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INTERNAL DAMPING DEPENDING ON THE VIBRATION AMPLITUDE MEASURED ON SPECIMENS AZ31 AND AZ91 IN AS CAST STATE AND AFTER HOMOGENIZATION ANNEALING

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1.Introduction

Naturally benefits of magnesium are unique combination of properties, such as high specific strength and toughness, low density, electric and thermal conductivity. Magnesium alloys are the lightest commercial alloys being developed, very attractive for automotive and electrochemical industry and their good combination of strength and damping make them usable also for other applications.

Engineering magnesium alloys are used especially for production of light weight-walled casting and except many covers and lockers in automotive engines are used for the mass production of parts of mobile phones, cameras or notebooks, so components, where low weight is ultimate. Magnesium alloys have also good damping properties (belong to the group of the HIDAMETS materials – High Damping METals).

Analysis of vibrations is important tool for eigenfrequency calculations of the systems and prediction of reaction from material to vibration excitations. Using this technique we can determine if the parts will subserve the functions, which are made for and also we can predict the cause resulting from dynamic loading, such as fatigue life, dynamic strain or noisiness. In many cases the only effectively solution for control and reduction of vibration amplitude is changing internal damping in structure of material.

Damping capacity of alloys is closely tied to the presence of defects including solute atoms, second phases and voids. The interaction between moving dislocations and point defects is one of the major internal damping mechanisms of magnesium alloys so the precipitates influence the damping capacity and contributes to damping properties.

2.Experimental material

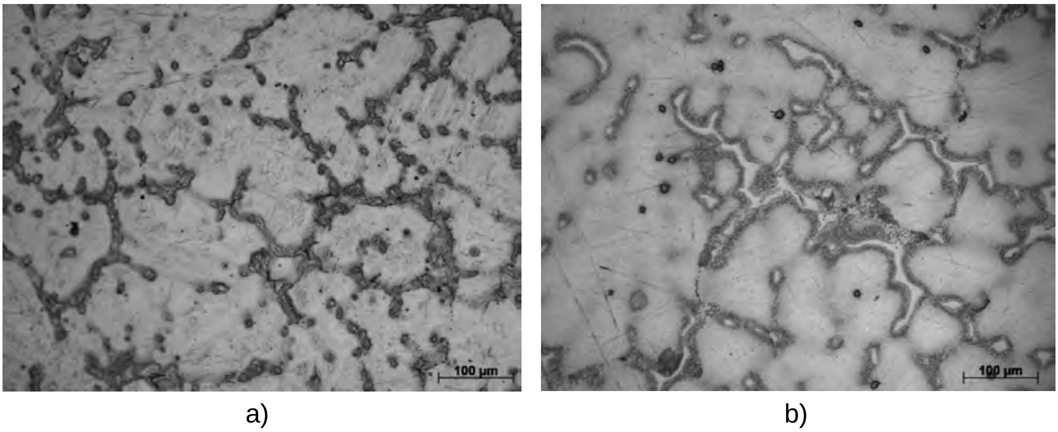
As an experimental material magnesium alloys AZ31 and AZ91 were used which were manufactured by squeeze casting and were delivered without heat treatment. Result of the spectrometer chemical analysis is shown in the Tab. 1.

Tab. 1 *Chemical composition of magnesium alloys AZ31 and AZ91*

Element		Al	Zn	Mn	Ca	Si	Fe	Mg
Content [wt. %]	**AZ31**	2.980	0.655	0.202	0.180	0.067	0.007	balance
	AZ91	7.280	0.554	0.202	0.001	0.007	0.008	balance

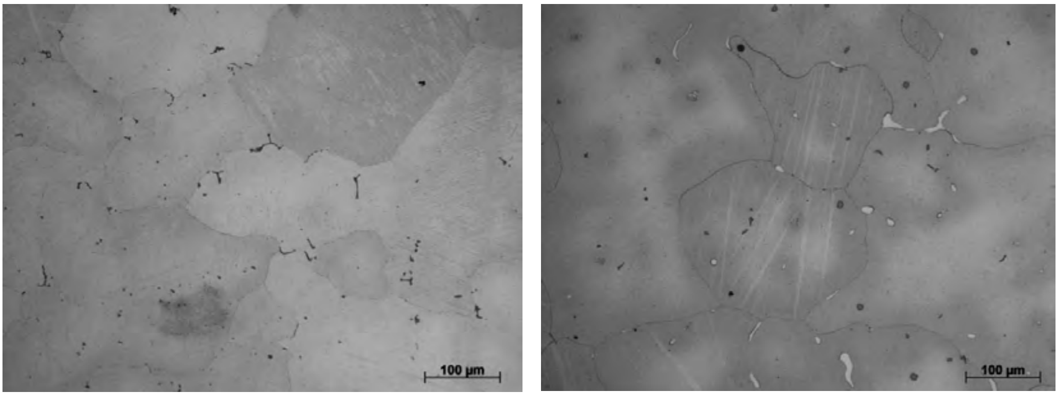
The experimental material before measuring of internal damping was submitted to metallographic analysis, which allows obtain information about the shape, size, type and quantity of structural components contained in the material, and thereby contributes to understanding of the ongoing processes in the material during cyclic loading. The microstructure of the magnesium alloys was analyzed in the as cast state and after homogenization annealing state. After squeeze casting the microstructure was dendritic (Fig. 1). In the interdendritic areas there were located many intermetallic phases. The most important is $Mg_{17}Al_{12}$ intermetallic phase.

