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# Ultrasound Wave Attenuation of Grain Refined High – Zinc Aluminium Sand-cast Alloys

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## Abstract

The paper presents results of measuring attenuation coefficient of the Al-20 wt.% Zn alloy (AlZn20) inoculated with different grain refiners. During experiments the melted alloys were doped with Al-Ti3-C0.15 refining master alloy. Basing on measurements performed by Krautkramer USLT2000 device with 1MHz ultrasound wave frequency it was stated that grain refinement reduces the attenuation coefficient by about 20-25%. However, the examined alloys can be still classified as the high-damping ones of attenuation greater than 150 dB/m.

**Keywords:** High-Zinc Al alloy, Sand casting, Grain refinement, Damping capacity, Attenuation of ultrasound wave, Strength properties

## 1. Introduction

Al-based foundry alloys of increased Zn 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 Al-20 wt.% Zn sand-cast alloys grain-refinement with the Al-3Ti-0.15C master alloy on the alloy structure, strength properties and damping properties measured by the attenuation coefficient changes.

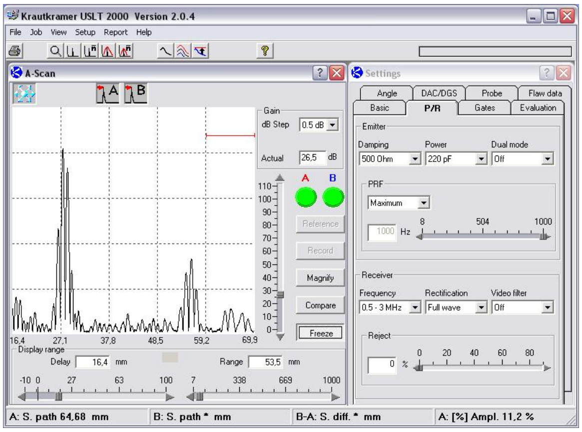
## 2. Experimental

The system used during these examinations was Al-20 wt. % Zn (Al-20Zn) binary alloy inoculated with the commercial Al-3 wt.% Ti – 0.15 wt.% C master alloy (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 and 400 ppm Ti.

The Al-20Zn alloy was melted from Zn and Al of minimum purity 99.95%. The melting, casting and inoculation of the Al-20Zn 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 about 10 in a series – Tables 1 and 2. Then mean arithmetic values of each series of the 10 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 USLT 2000 echogram [3, 6]

# 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 - 100 ppm 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 Fig. 3 (a) and (b). It should be however noted that the observed attenuation coefficient decreases only by 10 – 25 %, so also detailed examinations on the influence on strength properties should be performed to evaluate the total influence of the applied inoculation on the mechanical properties. Fig. 4 shows mean arithmetic values of grain sizes and attenuation coefficient obtained in the damping series of the Al-20Zn alloy, first non-modified and then doped with 400 ppm Ti.

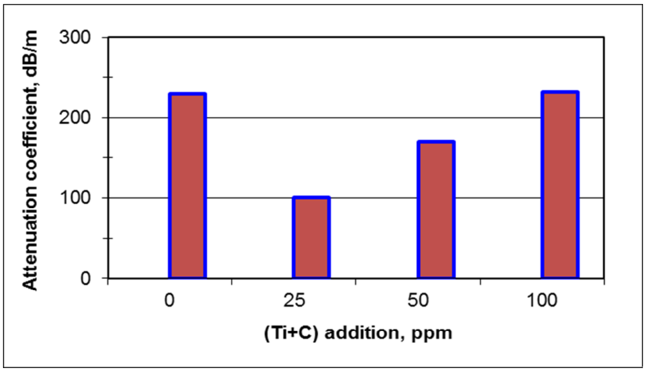
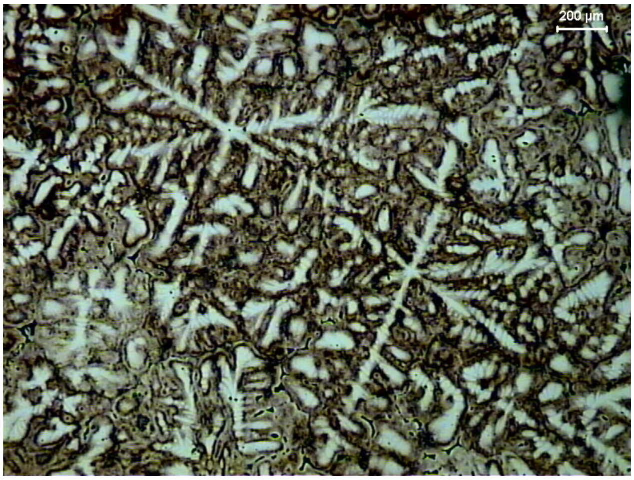
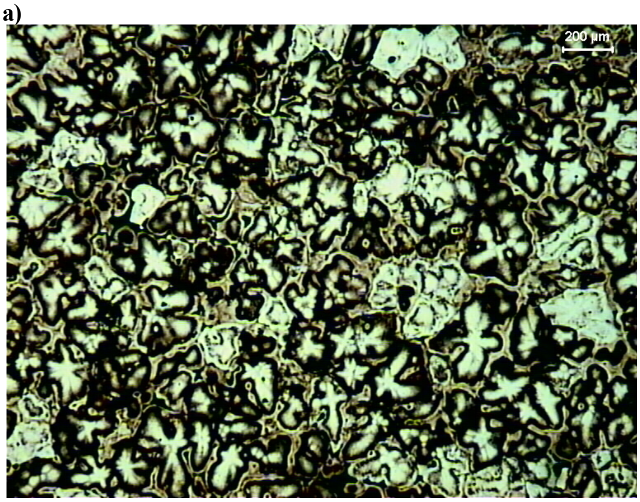



