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EFFECTS OF INITIAL MICROSTRUCTURE ON THE EARRING OF ALUMINIUM ALLOYS CARTRIDGE CASE

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Abstract

Defects obtained during impact extrusion of EN AW-5754 aluminium alloy during cartridge case production were investigated. In cartridge cases produced from the one metallurgical heat pronounced tendency to earring after impact extrusion observed/appeared. On the other hand, the earring in cartridge cases from the other heat was not observed. Presence of earring is due to the local difference in materials flow during extrusion. This behaviour is attributed to the difference in second phase particle distribution in used preforms (slugs).

Keywords: cartridge case; impact extrusion; earring; EN AW-5754 aluminium alloy.

Introduction

Impact extrusion is considered to be high production manufacturing techniques. In this process, the slugs are pressed between the die and punch with extreme force. Material flows by backward extrusion permitting large deformation at high speed and thin-walled, lightweight cylinders are produced. This process is more efficient than deep drawing when the base of the cylinder is thicker than the side walls, and when the wall length is more than twice the diameter. It is possible to obtain length/width ratio up to 8:1 in aluminium alloys and up to 4:1 ratio in steel in a single operation, while deep drawn parts are typically limited to a 1:1 wall/bottom ratio and a length/width ratio of 2:1. Compared to forging, during impact extrusion is possible to obtain a cylinder with a thinner wall and much closer tolerances [1].

Process parameters such as temperature, forming rate, lubrication, i.e. friction between slug and tooling influence metal flow during the forming process [2-3]. However, material properties also must be considered. Formability is related to mechanical properties, such as strength and ductility, as well as, microstructural variables

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such as work hardening, dynamic recovery, solute, strengthening, particle hardening, grain size and texture [4-5]. The microstructure homogeneity is the most important for formability [6]. Due to the differences in material flow, which can be caused by listed parameters, the earring is quite common during impact extrusion. It is well known that the main reason which causes earring are anisotropic characteristics of the blank sheet which has crystallographic texture [7]. However, the slugs sawn from the drawn bars are often used as a preform for production of cartridge cases by impact extrusion. It is considered that the drawn rod having a grain pattern in the direction of extrusion and grain flow during impact extrusion would result in optimum macrostructure and strength of the material [8]. There is no data about the effect of texture in the drawn rod on earring during impact extrusion.

This study aimed to establish the relationship between the initial properties of the slugs and earring formation during impact extrusion of the EN AW-5754 alloy.

Experimental

Two cartridge cases of EN AW-5754 alloy were tested. The cartridge cases were produced from slugs, ϕ42,8x12 mm, from different metallurgical heats, which chemical compositions are given in Table 1.

Table 1. The chemical composition of EN AW-5754 alloy slugs, wt. %

Slug	Mg	Mn	Si	Fe	Cu	Cr	Zn	Ti	Al
1	2.72	0.26	0.085	0.19	0.044	0.025	0.057	0.019	Bal.
3	2.87	0.29	0.16	0.36	0.046	0.048	0.057	0.017	Bal.

The slugs were sawn from extruded rods from two metallurgical heats (marked as 1 and 3). Slugs in as received condition were formed into cartridge cases by backward impact extrusion (Fig. 1).

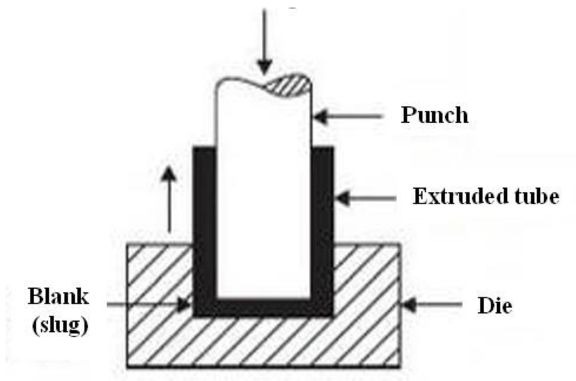


Fig. 1. Schematic illustration of the impact extrusion process.

