Available online at www.sciencedirect.com

ScienceDirect

Procedia Manufacturing 2 (2015) 337 – 341

Procedia MANUFACTURING

2nd International Materials, Industrial, and Manufacturing Engineering Conference, MIMEC2015, 4-6 February 2015, Bali Indonesia

The microstructure and mechanical properties of AZ31 magnesium alloy aircraft brackets produced by a new forging technology

Anna Dziubińska[a*], Andrzej Gontarz[a], Karina Horzelska[b], Paweł Pieśko[a]

[a] *Lublin University of Technology, Faculty of Mechanical Engineering, 36 Nadbystrzycka Street, 20-618 Lublin, Poland*
[b] *Silesian University of Technology, Faculty of Materials Engineering and Metallurgy,8 Krasińskiego Street, 40-019 Katowice, Poland*

Abstract

The AZ31 alloy is one of the most popular magnesium alloys with aluminum. Due to its low mass density and good mechanical properties, this structural material offers considerable potential for the aircraft manufacturing industry. The AZ31 alloy is used in the aircraft industry to produce flat parts with ribs, such as brackets. The paper presents the results of a quantitative study on the microstructure and mechanical properties of AZ31 alloy aircraft brackets produced by a new technology of semi-open die forging. The experimental tests of forming these flat ribbed parts were conducted at a temperature of 410 °C using a prototype forging press equipped with three moving tools. The microstructure and mechanical properties of the AZ31 alloy were examined at delivery and after hot forging.

Selection and Peer-review under responsibility of the Scientific Committee of MIMEC2015

Keywords: *AZ31 magnesium alloy; Microstructure; Mechanical properties; Semi-closed die forging; Aircraft brackets; Three-slide forging press*

1. Introduction

The development of technique, especially in the aircraft designing branch, caused the increase in demand of designing materials with small specific gravity. Magnesium alloys seem to fulfill these requirements (specific gravity 1.7 g/cm^3). In aircraft industry, AZ31 magnesium alloy from group Mg-Al-Zn, characterized by good plasticity, has been widely applied [1-5]. This alloys destined, e.g.: into parts with small load, such as brackets in aircraft flying controls.

* Corresponding author.
E-mail address: a.dziubinska@pollub.pl

Selection and Peer-review under responsibility of the Scientific Committee of MIMEC2015
doi:10.1016/j.promfg.2015.07.059

Manufacturing of brackets from magnesium alloys allows for considerable decrease of the plane weight, and, in consequence, for lowering of fuel consumption at simultaneous increase of the flight parameters. Depending on destination, brackets can differ within the number and shape of ribs (Fig. 1).

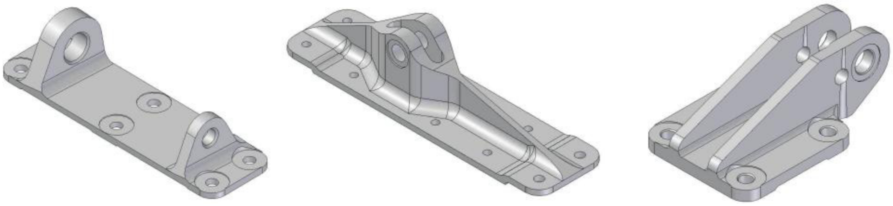


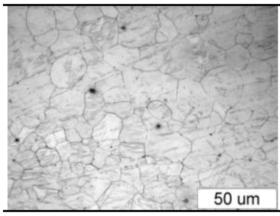
Fig.1. Exemplatory brackets applied in aircraft industry.

At present, for manufacturing of such type of parts, casting and machining are applied. Lowered resistance properties of casts and large material loss during machining (about 70% constitutes waste) lead to development of other manufacturing methods of these parts based on metal forming processes, for example: forging. This paper presents a new technology of aircraft brackets manufacturing by means of semi-open die forging in a three-slide forging press (TSFP). Qualitative research (structural and mechanical) were conducted for the formed forgings.

2. Description of research

Research works were conducted for AZ31 magnesium alloy, which chemical composition and structure is shown in Table 1. Initial material constituted forgings of dimensions 74x50x9,5 mm and 114x50x9,5 mm cut from a plate after metal forming (rolling).

Table 1. Chemical composition (%wt) and microstructure of initial material for research on AZ31 alloy.



