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PLASTICITY AND WORKABILITY OF ALUMINIUM ALLOY AT WARM TEMPERATURES

KAPUSTOVA, M[aria] & MARTINKOVIC, M[aros]

Abstract: *Warm forming of metal materials represents a lucrative method of precise forming pieces production due to energy and time savings, obtaining of higher surface quality and dimension precision of forming pieces in comparison with hot forming. This contribution provides information about mechanical properties, plasticity and workability of aluminium alloy at warm forming temperatures. Selected temperatures were verified by numeric simulation of upsetting forming process using finite element method.*
Key words: *plasticity, workability, warm forming, numeric simulation, aluminium alloy*

1. INTRODUCTION

The warm forming process passes at temperatures which are over recovery temperatures but below down hot forging temperatures. This forming process can obtain higher degree deformation in comparison with cold forming. Warm forming passes with partial strain hardening of metal above recovery temperature and below temperature of recrystallization (Forejt & Piska, 2006). Energy and time savings at warming up (Forcellese & Gabrielli, 2000) and higher surface quality and dimension precision of forming pieces after forming in comparison with hot forming are important arguments for investigation of properties of aluminium alloy at warm forming temperatures (Novotny, 2000). This information is necessary for further development of warm forming (Pernis, 2007).

2. EXPERIMENT

The subject of plasticity and workability research at warm forming temperatures is aluminium alloy AlSiMg type, its chemical composition is included in Table 1. This alloy, which belongs to the group "6000" of aluminium alloys, is determined primarily for hot forming. The alloy was in natural state, without any heat treatment (for instant solution treatment).

Suitability of examined Al alloy for warm bulk forming was verified by tensile test at higher temperatures (according to standard STN EN 10002-5). Cylindrical bar specimens were used for tensile test. The bar length was 80 mm, diameter 8 mm. The specimens were tested at temperatures 20, 150, 200 and 250^{o}C. At each temperature three specimens were tested.

Elemets	Si	Mg	Fe	Cu	Mn	Cr	Al
	wt.%						
min	0,45	0,4					
max	0,8	0,8	0,3	0,1	0,1	0,1	bal

Tab. 1. Chemical composition aluminium alloy

3. EXPERIMENTAL RESULTS

Strength limit R_m, characteristics of plasticity for workability at higher temperature (reduction of area Z, index of plasticity to rupture according to Kolmogorov λ_R, ductility A, Paur`s index of plasticity D_{sm}) and exponent of strain hardness n were calculated from measured results on three tested specimens at each tested temperatures.

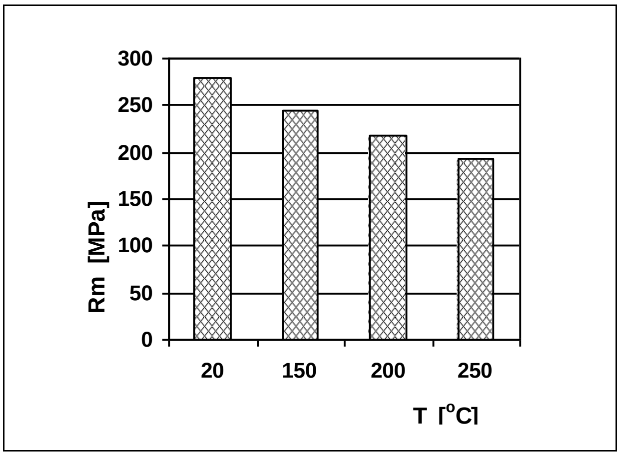

Fig. 1. Temperature course of tensile strength R_m

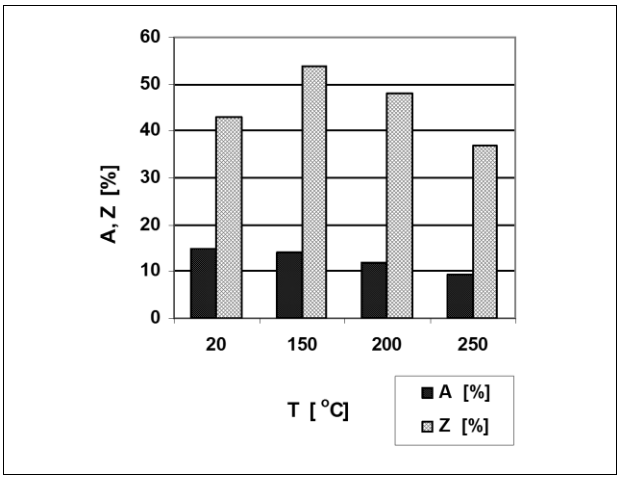

Fig. 2. Temperature courses of percentage reduction of area Z and ductility A

T [°C]	20	150	200	250
n	0,079	0,061	0,037	0,011

Tab. 2. Values of strain hardening index n

Temperature course of tensile strength R_m is illustrated in Fig. 1 and temperature courses of percentage reduction of area Z and ductility A are in Fig.2. Temperature courses of index of plasticity according to Kolmogorov λ_R and Paur`s index of forming capacity D_{sm} are demonstrated by Fig.3. Determined values of strain hardening index at examined temperatures includes Table 2.

