INFLUENCE OF PROCESSING CONDITIONS ON STRUCTURE AND MECHANICAL PROPERTIES OF EUTECTOID Zn-Al ALLOY

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Abstract: *In the present paper analyses concerning on the constituent properties in the eutectoid Zn-Al based alloys obtained by gravitational casting in various moulds and quenching from the two-phase area has been presented. Further presented are the results of microhardness and tribological analyses. Microhardness and tribological tests were performed using an AHOTEC FM-700 machine and a CSM Instruments tribometer. The obtained results were processed statistically. The functions of frequency distributions for properties analysed are presented.*

Keywords: *Zn-Al alloys, microstructure, microhardness, wear rate*

1. INTRODUCTION

For many years, Zn-Al based alloys are the most common used and investigated of all zinc alloys in various engineering and industrial applications due their several technological and exploitation properties. As regard concerning the technological properties one can remark their feature clean, low - temperature, energy – saving melting. One can remark that the exploitation properties display numerous advantages, as: excellent castability, fluidity and high strenght.
Compared with other casting used alloys they have better machinability, are harder and stronger and have superior tribological properties [1-5].
The disadvantage of these casting alloys is their instability of the structure in time, they undergo heat treatments meant to contribute to an increased dimensional stability during deployment [6, 7].
The tribological characteristics as wear and friction of zinc based alloys family have become an interested target for all researchers in the world [8].
The aim of this work was to determine the influence of the various processing conditions on the mechanical and tribological properties of Zn-Al alloys.

2. EXPERIMENTAL DETERMINATIONS

The composition of the alloy used in this study is shown in Table 1. Zn-Al eutectoid samples were prepared by melting quantities of Zn and Al (purity>99.99%) in an electric graphite crucible with silit bars (electrical resistors).
The alloy was melted to a temperature of 650 ºC and then poured gravitationally into steel (OL) and brick moulds (C). In order to maintain the β structure at room temperature, the cast alloy in metal moulds has been heated and quenched from to biphasic domain.
The temperature in the specimen was recorded by using K-TPN-101 – type coaxial thermocouples (0.6 mm in diameter), protected with refractory paste. Then, they were connected to a measurement unit consisting of a data-logger and a computer.
The experimental data were processed by using the EBI WIN-log 2000 software and ORIGIN PRO 8 programme.

Table 1. Chemical composition of Zn-22 Al

Mass concentration of the elements, wt %			
Al	***Cu***	***Mg***	***Cd***
21.852	0.195	0.002	0.006
Pb	***Fe***	***Sn***	***Zn***
0.0021	0.117	0.0009	77.825

Microstructural analysis were carried by optical microscopy (NIKON Eclipse MA100), Vickers microhardness measurements and tribological tests were performed using an AHOTEC FM-700 test device a CSM Instruments tribometer.
For each type of processing conditions, 50 measurements were performed under different loads from 0.001 to 0.1 kgf for the determination of Vickers microhardness to all constituents from gravity cast and quenched samples, for a dwell time of 10 seconds.
The tribotests were performed at applied load of 5 N and a linear speed of 11.31 – 15.08 cm/s. The duration of each test was 30 minutes.

3. RESULTS AND DISCUSSION

Figures 1 (a) and 1 (b) show the cooling and heating – maintaining – cooling curves recorded for Zn-22 wt % Al alloy in three processing conditions.

