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Influence of Ca, Sb and heat treatment on AlSi9CuMnNi alloy in frame of their properties from view of machining

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Abstract. Treatment of metal alloys is one of the ways to affect the quality and properties of the material At the Faculty of Mechanical Engineering of the Jan Evangelista Purkyně University in Ústí nad Labem, one part of the research consists of searching for the influence of various modifying and inoculating elements on selected aluminium alloys. One of the alloys undergoing the present research is the hardening aluminium alloy AlSi9CuMnNi. The article describes one from these experiments, than AlSi9CuMnNi alloy was modified with various amounts of calcium (0.05, 0.1 and 0.15 wt. % Ca) and 0.2 wt. % Sb. The alloy without modification and with 0.2 wt. % Sb was heat-treated, too. In the experiment were made three castings for each type of alloy. Experimental samples were evaluated form view of final hardness, were machined, too and there were analysed tool wear of using cutting inserts and final ship from machining (turning). Presented experiments are part of the extensive research undertaken at FME at JEPU in Ústí nad Labem.

Keywords: modification, alloy, machining, chip

1 Introduction

For various reasons, the alloy are adjusting (alloyed, inoculated and modified), which of course also applies to aluminum alloys. These reasons are eg. to improve the physical and technological properties. At the Faculty of Mechanical Engineering in this context implement various experiments just with aluminum alloys. One of them is research the effect of different amounts of selected elements to certain aluminum alloys and using of heat treatment, if it is possible, in particular of Al-Si alloys. In this case investigated elements were Ca and Sb and investigated alloy AlSi9CuMnNi. [1-3] These elements improve the morphology of silicon in the Al-Si alloy. Ca also improves the castability of aluminum alloys, but also it has negative effects, e.g. deterioration of the homogeneity of the resulting structure and is therefore considered as the harmful element. Ca and Sb in the role of modifiers can be considered relatively less common in the present area, Na and Sr are more commonly used. [4,5]

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Some types of aluminium alloys can be heat-treated. Heat treatment of aluminium alloys can be in the sense for CSN 42 0056 defined as the process by which a product or product parts in solid state is subjected to one or more cycles of annealing to achieve the desired structure or substructure and properties. [1, 6-9]

Modification of aluminum alloys is process by which the melt is deliberately modified by various elements in order to influence the mechanism of eutectic solidification. Modification changes the morphology and size of crystals of silicon (in the case of Silumin), causing a significant increase in mechanical properties compared to unmodified alloys. Large size silicon of crystals is lower strength properties of Al-Si al-loys. Strength and plastic properties of the modified alloys are therefore higher in comparison to unmodified alloys. Modification is meaningful only for aluminum alloys with a silicon content of more than 5%. Changing the structure may also affect the machinability of the modified alloy. [1-3, 10]

The article describes the one part of the experiments that are carried out at FME JEPU in Usti nad Labem in presented area based on the requirements of companies and deals with the analysis of tool wear after experimental alloys machining (turning) and their final chips.

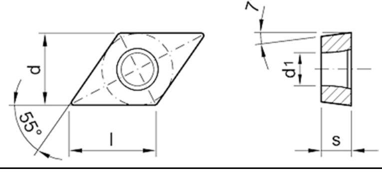
2 Experiment

For the experiment were made castings from alloy AlSi9CuMnNi for each type of alloy (0.05, 0.1 and 0.15 wt. % Ca and 0.2 wt. % Sb and alloy without modification and with 0.2 wt. % Sb with heat-treated, too). AlSi9CuMnNi belongs to the Al - Si - Cu group, which can be heat treated. In these alloys, the mechanical properties after the heat treatment vary greatly depending on the copper content. These alloys also have good foundry and mechanical properties, but the main disadvantage is low corrosion resistance. They are used for thin-walled castings in engine manufacturing, such as blocks, crankcase, air-cooled cylinder heads or carburettor parts. These alloys are heat-treatable (hardenable) and, in this state, they can achieve maximum strength properties. [1-3, 7, 11]

The alloy AlSi9CuMnNi was made at FME from individual components. There was not applied master alloy. Seven casting groups were made, which two were unalloyed (one was heat-threated), three were alloyed by varied amounts of calcium (0.05, 0.1 and 0.15 wt. %), and two groups were alloyed by 0.02 wt % Sb (one was heat-threated).

