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EWALUATION AND ANALYSIS OF THE LARGE-SIZE FORGED AND ROLLED EN AW – 7057 ALUMMINUM ALLOY RING STRUCTURE

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The article presents the results of tests on the structure and hardness of a large-size ring made of EN AW - 7075 aluminium alloy produced under industrial conditions at the Zarmen FPA forge according to the developed technology - a combined forging and rolling method. Studies of the ring were carried out in order to assess its structure and hardness after the forming processes. The scope of the study included microscopic observations (microstructure and EDS), X-ray phase analysis and hardness distribution measurements.

Keywords: aluminium 7075, forged, rolled rings, microstructure, hardness

INTRODUCTIONS AND PURPOSE OF THE STUDY

Ring products find a wide variety of uses in numerous industries, therefore their production volume is increasing every year [1]. In today's machines and equipment, reducing structural weight has been gaining importance, which necessitates the need to manufacture structural components from light alloys, e.g. aluminium, by modern plastic processing methods.Therefore, it is extremely important to research both the shaping technology and the ring quality assessment upon completion of every technological stage [2-5]. One of the industrial manufacturing method for seamless large-size rings is the combined forging and rolling [6-8].

Production launch of a new type of aluminium alloy EN AW - 7075 ring required development of a technology covering both preparation of the ring charge on the press and rolling the rings of their final size. Due to the specific nature of aluminium alloy components forming, it is necessary to precisely select the rolling process parameters, including the mandrel speed and the rotational speed of the main roll, which will enable the ring to be formed correctly within the specified temperature range of the plastic processing. These parameters will ensure the rings are rolled with a homogeneous structure and a uniform hardness distribution.

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The aim of the study was to evaluate the structure and hardness of a large-size EN AW - 7075 aluminium alloy ring made in industrial conditions based on a previously developed technology - a combined forging and rolling method.

STUDY MATERIAL METHODOLOGY AND RESULTS

Tests were carried out using samples taken from a ring made of aluminium-zinc-magnesium alloy EN AW - 7075, the chemical composition of which is shown in Table 1.

Table 1 **Chemical composition of tested Al alloy**

EN AW 7075	Elemental content /wt%				
	Si	Fe	Cu	Mn	Mg
	0,08	0,15	1,36	0,06	2,38
	Cr	Zn	Ti	Al	
	0,2	5,68	0,03	R	

For manufacturing of the forged-rolled EN AW-7075 alloy ring, a 150 kg cylindrical charge was used, measuring ø 500 x 271 mm. The feedstock was annealed at 480˚C for 14 h to soften it.

Prior to the swelling process, the charge was heated in a compact oven to 485°C and then held at this temperature for 2 hours. After the heating, the aluminium charge was transported to a 32 MN press station. The charge swelling was carried out until a disc 180 mm height was obtained. Height of 180 mm compared to the expected final height of 154 mm was dictated by the results obtained during model tests. Punching operation was performed on the same press station, using a 230 mm diameter punch with an inclined working surface.

After the hole-punching operation, an approximately 30 mm thick bottom remained in the disc. The bottom-punching operation was carried out with a 230 mm diameter punch.

After the forging process, a ring-shaped blank was obtained (Fig. 1) with dimensions: ø660/ø230 x 180 mm, which was the feedstock for the following rolling process.The aim of the rolling process was to obtain a ring with dimensions (hot): ø1660±9 /ø1 532±9 x 154±8 [mm x mm x mm]. The rolling process was started with the mill settings determined by the results of numerical tests. During the rolling process, the mill operator manually controlled the dynamic parameters of the mill, based on measured and calculated rolling process parameters. After the rolling process was completed, a ring with hot dimensions of ø1 660/ø 1 525x 154 mm was obtained, shown in Figure 1. Test specimens were cut from the ring produced by the rolling process, then a series of tests followed, including: microstructure observation, X-ray phase analysis, energy-dispersive X-ray microanalysis EDS and two-way hardness measurements.mm was obtained, shown in Figure 1.