Al	Zn	Mn	Cu	Mg
2,83	0,80	0,37	0,002	bal.

Forging tests of brackets with one and two ribs according to the new technology were realized in the three-slide forging press in accordance with the schemas given in Fig. 2 and 3 [6]. The assumed semi-open die forming process was based on upsetting of initial material in the form of a plate heated to the temperature t=410°C by means of two side tools, which were heated to the temperature t= 200°C. In the result of reciprocal, horizontal movement of these tools with constant velocity v= 6 mm/s, a rib was formed in the plate central part. Forgings with two ribs were obtained applying the upper punch (Fig. 3).

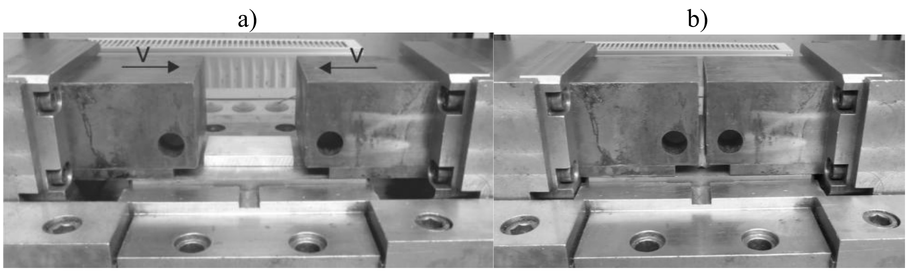


Fig. 2. Schema of the semi-open die forming of forgings with one rib from AZ31 alloy in the three-slide forging press: a) beginning of the process, b) end of the process.

a) b)

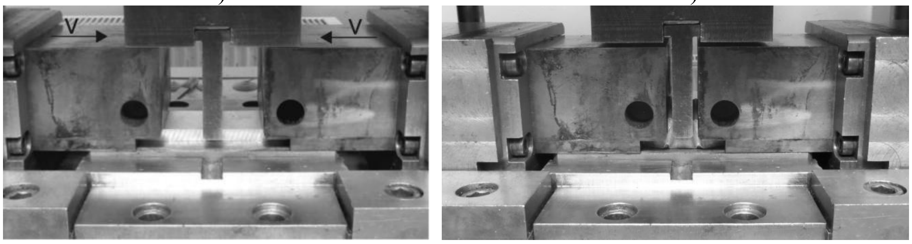


Fig. 3. Schema of the semi-open die forming process of forgings with two ribs from AZ31 alloy in the three-slide forging press: a) beginning of the process, b) end of the process.

a) b)

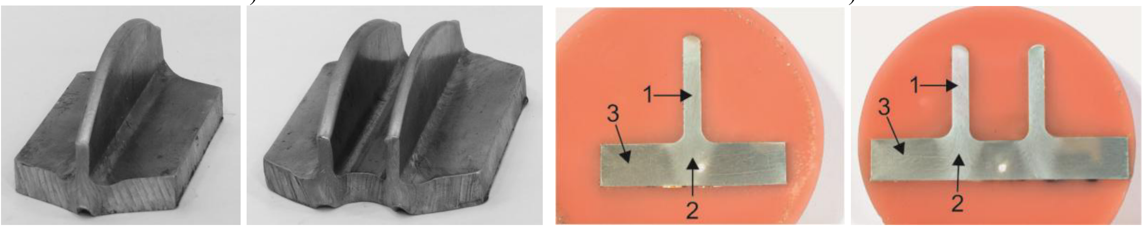


Fig. 4. Brackets forgings from AZ31 alloy obtained in the experimental tests (a) and made from them metallographic specimen for microstructural research (b).

Fig. 4a presents shape of products obtained during research works. Microstructure of AZ31 alloy in initial state and after forging was analyzed using optical microscopy (OM) and electron microscopy (SEM). Research works of the formed forgings structure were conducted on their cross sections in three areas marked in Fig. 4b. Evaluation of the grain mean size was made according to norm ASTM E112-10. Changes of microstructure caused by forging processes considerably influenced properties of the deformed AZ31 alloy. Taking into consideration the fact that the alloy is destined to be used as aircraft construction elements, it was assumed that research will concern determining of the initial material and formed forgings mechanical properties in a static test of tension and hardness measurement. Hardness was determined by Brinell method on forgings cross sections, applying intender in the form of a ball with radius 2.5 mm at load 31.25 kG. Static tests of tension were conducted in the room temperature on a resistance device of pressure 1000 kN. For tests needs, fivefold forgings were used, which were cut along forgings base (area 2 and 3) and from the ribs (area 1).

