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STRUCTURE AND MECHANICAL PROPERTIES OF EXTRUDED AlCuMg SECTIONS IN T5 TEMPER

STRUKTURA I WŁASNOŚCI MECHANICZNE KSZTAŁTOWNIKÓW AlCuMg WYCISKANYCH W STANIE T5

The metallurgical structure and mechanical properties of extruded product depend on material chemical composition, casting and homogenization conditions, extrusion technological parameters and a final heat treatment. In this work, indirect extrusion process of AlCuMg (2014A) flat sections in T5 temper was analyzed. Study investigates material structure and mechanical properties on extrudates cross-section, depending of extrusion temperature, the mode of solution heat treatment and the seasoning time before artificial ageing. Based on extrusion trials, the optimal process temperature was determined. The good fine-grained structure and higher yield strength $R_{0,2}$ and tensile strength R_m values were stated for sections extruded with solution heat treatment on the press (T5 temper) in comparison to those obtained in traditional T6 temper. However, no significant differences in the extrudates micro-hardness were observed. It was also found the seasoning time of extrudates (before artificial ageing) can be decreased, even by 50%, without negative impact on mechanical properties.
Keywords: Extrusion; AlCuMg alloys, solution heat treatment on the press, structure and mechanical properties

Struktura i własności mechaniczne wyrobów wyciskanych zależą od składu chemicznego stopu, warunków odlewania i homogenizacji wsadu do wyciskania (wlewków) oraz parametrów technologicznych procesu wyciskania i końcowej obróbki cieplnej. W niniejszej pracy analizowano proces wyciskania przeciwbieżnego płaskowników AlCuMg (2014A) w stanie T5. Przeprowadzono badania struktury i własności mechanicznych w przekroju poprzecznym wyciskanego wyrobu, w zależności od temperatury procesu wyciskania, sposobu przesycania i czasu „leżakowania” kształtowników przed starzeniem sztucznym. Na podstawie przeprowadzonych prób wyciskania określono optymalną temperaturę procesu. W przypadku kształtowników wyciskanych z jednoczesnym przesycaniem na wybiegu prasy (w stanie T5) stwierdzono drobnoziarnistą strukturę oraz wyższe wartości granicy plastyczności $R_{0,2}$ i wytrzymałości na rozciąganie R_m, w porównaniu do kształtowników uzyskanych w tradycyjnej technologii: wyciskania i późniejszej obróbki cieplnej (stan T6). Jakkolwiek, nie zaobserwowano istotnych różnic w poziomie mikrotwardości. Ponadto, badania wykazały, że możliwe jest skrócenie czasu „leżakowania” wyciskanych kształtowników przed starzeniem sztucznym nawet o 50%, bez negatywnego wpływu na własności mechaniczne wyrobu.

1. Introduction

Solution heat treatment of AlCuMg extruded sections in T6 temper needs an additional heating up of a material to solution temperature what increases the time required and costs of product manufacturing [1-3]. In addition, this mode of solution heat treatment worsen extrudates quality and an unfavorable grain growth and shape distortions are often observed. Therefore, extrusion with solution heat treatment on the press is more and more often applied technology in aluminium extrusion industry. However, for solution heat treatment on the press, a special cooling systems on the press run out called “water wave” must be installed [4-7]. Structure and mechanical properties of AlCuMg extrudates in T5 temper are now under investigations in many research centers.

2. Experimental work

The chemical composition of the material investigated is shown in table 1. Aluminium alloy 2014A billets of 246 mm in diameter and 700 mm in length were homogenized at 495 °C for 12 h and then cooled down in air to the room temperature. The billets were preheated for extrusion at three different temperatures: 380-400 °C, 400-420 °C and 420-440 °C. In all cases, the back of the billets had a higher temperature than billet head by 20 °C. The container was heated up to 380 °C, 400 °C and 420 °C respectively. The extrusions were carried out in

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a horizontal 2.800 T indirect press. The rectangular bars of dimensions 31.75 × 25.4 mm and 50.8 × 25.4 mm were extruded through the 2-hole flat dies. All extrusion process parameters are listed in table 2. Solution heat treatment on the press (water wave) in T5 temper and traditional solutionizing (separate heating operation in the furnace after extrusion process) in T6 temper were performed. In the case of traditional solution heat treatment, the extrudates were heated in a furnace to the temperature of 503 °C during 30 minutes and then cooled in the water. Different seasoning times: 48, 72, 96, 120 and 144 h before ageing operation (175 °C/11 h) were applied for all extrudates. The parameters of the solution heat treatment are shown in table 3. Finally, investigations of extrudates macrostructure and mechanical properties (yield strength, tensile strength, hardness and elongation) at the initial and the final stages of extrusion process were carried out. The yield strength, tensile strength and elongation testing were carried out on universal Instron 4484 strength machine. Brinell hardness was obtained on an Instron-Wolpert (Testor 930) tester.