Fig. 2. Summary the effect of the addition of Ti in the Al-3Ti-0.15C (TiCAl) master alloy on the mean value of attenuation coefficient. Frequency f=1 MHz




a)

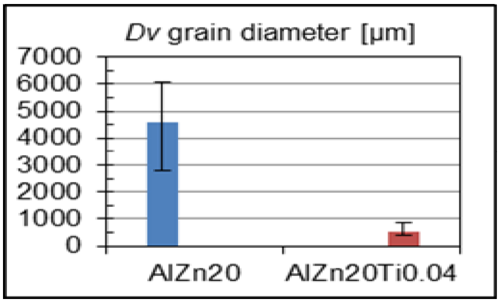



b)

Fig. 3. Changes of microstructure of the Al-20Zn 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

As it can be seen in Fig. 4 – the grain refinement causes decrease of the attenuation coefficient by about 20-25%.

The exemplary 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.



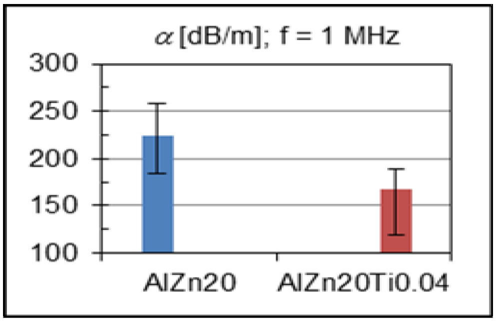




Fig. 4. Influence of the grain refinement on the attenuation coefficient [7]

Table 1.
Al-20Zn initial alloy – 0 ppm Ti; Krautkramer USLT 2000 – 1 MHz; 500 Ohm and 50 Ohm. Measured values of attenuation coefficient AC and their deviation percentage around the mean value

| 500 Ohm | | 50 Ohm | |
|---|---|---|---|
| α [dB/m] | Deviation, [%] | α [dB/m] | Deviation, [%] |
| 217.39 | -0.85 | 192.31 | -12.29 |
| 192.31 | -12.29 | 217.39 | -0.85 |
| 242.47 | 10.58 | 183.95 | -16.10 |
| 234.11 | 6.77 | 200.67 | -8.48 |
| 200.67 | -8.48 | 234.11 | 6.77 |
| 183.95 | -16.10 | 284.28 | 29.64 |
| 259.20 | 18.21 | 209.03 | -4.66 |
| 242.47 | 10.58 | 209.03 | -4.66 |
| | | 225.75 | 2.96 |
| Mean AC | | | |
| **221.57** | | **217.39** | |
| **Mean total value of AC: 219.36 dB/m** | | | |