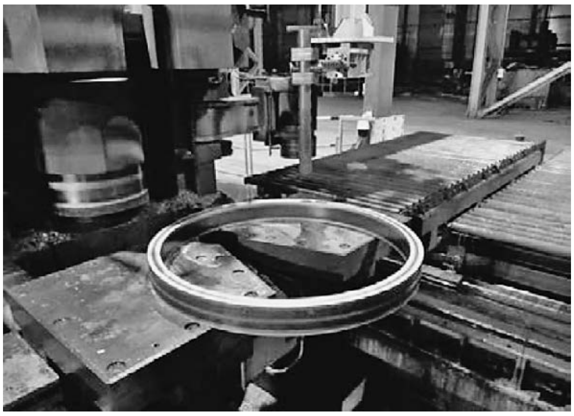


Figure 1. Rolled aluminium alloy EN AW - 7075 ring

List of test specimens with position in the fabricated EN AW - 7075 aluminium alloy ring:

- 1-1P S_W – sample taken longitudinally from the ring after rolling from the part with the outer surface,
- 1-2P S_W – sample taken longitudinally from the ring after rolling from the middle section,

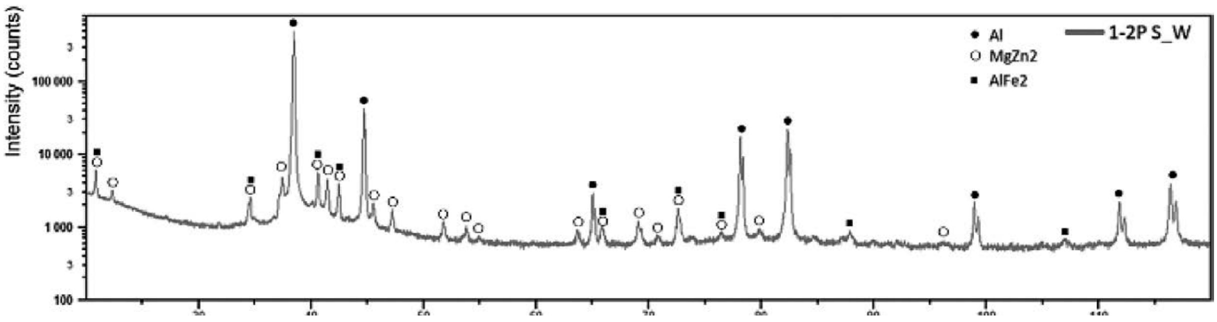
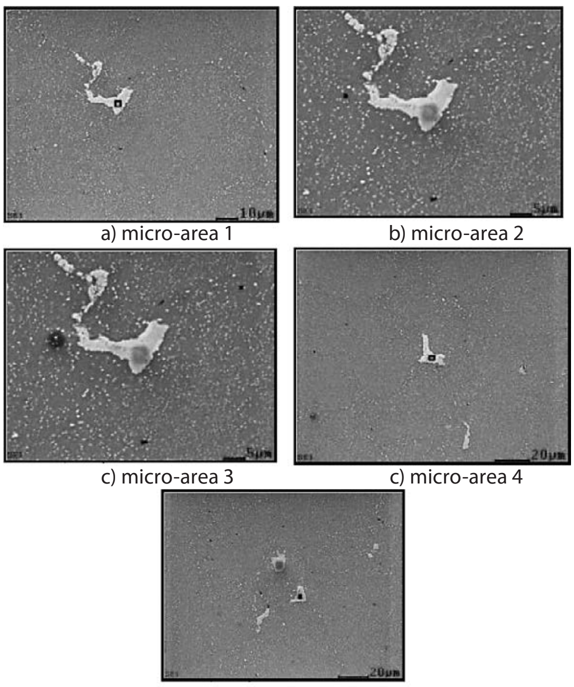


Figure 2 Diffractogramsample No. 1-2P S_W

- 1-3P S_W – sample taken longitudinally from a ring after rolling from a part with an inner surface.

X-RAY PHASE ANALYSIS

The results of the X-ray phase analysis of sample No. 1-2P S_W are shown in the diffractogram in Figure 2.



a) micro-area 1
b) micro-area 2
c) micro-area 3
c) micro-area 4
a) micro-area 5

Element/ spectral line	Elemental content / % of weight				
	Micro-area 1	Micro-area 2	Micro-area 3	Micro-area 4	Micro-area 5
Mg-K	---	4,10	5,89	---	---
Al-K	57,94	72,78	67,33	55,53	69,40
Cr-K	---	---	---	---	---
Mn-K	---	---	---	---	---
Fe-K	16,99	---	---	13,05	20,89
Cu-K	25,07	5,96	6,54	31,43	6,30
Zn-K	---	17,16	20,25	---	3,40

Figure 3 Results of EDS X-ray microanalysis of sample No. 1-2P S_W taken longitudinally from a rolled ring

The starting material of the rolled ring was EN AW-7075 alloy in the T6 condition, which was annealed, hence the pronounced peaks from the MgZn phase are visible. Some of the highest intensity peaks from the $AlFe_2$ phase overlap with peaks from the $MgZn_2$ phase (in the 2Θ angle range of approx. 20° to approx. 74°). The peaks from the α(Al) solid solution were the most intense.