TABLE 1

Chemical composition of alloy 2014A in wt. %

Element	Cu	Mg	Mn	Si	Fe	Zn	Cr	Ni	Ti
Weight %	4.54	0.7	0.77	0.82	0.29	0.08	0.03	0.03	0.03

TABLE 2

Parameters of the extrusion process

Billet material	Aluminium alloy 2014A		
Billet diameter and length	246 × 700 mm		
Billet temperature	380-400 °C	400-420 °C	420-440 °C
Container temperature	380 °C	400 °C	420 °C
Container diameter	252 mm		
Extrusion ratio	19.3 (50.8 × 25.4)	31.9 (31.75 × 25.4)	
Ram speed	2.3 mm/s	1.4 mm/s	

TABLE 3

Parameters of the solution heat treatment and aging

Solution heat treatment	503 °C/0.5 h in the furnace (after extrusion)	water wave on the press (during extrusion)
Seasoning time	48, 72, 96, 120, 144 h	
Precipitation (aging)	175 C/11 h	

3. Results and discussion

3.1. Material structure of extrudates

Figs 1-12 present the macrostructures of extrudates examined at the beginning and at the end of extrusion process for all billet temperatures, for two modes of solution heat treatment and different seasoning times before aging.

(a) (b) (c)

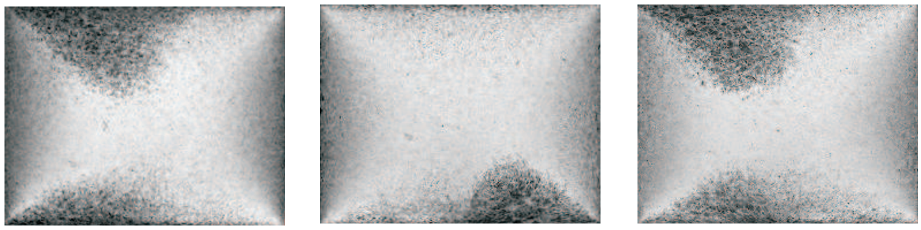

Fig. 1. acrostructures of extruded sections 31,75x25,4 mm at the initial stage of extrusion. (a-c); billet temperature 380-400°C, water-wave solution heat treatment, seasoning time 144 h, aging 175°C/11h

(a) (b) (c)

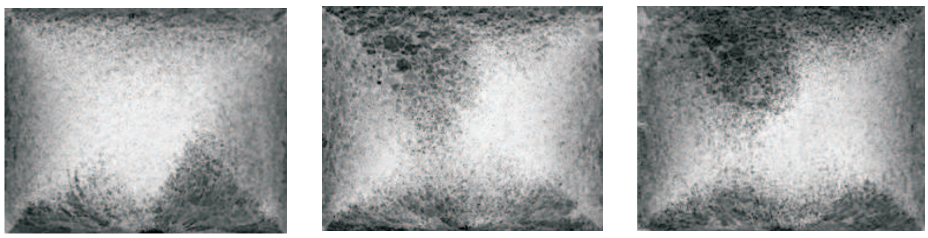

Fig. 2. Macrostructures of extruded sections 31,75x25,4 mm at the final stage of extrusion. (a-c); billet temperature 380-400°C, water-wave solution heat treatment, seasoning time 144 h, aging 175°C/11h

(a) (b) (c)

Fig. 3. Macrostructures of extruded sections 31,75x25,4 mm at the initial stage of extrusion. (a-c); billet temperature 400-420°C, water-wave solution heat treatment, seasoning time 144 h, aging 175°C/11h

(a) (b) (c)

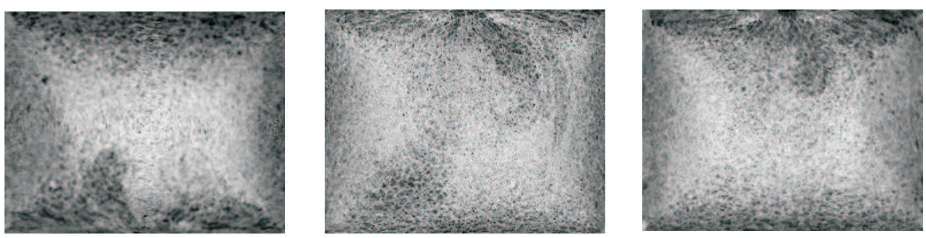

Fig. 4. Macrostructures of extruded sections 31,75x25,4 mm at the final stage of extrusion. (a-c); billet temperature 400-420°C, water-wave solution heat treatment, seasoning time 144 h, aging 175°C/11h

