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ALLOY AlZn9 CASTED IN THE PROCESS OF RAPID SOLIDIFICATION AND CONSOLIDATED IN THE PROCESS OF PLASTIC FORMING

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Abstract

AlZn alloys with high Zn content have good strength properties. The basic problem in the production of the classical methods of casting alloys AlZn containing Zn above 7% is cracking of the ingots during casting. One of the methods of obtaining alloys with unusually high content of components is casting method of rapid solidification and subsequent consolidation in the process of plastic forming.

This paper presents the results of the structure and properties of cast alloy AlZn9 casted in rapid solidification process on the wheel and consolidated in the process of extrusion and continuous rotary extrusion. The study was conducted using light microscopy, scanning electron microscopy and transmission electron microscopy. Property specified in the Brinell hardness test, static compression and tensile tests.

Introduction

One of the methods to obtain aluminium alloys with unusual composition and structure is by combining the casting process based on rapid solidification (RS) with plastic working.[1]

When modern methods of rapid cooling of the liquid are used, the structure of alloy crystallises in the form of powder in an atomiser or in the form of ribbons on a rapidly rotating copper wheel. If proper conditions are met to carry out the process of casting by melt spinning with further consolidation of the material, it is possible to control the structure parameters such as the size of grains, the size of precipitates, etc [2,3]. Additionally, the production of aluminium alloys by rapid solidification and melt spinning allows introducing constituents that are incompatible with the state of equilibrium. The consolidation of rapidly solidifying material is further effected in the process of plastic working, where the most commonly used techniques include the extrusion process or its more advanced variation, which is continuous rotary extrusion (CRE).[4-8]

AlZn alloys with a high content of Zn are characterised by high strength parameters. The basic problem in the production by traditional casting methods of AlZn alloys with zinc content above 7% is crack formation in ingots during casting. One of the methods to obtain alloys with unusually high level of constituents is by casting with rapid solidification and subsequent consolidation in the process of plastic working.

The paper presents the results of studies of the structure and properties of AlZn9 alloy cast by the melt spinning technique and consolidated in the process of extrusion and continuous rotary extrusion. The examinations were conducted by light microscopy, scanning electron microscopy and transmission electron microscopy. The properties were determined in the Brinell hardness test, and in static compression and tensile tests.

Test methods

For the purpose of research, AlZn9 alloy of the composition given in Table 1 was cast by the melt spinning process.

Table 1 The composition of an AlZn9 alloy (basic elements)

El.	Si	Fe	Cu	Mg	Zn	Ti	Al.
[wt.%]	0,05	0,1	1,,2	2,5	9,1	0,019	rest

The process of melt spinning involves pouring of molten metal onto a rapidly rotating copper wheel with a high rate of heat transfer. The result is an almost immediate solidification of metal, which leaves the wheel in the form of thin ribbons (Fig. 1). The ribbons are next fragmented into fine flakes (chips) in a special cutting mill (Fig. 2).

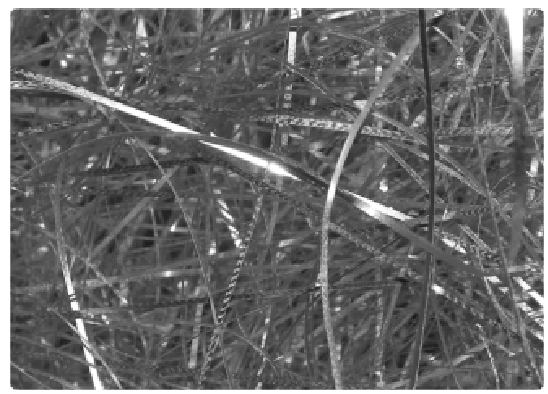

Fig. 1 A ribbon of AlAlZn9 alloy obtained by melt spinning

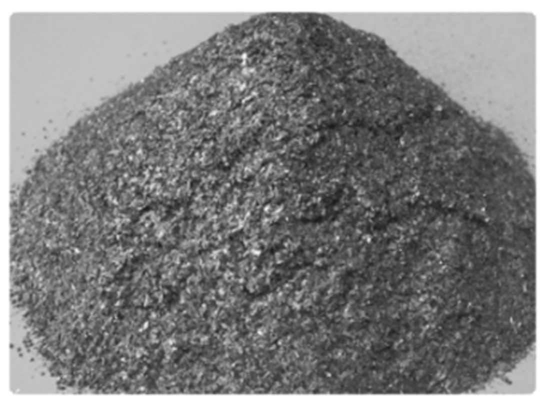

Fig.2 Chips made from a ribbon cut in a cutting mill

Thus obtained material was consolidated in direct extrusion process and in continuous rotary extrusion.