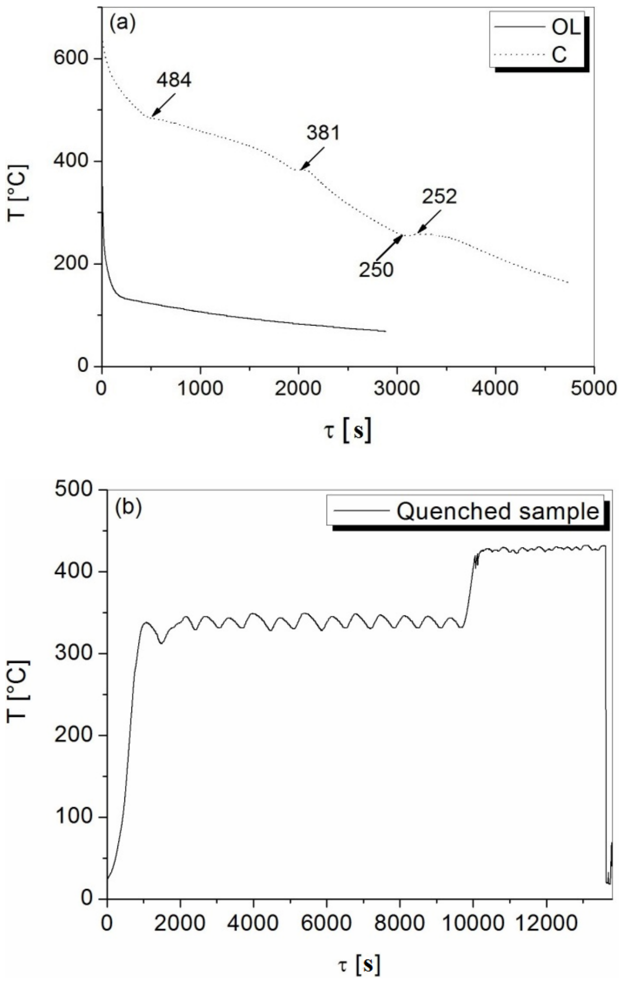


Fig. 1. (a) Cooling curves for Zn-22 wt % Al alloy cast in various moulds; (b) Heating – maintaining-cooling curve for quenched sample

It is seen that only for alloy cast in brick moulds Figure 1 (a), where was a low cooling rate (0.64 ºC/s), the cooling curve reveals significant inflection points corresponding to the structural transformations indicated by the thermal equilibrium diagram.

Figure 2 (a), (b) and (c) reports the obtained microstructures for the three variants of processing of Zn-22 wt % Al alloy cooled at different cooling rates, from liquid state, including from the two-phase area.

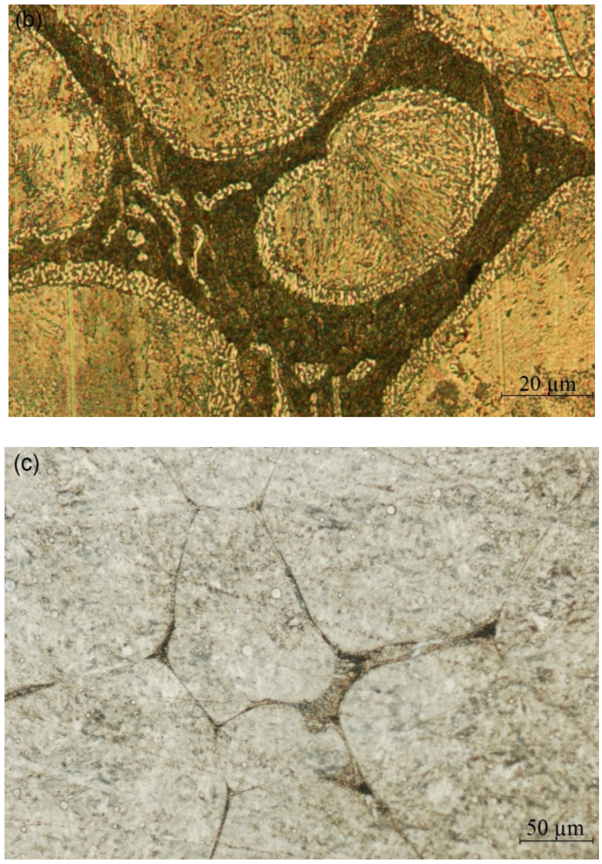
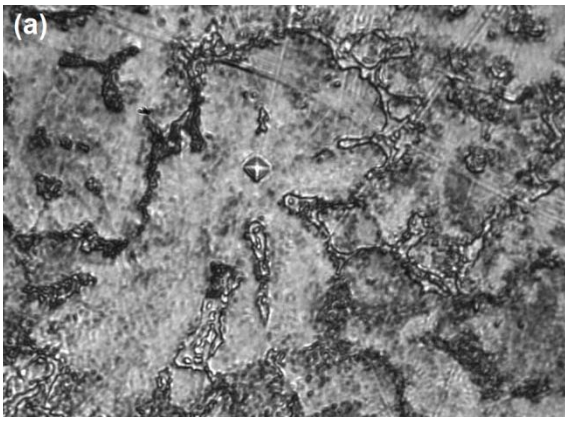