Microstructure

The microstructure was characterized by a Leitz optical microscope and scanning electron microscope (SEM-JEOL JSM-6610LV). Metallographic samples were prepared using traditional techniques, by mechanical grinding with sandpaper and mechanical polishing using diamond paste up to 1 µm grade. To reveal the grain structure, after electrolytic polishing in perchloric acid, the samples were etched in Barker's solution (25 ml HBF4 (40%), 1000 ml distilled water). The particle distribution was observed in polished samples in the longitudinal and transversal direction of slugs, while samples of the cartridge cases were cut as shown in Fig. 2 (pick-P, with the highest height of 38,70 mm and valley-V with the lowest height of 34,28 mm).

Hardness measurement

Hardness measurements of slugs were conducted by the Brinell method according to standard SRPS EN ISO 6506-1, HB2,5/62,5. The hardness of the cartridge case was measured by Vickers method, under test force of 4.9 N, according to standard SRPS EN ISO 6507-1.

Electrical conductivity

Electrical conductivity measurements were performed on slugs using Föerster Sigma Test D2.068 equipment at the operating frequency of f=60 kHz.

Results

The geometry of cartridge cases

The tested cartridge cases are shown in Fig. 2. It can be seen that the uneven edge of the cartridge case 3, i.e., in the specimen 3 earring occurred after backward impact extrusion.

Fig. 2. Cartridge cases without (1) and with earrings (3).

The results of wall height measurement (conducted on 11 measuring places) of both cartridge case are given in Table 2, where h_{min} is the minimal height at the valleys, h_{max} the maximal height of the earring peaks, and Δh the difference (h_{max}-h_{min}). The results showed that Δh was 1.1 mm and 4.42 mm at cartridge case 1 and 3, respectively.

Table 2. Wall height of the cartridge cases, mm.

Measuring point	1	2	3	4	5	6	7	8	9	10	11
Cartridge case 1	-	-	37.4	37.0	36.7	36.8	37.0	37.3	37.8	37.8	37.8
Cartridge case 3	34.3	38.4	38.1	36.8	36.2	37.6	38.7	38.7	38.3	37.4	38.1

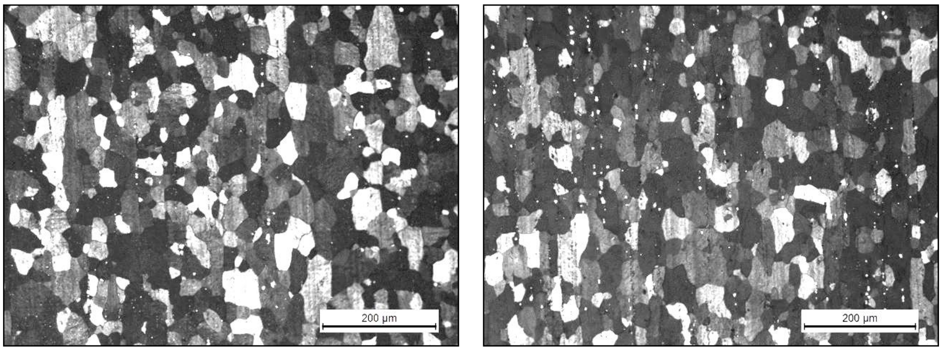
Table 3. Maximal and minimal wall height of the cartridge cases, mm.

Height	Cartridge case 1	Cartridge case 3
h_{max}	37.85	38.70
h_{min}	36.75	34.28
Δh	1.10	4.42

At the same time measurement of the wall thickness of cartridge cases show that the wall thickness is quite uniform.

