12th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2008, Istanbul, 26-30 August 2008

STRUCTURE AND FRACTURE CHARACTERISTICS OF MAGNESIUM - ALUMINIUM ALLOYS UNDER ELEVATED TEMPERATURES

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ABSTRACT
Magnesium alloys are primarily used in aeronautical and automobile industry in wide variety of structural characteristics because of their favourable combination of tensile strength (160 to 365 MPa), elastic modulus (45 GPa), and low density (1 740 kg/m^3***),** *which is two-thirds that of aluminium). Magnesium alloys have high strength-to-weight ratio (tensile strength/density), comparable to those of other structural metals.*
Knowledge of elastic-plastic properties at elevated temperatures is often important for complex evaluation of magnesium-aluminium alloys. Objective of the work was focused on determination of changes of elastic-plastic properties of magnesium-aluminium alloys, including investigation of fracture characteristics with use of light microscopy and SEM.
Keywords: Magnesium alloys, tensile test at elevated temperatures, structure, fracture characteristics

1. INTRODUCTION
At the contemporary stage of the development of the engineering thought, and the product technology itself, material engineering has entered the period of new possibilities of designing and manufacturing of elements, introducing new methods of melting, casting, forming, and heat treatment of the casting materials, finding wider and wider applications in many industry branches. Engineers whose employment calls for significant expenditure of labour and costs strive to reduce material consumption. Therefore the development of engineering aims at designs optimizing, reducing dimensions, weight, and extending the life of devices as well as improving their reliability.
Scope of utilisation of foundry magnesium alloys is continuously being extended, so if we want to operate as competitive producers, it is necessary to investigate very actively properties of individual alloys, optimise their chemical composition, study issues of their metallurgical preparation, including heat treatment [1-5]. A potential development direction of magnesium alloys is shown in Figure 1.
Complex evaluation of magnesium alloys requires very often knowledge of elastic-plastic properties at elevated temperatures. In the following paper there have been the structure and properties AZ61 under elevated temperatures presented.

2. MATERIAL AND EXPERIMENTAL PROCEDURES
Experimental investigation was made with use of cast plates (size 10x20x150 mm) of magnesium alloy AZ61 (after ASTM Standard) in initial state as cast. Chemical composition of alloys is given in Table 1.
Testing of mechanical properties under elevated temperatures was made on tensile testing machine INOVA- TSM 20. Temperature range of the equipment is up to 800°C. Samples for tensile test in cast state had a form of bar with length 115 mm, diameter 6 mm, in central part the diameter was reduced to 4 mm in the length of 30 mm.

