UDK 620.1:669.715:621.3.035.15
Original scientific article/Izvirni znanstveni članek

ISSN 1580-2949
MTAEC9, 50(4)601(2016)

DEVELOPMENT OF ALUMINIUM ALLOYS FOR AEROSOL CANS

RAZVOJ ALUMINIJEVIH ZLITIN ZA AEROSOL DOZE

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Prejem rokopisa – received: 2015-11-06; sprejem za objavo – accepted for publication: 2015-11-24

doi:10.17222/mit.2015.330

New aluminium alloys were developed for aluminium narrow strips, cast with a rotary strip caster, to produce slugs for aerosol cans. The newly developed alloys provide constant mechanical properties during the manufacturing of aerosol cans, a good transformation and high deformable and burst pressures of the aerosol cans. The problem that occurs during the manufacturing of aerosol cans is a decrease in the mechanical properties of the material up to 15 %. This is reflected in lower deformable and burst pressures for the aerosol cans. By increasing the mechanical properties of aerosol-can materials it is possible to produce aerosol cans with thinner walls, having a significant impact on the weight of the final aerosol cans. Using new aluminium alloys for aerosol cans, it is possible to increase the deformability and burst pressure by more than 10 %.

Keywords: aluminium alloys, rotary strip casting, slug, impact extrusion, aerosol cans

Razvite so bile nove aluminijeve zlitine za aluminijev ozki trak, ulit po sistemu rotary strip caster, za izdelavo surovcev za iztiskovanje aerosol doz. Nove zlitine imajo konstantne mehanske lastnosti skozi celoten proces izdelave aerosol doz, zato se dobro preoblikujejo in dosegajo visoke deformabilne in razpočne tlake. Problematika, ki se pojavlja pri izdelavi aerosol doz, je poslabšanje mehanskih lastnosti materiala, tudi do 15 %. To se kaže v nižjih deformabilnih in razpočnih tlakih aerosol doz. Z višanjem mehanskih lastnosti materiala za aerosol doze je možno izdelati aerosol doze s tanjšo steno, kar bistveno vpliva na težo končne doze. Z uporabno novih zlitin za izdelavo aerosol doz je mogoče doseči tudi več kot 10 % višje deformabilne in razpočne tlake doz.

Ključne besede: aluminijeve zlitine, sistem rotacijskega ulivanja traku, surovec, protismerno iztiskovanje, aerosol doze

1 INTRODUCTION

Aluminium aerosol cans are made either by impact extruding aluminium slugs or by deep drawing discs stamped out of an aluminium sheet. The aluminium sheet is mainly produced with the direct-chill (DC) cast technology. The continuous-casting (CC) technology, however, provides energy and economic savings, while reducing environmental emissions. Compared with the DC cast technology, the CC technology also takes advantage of high productivity.[1]

Some 7.6 billion aluminium aerosol cans a year are used worldwide. Almost 80 % of the production is attributable to the cosmetics industry.[2] Aluminium spray cans are not only user friendly, they also help conserve resources. Today, a typical cylindrical aerosol can (38 mm/138 mm) weighs 17 g and is about 30 % lighter than at the beginning of the 1970s, and there is still the potential for further savings. Aluminium is also readily recyclable and can be repeatedly processed to new, high-grade products without any loss in quality, and the same is true for aerosol cans.[3]

1.1 Aluminium narrow strip and slug production process

Aluminium aerosol cans for the cosmetics and food industries are manufactured from aluminium slugs using

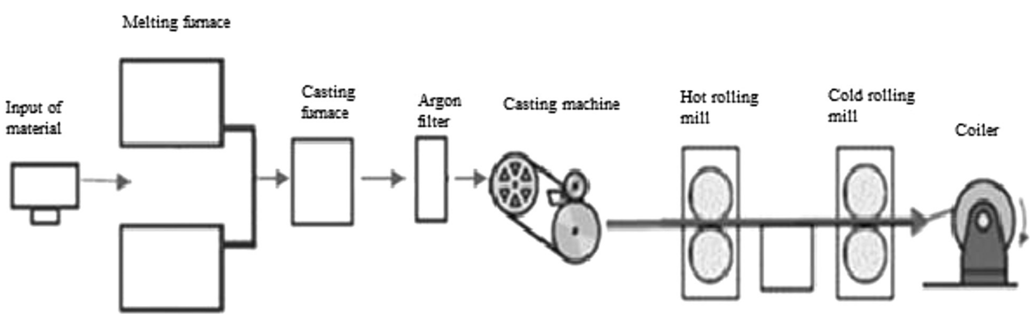

Figure 1: Production line of aluminium narrow strip
Slika 1: Proizvodna linija za izdelavo aluminijevega ozkega traku