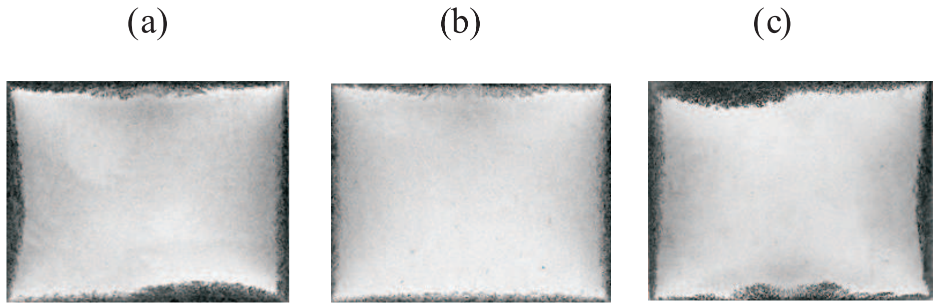

Fig. 5. Macrostructures of extruded sections 31,75x25,4 mm at the initial stage of extrusion. (a-c); billet temperature 420-440°C, water-wave solution heat treatment, seasoning time 144 h, aging 175°C/11h

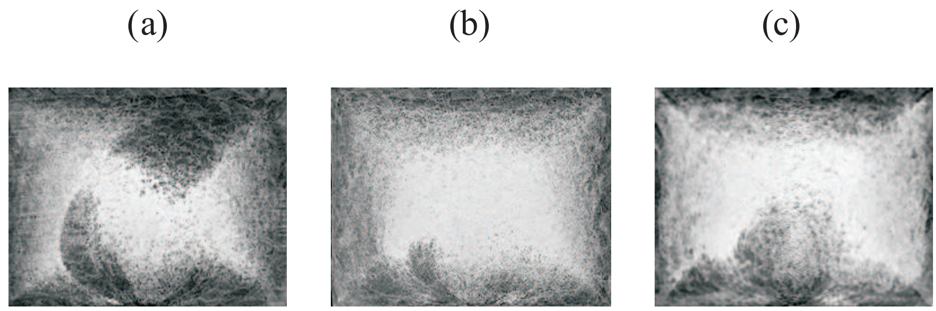

Fig. 6. Macrostructures of extruded sections 31,75x25,4 mm at the final stage of extrusion. (a-c); billet temperature 420-440°C, water-wave solution heat treatment, seasoning time 144 h, aging 175°C/11h

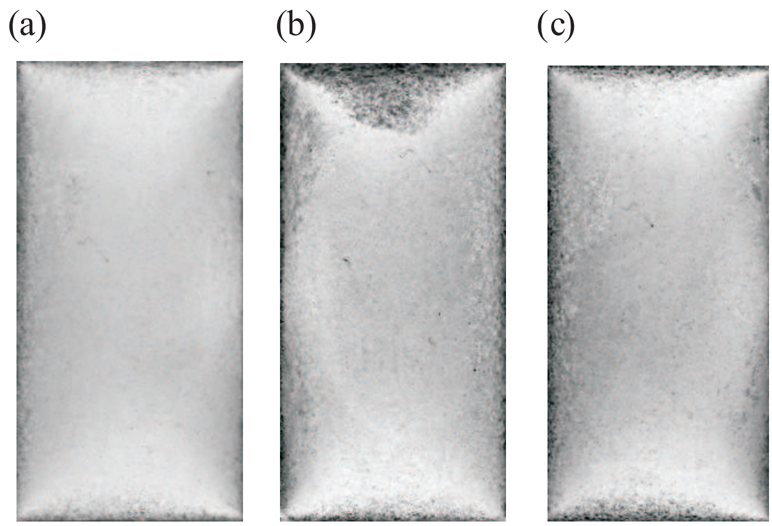

Fig. 7. Macrostructures of extruded sections 50,4x25,4 mm at the initial stage of extrusion. (a-c); billet temperature 380-400°C, water-wave solution heat treatment, seasoning time 120 h (a) and 144 h (b-c), aging 175°C/11h