Fig. 2. Microstructure of the cast Zn-22 wt % Al alloy: (a) in steel moulds; (b) in brick moulds; (c) quenched

The cast alloy in steel moulds (Figure 2 (a)) exhibited dendritic structure comprising *α* solid solution dendrites surrounded by a significant amount eutectic (α + η) in the interdendritic regions. While the structure of the quenched alloy consists of β phase crystal where has been observed the presence of very small amounts of eutectic at the limit of some crystals, Figure 2 (c).

In the alloys cast gravitationally into steel moulds the main grain is of 40 µm, in brick moulds is of 100 µm and in the quenched alloy increases up to 120 µm.

Figure 3 (a), respectively (b) reports the indentation measurements on α-Al solid solution phase and eutectic (α + η) constituent of the cast Zn-22 wt % Al alloy in steel moulds.



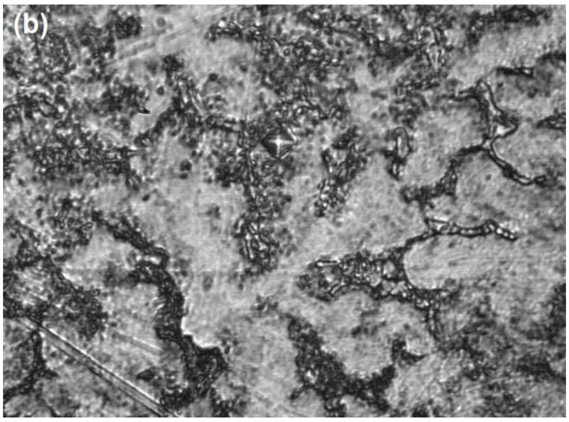


Fig. 3. Indentations on phase and constituent of the cast Zn-22 wt % Al alloy in steel moulds: (a) α; (b) eutectic (α + η)

Figure 4 reports the indentation measurements on α-Al solid solution phase (1), inter-dendritic spacing (2) and eutectic (α + η) constituents (3) of the cast Zn-22 wt % Al alloy in brick moulds.

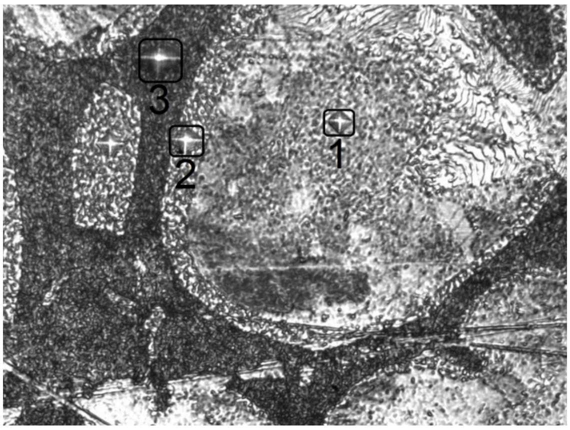
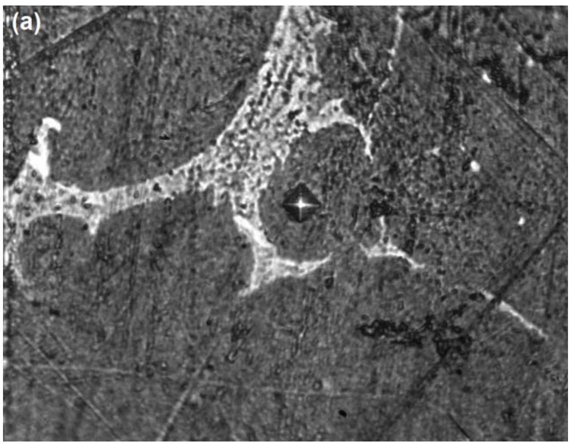