Microstructure

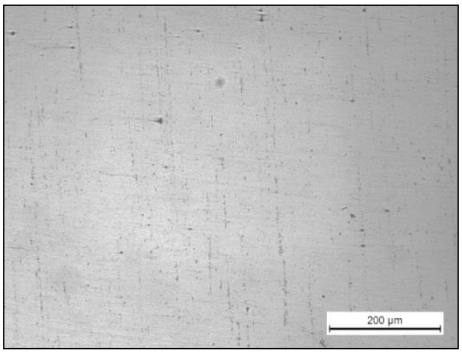
The microstructure of the slugs is shown in Fig. 3. Grain structure analysis revealed recrystallized microstructure with slightly elongated grains in the longitudinal direction of both slugs. The difference between the grain size of specimens can be neglected.



a) *b)*

Fig. 3. Grain structure in the longitudinal section of slugs 1 and 3; etched.

Particle distribution of the slugs observed with a light microscope and SEM is shown in the Figs 4 and 5. It was noted the stringer-like distribution of second phase particles in the longitudinal direction of both slugs. Higher content of the second-phase particles was observed in the slug 3 than in the slug 1. This is also confirmed at the microstructures in the cross section (Figs. 5a and 5b). The second-phase particles in the cross section of the slugs were found to be randomly distributed in both specimens, but larger particles were identified in slug 3.



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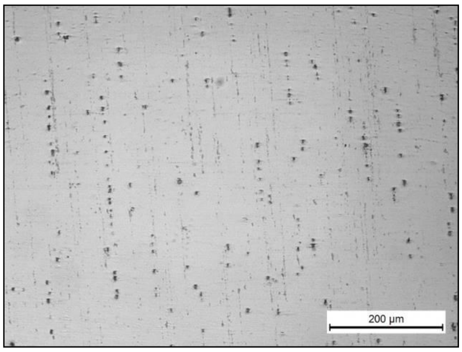

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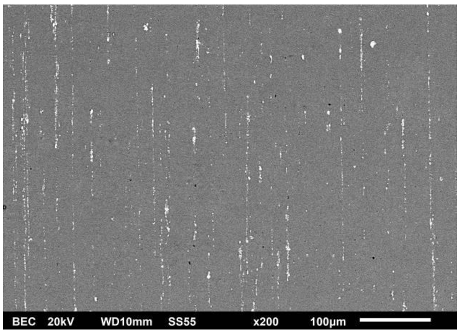

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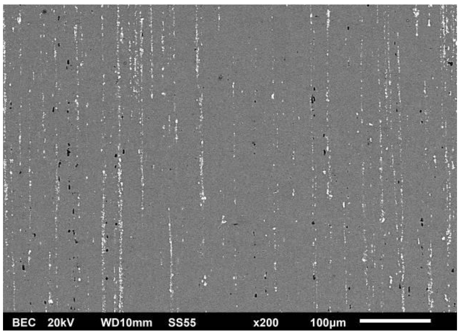

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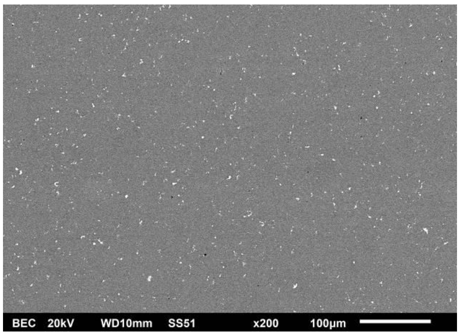
Fig. 4. Particle distribution in the longitudinal direction of: a), c) slug 1; b), d) slug 3; a), b) LM; c), d) SEM.



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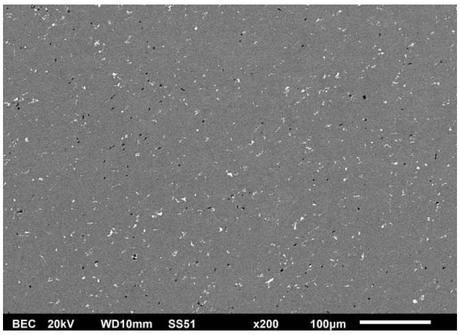