3. Research results and analysis

Forgings in initial state from AZ31 alloy have homogenous microstructure consisting of equiaxial grains of mean diameter about 11.2÷15.9 µm, which is characteristic for annealed state (table 1). Changes taking place in initial material microstructure caused by semi-open die forming process shown on the example of forging with one rib are presented in Fig. 5. For brackets forgings with two ribs, in the analyzed areas, similar structure views were obtained. In cross sections of the formed forgings, strong localization of strain was observed in the areas of material flow in the rib area and in the base under rib (areas 1 and 2 which is shown in macro photos in Fig. 4b). Material in these areas is upset and squeezed up into the open space limited by side tools surfaces. Microscope observation showed that in the areas 1and 2 very small recrystallized dynamically grains of mean size about 2.8÷4.7 µm, which is connected with localization of strains large values in these areas (Fig. 5a and 5b). In these areas, recrystallization process is the most advanced. Moreover, in the rib microstructure in the area 1, additional primary grains of mean size 11.2÷15.9 µm elongated in the strain direction were localize, which shows that the recrystallization process in this area is not fully finished (Fig. 5a).

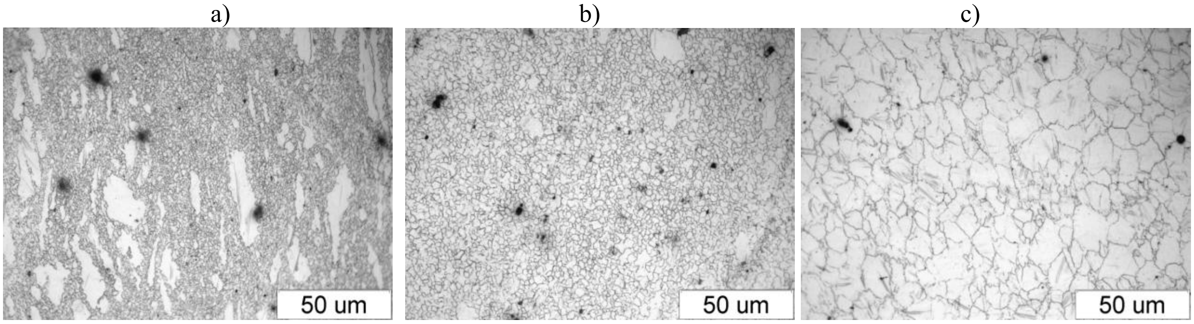


Fig. 5. Microstructure of brackets forging with one rib from AZ31 alloy read in the area: a) 1, b) 2, c) 3; OM.

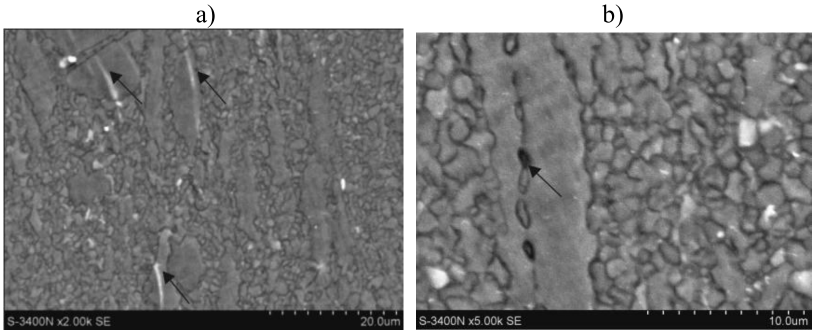


Fig. 6. Microstructure observed in the bracket forging rib from AZ31 alloy read in the area 1; SEM.

Observations conducted on scanning electron microscope in the area 1 revealed twin strains (marked in Fig. 6a) and presence in grains of elongated twin limits (marked in Fig. 6b), which are characterized at magnesium alloys deformation [7]. In the microstructure of forgings base in the area 3 a region was localized, which underwent a small deformation. In this area grains of mean size 7.9÷11.2 µm are slightly deformed, which is confirmed by their small elongation in comparison with initial state (Fig. 5c). Visible darker places (spots) on the placed microstructures (Fig. 5) can mean appearance of micro hollows or impurity in initial material.