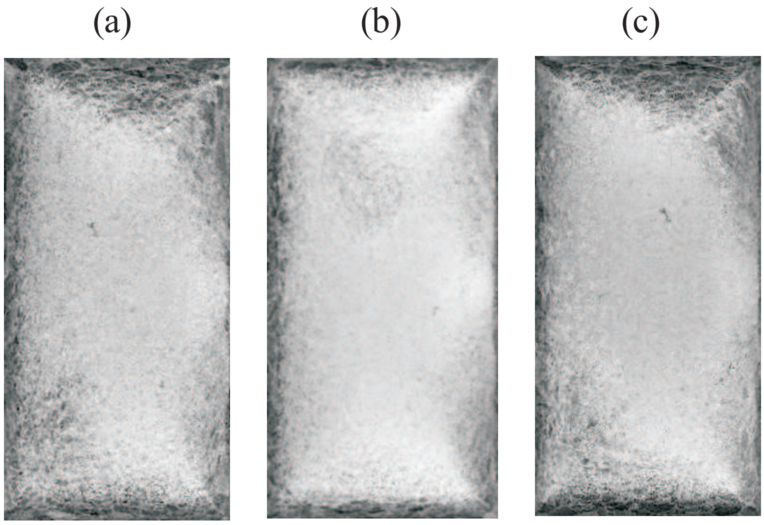

Fig. 8. Macrostructures of extruded sections 50,4x25,4 mm at the final stage of extrusion. (a-c); billet temperature 380-400°C, water-wave solution heat treatment, seasoning time 120 h, aging 175°C/11h

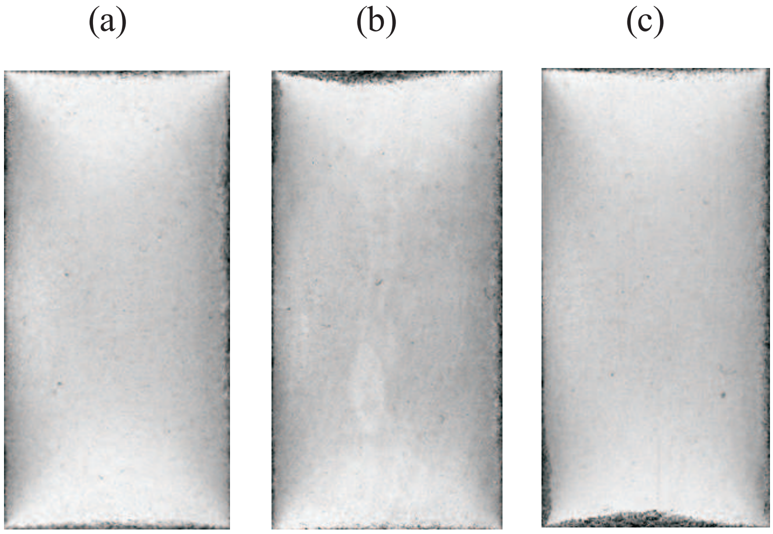

Fig. 9. Macrostructures of extruded sections 50,4x25,4 mm at the initial stage of extrusion. (a-c); billet temperature 400-420°C, water-wave solution heat treatment, seasoning time 120 h (a) and 144 h (b-c), aging 175°C/11h

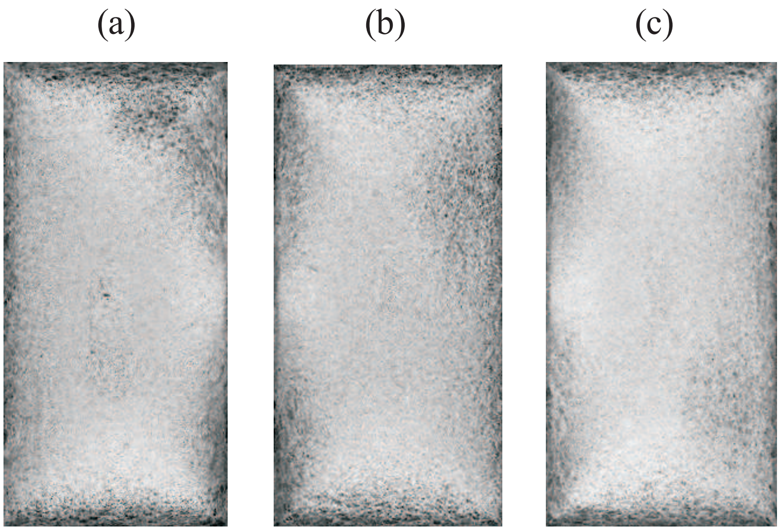

Fig. 10. Macrostructures of extruded sections 50,4x25,4 mm at the final stage of extrusion. (a-c); billet temperature 400-420°C, water-wave solution heat treatment, seasoning time 120 h, aging 175°C/11h