For the direct extrusion process (DE), the material was subjected to cold pre-consolidation in a “jacket” made of the 6xxx alloy tube and, as a next step, was hot-extruded in a vertical hydraulic 60T press with tooling adapted to the extrusion process. The process was carried out at 460°C and with the extrusion ratio $\lambda = 14$, the diameter of the extruded rods was $\phi = 8$mm.

The continuous rotary extrusion (CRE) was carried out in an MC-260 device. The die temperature was 350°C. As a result of this process, $\phi = 15$mm rods were produced.

Microstructure was examined under an Olympus GX71 light microscope and INSPECT F50 scanning electron microscope with an attachment for the chemical analysis in microregions by EDX and using a Tecnai G20 transmission electron microscope with an EDX attachment, and with STEM and HAADF detector.

Mechanical properties were determined in static tensile test conducted on an INSTRON 5582 machine; hardness was measured with a DURAMIN 2500 durometer.

Results

The examinations by light microscopy of rods made in the process of DE and CRE showed that the rods obtained by DE contained fine precipitates of a uniform distribution. In rods obtained by CRE, the visible precipitates were even finer and arranged in bands (Fig. 3).

a)

b)

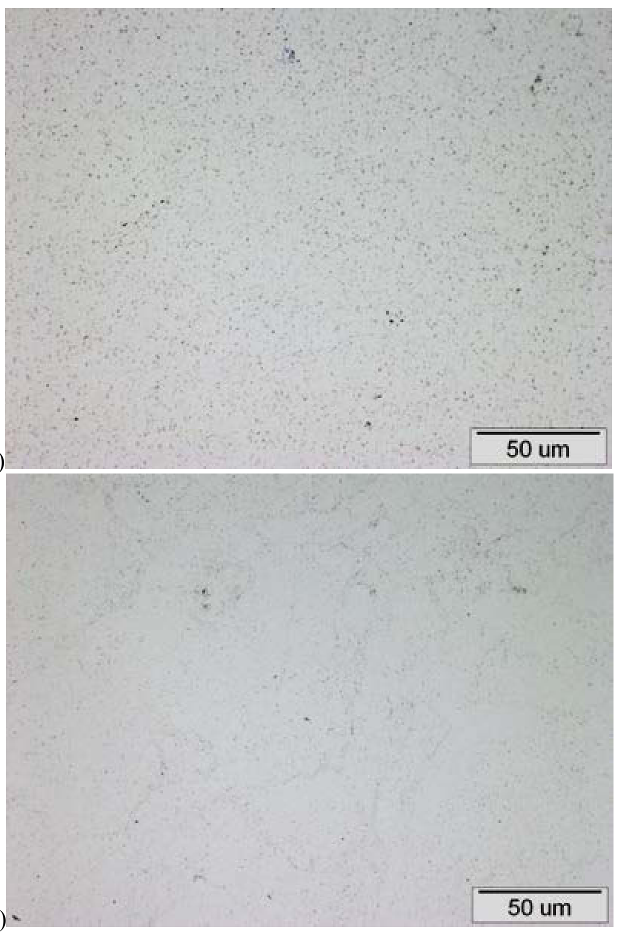

Fig.3 Microstructure of AlSi30 alloy consolidated by direct extrusion (a) and by CRE (b)

The scanning electron microscopy (Fig. 4,5) showed that both materials mainly contained the precipitates with Zn, Cu and Mg. Yet, while in the rods obtained by DE, those precipitates had the size of about 0.5 μm and were distributed along the grain boundaries, in rods obtained by CRE, a large number of the precipitates of the size of about 50-200 nm was located inside the grains.