ENERGY DISPERSIVE X-RAY MICROANALYSIS EDS

These tests were carried out on specimen No. 1-2P S_W taken longitudinally from the ring and a metallographic deposit was prepared from it, in accordance with test instruction No. Z-IB/3-05. The aim of the study was to determine the chemical composition of the intermetallic phases in the aluminium alloy after rolling. The tests used a voltage of 15 kV and a working distance (WD) of 10 mm. The test results are presented in Figure 3.

Large phase separations were observed in sample no. 1-2P S_W: Al-Cu-Fe - in micro-areas 1, 4 and 5, and dispersive$MgZn_2$-type phase separations - in micro-areas 2 and 3.

MICROSTRUCTURE OBSERVATIONS - LM

These tests were performed on samples No. 1-1P S_W, 1-2P S_W, 1-3P S_W, which were taken along the height of the EN AW-7075 alloy rings. The microstructure of the samples was revealed after etching in an aqueous solution reagent of hydrochloric (HCl), nitric (HNO_3) and hydrofluoric (HF) acids. The study was performed at an image magnification of 500x. Observations of the microstructure of samples taken from the ring after rolling were made in bright field. Microphoto-

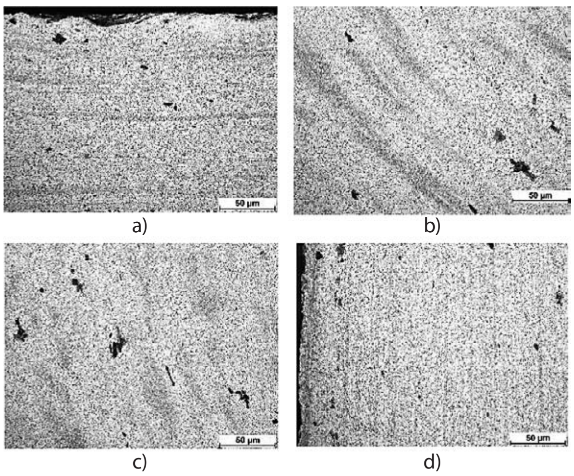


Figure 4 Microstructure on the longitudinal section of sample No. 1-1P S_W. LM: a - area 1 close to the upper surface of the ring, b - area 2 close to the centre of the sample, c - area 3 in the middle zone of the ring, d - area 4 close to the outer surface of the ring

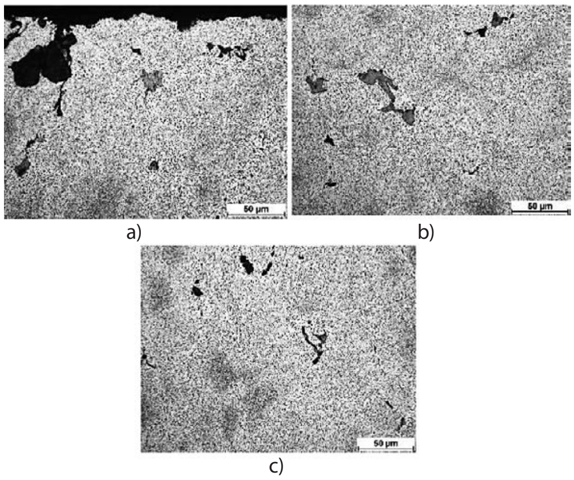


Figure 5 Microstructure on the longitudinal section of sample No. 1-1P S_W. LM: a - area 1 close to the surface of the ring, b - area 2 close to the centre of the sample, c - area 3 close to the centre of the ring

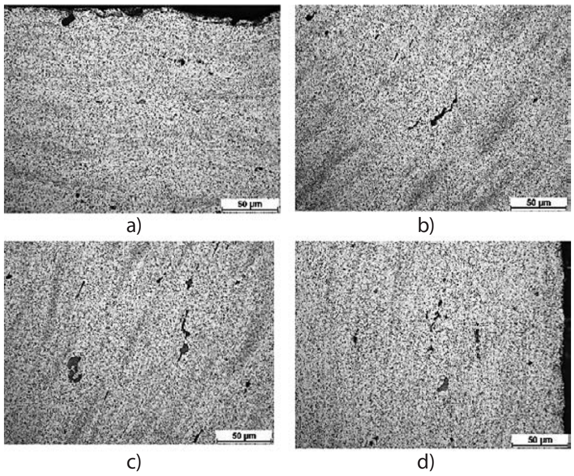


Figure 6 Microstructure on the longitudinal section of sample No. 1-1P S_W. LM: a) area 1 close to the surface of the ring, b) area 2 close to the centre of the sample, c) area 3 in the middle zone of the ring, d - area 4 close to the inner surface of the ring

graphs of the microstructure were recorded at an image magnification of 310x. Structure images are presented in Figures 4 - 6.