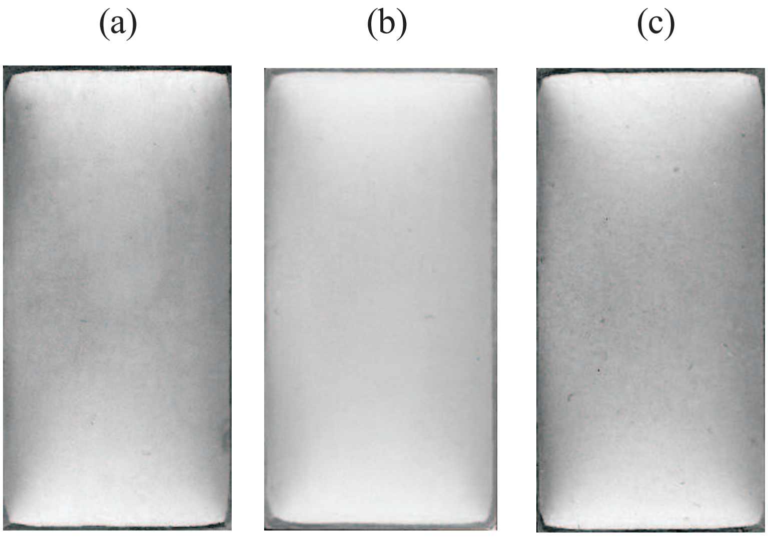

Fig. 11. Macrostructures of extruded sections 50,4x25,4 mm at the initial stage of extrusion. (a-d); billet temperature 420-440°C, water-wave solution heat treatment, seasoning time 48 h, aging 175°C/11h

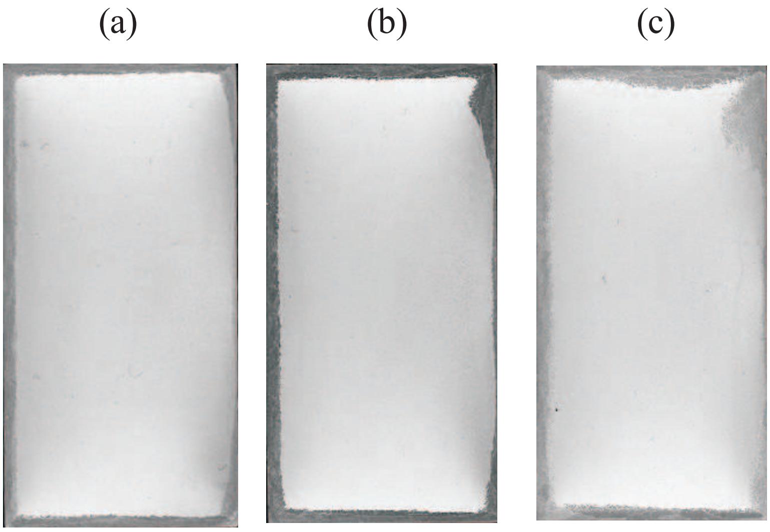

Fig. 12. Macrostructures of extruded sections 50,4x25,4 mm at the final stage of extrusion. (a-d); billet temperature 420-440°C, traditional solution heat treatment in the furnace 503°C/0.5 h, seasoning time 48 h (a-b), 72 h (c) i 96 h (d), aging 175°C/11h

One can notice that fine thin-grained structure was produced for highest billet temperatures 420-440 °C (Figure 5 and Figs 11-12), whereas the no uniform thick-grained structure was observed for lower billet temperatures 380-400 °C and 400-420 °C (Figs 1-2, 4 and 7-8, 10), especially for samples taken from the final stage of the process. This is a result of a high value of an energy stored in the case of extrusion at low billet temperatures, what finally leads to the recrystalization and a grain growth during subsequent heat treatment. However, a narrow peripheral coarse grain (PCG) was observed in extrudates obtained from the highest billet temperature 400-420 °C (Figs 5 and 11). As it can be seen from Figs 11-12, extrusion with water wave solution heat treatment on the press allowed obtaining fine-grained structure, whereas the wide peripheral coarse grain (PCG) was observed while applying traditional solutionizing.

3.2. Mechanical properties of extrudates

Mechanical properties of extrudates for a water-wave solution heat treatment (seasoning time 144 h, aging 175°C/11 h) are shown in Figs 13-15. Graphs in figs 13-14 show the influence of billet temperature on the yield strength, tensile strength and elongation of sections: 31.75 x 25.4 mm (Fig. 13) and 50.8 x 25.4 mm (Fig. 14) respectively. As it can be seen, there is a tendency to increase the strength properties (yield strength $R_{0,2}$ and tensile strength R_m) with increasing billet temperatures. In both extruded sections the highest strength properties were obtained for the highest billet temperatures (420-440°C). Especially low strength properties were stated for extrudates 31.75 x 25.4 mm when applying the lowest billet temperatures (380-400°C). As the same time, only slight decrease in plasticity (elongation A) was observed as the billet temperatures increased (Figs 13-14).