As a kind of heat treatment was carried out solution annealing leading to an increase in material hardness and uniformity of the chemical composition. In the first part, the hardening of the material supercritical cooling, and in the second part of the artificial aging. The entire course of the heat treatment process took approximately 16 hours. [1, 6-9]

Tab. 1 Characteristics of cutting plate (insert) DCMT 070202 E-UR

Dimensions of insert [mm]					f [mm·rev^{-1}]		a_p [mm]	
l	d	d_l	s	r_z	f_{min}	f_{max}	a_{pmin}	a_{pmax}
7,8	6,350	2,8	2,38	0,2	0,05	0,12	0,2	1,0
								

Experimental samples were machined on a lathe Emco Mat - 14 S (at the FME available). Set cutting conditions were based primarily from the type of machine and tool (tab. 1) and based on the material to be machined and used machine and tool was set depth of cut a_p=1 mm and feed per revolution f = 0.12 mm. On the base of possibilities and calculations the cutting speed for actual machining v_c was adapted to used lathe for resulting value $v_c = 200\ \mathrm{m \cdot min^{-1}}$ (maximum possible cutting conditions). [10, 12]

The wear of cutting inserts after machining was measured in the back and were examined the following parameters:

- wear in the peak VBc,
- back wear VB,
- maximum back wear VBmax.

Each area for measuring of tool wear shown in Fig. 1 (only for ilustration). Evaluation was carried out according to the wear characte-ristics of the standard ISO 3685. Evaluation carried out according to the wear characteristics of the standard ISO 3685. On Fig 2 is example of chip lenght measuring. For measurement of tool wear and chip length was used the software Quick PHOTO CAMERA 3.2. [9, 13-15]

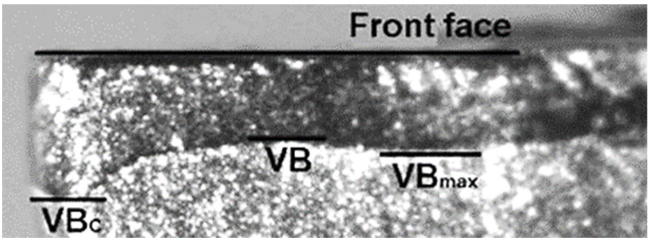


Fig. 1. Principle of measurement of wear values of cutting plate (insert)

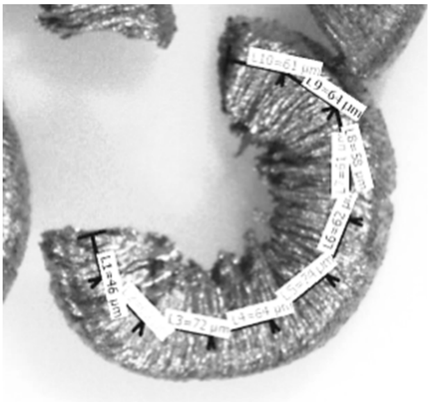


Fig. 2. Principle of chip leght measurement

The Brinell hardness of samples was also measured according to standard EN ISO 6506-1 on the hardness tester Ernst AT 250X. The hardness measurement was performed on turned samples by injection a ball with 2.5 mm diameter at a load 612.916N for 10 seconds. [15, 16]

3 Results and discussion

Other step was measuring of cutting inserts tool wear after cutting of individual alloys. Generally speaking, that the each all plates wear was very small, by visual observation difficult to see. The main reason was that the machined samples were from aluminium alloy, and the time during which the plate was in the work was about 25 minutes. Even though it was possible to identify and measure the tool wear using a microscope in order to identify differences between the different types of alloys. Generally true that on the plates formed up edge (built-up), see Fig. 3.

