The Effect of Different Modifiers on Cutting Temperature in Turning of AlSi7Mg0.3 Alloy

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One of the problems in machining Al alloys represents machinability of these materials. Machinability is a characterised by several characteristics. One of these characteristics is a cutting temperature. This paper is focused on the effect of selected modifiers in AlSi7Mg0.3 alloy on this temperature. Several variants of this material modified by strontium, calcium and antimony are used. All these materials are compared with non-modified alloy. Moulded castings of non-modified alloy and for each modified variant were made. Gravity-die castings into a metal mould with a thermal insulation were used.

Keywords: AlSi7Mg0.3 alloy, Modifiers, Machining, Machinability.

1 Introduction

Machinability is the ability of work material to be machined under definite working conditions. In the broad sense, machinability has many different meanings. It is mostly described by the following criteria:

- Cutting tool wear.
- Tre ratio of the cutting speed for the given tool life when machining the work material and the cutting speed for the same tool life when machining the standard material under the same working conditions.
- Cutting temperature.
- Chip formation.
- Built-up edge tendency.
- Cutting forces.
- Power consumption.
- Surface roughness.

Tool wear is primarily affected by cutting temperature. Cutting temperature is the average temperature at the contact between the workpiece and the cutting tool. This temperature relates primarily to cutting speed, but also to feed rate and depth of cut.

Cutting temperature is possible to measure by thermocouple method. The electromotive force is generated in the contact between two different materials and is proportional to cutting temperature. [1,2,3]

2 Modification of AlSi7Mg0.3 alloy

Several variants of this material modified by strontium, calcium and antimony were used. All these materials are compared with non-modified alloy. Modification affects properties of materials. [4,5,6,7]

Stroncium, calcium and antimony were used as modifiers in experimental research.

Strontium is considered as one of the most progressive modifiers of eutectic Si in hypoeutectic and eutectic AlSi alloys. [8] The weight portion of strontium ranges from 0.01 to 1.0 % in Al-Si alloys. [9] Strontium affects the conversion of the shape of eutectic silicon. Large and coarse platelets are converted to curve rods, which leads to increasing strength of castings. [9] Alloy used for the experiment contained 0.03 wt. % of strontium.

Modifying effect of calcium has not yet been fully verified. Some experts consider calcium as a modifier and some of them consider calcium as damaging element. [9] Alloy used for experiment contained 0.20 wt. % of calcium.

Under eutectic Al-Si alloys modified by antimony have an excellent casting properties compared to alloys modified by strontium. Antimony increases tensile strength of materials. It has little temporal stability and little inclination to oxidation. [8] The disadvantage of antimony is that it interferes with strontium and sodium. The alloy for the experiment contained 0.10 wt. % of antimony.

3 Experimental research of built-up edge formation

Work materials

Experimental research was performed in turning on material without heat treatment and is also on heat treated material – mark HT.

- AlSi7Mg0.3 – non modified (in Tab. 3 mark NO).
- AlSi7Mg0.3 – non modified, heat treated (in Tab. 3 mark NO-HT).
- AlSi7Mg0.3 – modified with Sr (in Tab. 3 mark Sr).
- AlSi7Mg0.3 – modified with Sr, heat treated (in Tab. 3 mark Sr-HT).
- AlSi7Mg0.3 – modified with Ca (in Tab. 4 mark Ca).
- AlSi7Mg0.3 – modified with Ca, heat treated (in Tab. 4 mark Ca-HT).
- AlSi7Mg0.3 – modified with Sb (in Tab. 4 mark Sb).
- AlSi7Mg0.3 – modified with Sb, heat treated (in Tab. 4 mark Sb-HT).
- Al – Al 99.8 %.

All workpiece materials were also heat treated. Heat treatment of castings was performed to improve primarily hardness in the following way: [4, 5]

- Heating of the castings from 0_°C to 520_°C in 60 minutes.
- Dwelling at temperature 520 °C for 4 hours.
- Cooling of castings in a water bath at 50 °C.
- Drying in the dryer at 170 °C for 8 hours.

Chemical composition of work material according to CSN EN 1706 is in Tab.1.

Tab. 1 *Chemical composition of the alloy AlSi7Mg0.3 according to CSN EN 1706 [6]*

The chemical composition of the alloy cast [%]						
Si	**Fe**	**Cu**	**Mn**	**Mg**	**Cr**	**Ni**
6.50 – 7.50	0.19 (0.15)	0.05 (0.03)	0.10	0.25 – 0.45 (0.30 – 0.45)	-	-
Zn	**Pb**	**Sn**	**Ti**	**Other**		**Al**
0.07	-	-	0.25 (0.18)	0.03	0.1	Residue

Chemical composition of modified work materials is in Tab. 2.