Table 2.
Al-20Zn–50 ppm Ti; Krautkramer USLT 2000 – 1 MHz; 500 Ohm and 50 Ohm. Measured values of attenuation coefficient AC and their deviation percentage around the mean value

| 500 Ohm | | 50 Ohm | |
|---|---|---|---|
| α [dB/m] | Deviation, [%] | α [dB/m] | Deviation, [%] |
| 192.31 | 12.77 | 183.95 | 7.87 |
| 158.86 | -6.84 | 158.86 | -6.84 |
| 200.67 | 17.67 | 185.62 | 8.85 |
| 192.31 | 12.77 | 183.95 | 7.87 |
| 158.86 | -6.84 | 150.50 | -11.74 |
| 133.78 | -21.55 | 133.78 | -21.55 |
| 192.31 | 12.77 | 200.67 | 17.67 |
| 158.86 | -6.84 | 158.86 | -6.84 |
| 158.86 | -6.84 | 177.26 | 3.95 |
| 132.11 | -22.53 | 175.59 | 2.96 |
| 183.95 | 7.87 | 179.77 | 5.42 |
| Mean AC | | | |
| **169.35** | | **171.71** | |
| **Mean total value of AC: 170.53 dB/m** | | | |

As mentioned above the grain refinement is aimed mainly at improving ductility. Figures 5 and 6 show strength properties of the cast samples of initial non-modified Al-20Zn alloy (Fig. 5) and the samples of the same alloy grain refined with 100 ppm Ti (Fig. 6). From Fig. 5 it appears that mean values of the non-modified Al-20Zn alloy are: M-UTS ultimate tensile strength ~230 MPa and M-A5 ~1.8%. On the other hand from Fig. 6 it can be seen that mean values of the modified Al-20Zn alloy are: M-UTS ultimate tensile strength ~250 MPa and M-A5 ~2.4%.

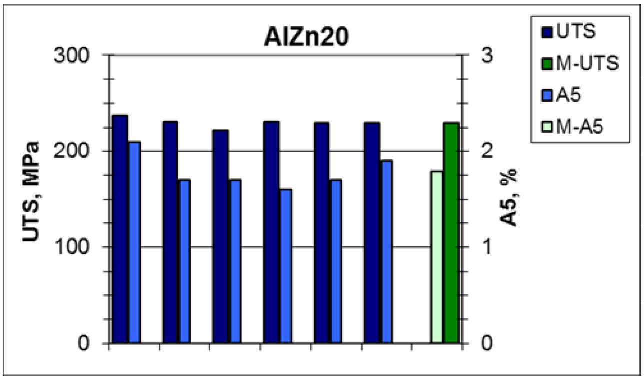



Fig. 5. Strength properties of the series of non-modified AlZn20 alloy. M-UTS and M-A5 are, accordingly, mean values of ultimate tensile strength (UTS) and elongation (A5)

Thus, the applied grain refinement leads to significant increase of the alloy ductility, i.e. by about 30%, while tensile strength also increases, but only by about 10%.

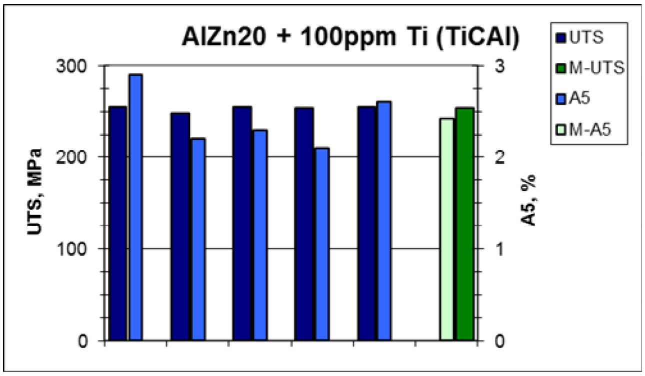



Fig. 6. Strength properties of the series of modified AlZn20 alloy doped with 100 ppm Ti introduced with Al-3Ti-0.15C master alloy. M-UTS and M-A5 are, accordingly, mean values of ultimate tensile strength (UTS) and elongation (A5)

# 4. Conclusions

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

1. Doping the Al-20Zn alloy with small Ti addition increases microstructure fineness.
2. The damping properties of Al-20Zn alloy with refined microstructure decrease by 20 – 25 % in comparison with the initial alloy without Ti addition. However, the attenuation (above 150 dB/m) remains still at the high level which is typical for the high-damping alloys.
3. The observed structure refinement increases ductility of the grain refined Al-20Zn alloy by about 30% while the alloy tensile strength increases by about 10%.

The improved ductility and basically preserved high damping properties are positive results of the performed grain refinement process.


# Acknowledgements

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