A heat treatment was performed at the temperature of 390 °C for 22 hours followed by quenching in the water with the purpose to obtain a solid solution of aluminum and zinc and other elements in the magnesium matrix. Almost all intermetallic particles were dissolved and the microstructure of the alloy was homogenized. The microstructure after annealing is created by polyedric grains and the grain boundaries are clearly visible. The homogenization annealing led to dissolution of intermetallic phases, diffusion equalizing of concentrations of alloying elements in the alloy and creating polyedric structure (Fig. 2).



a) b)

Fig. 1 *Microstructure of as cast state alloys a) AZ31, b) AZ91*



a) b)

Fig. 2 *Microstructure of alloys after* homogenization annealing *a) AZ31, b) AZ91*

3.Measurement method

The internal damping was measured using indirect ultrasonic method of determining the quality factor resonant system. This method is based on continuous excitation of oscillations of the specimen, and the entire apparatus vibrates at a frequency which is close to the resonance. Quality of the resonance system Q^{-1} is calculated by measuring the resonance peak and determining its width for 3 decibel level.

$$Q^{-1} = \frac{\Delta f_{r3dB}}{f_r}, \qquad (1)$$

where:

f_r .... resonant frequency [Hz],
$\Delta f_{r3dB} = f_2 - f_1$ .... width of resonance curve for 3 decibel level [Hz].

The experimental equipment (Fig. 4) consists of electronic and mechanical part (Fig. 3). One of the electronic part is generator which produces a sine wave. The electric signal is then amplified and transformed into the mechanical wave by using the piezoceramic transducer. The ultrasonic wave is amplified in aluminium horn and spreads into the specimen by the titanium rod. After passing through the specimen the wave is reflected at the free end and spreads back through the entire device. The amplitude of resulting oscillations is measured by multimeter.

Fig. 3 *Mechanical part of device*

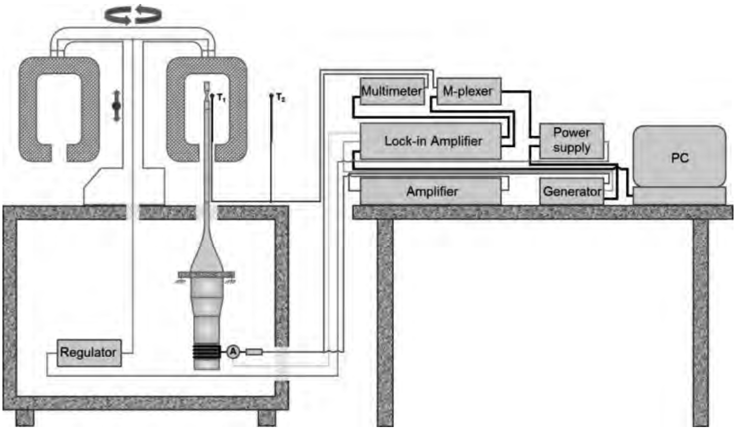


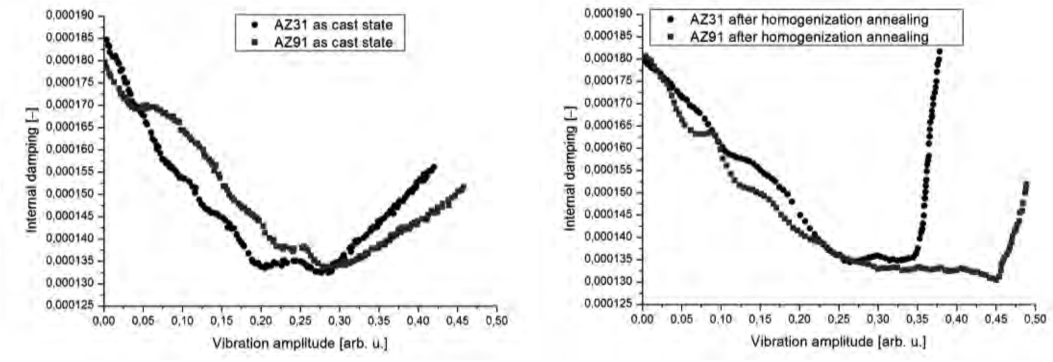
Fig. 4 *Ultrasonic resonance device for internal damping measurement*

4.Measurement results

Internal damping depending on the vibration amplitude was measured on specimens in as cast state and after homogenization annealing. Starting resonance frequency for all measurements was about f = 20500 Hz. The value of input excitation voltage was 100 mV. The measurement was performed in increments of 50 mV, at room temperature (20 ° C) to the finally chosen excitation voltage.