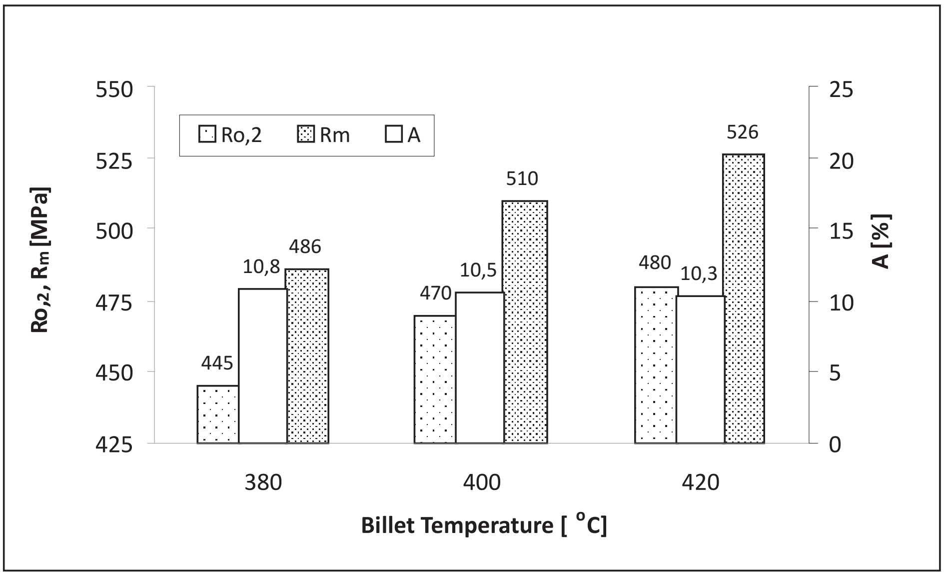

Fig. 13. Influence of billet temperature on the extrudates (31.75 x 25.4 mm) yield strength, tensile strength and elongation (water-wave solution heat treatment, seasoning time 144 h, aging 175°C/11h)

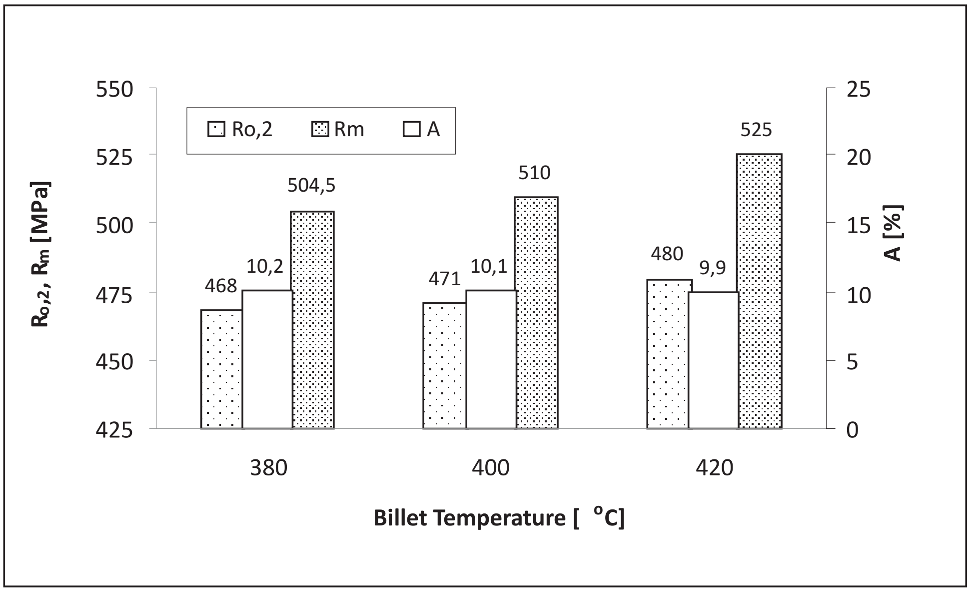

Fig. 14. Influence of billet temperature on the extrudates (50.4 x 25.4 mm) yield strength, tensile strength and elongation (water-wave solution heat treatment, seasoning time 144 h, aging 175°C/11h)

Increasing the cooling rate after billets homogenization should ensure the structure with smaller particles of interdendritic phases, which would be able to dissolve before an alloy outflow from a die. As a consequence, more effective solution heat treatment at the press output and increased strength properties of extrudates should be expected. The values of micro-hardness in dependence of the billet temperature for both extruded sections in case of water-wave solution heat treatment are presented in Fig 15. The results indicate that practically there is no influence of billet temperature on material micro-hardness.