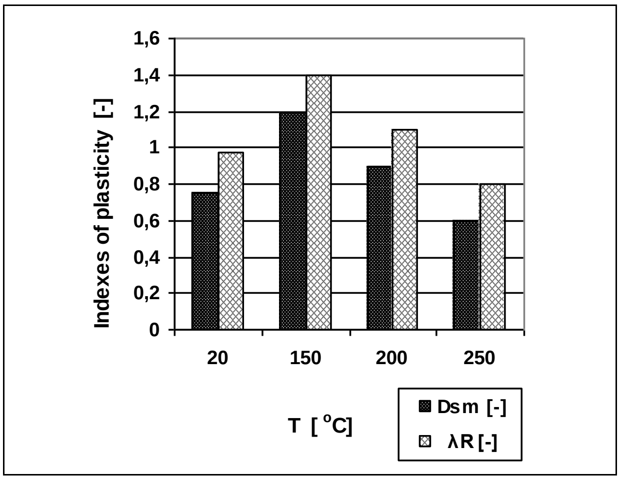

Fig. 3. Temperature courses of index of plasticity λ_R and forming capacity D_{sm}

4. NUMERIC SIMULATION

Numeric simulation of upsetting forming process was exercised to find out material plastic flow at warm forming temperatures. A simulation software MSC SuperForge was used with application of finite element method. The input parameters for numeric simulation were: forming on hydraulic press, tool temperature 100°C, friction coefficient 0,4, cylindrical bar (semi-product) from aluminium alloy 6060 with diameter 25 mm and height 50 mm, warm temperatures 150, 200 and 250°C, semi-product height after deformation 30 mm. The simulation process enabled to observe these results: effective plastic strain, temperature in longitudinal section in the middle of cylindrical bar and contact pressure. In Fig. 4 courses of strain, temperature and pressures during upsetting process simulation are represented. During deformation at 250°C in the middle of the workpiece the temperature of the material increased to 270°C, which exceeds the recrystallization temperature and recrystallization may pass. This result was also experimentally verified. Warm forming of the real part from aluminium alloy at 250°C was realized at the same basic parameters as are described hereinbefore. Its microstructure was observed on a light microscope on metallographic cut of longitudinal section in the middle of cylindrical bar. Degree of planar grain boundaries orientation caused by deformation was measured using oriented test lines method (Martinkovic, 2011). In all places on metallographic cut degree of orientation was in very good coincidence with numeric simulated effective strains with exception of area in the middle of the specimen.

5. DISCUSSION

From the result of mechanical testing at warm temperatures we can see that the best plastic properties of Al alloy are at 150°C, on the other hand tensile strength has the maximum value. From the values of strain hardening index is evident, that area of equilibrium plastic deformation at temperature 200°C rapidly decreased. Numeric simulation of upsetting process at warm temperatures 150, 200 and 250°C showed very good material flow. At 250°C during deformation the temperature of the material in the middle of the workpiece increased to 270°C (see Fig. 4b), which exceeds the recrystallization temperature which was verified by microstructural analysis. Microstructural analysis also showed coincidence of numeric simulation with real state. The result showed possibilities of forming of aluminium alloy of group “6000” in natural state at warm temperature. As optimal warm forming temperature for the alloy AlSiMg 200°C is recommended. In comparison with 150°C is at this temperature lower plasticity, on the other hand lower strength and lower contact pressure (see Fig. 4c, d). It leads to higher lifetime of tool and lower energy consumption .

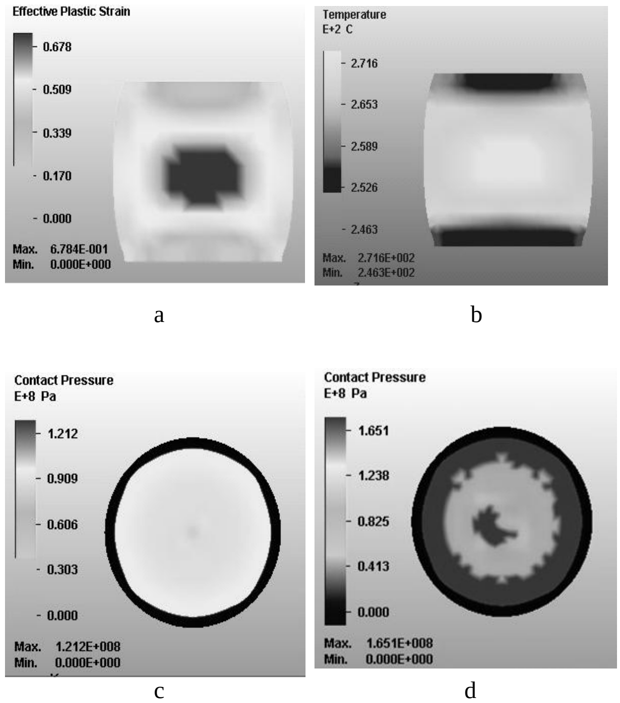

Fig. 4. Results of upsetting process simulation at 250°C (a,b), 200°C (c) and 150°C (d)

6. CONCLUSION

On the basis of mentioned results it is possible to apply the technology of warm forming. The results of numeric simulation confirm that the choice of the temperature 200 °C at warm forming was correct. Forming of aluminium alloy in natural state at warm temperature leads to time and energy consumption saving in comparison with hot forming. Also warm forming leads to better surface quality and higher dimension precision of forming pieces.

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