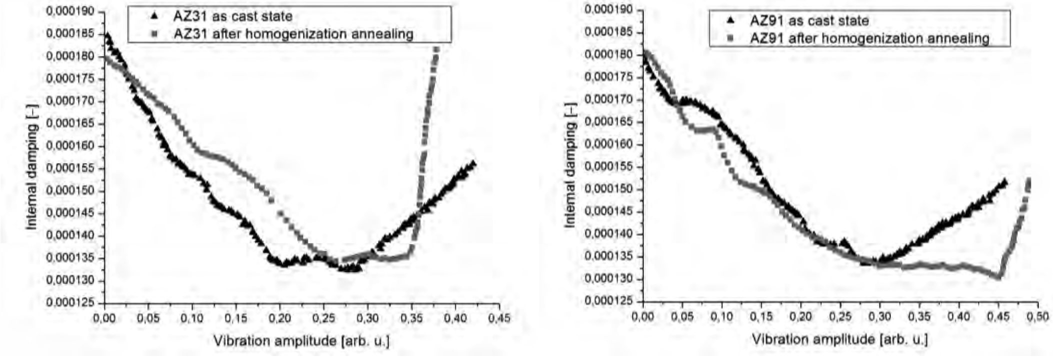
In the Fig. 5, there are results of the measurement of the internal damping depending on the vibration amplitude of the magnesium alloy AZ31 and AZ91 in as cast state and after homogenization annealing. The first measurement was carry out on the specimen in as cast state, then the same specimen was homogenization annealed and the measurement was repeated. Value of internal damping for alloy AZ31 was at the beginning of the measurement $Q^{-1} = 1.85 \times 10^{-4}$ and for alloy AZ91 $Q^{-1} = 1.78 \times 10^{-4}$. With increasing of excitation voltage the internal damping decreased at first and at vibration amplitude 0.28 there was a linear increase of the internal damping in both materials. The magnesium alloy AZ31 reached slightly higher values of internal damping at the same amplitude oscillations than the alloy AZ91. Point of the curve from which there is an increase of internal damping represents the transition from the elastic range behavior of the material to microplastic range behavior and it is described as a second critical amplitude of deformation.

The initial value of the internal damping after heat treatment was approximately the same as in as cast state. For alloy AZ31 $Q^{-1} = 1.80 \times 10^{-4}$ and for alloy AZ91 $Q^{-1} = 1.81 \times 10^{-4}$. With increasing of excitation voltage, as in the previous case, the internal damping had a downward trend at first, but there was a difference in their growth. By comparing the measurements of the internal damping after homogenization annealing and the measurements in as cast state (Fig. 6), we can see that an increase of the internal damping after homogenization annealing was observer at higher vibration amplitudes and this increase was steeper.



a) b)

Fig. 5 *Results of measurement of the internal damping depending on the vibration amplitude of the magnesium alloys, a) as cast state, b) after homogenization annealing*



a) b)

Fig. 6 *Results of measurement of the internal damping depending on the vibration amplitude of the magnesium alloys, a) AZ31 and b) AZ91*

5.Conclusion

Based on experimental results can be stated:

- The value of the first critical amplitude of deformation ε_{cr1} (from which started the amplitude-dependent mechanisms) wasn't recorded during any measurement.
- After reaching a certain vibration amplitude linear increase of the internal damping was observed, which can be explained that it has reached the second critical amplitude of deformation ε_{cr2}.
- After heat treatment, the second critical amplitude of deformation ε_{cr2} shifted to higher vibration amplitudes and the increase of the internal damping was steeper than in as cast state.
- The results will provide basis for further study of the amplitude dependence of the internal damping of magnesium alloys AZ31, AZ61 and AZ91.

Acknowledgement

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Summary

Internal damping depending on the vibration amplitude measured on specimens AZ31 and AZ91 in as cast state and after homogenization annealing

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The article is focused on the analysis of the internal damping changes depending on the amplitude of the magnesium alloys AZ31 and AZ91 and their comparison. Internal damping reflects the ability of the material irreversibly dissipating mechanical energy of oscillations. That means, the material of high internal damping ability is able to significantly reduce the vibration amplitude. Dispersion of mechanical energy in the material is just one of the ways of energy transformation for example conversion of mechanical energy to heat energy. In experimental measurements only ultrasonic resonance method was used. This method is based on continuous excitation of oscillations of the test bar, and the entire apparatus vibrates at a frequency which is close to the resonance.