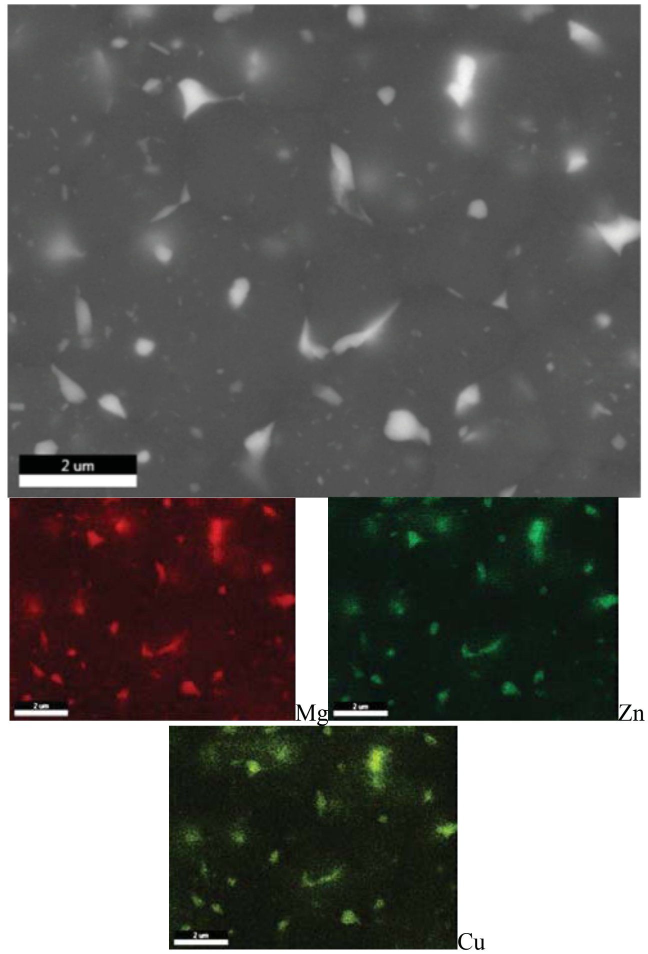

Fig.4 Microstructure of AlZn9 alloy after consolidation by direct extrusion with distribution of Mg, Zn and Cu

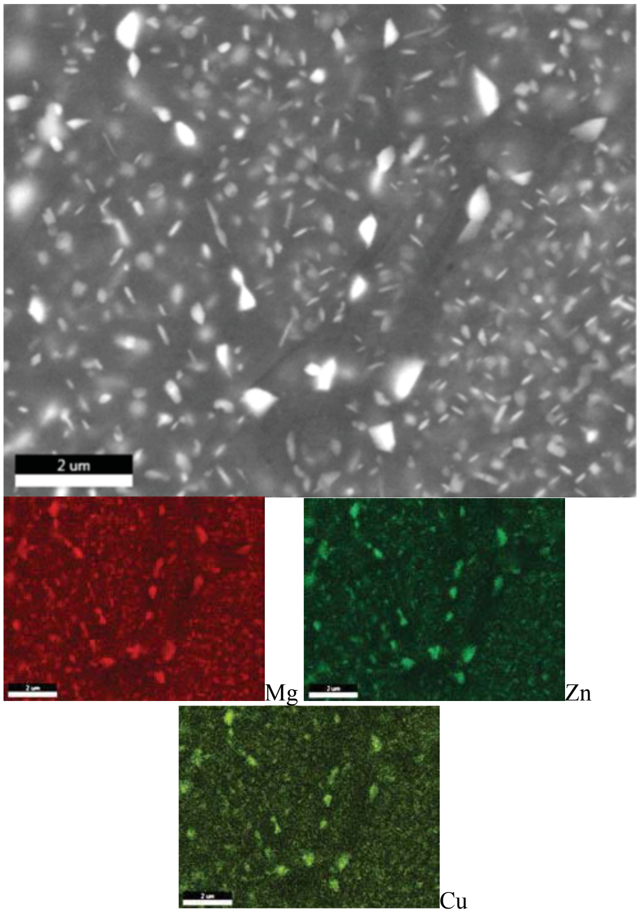

Fig.4 Microstructure of AlZn9 alloy after consolidation by CRE process with distribution of Mg, Zn and Cu

Studies by TEM confirmed the presence of very fine precipitates containing Mg, Zn and Cu in the material consolidated by CRE (Fig. 5,6). The measurement of particle size showed that in the material consolidated by DE, average grain size was about 2.8 µm, and in the material consolidated by CRE, the grain size was about 1.7 µm.

