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Lightweight, high-strength aluminum AlZnMgCu alloy castings.

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The paper presents research work and application of AlZnMgCu alloys in the swing arm as cast element. The chemical composition was developed to obtain optimal mechanical properties (UTS >400MPa) and elongation ($A_5 \approx 1.5\%$) along with the proper heat treatment procedure. Investment casting was chosen as a manufacturing method. Test samples were obtained directly from the casting structure. The results are very similar to the tensile strength UTS in the cast, which is about 420 MPa, with the results obtained from the simulation analysis of the casting using the MAGMASOFT software. The fatigue strength simulation of the swing arm were performed in the ANSYS software. The research work shoed that the ration of the fatigue strength to the tensile strength is 0,4, which is higher compared to the generally accepted ration of 0.2 - 0.25 for the aluminum alloys.

Keywords: *AlZnMgCu alloy, computer simulation, fatigue tests*

1. Introduction

The increased focus on the reduction of the emission of the CO_2 gases in the atmosphere is forcing the vehicle designers to reduce the fuel consumption which is connected to the overall reduction of weight [1]. The solution, could be an application of high strength aluminum alloys, which were commonly used in plastic working and known as 7xxx series to be used as castings. The use of the alloys in the manufacturing process of high-strength castings is still at the initial research stage. The strength properties of the alloys generally increase along with the amount of the Zn and Mg. However, along with the increase of the amount of these elements, particularly for Zn content above 7%, the tendency of hot cracking during the solidification and rapid cooling process increases. This is the technological issue. The high strength of the AlZnMgCu alloys results from a phenomenon of the separation of the particles of the certain phase from the supersaturated solution. The phase which affects the strength properties is η – $MgZn_2$. The literature analysis allowed to explore the dynamics and kinetics of the formation of phases such as: T (Al_6CuMg_4), S (Al_2CuMg) η ($AlZn_2$), which have a significant effect on the final properties which are dependent on the content of Zn, Mg and Cu. The study was based primarily on the use of the JMatPro program [2-4]. Increased amount of Zn is preferred due to the influence on the strength which is based on the decreasing of the amount of T phase. The T phase inhibits the fine yield in the casting. Therefore, the content of Zn in the alloy was determined in the range of 5 to 6%. Also, Cu and Mg content have significant influence on the final properties of the alloy which must be well chosen, because of the increase of Mg increases the amount of unfavorable T (Al_6CuMg_4) phase. While increasing the Cu content increases the separation of the S (Al_2CuMg) phase occurs.

2. Research procedure

The alloy with chemical compositions presented in the table 1 was chosen in the research work:

Table 1 Chosen chemical compositions

No	Zn	Mg	Cu	Fe	Si
1	**5,53**	**2,37**	**1,56**	**0,2**	**0,1**
2	**4,70**	**1,50**	**0,71**	**0,10**	**0,06**

Based on the DSC curves the fallowing heat treatment procedure parameter was applied:

- Solutioning – 450 ^oC, 2h + 530 ^oC, 2h + 560 ^oC, 2 h, cooling in the water in 80 ^oC
- Aging – 120 ^oC, 4h + 150 ^oC , 8h,

Experimental castings were prepared by the investment casting process without and with additional cooling by dipping the ceramic mold after pouring in a specially prepared cooling medium (Fig. 1). The research work was performed in order to obtain parameters: mechanical properties, the size of microporosities, interphase precipitations, influence of solidification rate and fatigue strength curve. Conducted numerical analysis of the casting process allowed to determine the final casting properties

including tensile strength and distribution of microporosity. The results were compared with the experimental results. The next step was the fatigue analysis of the swing arm for 10^8 cycles.

Tabel 2 Mean properties of the samples - composition 2

Additional Cooling	UTS MPa	YS MPa	A_5 %	Grain µm
No	**422**	**403**	**0,5**	**138**
Yes	**443**	**404**	**1,4**	**110**

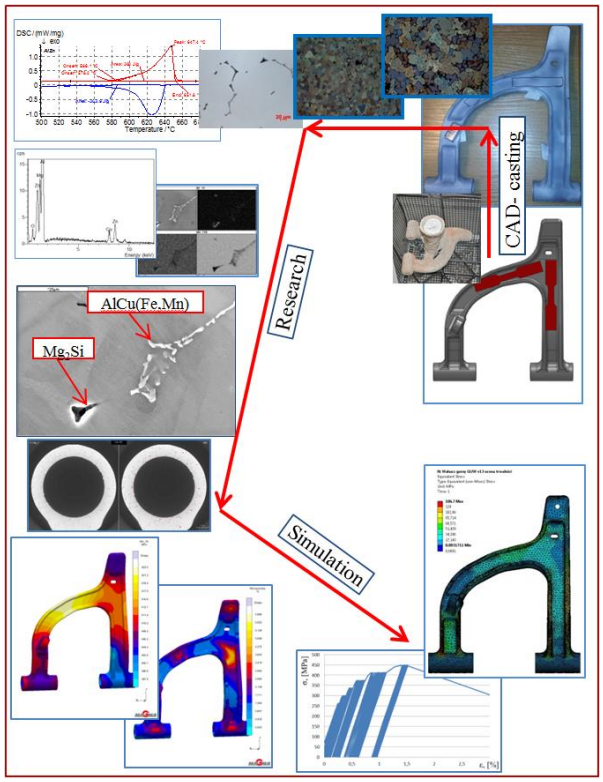

Fig. 1. Diagram of conducted research procedure.

3. Results

Expected tensile strength UTS (near 420 MPa) in the casting from AlZnMgCu alloys is possible to achieve (Table 2). Unfortunately the elongation achieved in the composition 1 is highly unsatisfactory. The chemical composition 2 is characterized with higher elongation with decreased tensile strength. It has been observed that the alloys have a high tendency to create the microporosity. This is a result of width crystallization range $\Delta T = T_{lq}$ (637 ^oC) – T_{sol} (475,5 ^oC) = 167,5 ^oC. High solidification rate influence on the grain refinement which results in the increased tensile strength. The calculated mean value of the grain after the heat treatment is:

- Without additional cooling - 138 µm,
- With additional cooling – 110 µm.

In the case of the precipitation hardening alloys like AlZnMgCu, very important is the heat treatment process. The procedure should be multistage in order to dissolve the intermetallic phases in the matrix and create dispersion precipitates which are strengthening the microstructure. The separation of brittle and hard intermetallic phases were observed at the grain boundaries. This is a factor lowering the elongation of the alloy. Comparison of the results of the computer simulation with the results of the test samples obtained from the castings indicates good compatibility. The strength of the cast element is varied depending on the solidification rate and ranges from 390 MPa to 435 MPa. A similar agreement is obtained in comparison of the micro-porosity determined in the computer simulation and computer tomography evaluation. The microporosity of the swing arm is approximately 1.5%. The maximum value of the deformation of the swing arm structure does not exceed the permissible range during the fatigue testing.

4. Conclusions

- AlZnCuMg alloys are suitable in the casting process as a material for enhanced operating condition elements,
- Further studies will be conducted for the increase of the elongation and corrosion resistance.

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