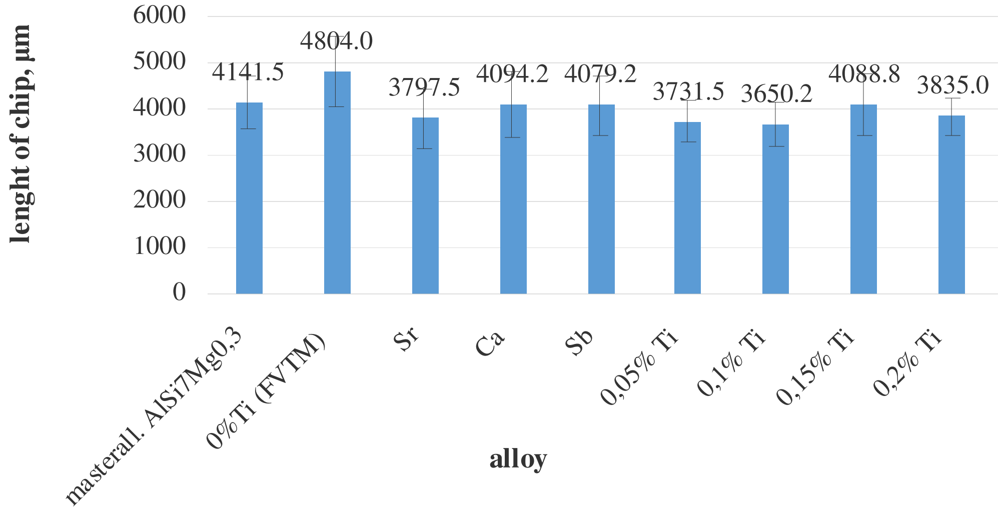

Fig. 8. **Comparison of the lengths of the chips for each alloy**

Conclusions

At FPTM JEPU in Ústí nad Labem experiments were performed with inoculation and modifying of AlSi7Mg0.3 alloy in terms of the quantity and type of modifier (Sr, Sb, Ca) and the amount of inoculant (0 % Ti, 0.05 % Ti, 0.1 % Ti, 0.15 % Ti and 0.2 % Ti). For the experiments castings from master alloy AlSi7Mg0.3 and alloy AlSi7Mg0.3 were made which was at FVTM comprised of components (Al, Si and Mg), then these alloys were modified and inoculated. In total, in the frame of these experiments 32 castings were made, which were machined and then the tool wear was evaluated for the used inserts, which were chosen because of their suitability for machining nonferrous metals and also the size and shape of the produced chip for all alloys were evaluated. Measurements of insert wear and of the size and shape of the resulting chip were implemented.

From the measured values it was possible to say that in the case of the experiments with the amount of used inoculant on the base of Ti wear inserts magnified with increasing Ti content (wt.%) in the alloy. This was due to the increasing content of Ti and B (to the alloys they have been inserted as an inoculant), which were contained in the casting in the form of hard particles (e.g., TiB_2, $(TiV)B_2$, AlB_2, AlB_{12}). The most significant tool wear was evident as expected for the inoculation by 0.2 wt. % Ti. For modifications the difference was not so big (master alloy AlSi7Mg0.3 without further modifications has always been compared and this master alloy subsequently modified, namely by Ca, Sr or Sb), but it can be concluded that the insert wear was, though slightly, usually smaller for alloys subsequently modified. The most significant difference was observed for the modified castings by Ca, therefore, there were the smallest wear values of the inserts. The smallest, almost imperceptible, was the difference in the modification of antimony, this modification did not practically show wear on the inserts as compared to machining master alloy.

For all machined alloys, whether modified and inoculated or unmodified, it was determined that chips had always made spiral shape and were not great. The shape of the chips was advantageous from the viewpoint of the conventional machining requirements. The alloy made at the FPTM from components had the longest chip and next - the master alloy AlSi7Mg0.3. The alloy inoculated with

0.1 wt. % Ti has the smallest chip. Generally, we can say from the experiments that both the modifications and inoculation had positive effect on the formation of chips. Although in some cases the differences were very small. The chip during machining of modified and inoculated alloys was formed always smaller. After summarizing all the measurements and analyzes it can be stated that both modifications and inoculation have in some cases not so great influence on the machining of the given alloy in the positive sense, except Ti inoculation when the wear plate was always greater, which was expected.

Acknowledgment

The authors are grateful for the support of grant SGS 2014 UJEP and of grant OP 2.2 No. CZ.1.07/2.2.00/28.0296.

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