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The Effect of Grain-refinement on Zn-10Al Alloy Damping Properties

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Abstract

The paper is devoted to grain-refinement of the medium-aluminium zinc based alloys (MAl-Zn). The system examined was sand cast Zn-10 wt. %. Al binary alloy (Zn-10Al) doped with commercial Al-3 wt. % Ti – 0.15 wt. % C grain refiner (Al-3Ti-0.15C GR). Basing on the measured attenuation coefficient of ultrasonic wave it was stated that together with significantly increased structure fineness damping decreases only by about 10 – 20%. The following examinations should establish the influence of the mentioned grain-refinement on strength and ductility of MAl-Zn cast alloys.

Keywords: Zinc-Aluminium cast alloys, Inoculation, Grain-refinement, Damping, Attenuation coefficient

1. Introduction

ZnAl-based foundry alloys of increased Al content have enhanced damping properties. On the other hand they show a coarse grain-structure after solidification in sand moulds, which decreases their ductility. The refinement of the coarse macrostructure positively influences plastic properties but the increased structure fineness can decrease the damping properties. This work is aimed at presenting results of the influence of Zn-10Al sand-cast alloys grain-refinement with the Al-3Ti-0.15C master alloy on the alloy damping properties measured by the attenuation coefficient changes.

2. Experimental

The system used during these examinations was Zn-10 wt. % Al (Zn-10Al) binary alloy inoculated with the commercial Al-3 wt.% Ti – 0.15 wt.% C (Al-3Ti-0.15C master alloy or TiCAl MA). During this study the melted alloy was inoculated with the TiCAl MA in an amount introducing, accordingly, 25, 50, 100, 200 and 400 ppm Ti.

The Zn-10Al alloy was melted from Zn and Al of minimum purity 99.95%. The melting, casting and inoculation of the Zn-10Al was performed in the same manner as previously described in detail in [1 – 3].

The measurements of damping properties were performed using the Krautkramer USLT 2000 device and the attenuation of 1 MHz ultrasound wave - Fig. 1, [3 – 5]. The measurements were performed for two damping values (sensitivities), i.e. 50 and 500 Ohms. The number of the measurements for each of the examined sample was 20 in a series. Then mean arithmetic values of each series of the 20 measurements were calculated as representative values of the attenuation coefficient.

a)

b)

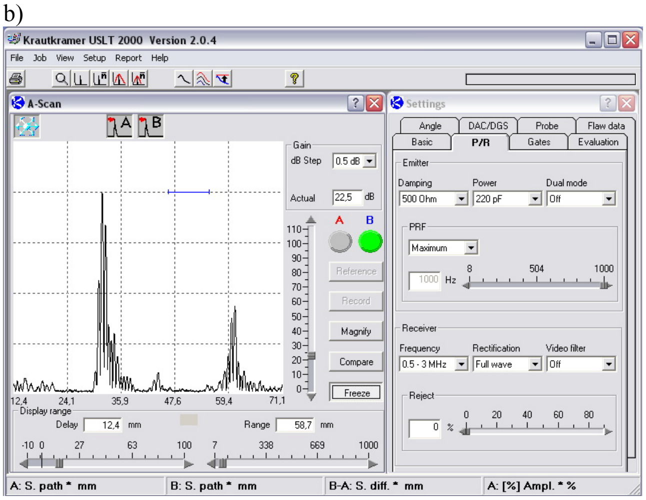


Fig. 1. **(a)**: Krautkramer USLT 2000 stand; **(b)**: Exemplary image of peaks in an echogram of the examined Zn-10Al alloy

3. Results and discussion

The results of the attenuation coefficient changes vs. addition of Ti, obtained during the performed measurements, are shown in Fig. 2. From Fig. 2 it can be seen that the addition of TiCAl master alloy, in the amount of about 25 - 400 ppm, generally decreases the attenuation coefficient in comparison with the initial, non inoculated alloy. This can be attributed to the significant structure refinement, as it is clearly seen in Figs 4 and 5. It should be however noted that the observed attenuation coefficient decreases only by 10 – 25 %, so also detail examinations on the influence on strength properties should be performed to evaluate a total influence of the applied inoculation on the mechanical properties. These examinations will be presented in a close future in [6]. Fig. 3 shows mean arithmetic values obtained in the damping series of 50 and 500 Ohms. As it can be seen in Fig. 3 – the results in the series 50 and 500 Ohms differ slightly. The results of the individual measurements are collected in Tables 1 - 2. The left hand side results presented in the Tables 1 – 2 show their significant scatter around the mean values. It can suggest a significant structural heterogeneity and/or a presence of inner defects.