The microstructure of samples 1-1P S_W, 1-2P S_W and 1-3P S_W, which were taken longitudinally from the rings after rolling, did not reveal any grain boundaries of the α(Al) solid solution after etching in reagents with different proportions of hydrochloric (HCl, 0-6 ml), nitric ($HNO_{3,}$ 2-20 ml) and hydrofluoric (HF, 5-6 ml) acids in 100 ml of water. Only thick (primary) separations of intermetallic phases and bands of dispersive secondary separations of intermetallic phases are visible. The direction of the secondary precipitates alignment varies depending on the distance from the ring surface. At the top, outer and inner surfaces of the ring, bands with secondary non-metallic separations are distributed almost parallel to the surface (Fig. 5 a and d). Voids were noted on thesurface of sample no. 1-2P S_W (upper surface of the ring) (fig. 6 a).

According to the authors, grain size measurements will be possible after heat treatment.

HARDNESS TESTS

Vickers hardness measurements were carried out at a loading force of 4,903 N on samples subjected to microstructural tests. One HV 0.5-1 hardness distribution was carried out from the top surface of the ring deep into the sample to the central zone, and another perpendicularly HV 0.5-2 in the central zone of the ring. Mean hardness of each hardness distribution for a series of samples taken from the rolled ring are shown in Figure 7.

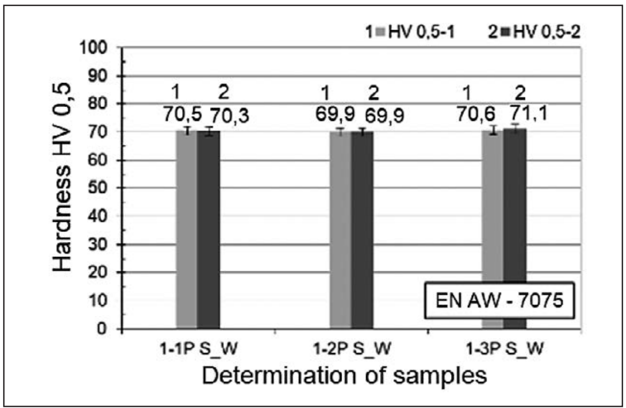


Figure 7 Mean hardness of two perpendicularly placed hardness distributions HV 0.5-1 and HV0.5-2 of samples No. 1-1P S_W, 1-2P S_W and 1-3P S_W

The mean HV hardness of 0.5 on the ring section after rolling was very even at approx. 70 HV 0.5.

SUMMARY

The following final conclusions were drawn from the research:

1. The microstructure of samples taken along the height of the rings after the rolling process from the outer, middle and inner parts did not reveal grain boundaries of the α(Al) solid solution after etching in reagents with different proportions of hydrochloric acid. This made it impossible to assess ring structure homogeneity after forging and rolling process.

2. Annealing the charge prior to shaping processes at 480˚C for 14 h to soften it, allowed the X-ray phase analysis to reveal distinct peaks from the MgZn phase. Some of the highest intensity peaks from the $AlFe_2$ phase overlap with peaks from the $MgZn_2$ phase (in the 2Θ angle range of approx. 20˚ to approx. 74˚). The peaks from the α(Al) solid solution were the most intense.

3. Energy-dispersive X-ray microanalysis (EDS) performed on a sample taken longitudinally from a rolled middle section showed large Al-Cu-Fe phase separations and dispersive $MgZn_2$-type phase separations.

4. Observations of the microstructure allowed only for the observation of thick (primary) precipitates of intermetallic phases and a band of dispersive secondary precipitates of intermetallic phases. The direction of the secondary precipitates alignment varies depending on the distance from the ring surface.

5. The Vickers hardness measurements carried out on the specimens showed aligned hardness values for two perpendicular distributions. The mean HV hardness of 0.5 on the ring section after rolling was approx. 70 HV 0.5.

6. The use of the combined method of forging and rolling to produce large-size rings made of EN AW – 7075 alloy allows to obtain rings with proper structure and uniform hardness in directions perpendicular to each other.

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Note: The responsible translator for English language is dogadamycie.pl Sp. z o. o., Koszalin, Poland