impact extrusion. In the company Talum d.d., the aluminium slugs are semi-manufactured products stamped from an aluminium narrow strip produced by a rotary strip-casting machine (**Figure 1**).

An aluminium strip is usually cast with a horizontal casting system, which enables the casting of a wide spectrum of aluminium alloys. A narrow aluminium strip, which is cast using a rotary strip-caster system, is limited to the casting of the AA1XXX and AA3XXX-series aluminium alloys. The 1XXX and 3XXX-series aluminium alloys find wide applications in the transportation, food, beverage and packaging industries. In these applications, control of the plastic anisotropy of the sheet is of great importance in order to ensure the formability of the final product and to reduce the waste of the material resulting from earring behaviour.[4] The 1XXX and 3XXX-series distinguish good formability and corrosion resistance, the AA3XXX-series aluminium alloys also have good weldability and relatively good mechanical properties.[5] Good mechanical properties mean achieving a high deformation and burst pressure.[6]

The rotary strip-casting machine[7] consists of a casting wheel and a steel belt. The melt flows from the casting channel into the area between the endless steel belt and the water-cooled wheel (**Figure 2**). The casting wheel is manufactured from a copper or steel alloy.

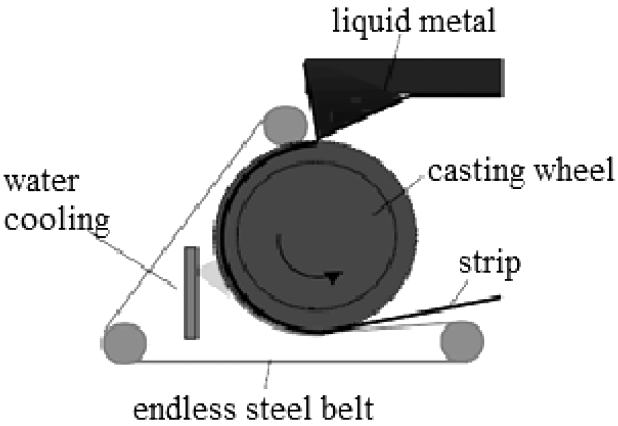

Figure 2: Rotary strip-casting system[7]
Slika 2: Sistem rotacijskega ulivanja traku[7]

From the casting machine the aluminium strip is led to the hot-rolling mill and then to the cold-rolling mill through a roller track. In the hot-rolling mill the strip thickness is reduced by 40–70 %, while in the cold-rolling mill it reaches 30–50 %.

The rolled narrow aluminium alloy strip then travels to the stamping line, where slugs are stamped using a stamping machine. From the stamping machine the slugs are led into annealing furnaces, where the slugs are softened and the oil remaining from the stamping is burned off. After the annealing the slugs are surface-treated by sandblasting, vibrating or tumbling.

1.2 Aerosol can manufacturing with impact extrusion

Impact extrusion is the most widely used process to manufacture aluminium aerosol cans. With impact extrusion the aerosol cans are produced as a single piece without a seam or joint from the aluminium slugs. The cold disc is placed in a steel die and a punch at high pressure is then forced into the disc. Deformation of the aluminium generates heat and the metal flows in the opposite direction to the punch and takes on the form determined by the shape of the die.[3]

The can blank is subsequently cut to length and washed to remove any lubricants. After drying the interior is lacquered to protect the contents from direct contact with the metal. Once the cans have been formed, an internal lacquer is applied to each can and a polymerization step is performed. Additional operations are lacquering of the outside, printing, coating with the transparent protective lacquer layer and the appropriate intermediate drying processes. The final manufacturing step is the draw in the can shoulder and – in case of shaped cans – the can body in a multi-die necking machine.[3]

The manufacturing process for aerosol cans consists of the following steps (**Figure 3**): (1) Slug → (2) impact extrusion → (3) washing and drying → (4) internal lacquering and polymerization → (5) external lacquering