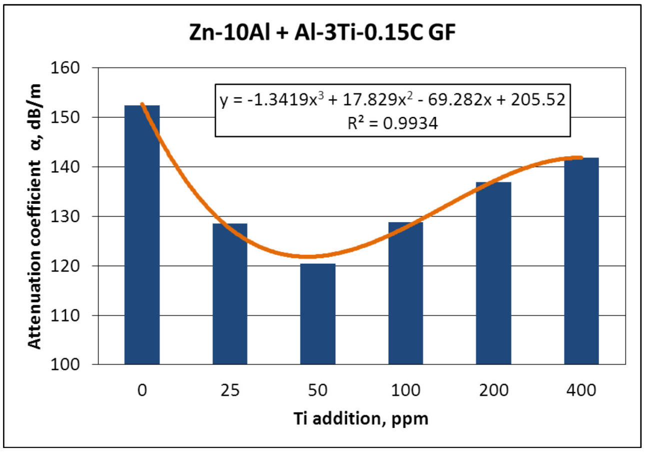


Fig. 2. Summary the effect of the addition of Ti in the Al-3Ti-0.15C (TiCAl) master alloy on the mean value of attenuation coefficient

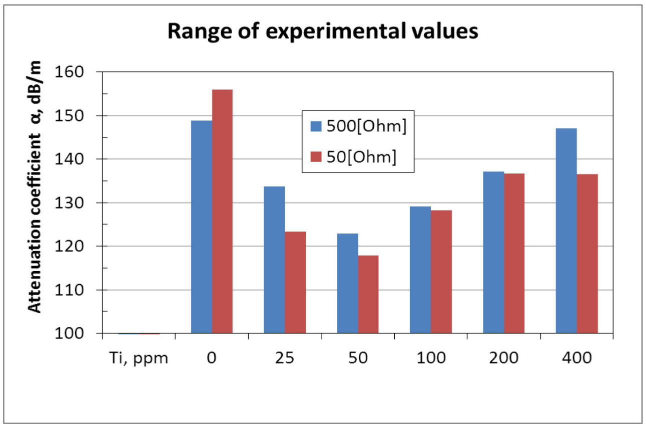
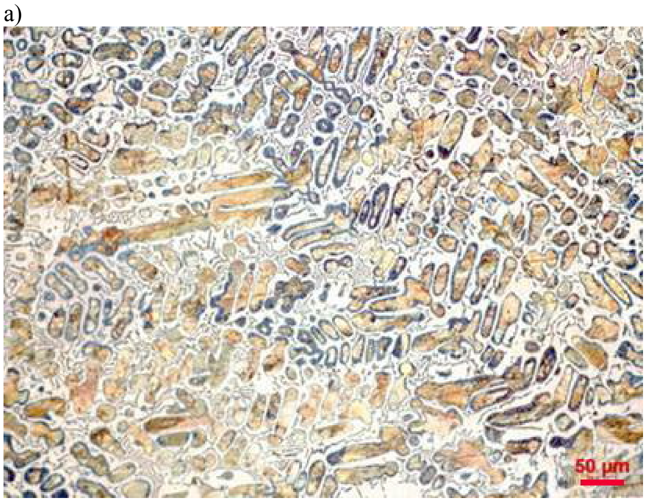


Fig. 3. Range of experimental mean values obtained for the two Krautkramer USLT2000 measurement sensitivities of 50 and 500 Ohm

a)



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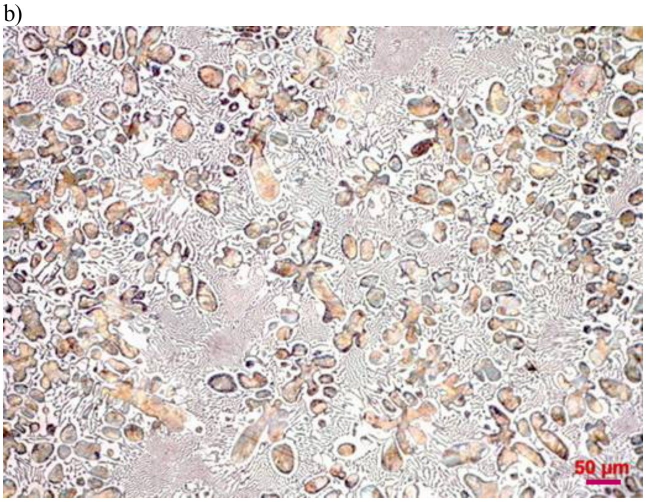

Fig. 4. Changes of microstructure of the Zn-10Al alloy. (a) initial alloy without Ti addition, (b) the same alloy doped with 50 ppm Ti introduced with the Al-3Ti-0.15C grain refiner, Light microscopy [5]

a)

b)

