MONITORING OF ALUMINIUM ALLOY’S STRUCTURE BEFORE AND AFTER PLASTIC DEFORMATION

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Abstract

The paper deals with the monitoring structure changes of aluminium alloy EN AW 6056 after plastic deformation. For experiments were used samples with diameter 20mm and height 29mm. One cylindrical semi-product designed for experiment was prepared by rolling and another one was casted. To monitor structure changes was used upsetting test on hydraulic press. Structure of alloy EN AW 6056 was monitored before the upsetting test and after deformation. The change on structure was evaluated on the basis of metallographic scratch patterns.

1. INTRODUCTION

Nowadays is given great attention to physical processes which can be used during processing of different materials. Among such processes also belongs metal plastic deformation. This material property can be used by material forming. Among these perspective material is taken more and more place aluminium and its alloys. Aluminium alloys have found their place mainly due to low weight and good mechanical properties which can be improved by another treatment (e.g. precipitation hardening). With the aluminium alloys formability nowadays deals workplace of Department of Engineering Technology on Faculty of Mechanical Engineering TU of Liberec in the frame of solving grant project GAČR 101/09/1996. “Influence of material structure on aluminium alloys formability”. All aluminium properties, like for the other metals, are derivate from its inner structure. This is valid also for aluminium alloys forming properties where is important not only atoms structure, atomic bonds and crystalline structure or more precisely material structure, but also faults of crystalline lattices and character of semi-product used for forming. Material ability for forming is evaluated by property which is called like formability (plasticity). This general property of formed material is necessary refer to certain forming technology thereby are defined states of stress. Under given state of stress is formability influenced by temperature and strain rate. Aluminium alloys are sensitive to strain rate [1], the highest degree of deformation is so achieved e.g. under super-plastic forming (up to 0,0001 s⁻¹). With increasing strain rate, there is also increasing formresistance. Important influence also has material structure and very important is forming material temperature which enhanced material formability. Aluminium alloys are very suitable material for forming (namely if their structure is created by solid solution) which is, like for the other metals, closely connected with physical, thermal and metallurgical properties of this material. There are great problem during forming of semi-products with casted structure because there is no grain flow. At hot forming of hardened-able aluminium alloys must not be exceed melting temperature. Also at hot forming of non hardened-able aluminium alloys is necessary during semi-product heating be very carefully because too high temperatures can lead to melt some low-melting elements (that is why during aluminium alloys cold forming to heat over recrystallization temperature – c. 150 [°C]). Mechanism of metals plastic deformation is in the case of polycrystalline materials different then for monocrystals to which is given more attention during study of plastic deformation. Different orientation and grain boundaries of polycrystalline material have important influence onto positions and slip mechanism. Some grains are oriented favorably and is possible to
deform them by low force. On the contrary some grains show unfavorable orientation and there is necessary to use much higher force to deform them. Each grain is deformed also with regard to deformation course of its neighbor. For aluminium and its alloys is, in light of great number of slip planes systems, ability to plastic deformation high.

2. EXPERIMENTAL PART

2.1. Upsetting test
Evaluation of forming influence on structure before and after forming was done by means of upsetting sample with simple shape (20 x 29 mm) under hot and cold forming. For this purpose was already chosen alloys EN AX 6056 in the formed tubes form Ø 50 x 500 mm. Samples for experiments were divided into two groups. In the first case was this tube melted and subsequently continuously casted into mould and thus was make several semi-products for one group of testing samples. In the second case were testing samples for static tensile test machined right from material semi-product AA 6056.

Upsetting tests for both groups of samples were carried out on hydraulic forming press CBA 300/63. Force during forming was measured by means of measuring device which is based on strain-gauge sensor and output of force with respect to movement of deformed sample is recorded by PC. Were make scratch patterns for 6 groups of samples divided according table 1.

Table 1. Overview of experiments from aluminium alloy EN AW 6056

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<td>1.</td>
<td>Not done. Initial formed material.</td>
<td>20 x 29 mm</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>A</td>
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<tr>
<td>2.</td>
<td>Not done. Initial casted material.</td>
<td>20 x 29 mm</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>B</td>
</tr>
<tr>
<td>3.</td>
<td>Upsetting of formed semiproduct.</td>
<td>20 x 29 mm</td>
<td>200</td>
<td>312765</td>
<td>645</td>
<td>C</td>
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<tr>
<td>4.</td>
<td>Upsetting of casted semiproduct.</td>
<td>20 x 29 mm</td>
<td>200</td>
<td>217391</td>
<td>425</td>
<td>D</td>
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<td>5.</td>
<td>Upsetting of formed semiproduct.</td>
<td>20 x 29 mm</td>
<td>20</td>
<td>363069</td>
<td>732</td>
<td>E</td>
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<tr>
<td>6.</td>
<td>Upsetting of casted semiproduct.</td>
<td>20 x 29 mm</td>
<td>20</td>
<td>217821</td>
<td>427</td>
<td>F</td>
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2.2. Aluminium alloy metallographic structure evaluation before and after forming
Metallographic structure evaluation from alloy EN AW 6056 was carried out by means of light and electron microscope. At light microscope Neophot 21 (Carl Zeiss Jena) was observed sample’s structure before and after forming. Samples for metallographic observation at light microscope Neophot 21 were prepared by common metallographic method (grinding and polished). To highlight structure was used HF 0,5 %. Results from metallographic observation are shown in fig. 1 up to 5.
Fig. 1. Semi-product initial material structure (EN AW 6056); A) – produced by forming; B) – produced by casting

Fig. 2. Formed material structure (EN AW 6056) under temperature 200°C; C) - formed semi-product; D) – casted semi-product

Fig. 3. Formed material structure (EN AW 6056) under temperature 20°C; E) - formed semi-product; F) – casted semi-product
From these figures is clear material structure importance for subsequent plastic deformation. Semi-product, which underwent plastic deformation, has finer structure and grain flow. On the contrary semi-product which was pre-casted has coarse crystallic structure. From figures is evident that cold forming plastic deformation (i.e. the most often under material temperature c. 20°C) influences also structure of metal. Metal grains are deformed along forming force. If forming of metal is under recrystallization temperature there is deformation hardening. If hot forming is over recrystallization temperature (200°C for alloy EN AW 6056), there is recrystallization which partly or fully counterworks hardening. During hot forming taken place grain refinement which contributes to improve mechanical material properties. Material microstructure for each combination of tested samples is clear from fig. 6 and fig. 7.

From fig. 7 is clear that formed semi-product doesn’t embody essentially different structure than after cold and hot forming. However plastic deformation of heated sample at temperature 200°C leads to finer structure.
3. CONCLUSION

From results of measurement is evident that casted semi-products from aluminium alloy are not suitable for following processing by forming technologies. Structure created during aluminium alloy solidification in metal mould or sand mould is heterogeneous and non-suitable for high plastic deformation. The aim of aluminium alloys processing research is to find combination of chemical composition, thermal treatment and forming process which would lead to produce parts with requested mechanical properties. Such technology would combine advantages of forming and casting technologies which would lead to material reduction and reengineering of production processes.

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