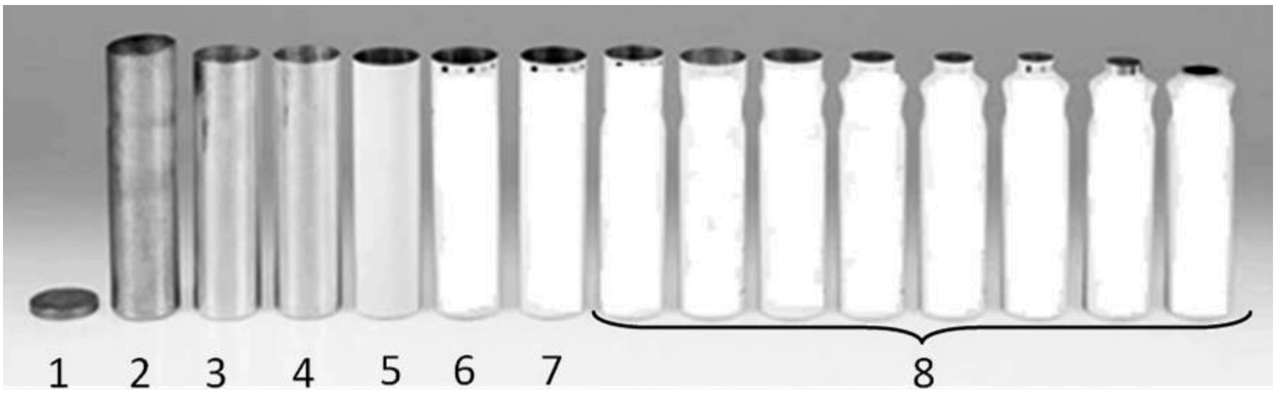

Figure 3: Sequence of aerosol can manufacturing
Slika 3: Koraki izdelave aerosol doz

→ (6) printing → (7) coating with protective lacquer layer → (8) draw in the can shoulder and body in a multi-die necking machine.

The drying of washed, externally lacquered and printed cans is performed at temperatures of 140–180 °C. The polymerization of internal lacquering occurs at temperatures around 250–280 °C.

2 EXPERIMENTAL PART

2.1 Aluminium alloys for aerosol cans

Aerosol cans are generally made from an aluminium-based alloy containing 99.5 % or 99.7 % of the mass fractions of Al. The Talum company produces slugs for aerosol cans from the alloys presented in **Table 1**.

Table 1: Mechanical properties of standard aluminium alloys for aerosol cans
Tabela 1: Mehanske lastnosti standardnih aluminijevih zlitin za izdelavo aerosol doz

Mechanical properties					
Alloy	Hardness ($HB_{2.5/15.625}$)	R_m (MPa)	$R_{p0.2}$ (MPa)	Elongation (%)	Grain number/mm^2
99.7	18.5	70	34	42	60-100
99.5	19.5	75	37	41	60-100
AlMn0.3	22	80	41	40	20-30
AlMn0.6	27	92	55	38	30-60

Samples from heat treated slugs

A very important factor in impact extrusion is the grain number/mm^2. Slugs produced from pure aluminium 99.5 % and 99.7 % have smaller grains than slugs from the AlMn0.3 and AlMn0.6 alloys (**Figure 4**).

2.2 Methods and material

First, some basic examinations with the Thermo-Calc program were made at the Faculty of Natural Sciences and Engineering, Department of Materials and Metallurgy: simple thermal analysis, DSC and observation under light and scanning electron microscopes.

For the development of aluminium alloys, standard alloys for aerosol cans (**Table 1**) were used as the base material. These alloys were modified with the combination of different alloying elements. The base of alloy T1 is pure aluminium Al99.7 %, of alloy T3 AlMn0.3 alloy and the base of T4, T4+ AlMn0.6 alloy.

The reason for the development of new aluminium alloys for aerosol cans was in the decrease of the mechanical properties during the manufacturing process. The question was how to eliminate the decrease in mechanical properties and at the same time be able to cast aluminium narrow strip on a rotary strip-casting machine.