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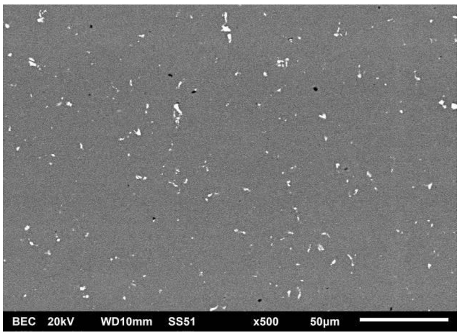

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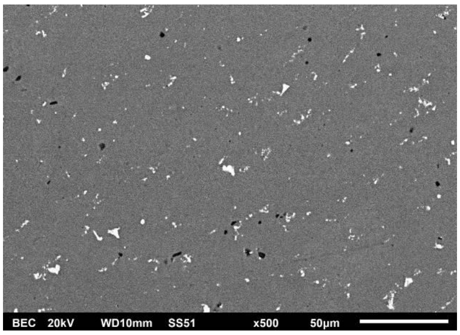

d)

Fig. 5. Particle distribution in the cross-section of the slugs 1 and 3.

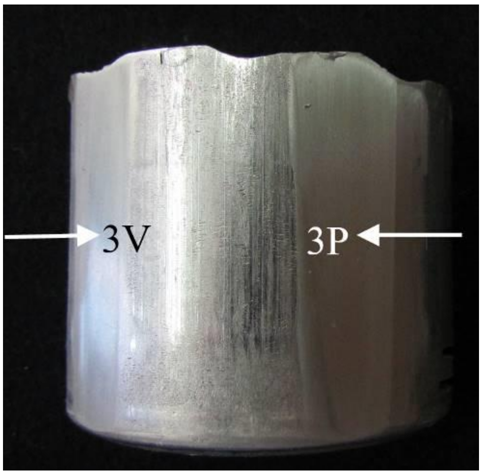

Fig. 6. Specimen for testing microstructure and microhardness of the cartridge case 3. V-valley and P-peak areas.

Microstructures of the wall surface of the cartridge case 3 in the area of the valley (h_{min}), and peak (h_{max}) (Fig. 6) are shown in Fig. 7. The clear difference in second phase particles content of valley and pick area in the wall surface was observed (Fig. 7). From the micrograph given at Figs 7a and c, it seems that in the valley area a larger number of particles could be observed.