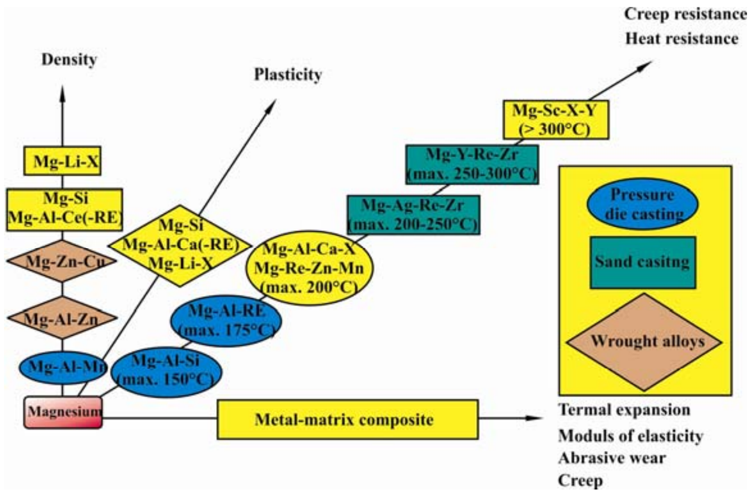


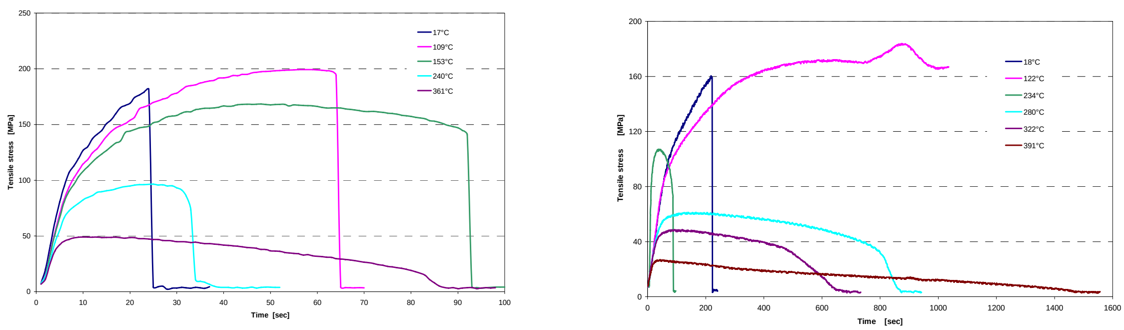
Figure 1. Potential development directions of new magnesium alloys [4]

Table 1. Chemical composition of alloy (weight %)

Al	Zn	Mn	Si	Cu	Fe	Be	Zr	Sn	Ni	Pb	Ce
5,92	0,49	0,15	0,037	0,003	0,007	0,0003	0,003	0,01	0,003	0,034	0,01

3. RESULTS OF TESTS AND THEIR ANALYSIS

Results of tensile test dependence on temperature of alloy AZ61 are summarised in the Figure 2 and Table 2. DE is integral deformation energy. Dependency of sample deformation course until its destruction at various sample temperature at the crosshead pace of 6 mm/min was monitored in the first series of trials (Figure 2a) and 0,6 mm/min was monitored in the second series of trials (Figure 2b). The measurement was performed at temperature levels at a temperature range from 15°C to 400°C (see Table 2).



a) *b)*

Figure 2. Temperature dependence of mechanical properties alloy AZ61 loading pace of a crosshead of a) 6 mm/min, b) 0,6mm/min

Table 2. Results of tensile tests of alloy AZ61 as cast at elevated temperatures (loading pace of a crosshead of 6 mm/min)

Sample	T [°C]	DE [J]	R_m [MPa]	Z [%]	A [%]
1	21	4,65	181,7	8	7,4
4	109	13,94	199,5	20	17,2
5	153	18,17	168,4	36	24,6
7	240	3,80	96,5	14	10,3
11	361	3,81	49,2	69	21,5

As it is seen in these Figures values of R_m swiftly decrease with increasing temperature of the test. In other measured values there was registered initial growth with indistinctive maximum in temperature zone of approx. 250^{o}C for work to rupture, and approx. 300^{0}C for elongation and reduction. Optimal mechanical properties are achieved approximately at 150^{o}C.
After achieving of the maximum there follows sharp fall, at the highest temperatures the achieved values are mostly lower than the values at the temperature of 20^{0}C. Maximum of plasticity at 361^{o}C is occurred probably from the reason of quasiliquid state in interdendritic areas.
The different pace of sample loading (6mm/min and 0.6mm/min) leads to a situation when the material is strengthened more intensively as far as deformation is concerned. The consequence includes reaching of higher strength values.
In order to complete the obtained results and to clarify dependencies in the Figure 2 an evaluation of microstructure and character of fracture was performed in the relevant samples.
The examples of fracture areas and microstructure near of fracture surface after testing in the cutting plane parallel with its axis of the samples at selected temperatures are shown in the Figures 3-5.
Light microscope NEOPHOT 2 was used for evaluation of microstructure of alloys. Fracture characteristics were investigated with aim of SEM JEOL 50A.