Fig. 4. Indentation on phase and constituents of the cast Zn-22 wt % Al alloy in brick moulds: 1 - α, 2 – inter-dendritic spacing (α + η), 3 - eutectic

Figure 5 (a), respectively (b) reports the indentation measurements on β solid solution phase and eutectic (α + η) constituent of the quenched Zn-22 wt % Al alloy.



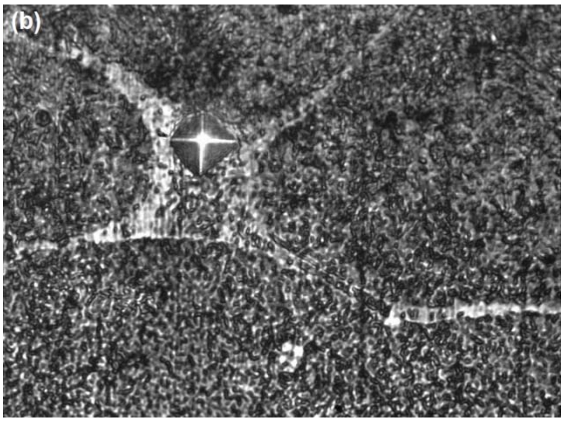


Fig. 5. Indentations on phase and constituent of the quenched Zn-22 wt % Al alloy: (a) β; (b) eutectic (α + η)

Figure 6 shows the frequency distribution curves obtained by statistical processing of the results microhardness measurements for Zn-22 wt % Al alloy processed in different conditions. According to the statistical parameters ($\bar{x}$, s), the probability is approximately 68.3% that the random variable values fit into the $\bar{x} \pm s$ interval; similarly, the probability is approximately 95.5%, into the $\bar{x} \pm 2s$ interval; an over probability of 99.75% in the $\bar{x} \pm 3s$ interval and less of 0.3% will not be within into this interval [9].

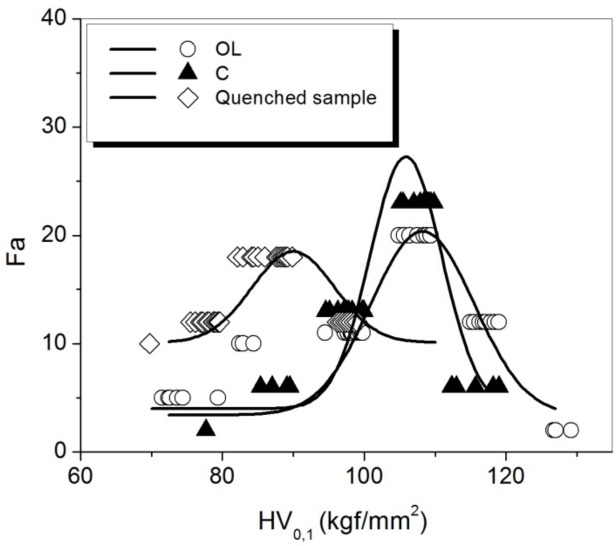


Fig. 6. Frequency distribution function to $HV_{0.1}$ for s.s.α and s.s.β of Zn-22 wt % Al alloy obtained in different processing conditions

Regardless of casting technology used, it can be noticed as in the case to microhardness determination with an 0.1 kgf applied load, the average hardness values are higher and the same for α solid solution than for metastable β phase. The spread of the microhardness values obtained is greater in the case of the β solid solution than α solid solution from samples cast, Figure 6, Table 2.