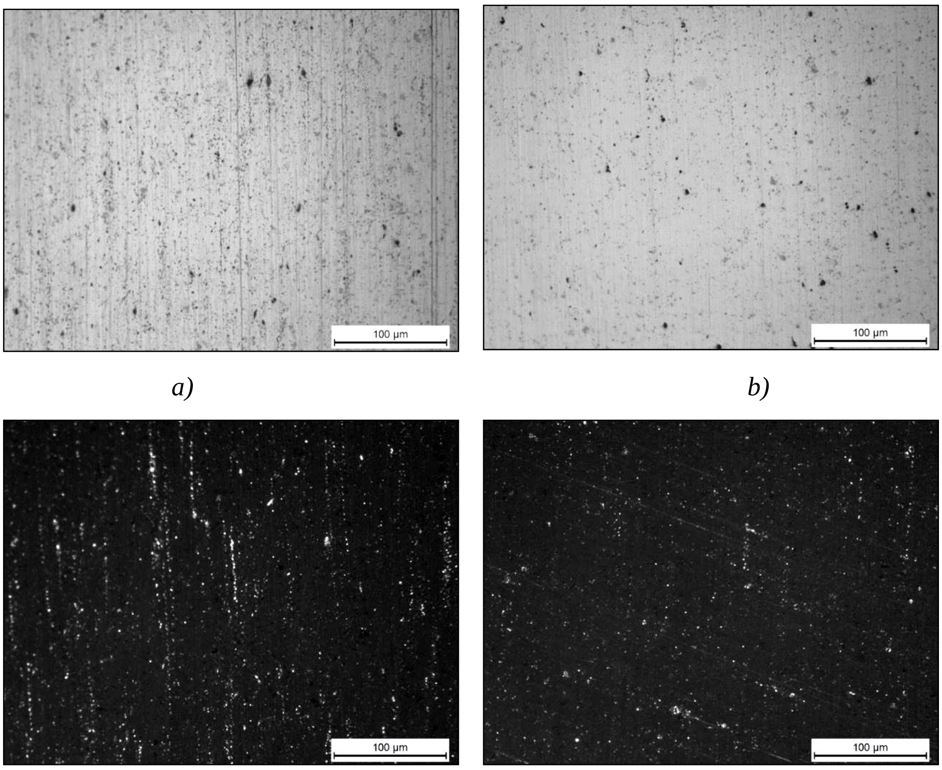

Fig 7. Particle distribution in the wall surface of the cartridge case 3: a), c) valley; b), d) peak. Polished. a), б) bright field; c), d) dark field.

The second phase particles have been identified by EDS as Al-Fe-Mn(Ni) (white in BS images) and Mg-Si phases, as shown in Fig. 8. Other particles (Al-Mg-Fe, Al-Mg), were also observed. According to [9-11], the light coarse particles which dominated in microstructures were identified as (Fe, Mn)Al_6.

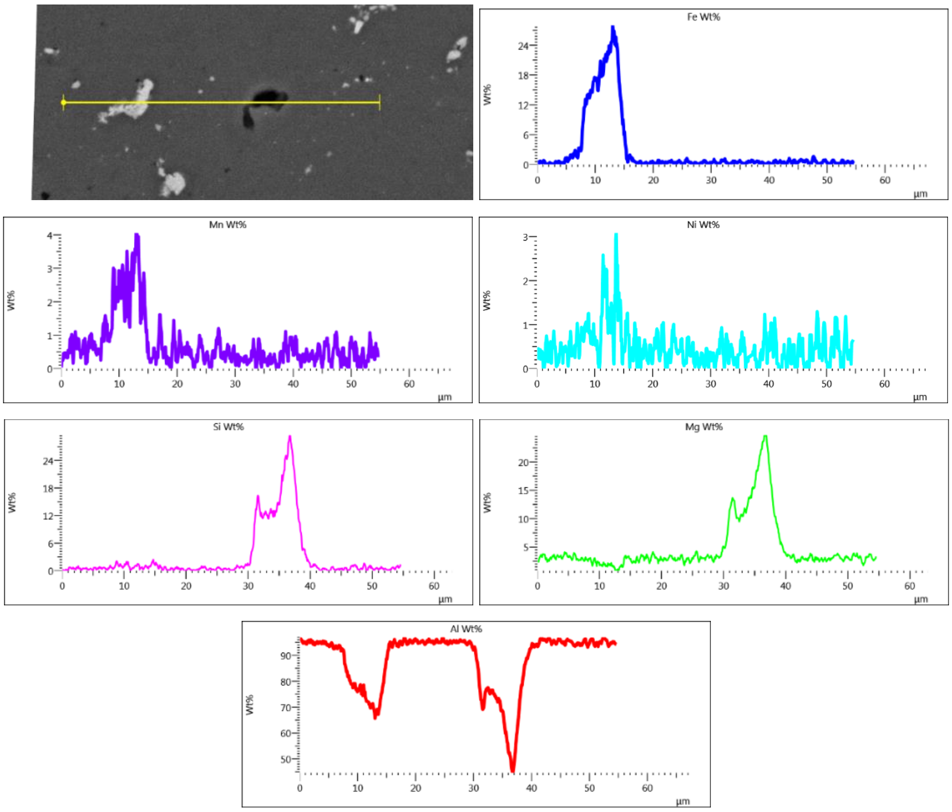

Fig. 8. EDS of second phase particles in EN AW-5754 alloy.

Hardness

Results of hardness measurement are given in Table 4. It was found that the hardness of the slug 3 is slightly higher compared to the hardness of the slug 1.

Table 4. The hardness of the slugs 1 and 3.