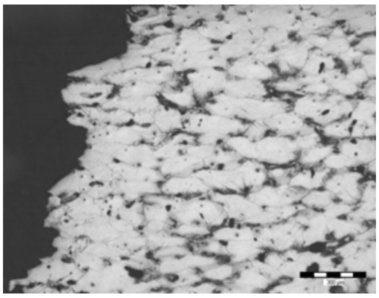


Figure3a. Microstructure of sample at temperature 153°C

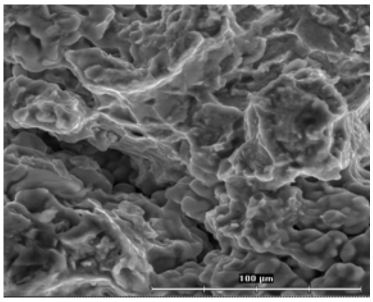


Figure 3b. Fracture areas of sample at temperature 153°C

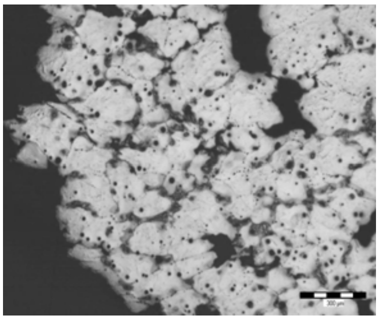


Figure 4a. Microstructure of sample at temperature 240°C

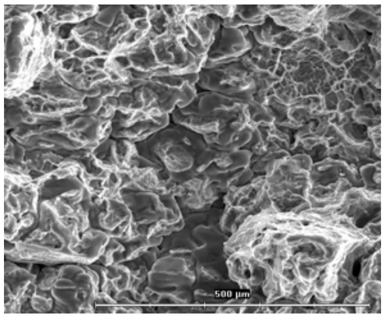


Figure 4b. Fracture areas at temperature 240°C

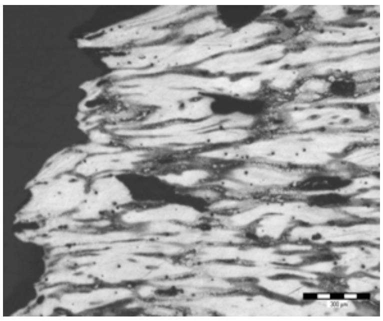


Figure 5a. Microstructure of sample at temperature 361°C

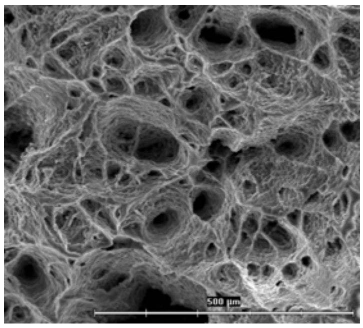


Figure 5b. Fracture areas at temperature 361°C

Microstructure in initial as cast state is formed by crystals of matrix on the basis of magnesium, surrounded by minority phases of the type $Mg_{17}Al_{12}$ in almost continuous formations in interdendritic areas, which may represent places of initiation and propagation of failure at tensile test [3,4,5].
At temperatures from 240^{0}C to 361^{0}C there occurs partial dissolution and coagulation of the massive phase (Figures 3a-5a). These processes are accompanied by forming of micro-pores in interdendritic areas contributing also to initiation of crack propagation along the phase boundary [5].
Fracture areas at selected temperatures are shown in Figures 3b-5b. Predominant fragile interdendritic character of failure was demonstrated on fracture surfaces at all temperatures exception temperature 361^{0}C, where ductile fracture prevailed.

4. CONCLUSIONS

The authors of the presented work solve an experimental determination of the elastic-plastic condition of the magnesium alloy depending on the temperature and loading pace of a crosspiece shift of the sample at tensile test. It was found out that:

- within app. 110°C, the strength limit with the temperature and deformation pace increase and then decrease
- the increased loading pace of a crosspiece shift of 6 mm/min generates higher strength at both of the materials than the pace of 0.6 mm/min
- Microstructure of the alloy in initial state is formed by solid solution and by minority phases $Mg_{17}(Al,Zn)_{12}$ in massive and dispersion form.
- Microstructure has dendritic character, minority phases are comparatively continuously distributed in interdendritic areas, which represent suitable places for initiation and propagation of cracks under load.
- During heating at chosen temperatures there occurs partial dissolution of minority phases. Homogenisation of microstructure is, however, accompanied by simultaneous forming of inter-granular non-integrities, which is unfavourable from the viewpoint of strength and plastic properties, especially at higher temperatures.
- During increasing of plastic properties in the temperature interval from 250 to 300^{0}C some role is played, among others, also by certain homogenisation of microstructure, their decrease at the temperature above 300^{0}C can be connected with formation of continuous non-integrities, or with melting of residues eutectic phase in interdendritic areas (quasiliquid state respectively).
- Failure occurs practically at all temperatures basically by inter-crystalline splitting along the boundaries of original dendrites exception temperature 361^{0}C, where ductile fracture prevailed.

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The work was financed by aim of projects MSM 6198910015, MSM 6198910013 and sponzored by projects GAČR GA-101/08/1110 and R15 0702