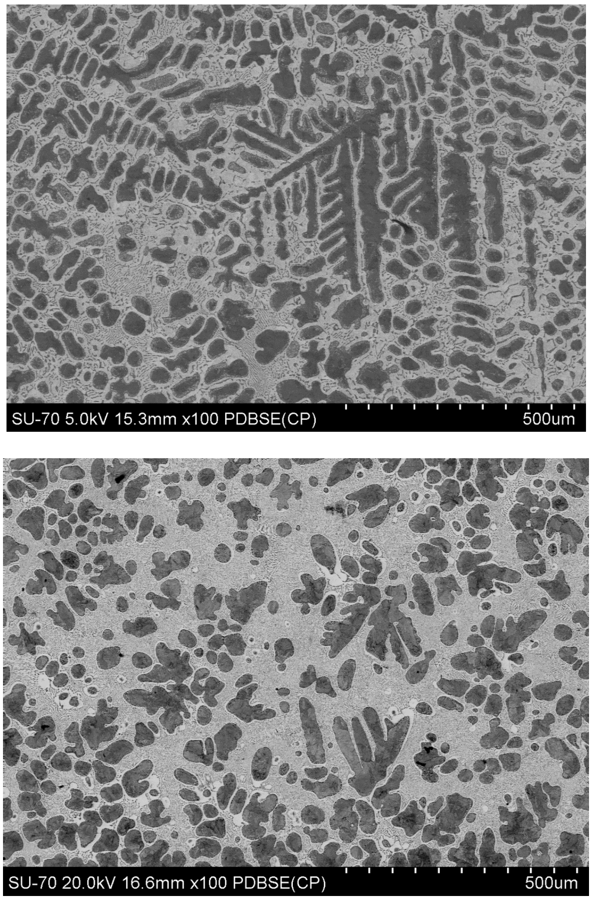

Fig. 5. Changes of microstructure of the Zn-10Al alloy. (a) initial alloy without Ti addition, (b) the same alloy doped with 100 ppm Ti introduced with the Al-3Ti-0.15C grain refiner, SEM [6]

Table 1.
Zn-10Al – 0 ppm Ti; Krautkramer USLT 2000 – 1 MHz; 500 Ohm. Measured values of attenuation coefficient AC and their % deviations around the mean value

α [dB/m]	Deviation, [%]	α [dB/m]	Deviation, [%]
209.73	40.84		
151.01	1.41	151.01	4.76
151.01	1.41	151.01	4.76
142.62	-4.22	142.62	-1.06
142.62	-4.22	142.62	-1.06
151.01	1.41	151.01	4.76
142.62	-4.22	142.62	-1.06
176.17	18.31		
151.01	1.41	151.01	4.76
167.79	12.68		
184.56	23.94		
134.23	-9.86	134.23	-6.88
151.01	1.41	151.01	4.76
125.84	-15.49		
134.23	-9.86	134.23	-6.88
184.56	23.94		
109.06	-26.76		
117.45	-21.13		
117.45	-21.13		
134.23	-9.86	134.23	-6.88
Mean AC			
148.91		**144.15**	

Table 2.
Zn-10Al – 25 ppm Ti; Krautkramer USLT 2000 – 1 MHz; 500 Ohm. Measured values of attenuation coefficient AC and their % deviations around the mean value

α [dB/m]	Deviation, [%]	α [dB/m]	Deviation, [%]
192.95	67.88		
117.45	2.19	117.45	7.69
100.67	-12.41	100.67	-7.69
109.06	-5.11	109.06	0.00
109.06	-5.11	109.06	0.00
109.06	-5.11	109.06	0.00
109.06	-5.11	109.06	0.00
109.06	-5.11	109.06	0.00
100.67	-12.41	100.67	-7.69
117.45	2.19	117.45	7.69
134.23	16.79		
109.06	-5.11	109.06	0.00
109.06	-5.11	109.06	0.00
117.45	2.19	117.45	7.69
109.06	-5.11	109.06	0.00
100.67	-12.41	100.67	-7.69
92.28	-19.71		
117.45	2.19	117.45	7.69
100.67	-12.41	100.67	-7.69
134.23	16.79		
Mean AC			
114.9		**109.1**	

However, from the right hand side results, i.e. after eleminating results of the scatter larger than 20% it can be seen, that the range around the mean value is much more narrow. The latter exemplary results are shown in Fig. 6.

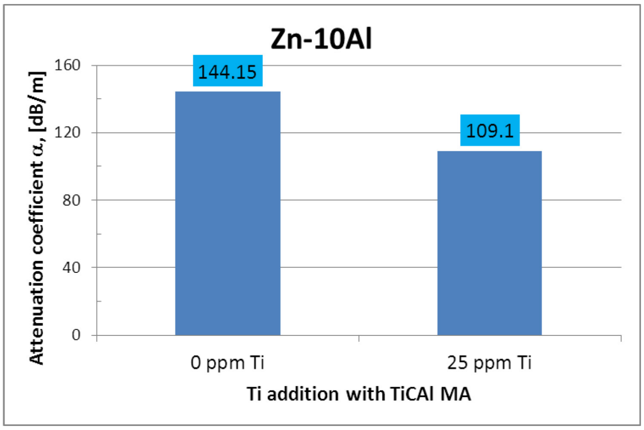

Fig. 6. The attenuation coefficient made for results of scatter ± 10% around the mean

4. Conclusions

Basing on the performed examinations and calculations the following conclusions can be drawn:

1. Doping the Zn-10Al alloy with small Ti addition increases microstructure fineness.
2. The Zn-10Al alloy with refined microstructure has decreased damping properties by 10 – 25 % in comparison to the initial alloy without Ti addition.
3. The effect of the observed structure refinement should be confronted with changes of the alloy ductility. The later should be a subject of expanded detail examinations [6].

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