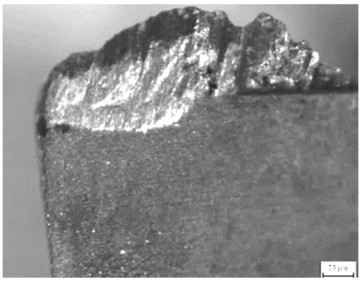


Fig. 3. Up edge (built-up) on the tool after machining (without modification and HT)

Graph on the Fig. 4. shows the tool wear VB for each group of samples. From this is can be seen that the greatest tool wear at this parameter is for the unmodified alloy. For this type of alloy after heat-threated is tool wear smaller and it is smaller, than for alloy modified by Ca. Between unmodified and Ca modified alloys is for this parameter very small different in favor modification of Ca (the worst is for 0.15 wt. % Ca). Better results for this parameter show Sb modification and heat treatment.

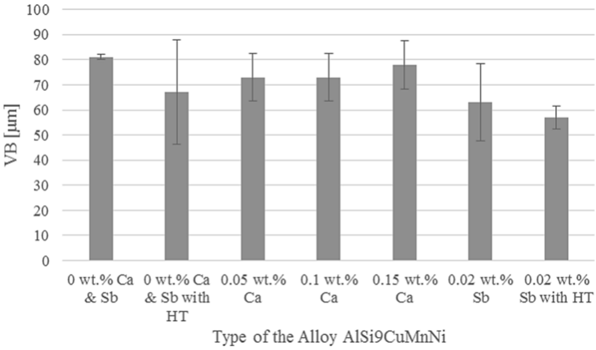


Fig. 4 Tool wear parameter VB (after 25 min of machining)

Graph on the Fig. 5 shows the tool wear VBc for each group of samples. From this is can be seen that the greatest tool wear at this parameter is for the unmodified alloy, like for parameter VB. For this type of alloy after heat-threated is tool wear smaller and it is smaller, than for alloy modified by Ca, like for VB too. Between unmodified and Ca modified alloys is for this parameter very small different in favor modification of Ca, too. Better results for this parameter show Sb modification and heat treatment. For all types of alloy the same course as for parameter VB could be observed.

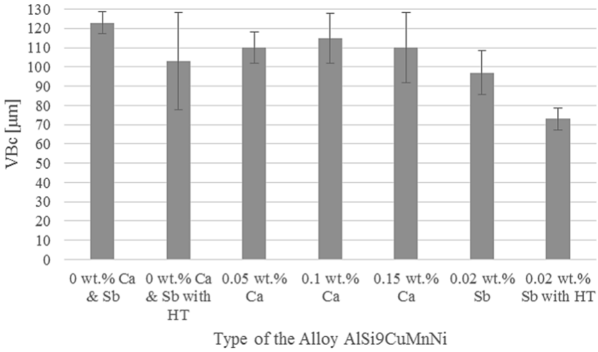


Fig. 5 Tool wear parameter VBc (after 25 min of machining)

Graph on the Fig. 6. shows the tool wear VBmax for each group of samples. The greatest tool wear at this parameter is for the unmodified alloy, too, like for VB and VBc. In this case the tool wear is the smallest for 0.1 wt. % Ca and next for 0.5 wt. % Sb with heat-treatment. There the difference is very small.

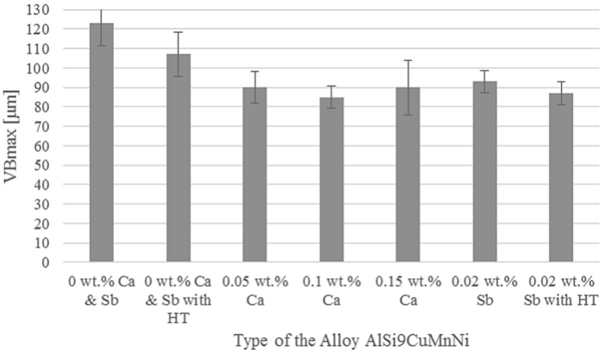


Fig. 6 Tool wear parameter VBmax after 25 min of machining)

From the point of view of wear, where the VBmax criterion is more often used than the VBc criterion for the wear evaluation of tools, it is possible to add that, in terms of wear, better results show (although there is a relatively small difference) a modification of 0.1 wt. % Ca. Practically the best results for all adjustments due to the evaluated wear criteria of the tool show modification 0.2.wt. % Sb with using heat treatment.