Specimen		HB		Aver.
Slug 1	59.0	58.0	57.7	58
Slug 3	61.4	61.0	59.4	61

The hardness of the cartridge case 3, measured in circumference (Fig. 6) is given in Table 5. It was found that the hardness of the valley area (V) is higher compared to the wall pick area (P).

Table 5. Wall hardness of the cartridge case 3.

Specimen		HV0.5		Aver.
3 P	104.6	102.5	104.1	104
3 V	112.0	112.9	114.4	113

Electrical conductivity

Results of electrical conductivity measurements are given in Table 6. Lower values of electrical conductivity were measured in the slug 3.

Table 6. The electrical conductivity of the slugs.

Specimen	Electrical conductivity, %IACS					Aver.
Slug 1	34.67	34.57	34.55	34.66	34.55	34.60
Slug 3	33.71	33.69	33.74	33.74	33.69	33.71

Discussion

The cartridge cases were produced from two metallurgical heats. It was found that they had somewhat different properties. Slug 3 was produced from metallurgical heat with higher content of alloying elements and impurities, Mg, Mn, Fe, Si and Cr (Table 1). Aluminium alloys commonly contain significant impurity levels which lead to the formation of second phase particles. In Al-Mg based alloys, Fe is considered as the main impurity which forms the Fe-rich intermetallic [12-13]. Higher content of alloying elements and impurities resulted in the formation of higher content and larger second phase particles in slug 3, what was confirmed by microstructure examination (Figs. 4 and 5). This resulted in a higher hardness value (Table 4). It is known that the electrical conductivity of aluminium alloys is highly sensitive to detect different microstructural features in Al-Mg alloys. The electrical conductivity decreases with the increase of alloying elements and impurities. [14-16]. The electrical conductivity of the slug 3 (Table 6) is lower than the slug 1, in accordance to the results of chemical composition, as with the hardness and microstructure (Table 1 and 4, Figs. 4 and 5).

It is known that the distribution of second phase particles in aluminium alloys is strongly non-homogeneous [17]. In this study, the distribution of the second phase particles in cartridge case 3 was rather non-homogenous, so the areas with larger and smaller ones are distinguished (Fig. 6). The higher content of second phase particles was observed in the valley (V) area (Fig. 6a, c).

Consequently, this resulted in non-homogenous hardness distribution of the cartridge wall in circumference after impact extrusion. The hardness of the valley (V) is higher compared to wall pick (P) area, as given in Table 5. Such hardness distribution is a result of both, non-homogenous second phase distribution and non-homogenous strengthening during cold deformation (impact extrusion). In an area with higher content of the second phase particles (valley wall), the rate of deformation strengthening is higher [18-19].

At the same time measurement of the wall thickness of cartridge cases show that the wall thickness is quite uniform. It can be concluded that the backward extrusion process provides excellent control on the sidewall thickness.

Conclusion

The cartridge cases were produced from slugs by backward impact extrusion. It was found that the two tested slugs, produced from different metallurgical heats, had a slightly different chemical composition. The difference in the microstructure, mechanical and physical properties of the tested slugs produced from different metallurgical heats, also found.

More second phase particles were observed in the slug 3 compared to slug 1, due to the slightly higher content of the alloying elements (Mg) as well as impurities (Fe, Si and Cr). Moreover, the distribution of the second phase particles is more non-homogenous in slug 3. The higher hardness and lower electrical conductivity of this slug compared to slug 1 agree with chemical composition and microstructure.

In cartridge cases produced from the slug 3 after impact extrusion the earring appeared. The areas of the different wall height had a different hardness. The wall picks have a higher hardness than the valleys. Also, higher content of the second phase particles was observed in the valley area compared to the wall picks. These differences are caused by the non-homogenous size and distribution area of the second phase particles in the initial slugs. This resulted in the non-homogeneous deformation, i.e. the local difference in materials flow during impact extrusion of the cartridge case and caused the earring.

Backward extrusion process provided good control on the sidewall thickness.

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