The properties of AlZn9 alloy determined in static tensile test and by hardness measurements are shown in Table 2.

Table 2. The properties of AlZn9

Consolidated by	Tensile Strength [MPa]	Yield Strength [MPa]	Elongation A_5 [%]	Hardness HBW
Direct Extrusion	405	250	17	106
Continuous Rotary Extrusion	379	248	12	104

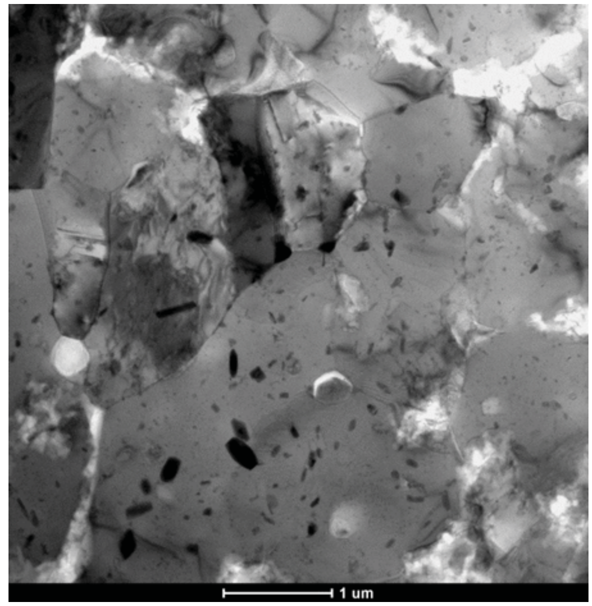

Fig.5 Microstructure of AlZn9 alloy after consolidation by direct extrusion

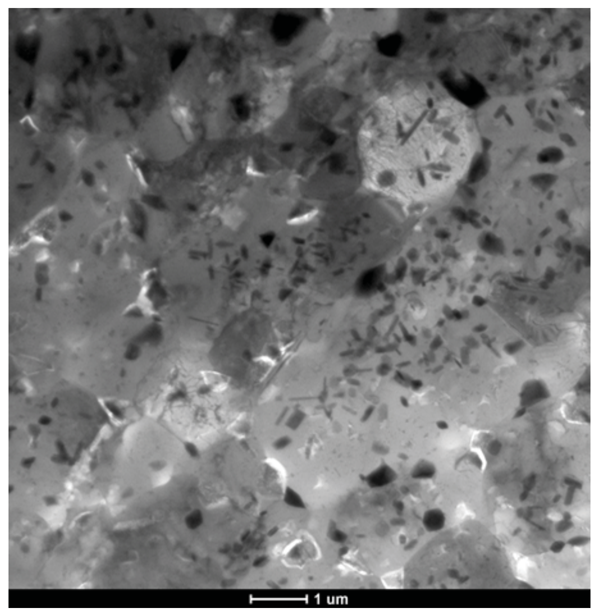

Fig.6 Microstructure of AlZn9 alloy after consolidation by CRE process

Summary

The application of melt spinning process to AlZn9 alloy, followed by consolidation in the direct extrusion process or by continuous rotary extrusion, gave the material with fine (approx. 0.5 µm) precipitates containing Al, Zn, Mg and Cu (the phases of Al_2Cu and $MgZn_2$) characterised by a uniform distribution in the matrix. The material consolidated by CRE showed inside the grains the presence of small (50-200 nm) precipitates of these phases, which may indicate its overaging. Both this fact as well as the size of grains in the material consolidated by CRE, which was smaller than in the material consolidated by DE, are probably the effect of a shorter duration of the impact of high temperature on the examined material, which for the CRE process did not have to be pre-heated, contrary to the case of direct extrusion. Lower values of the tensile strength and elongation obtained in the material consolidated by CRE were due to some defects caused by incomplete consolidation.

The difference in diameters obtained rods (8mm-DE and 15mm-CRE) should not be decisive for the resulting differences in the structure and properties of materials. Direct Extrusion and Continuous Rotary Extrusion are very different as a method of deformation processes that can be compared only on the structure and properties of the resultant products

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