Another evaluation was evaluation in terms of length and shape of the obtained chips. The chips collected after machining of experimental castings had spiral trace for every type of cast alloy. For modified types of alloy chips were rather long shape in comparison with unmodified alloy. The heat-treatment has positive effect on the chip length. Wherein the effect of calcium on the chip shape was observed primarily a larger quantity of chips more twisted into a spiral when this amount is increased with higher calcium content. The Fig. 7. shows a graph comparing the average chip size for each type of the experimental alloy. It is evident that the heat-treated alloys had the shortest chip. The shorter chips also had modification 0.2 wt. % Sb. The calcium modification had a negative effect on the chips length. The longest chip was for 0.1 wt. % Ca modification.

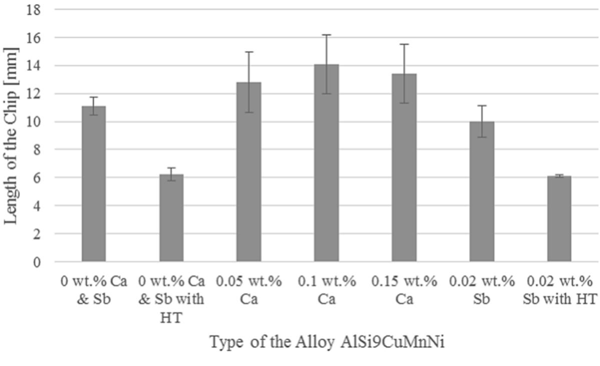


Fig. 7 Comparison of chip sizes for each for individual alloys

Next was the hardness measurement of each alloy type. The measured values are summarized in the graph in Fig. 8. The highest values had heat treated alloys. The modification of Ca had the opposite effect (for each amount of Ca in alloy).

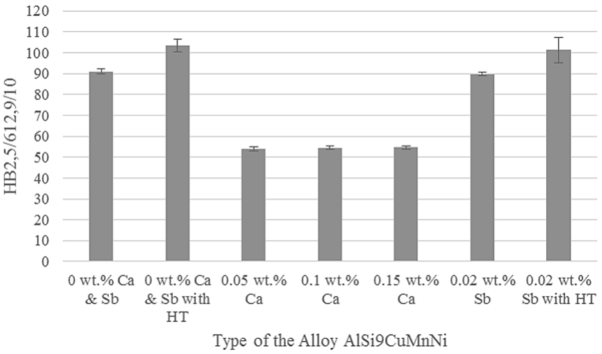


Fig. 8 Comparison of hardness for individual alloys

Further, when comparing the hardness for each type of alloy, it appears that the unmodified alloy with heat-treatment has the highest hardness. The second is modified alloy by 0.2 wt. % Sb with heat-treatment. The Sb modification itself also had a positive effect on hardness. For modification of calcium to AlSi9CuMnNi alloy is possible to that the overall hardness was reduced.

4 Conclusion

In the context of the presented experiment the alloy AlSi9CuMnNi was made at FME using pure metals and were prepared samples with defined amount of Ca and Sb and some types of presented alloy were heat-treated. Castings were analyzed in terms of their influence to machining (tool wear, chip length).

Subsequently, the alloys were machined and the tool wear of cutting inserts and the shape and length of the chip were evaluated. The hardness of the experimental alloys was also measured.

The tool wear measurement, when the VB, VBc and VBmax parameters were measured, showed that the largest tool wear was reported during machining of the unmodified alloy, which was likely to be caused by large unmodified Si boards. Modification Ca showed a little positive effect on insert tool wear, however, the difference between individual alloys with varying amounts of Ca was not significant. Somewhat better results are Sb modifications and heat treatment.

The chips collected after machining were in terms of their shape tended to be longer with a trace in a spiral shape, with the effect of calcium at chip shape were observed mainly higher incidence spiral chip with increasing calcium content. The impact of Ca on the chip length had a negative impact because the shortest chip had an unmodified alloy. Somewhat better results are Sb modifications and heat treatment, like for tool wear.