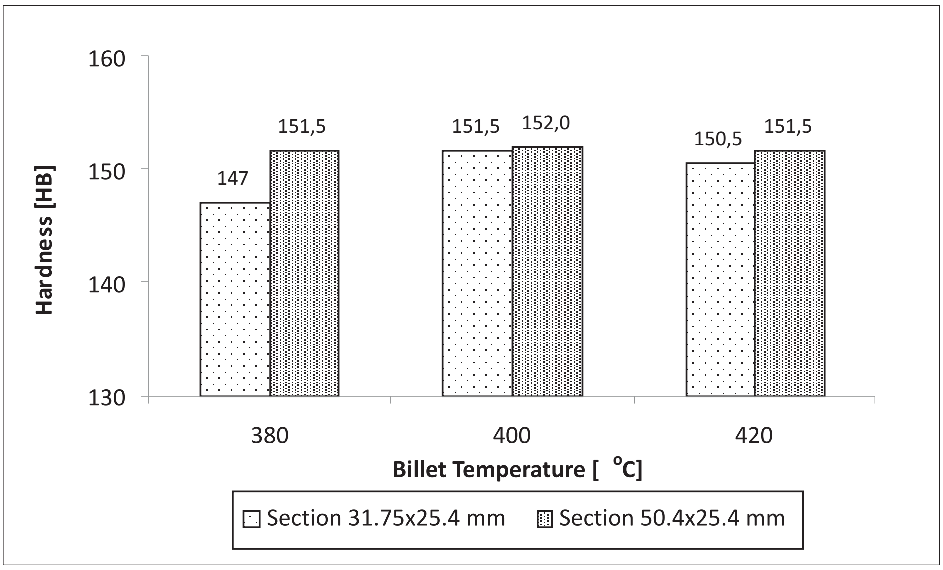

Fig. 15. Influence of billet temperature on the extrudates (31.75 x 25.4 and 50.4 x 25.4 mm) micro-hardness (water-wave solution heat treatment, seasoning time 144 h, aging 175°C/11h)

The influence of seasoning time on the 50.4 x 25.4 mm extrudates mechanical properties for a water-wave solution heat treatment and traditional solution heat treatment (503°C/0.5 h) was presented in figs 16-18 (billet temperature 420-440°C, aging 175°C/11h). The decrease in the seasoning time before ageing from 96 h to 48 h leads to almost the same level of mechanical properties. The mechanical properties in T6 temper are only slightly lower whereas in T5 temper are slightly higher in relation to those obtained for seasoning time of 96 h.

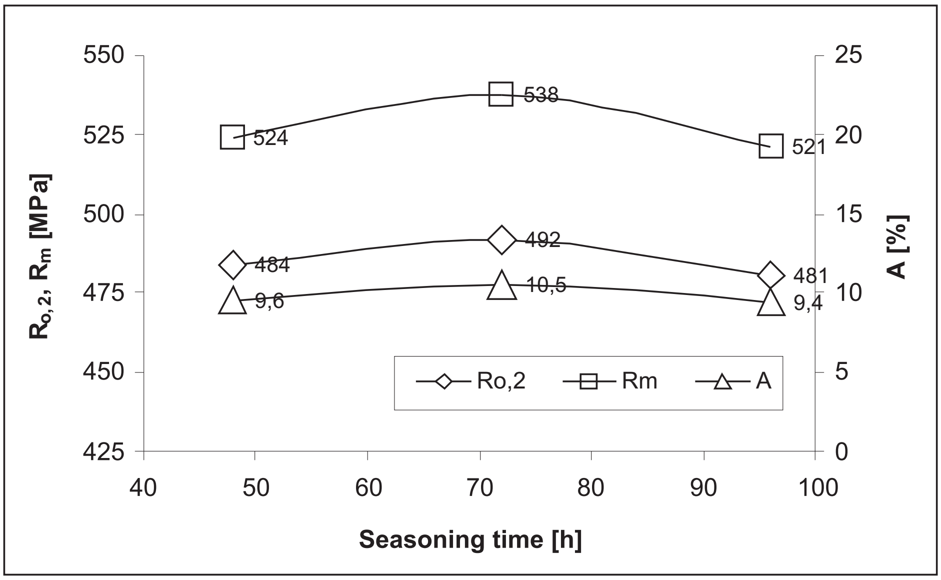

Fig. 16. Influence of seasoning time on the extrudates (50.4 x 25.4 mm) yield strength, tensile strength and elongation for a water-wave solution heat treatment (billet temperature 420-440°C, aging 175°C/11h)