3 RESULTS AND DISCUSSION

3.1 Material properties during the manufacturing process

During the manufacturing process for aerosol cans the mechanical properties of the material decrease by up to 15 % after polymerization. This is reflected in achieving lower deformable and burst pressures of the aerosol cans.

Figure 5 shows the mechanical properties of the aerosol can material during the manufacturing process – after extrusion and after polymerization.

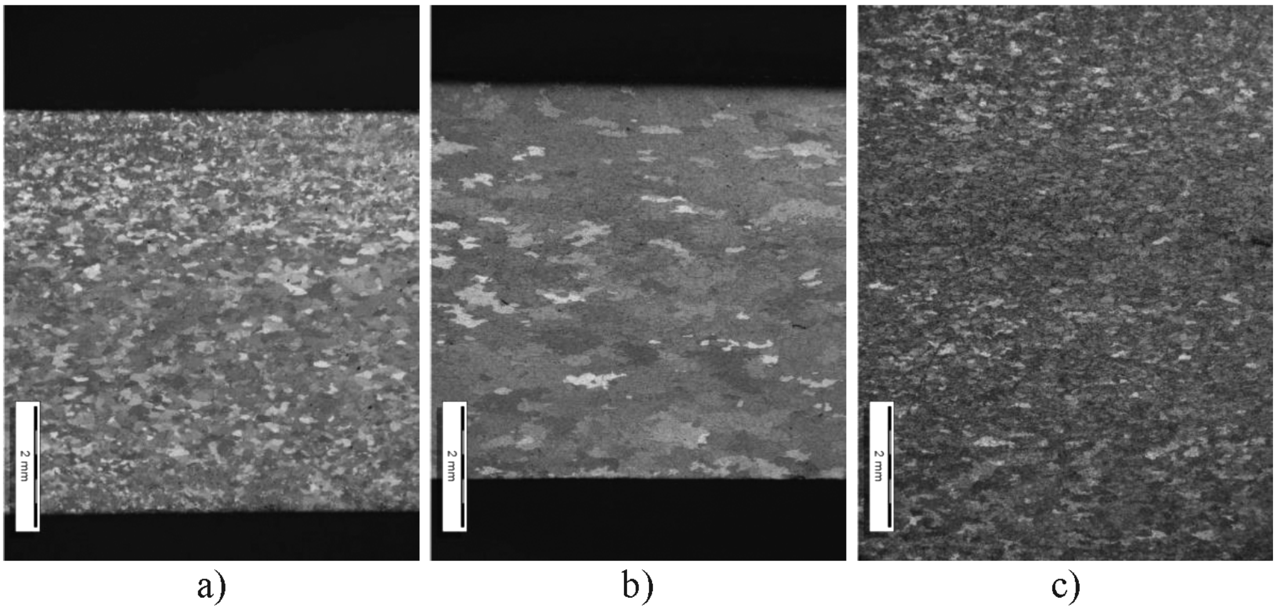

Figure 4: Grain structure of standard aluminium alloys for aerosol cans: a) Al99.5 %, b) AlMn0.3 and c) AlMn0.6 in polarized light
Slika 4: Zrnatost standardnih aluminijevih zlitin za izdelavo aerosol doz: a) Al99.5 %, b) AlMn0.3 in c) AlMn0.6 v polarizirani svetlobi

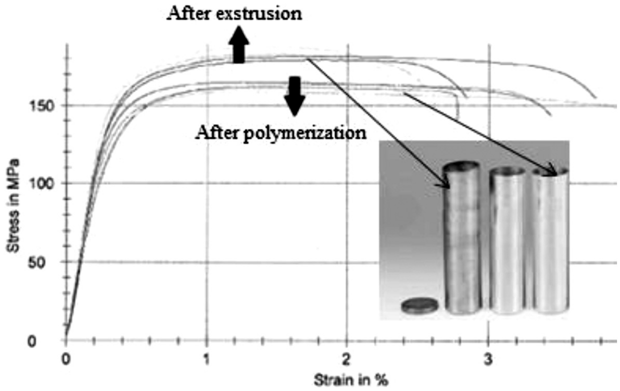

Figure 5: Mechanical properties of Al99.7 % aerosol cans after extrusion and after polymerization
Slika 5: Mehanske lastnosti aerosol doze iz Al99.7 % po izstiskovanju in polimerizaciji