The Ca modification had a negative impact on alloy hardness. since the unmodified alloy had a higher hardness. As expected, heat treatment had a positive effect. Good effect had modification by Sb, too.

The presented results are part of a larger research, which is realized at FME JEPU in Ústí nad Labem.

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References

1. S. Michna, I. Lukac, P. Louda, V. Ocenasek, H. Schneider, J. Drapala, R. Koreny, A. Miškufova, et al. *Aluminium Materials and Technologies from A to Z.* Adin, Prešov (2007)
2. M. Michalski, F. Romankiewicz. *AlSi21CuNi silumin modification with phosphor and strontium micro additions E3S*. Web of Conferences, 19, Article number 03026 (2017)
3. J. Formanek,, L. Kucerova, M. Tochylin. *The Hazards of Defects and Poor Quality of Aluminium Materials.* Proceedings of 24th Internatioal Conference on Metallurgy and Materials Metal, 1552-1557 (2015)
4. I. A. Petrov, D. V. Berezhnoi, A. P. Ryakhovskii, V. S. Moiseev. Effect of modification on the solidification of Al–Si aluminum alloys. Russian Metallurgy (Metally), Springer Nature 2017(**3**), 184-187 (2017)
5. N. Naprstkova, J. Cais, M. Ingaldi. *Modification of AlSi9CuMnNi Alloy by Antimony and Heat Treatment and their Influence on Tool Wear after Turning.* Manufacturing Technology, FME JEPU 16(**1**), 209-214 (2016)
6. N. Naprstkova, J. Cais, J. Sviantek, H. Cierna. *Change of selected resulting properties of AlSi9CuMnNi alloy by heat treatment and antimony.* Proceedings of 15th international scientific conference Engineering for Rural Development, Latvia, 1133-1138 (2016)
7. V. Weiss, E. Střihavková. *Influence of the homogenization annealing on microstructure and mechanical properties of AlZn5,5Mg2,5Cu1,5 alloy.* Manufacturing Technology, 12(**12**), 297-302 (2012)
8. P. Wieroński, J. Pezda, L. Ponikwia. Effect of Heat Treatment on Machining Properties of the AlSi9Cu3(Fe) Alloy. Archives of Foundry Engineering, Walter de Gruyter 16(**3**), 137-140 (2016)
9. N. Naprstkova, D. Kalincova. *Influence of Additional Chemical Components on Machining Properties of Selected Aluminium - Silicon Alloy*. Proceedings of 14th international scientific conference Engineering for Rural Development, Latvia, 766-771, (2015)
10. N. Naprstkova, S. Kusmierczak, J. Cais. *Modification of AlSi7Mg0.3 alloy by strontium*. Manufacturing Technology, FME UJEP, 13(**3**), 373-380 (2013)
11. J. Petru, J. Schiffner, T. Zlamal, M. Sadilek, D. Stancekova. *Investigations of Cutting Tool Wear While Machining Inconel 718*. Manufacturing Technology, 15(3), 396-403 (2015)
12. N. Naprstkova, S. Kusmierczak, J. Cais. *Modification of AlSi7Mg0.3 alloy by strontium*. Manufacturing Technology, FME UJEP, 13(**3**), 373-380 (2013)
13. Zetek, M., Bakša, T., Schorník, V., Zetková, I. *Monitoring and Evaluating Cutting Tool Wear using a IFM G4 Microscope*. Manufacturing Technology, FME UJEP, 16(**5**), 1211-1216 (2016)
14. J. Petru, T. Zlamal, R. Cep, D. Stancekova, M. Pagac, O. Vorel. *Mechanisms of cutting insert wear and their influence on cutting ability of the tool during machining of special alloys.* Proceedings METMG 2015, Canada, 36-40, (2015)
15. S. Kusmierczak. *Usage of Technical Equipment in Teaching Technical Subjects.* Proceedings of 14th international scientific conference Engineering for Rural Development, Latvia, 748-752 (2015)
16. I. Novakova, J. Stverak, J. Moravec. *Hardness of the High Pressure Die Castings from Alloy AlSi9Cu3 in dependence on the Subsequent Processing Technology*. Manufacturing Technology. FME JEPU, 15(**4**), 647-652 (2015)