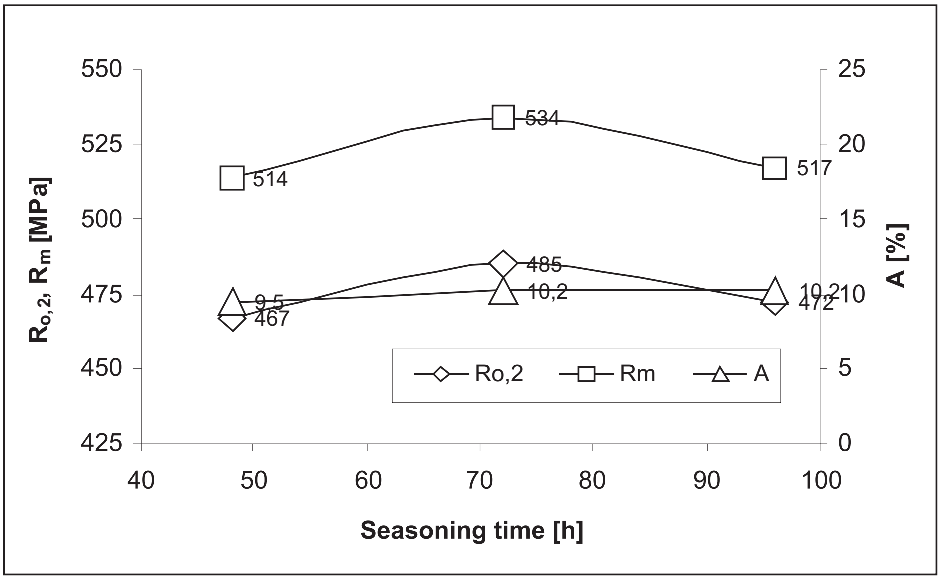

Fig. 17. Influence of seasoning time on the extrudates (50.4 x 25.4 mm) yield strength, tensile strength and elongation for a traditional solution heat treatment 503°C/0.5 h (billet temperature 420-440°C, aging 175°C/11h)

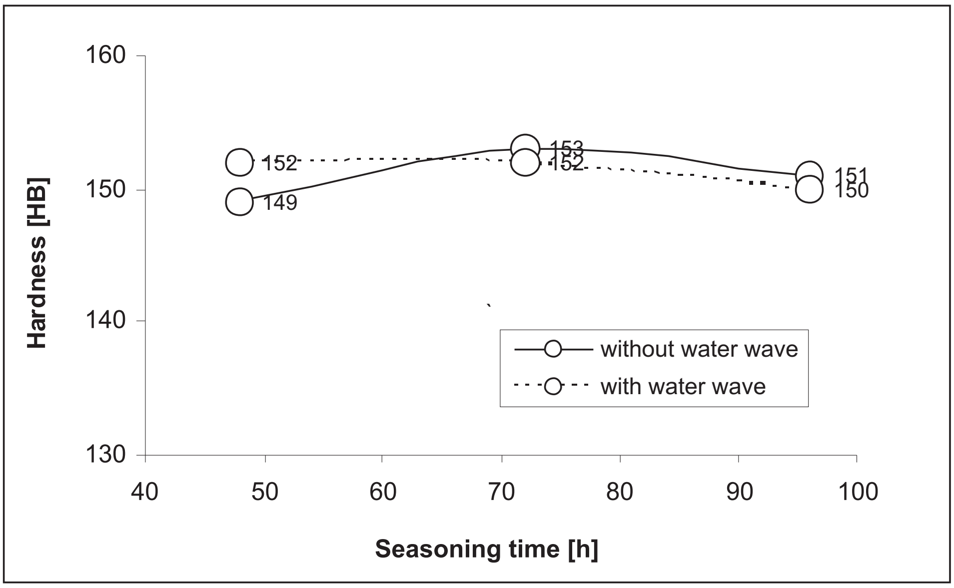

Fig. 18. Influence of seasoning time on the extrudates (50.4 x 25.4 mm) micro-hardness for a traditional 503°C/0.5 h and a water-wave solution heat treatment (billet temperature 420-440°C, aging 175°C/11h)

4. Conclusions

Based on the experimental trials performed on the AlCuMg sections extruded with solution heat treatment on the press, the following conclusions can be drawn:

(1) Extrusion with the water wave solution heat treatment on the press (T5 temper) allowed obtaining the fine-grained structure of extrudates, whereas the peripheral coarse grain (PCG) was observed while applying the traditional solutioning for AlCuMg alloys.

(2) Material extruded with the water wave solution heat treatment reveals a little higher yield strength and tensile strength values in comparison with those obtained after traditional heat treatment. However, no significant differences in extrudates micro-hardness were stated.

(3) It was also found the considerable decrease in extrudates seasoning time (by approximately 50%) is possible before ageing without negative impact on the material mechanical properties.

(4) The best fine-grained material structure and high mechanical properties of extrudates were obtained in indirect extrusion of the rectangular shaped profiles when applied the highest billet heating temperature of 420-440°C, whereas the no uniform thick-grained

structure was observed for the lower billet temperatures of 380-400 °C and 400-420 °C.

(5) It is recommended to increase the temperature of the back of billet by approximately 20 °C to obtain uniform structure and mechanical properties on the extrudates length. In general, the more thick-grained structure was produced at the final stage of extrusion, in relation to the beginning stage of the process.

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