Research results on initial material mechanical properties and formed brackets forgings are presented in table 2. In the static test of tension such parameters as: tensile strength R_m, yield strength R_e, elongation A_5 were determined. Hardness in particular forgings areas marked during structure research (Fig. 4b) was determined.

Table 2. Mechanical properties of initial material and formed brackets forgings from AZ31 alloy.

Material used in research	Tensile strength R_m [MPa]	Yield strength R_e [MPa]	Elongation A_5 [%]	Hardness [HB]
Initial material	290	171	11	64
Area1 forging with one rib	365	298	16	76
Area 2 forging with one rib	335	270	13	72
Area 3 forging with one rib	310	220	11	69
Area 1 forging with two ribs	350	303	15,5	78
Area 2 forging with two ribs	330	250	13,5	76
Area 3 forging with two ribs	303	216	12	66

The obtained results show diversified mechanical properties of formed brackets forgings in the whole volume of material. In the rib area tensile strength and hardness are considerably larger than in comparison with the rest of the semi-finished product and initial material. This results from the specificity of the assumed schema of the process, which considers intensive deformation in the initial material central part, which results in forming of rib in the space between side tools. The best plastic properties are to be found in the forgings area which underwent large strains in the areas 1 and 2, for which elongation A_5 assumes values within the scope 13÷16 %. Large plasticity in these areas is caused by fine-grained, in large part recrystallized structure. The area which underwent small strains-area 3 shows elongation A_5 equal 11÷12 % at the initial material level.
It should be mentioned that a phenomena typical in forging processes is homogeneous distribution of strain parameters in the forging. Obtaining good mechanical properties of products is strictly depended on the forging parameters choice (temperature, strain rate, strain values), which, for the analyzed forging process of bracket from AZ31 alloy, was made basing on results of plastometric research on analyzed alloy, conducted FEM simulations and initial experiments.

4. Conclusions

On the basis of qualitative research results analysis of the brackets forgings by means of semi-open die forming in the three-slide forging press, the following conclusions were made:

- Forgings formed by means of the proposed method are characterized by large heterogeneity of structure. This is connected mainly with complex schema of material flow during such a process.
- The largest strains values are localized in the areas of formed ribs, in these areas also the largest fragmentation of structure takes place.
- Strength properties of the formed forgings show large heterogeneity in particular areas of the analyzed semi finished products.
- In order to homogenize structure and strength properties of forgings from magnesium alloys, formed by means of the proposed method, it is advised to conduct, after forging, additional heat treatment, which type and parameters will be determined at the further stage of research works.

Acknowledgements

Financial support of Structural Funds in the Operational Programme - Innovative Economy (IE OP) financed from the European Regional Development Fund - Project "Modern material technologies in aerospace industry", POIG.01.01.02-00-015/08-00 is gratefully acknowledged.

References

[1] M. Advesian, H. Baker, ASM Speciality Handbook, Magnesium and Magnesium Alloys, ASM International, The Materials Information Society, 1999.
[2] K. U. Kainer, Magnesium – Alloys and Technology, Wiley-VCH Verlag GmbH & Co. KGaA, 2003.
[3] J. Tomczak, Z. Pater, T. Bulzak, Thermo-mechanical analysis of a lever preform forming from magnesium alloy AZ31, Archives of Metallurgy and Materials 57 (2012) 1211-1218.
[4] A. Kennedy, A. Sollars, Magnesium and aircraft engineering, Aircraft Engineering and Aerospace Technology 82 (2010) 267-273.
[5] P. Skubisz, J. Sińczak, Precision forging of thin-walled parts of AZ31 magnesium alloy, Archives of Metallurgy and Materials 52 (2007) 329-336.
[6] A. Gontarz, A. Dziubińska, Forming of flat parts with ribs from magnesium alloy, Journal Aircraft Engineering and Aerospace Technology 86 (2014) 356-360.
[7] D. Kuc, Modelling of structure and plasticity changes in hot deformed magnesium Mg-Al-Zn alloy, Ores and Non-ferrous Metals 4 (2012) 257-262.