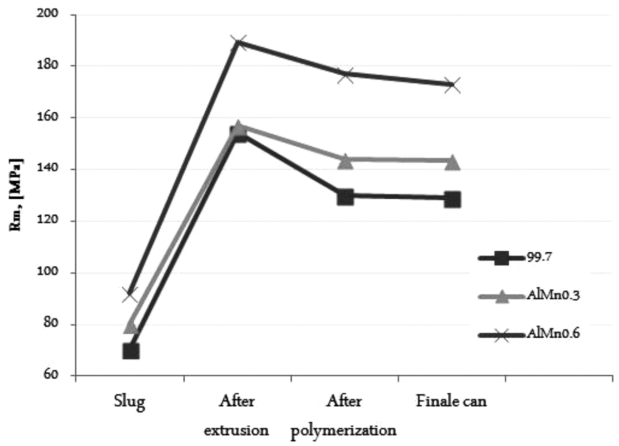

Figure 6: Mechanical properties of the aerosol can material during manufacturing
Slika 6: Mehanske lastnosti materiala aerosol doz med izdelavo

Samples of the standard material for aerosol cans were taken from the cans and with the standard tensile test the mechanical properties were measured. After polymerization the mechanical properties of the aerosol cans from the Al99.7 % decreased by 15.9 %, those of the cans from the AlMn0.3 alloy by 8.5 % and the mechanical properties of aerosol cans made from AlMn0.6 alloy decreased by 6.5 %. **Figure 6** shows the tensile strength of the measured aluminium alloys at an essential step of the manufacturing process for aerosol cans.

3.2 Newly developed aluminium alloys for aerosol cans

The goal of the development of new aluminium alloys for aerosol cans was to develop such an alloy, from which it is possible to produce an aluminium narrow strip with the rotary strip-casting machine on an existing casting-rolling line.

Table 2: Mechanical properties of newly developed aluminium alloys for aerosol cans
Tabela 2: Mehanske lastnosti novo razvitih aluminijevih zlitin za aerosol doze

Mechanical properties					
Alloy	Hardness ($HB_{2.5/15.625}$)	R_m (MPa)	$R_{p0.2}$ (MPa)	Elongation (%)	Grain number/ mm^2
T 1	21.7	78	48	36.5	16-21
T 3	23.4	80.3	52	24.9	5-7
T 4	28.9	113	82	19.9	7-14
T 4+	30.9	110.7	72.3	26.9	119

Samples from heat treated slugs

With the combination of different alloying elements a higher hardness, tensile strength and yield strength of the slugs were achieved. The elongation of the new alloy de-