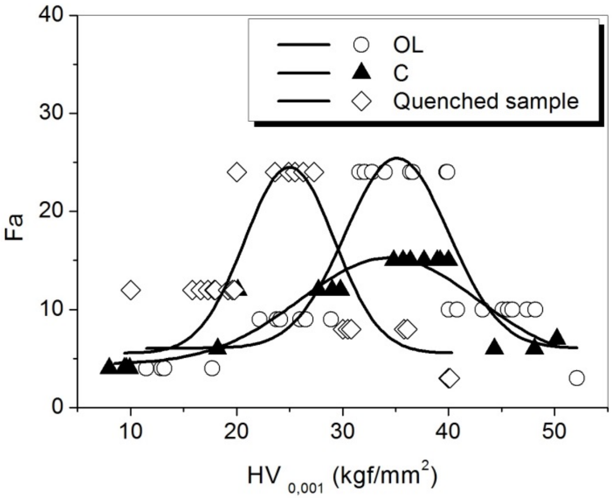


Fig. 7. Frequency distribution function to $HV_{0.001}$ for s.s.α and s.s.β of Zn-22 wt % Al alloy obtained in different processing conditions

Figure 7 shows the frequency distribution function for microhardness with an 0.001 kgf applied load. Also, in this case the average microhardness of β solid solution phase obtained by quenching is less than of α solid solution from sample cast in steel and brick moulds.
It needs be pointed out that, the microhardness values obtained are much lower at this load than those obtained at a much higher applied load (0.1 kgf).

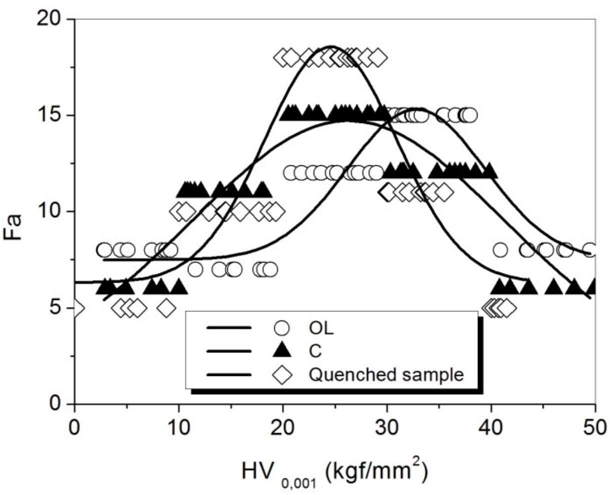


Fig. 8. Frequency distribution function to $HV_{0.001}$ for interdendritic eutectic (α + η) of Zn-22 wt.% Al alloy obtained in different processing conditions

In the case of sample cast in steel moulds, the eutectic constituent (eutectoid) shows the maximum microhardness values recorded, and in the case of sample obtained by quenching from two-phase area, the β phase presents the lower values recorded.
In the case of the casting in steel and brick moulds the average microhardness eutectic constituent is comparable, Figure 8, Table 2.

Table 2. Statistical parameters of the analysed phases/constituents by Vickers microhardness

Sample types	*Phase/ Constituent*	*F [kgf]*	$\bar{x}$	*s*
Cast in steel moulds	**s.s.α**	0.1	103	13
		0.001	35	10
	Eutectic	0.001	35	8
Cast in brick moulds	**s.s.α**	0.1	103	10
		0.001	35	14
	Eutectic	0.001	25	12
Quenched	**s.s.β**	0.1	86	9
		0.001	24	8
	Eutectic	0.001	25	10

In order to analyse the tribological properties a determination of the friction coefficient value was applied. The curves obtained for the three types of alloys are presented in Figure 9.
Figure 10 shows the average value of the friction coefficient.