Tab. 2 *Chemical composition of the analysed alloys AlSi7Mg0.3*

cast number	Alloy	Chemical elements						
		%						Appropri-ate modifier
		Al	Si	Mg	Fe	Cu	Mn	Sr – Ca – Sb
I.	AlSi7Mg0.3	92.218	7.336	0.257	0.115	0.023	<0.0020	-
II.	AlSi7Mg0.3Sr0.03	92.219	7.329	0.266	0.099	0.017		0.0250
III.	AlSi7Mg0.3Ca0.20	92.170	7.367	0.260	0.099	0.023		0.2100
IV.	AlSi7Mg0.3Sb0.05	92.589	6.944	0.295	0.082	0.001		0.0505
V.	Pure aluminium 99.8 %	99.650	0.042	0.004	0.042	0.005		-

Cutting tools

- Cutting inserts holder: SCLCR 1212 F 09 505102 (PRAMET).
- Cutting inserts: CCMT 09T308E-UR, TiC coated sintered carbides.

Cutting conditions

- Depth of cut: 1.0 mm.
- Feed per revolution: 0.1 mm.
- Cutting speeds: 50; 100; 200; 300; 400; 500; 600 m.min^{-1}.
- Dry machining.

Experimental devices

- Lathe: EMCOMAT-14S.
- Software: measuring station Dites.

To eliminate parasite thermocouple between the cutting plate and the body of the cutting tool after heating the cutting tool in cutting, all experiments started otter cutting tool getting cold.

The results of electromotive force measured in turning in Tab. 2 and Fig. 1 (no heat treatment) and Tab. 3 and Fig. 2. (heat treated materials).

Tab. 3 *Thermocouple voltage for different cutting speeds for materials without heat treatment*

Sample mark	Cutting speed [m.min^{-1}]						
	50	100	200	300	400	500	600
Al	20.04	23.44	25.19	26.25	27.82	30.10	34.94
NO	26.52	32.51	34.68	34.75	39.28	43.24	44.06
Sr	27.28	34.54	40.79	44.14	45.37	46.85	52.34
Sb	26.74	28.37	33.39	38.54	41.72	46.07	47.36
Ca	25.04	33.36	38.50	41.54	42.16	43.74	46.84

Tab. 4 *Thermocouple voltage for different cutting speeds for materials with heat treatment*

Sample mark	Cutting speed [m.min^{-1}]						
	50	**100**	**200**	**300**	**400**	**500**	**600**
Al	20.04	23.44	25.19	26.25	27.82	30.10	34.94
NO-HT	27.77	33.04	38.68	43.78	43.86	46.29	49.92
Sr-HT	24.99	32.96	33.35	34.35	35.79	41.43	52.57
Sb-HT	18.28	25.63	30.99	35.62	39.29	41.86	45.27
Ca-HT	20.23	28.66	37.01	38.20	45.27	47.03	52.22