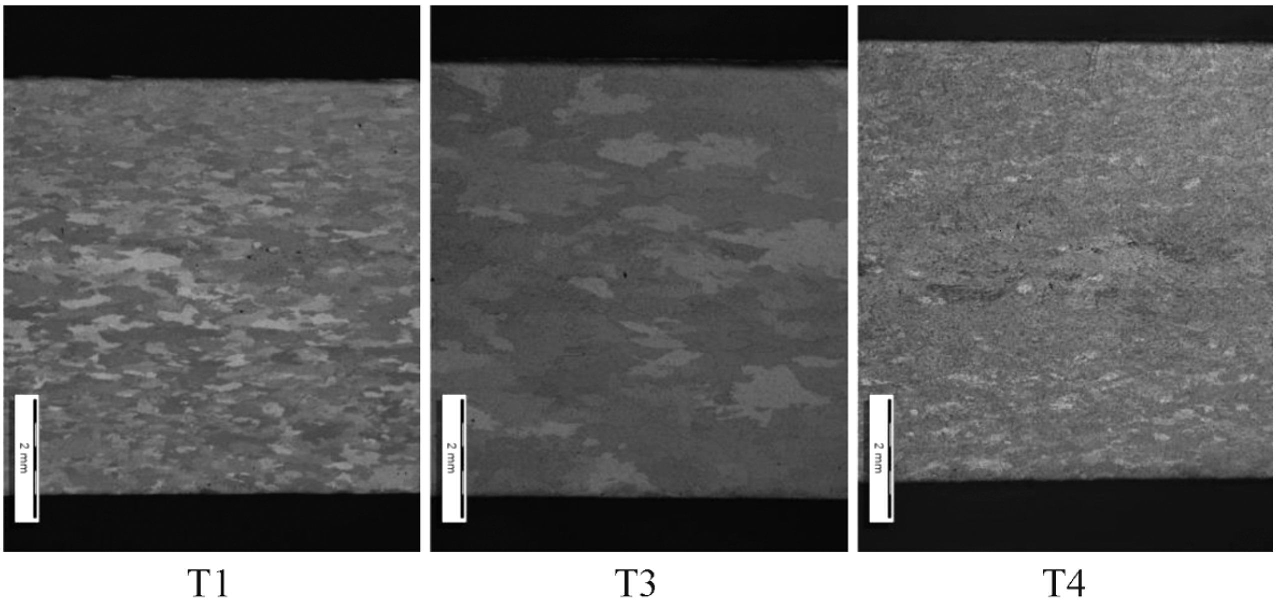

Figure 7: Grain structure of newly developed aluminium alloys for aerosol cans under polarized light
Slika 7: Zrnatost novo razvitih aluminijevih zlitin aerosol doze v polarizirani svetlobi

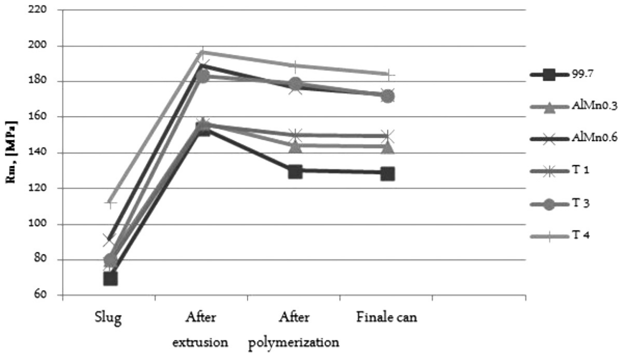

Figure 8: Comparison of mechanical properties of standard aluminium alloys and newly developed aluminium alloys for aerosol cans
Slika 8: Primerjava mehanskih lastnosti standardnih aluminijevih zlitin z novo razvitimi zlitinami za aerosol doze

creased. Moreover, the grain number/mm^2 decreased compared with the standard alloys.

Figure 7 shows the grain structure of the samples of new alloys taken from the slugs under polarized light. Alloy T1 has a more-or-less uniform and homogeneous grain structure, while alloy T3 has a rougher grain structure, and alloy T4 an inhomogeneous grain structure.

Figure 8 presents the tensile strengths of standard and newly developed aluminium alloys for aerosol cans. From the figure it is evident that the drop in the mechanical properties after polymerization on 2–3 % was eliminated. The mechanical properties of the alloy T1 are in the range of the AlMn0.3 alloy, but due to the lower grain number/mm^2 alloy T1 shows better manufacturability. With the T4 and T4+ alloy it is possible to achieve a high deformation and burst pressure, consequently this alloy shows the potential on the market where steel cans are used for packaging.

A comparison of the standard alloy Al99.7 % with the T1 alloy shows that the T1 alloy has excellent manufacturability properties, an excellent surface of the aerosol cans and a higher deformation and burst pressure. Also, a comparison of the AlMn0.3 alloy with the T3 alloy shows the same properties and the T4 alloys compared with the AlMn0.6 alloy shows a significant increase in the deformation and burst pressure, but worse manufacturability properties (**Figure 7**).

With the cooperation of aerosol can manufacturers the first test showed a 10-15 % higher deformation and burst pressure for the aerosol cans. That means it is possible to produce aerosol cans with thinner walls and thus reduce their weight and save on material.

4 CONCLUSIONS

On an existing casting-rolling line, aluminium alloys were developed to produce the aluminium narrow strip for the production of slugs, which enables:

- casting of an aluminium narrow strip with high casting speeds by using a rotary strip-caster system with an excellent surface and a minimum number of defects,
- constant mechanical properties of the material after polymerization and during the whole manufacturing process of aerosol cans, which is reflected by a more than 10 % higher burst and deformable pressures of the aerosol cans,
- good manufacturability, transformation and surface of aerosol cans from developed aluminium alloy slugs,
- improved mechanical properties of aerosol can material so as to produce aerosol cans with thinner walls and reduce their weight.

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