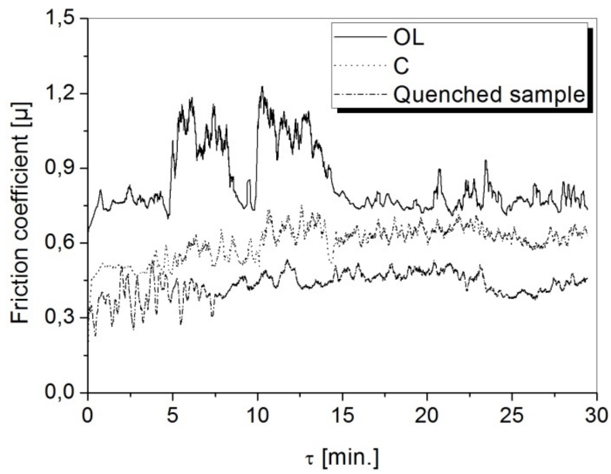


Fig. 9. Coefficient of friction *versus* time for Zn-22 wt % Al alloy

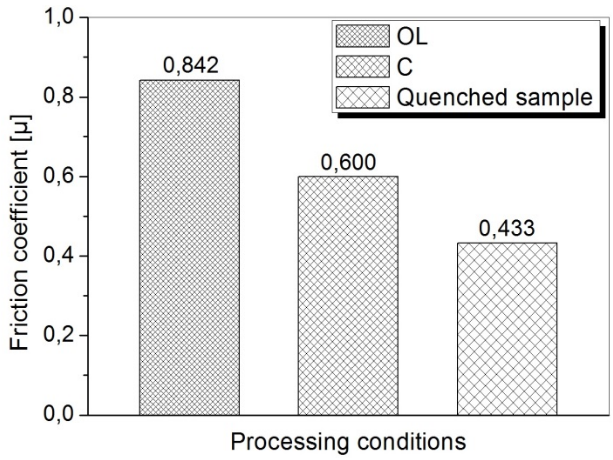


Fig. 10. Coefficient of friction *versus* processing conditions for Zn-22 wt % Al alloy

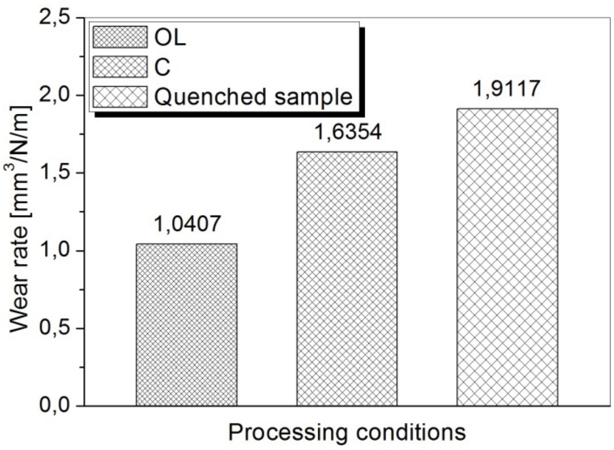


Fig. 11. Wear rate *versus* processing conditions Zn-22 wt % Al alloy

Figures 10, respectively 11 report that the alloy with metastable β phase, obtained by quenching from the two-phase area, presents the superior tribological properties: the friction coefficient and wear rate values are lower, resulting the increasing exploitation duration. and the wear rate value the same.

4. CONCLUSIONS

This research paper was aimed at comparing the properties of stable phases/constituents at room temperature with the properties of metastable β phase obtained by quenching from the two-phase area.
The obtained metastable beta phase in the experimental determinations has higher stability in time, over 180 days compared with 10 days duration reported in the scientific literature data [10, 11].
For analyzed phases the microhardness recorded present a higher dispersion that reveals the non-homogeneous structure of these alloys. The non-homogeneous structure of the occured phases of casting samples is determined by the segregation phenomenon at the dendrites level.
Experimental determinations on the friction coefficient and wear rate reveal that the obtained metastable β phase by quenching from the two-phase area presents the best tribological properties.

5. ACKNOWLEDGEMENTS

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