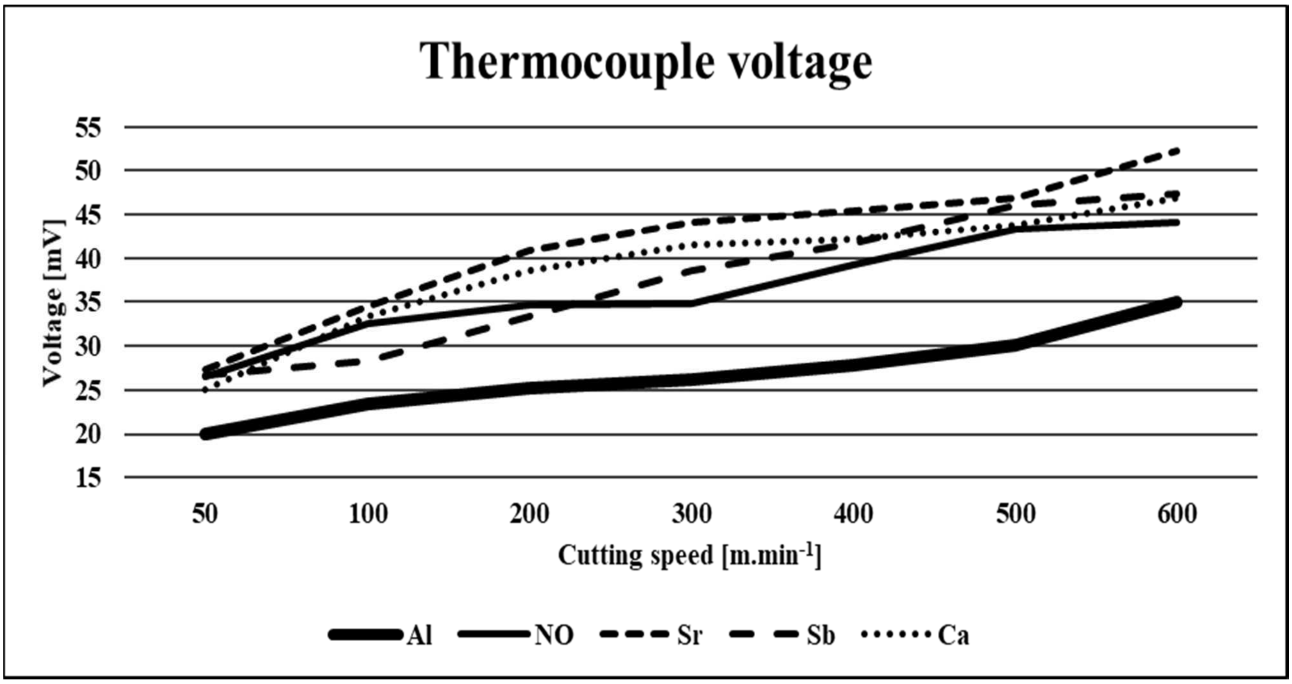

Fig. 1 *Relation between thermocouple voltage and cutting speed for materials without heat treatment*

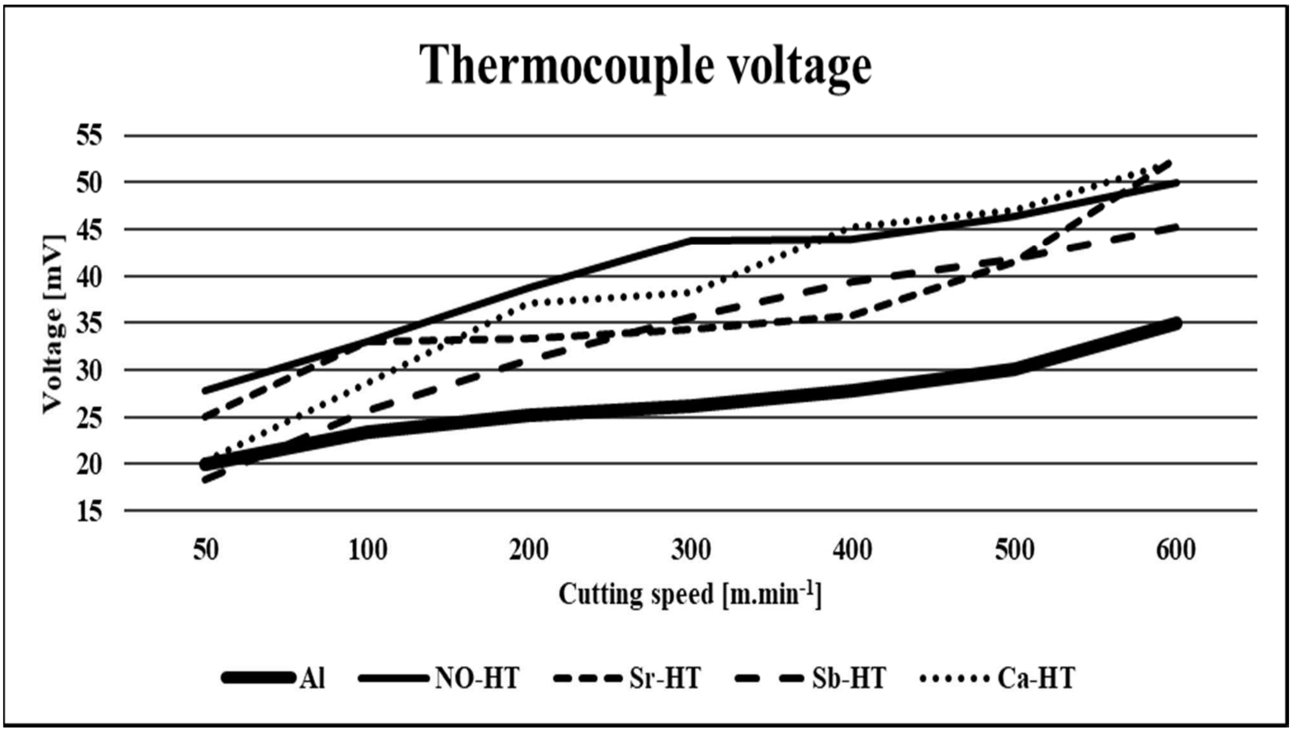

Fig. 2 *Relation between thermocouple voltage and cutting speed for materials with heat treatment*

4 Conclusion

- The best machinability in comparison with other experimental materials shows Al (Al 99.8 %.).
- The worst machinability from the group of materials without heat treatment show materials modified by Sr followed by material modified by Ca.
- The worst machinability from the group of materials with heat treatment show materials modified by Sb and Ca.
- But there are differences in machinability according to cutting speed. For practical use machinability ought to be assessed in the range of cutting speed from 200 to 500 $m.min^{-1}$.

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