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ALLOY ALSI30 CAST IN THE PROCESS OF RAPID SOLIDIFICATION AND CONSOLIDATED IN THE PROCESS OF PLASTIC FORMING

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Abstract

AlSi alloys with high Si content have good strength properties at elevated temperatures and resistance to thermal expansion. The main problem in the production of the classic methods of casting AlSi alloys with Si content above 20% is the formation of large precipitates of primary silicon. To prevent the formation of large precipitates of silicon can be used casting methods of rapid solidification and subsequent consolidation in the process of plastic forming. This paper presents the results of structure alloy AlSi30 cast in rapid solidification process on the wheel and consolidated in the process of extrusion and continuous rotary extrusion. The study was conducted on light microscopy and scanning electron microscope. It was found that the entire volume of the alloy is uniformly distributed fine Si particles.

Introduction

One of the methods to produce aluminium alloys of an uncommon composition and structure is by the combined process of casting with rapid solidification and the following plastic forming. [1]

When modern advanced methods of rapid cooling of the melt are used, the alloy structure solidifies as a powder in the atomiser or as ribbons when cast onto a rapidly rotating copper wheel. If optimum conditions for the process of casting and rapid consolidation are satisfied, it is possible to control some structure parameters like the size of the particles, the size of the precipitates, etc[2, 3]. Additionally, the production of aluminium alloys by rapid solidification allows introducing the alloying constituents that are incompatible with the state of equilibrium. The consolidation of material made by rapid solidification is achieved in one of the numerous variations of the plastic forming processes, among which the most commonly used are the direct extrusion and continuous rotary extrusion (CRE).[4-8]

AlSi alloys with high Si content are characterised by satisfactory mechanical properties at elevated temperatures and resistance to thermal expansion. The basic problem in the production of AlSi alloys with Si content above 20% by the traditional casting route is the formation of large primary silicon precipitates. To prevent this adverse phenomenon, casting by rapid solidification methods followed by consolidation in a plastic forming process can be applied.

This paper presents the results of examinations of the structure of an AlSi30 alloy cast in the process of rapid solidification by melt spinning and consolidated in the processes of direct extrusion and continuous rotary extrusion.

Methodology

Tests were carried out on an AlSi30 alloy of the composition given in Table 1 cast in the rapid solidification process by melt spinning.

Table 1 The composition of an AlSi30 alloy (basic elements)

El.	Si	Fe	Cu	Ni	Mg	Zn	Ti	Al.
[wt.%]	30,5	1,014	1,55	1,51	1,07	0,014	0,019	rest

The rapid solidification by melt spinning consists in pouring the molten metal onto a spinning copper wheel, providing very rapid heat transfer. The result is almost immediate solidification and metal leaves the wheel in the form of a thin ribbon (Fig. 1).

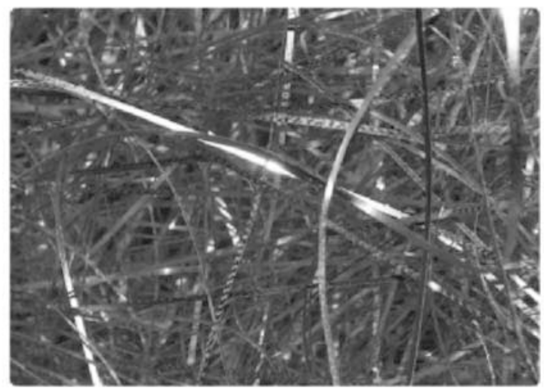

Fig. 1 A ribbon of AlSi30 alloy obtained by melt spinning

This ribbon is next cut into small chips in a special mill (Fig. 2).

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

Thus obtained material was next consolidated by direct extrusion and continuous rotary extrusion.

For the direct extrusion process, the material was first subjected to cold pre-consolidation in a tube made of a 6xxx alloy, to be next hot extruded in a 60Tz vertical hydraulic press with instrumentation adapted to the extrusion process. The process was carried out at 460°C and the extrusion ratio was λ = 14, the diameter of the extruded rod was ϕ = 8mm.

The continuous rotary extrusion (CRE) was carried out in an MC-260 device. The die temperature was about 350°C. The produced rod had a diameter ϕ = 15mm.

For microstructure examinations, an Olympus GX71 light microscope and a Philips XL30 scanning electron microscope with an attachment for the EDX chemical analysis in microregions were used.

The size of the crystallites was measured by Sherrer method using Bruker D8 Advance X-ray apparatus.

Results

Examinations have proved that, from the wheel side, the ribbon microstructure was characterised by the presence of a layer of the supersaturated AlSi solution. Moving away from the wheel, the supersaturated solution underwent decomposition and silicon precipitates in the form of rosettes started appearing, and then coagulated into particles of 1-3μm size (Fig. 3).

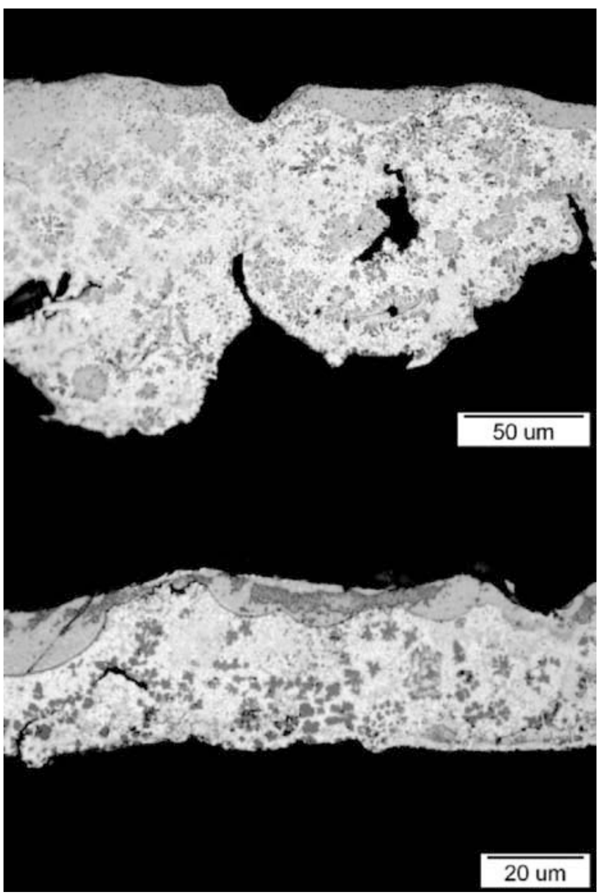

Fig. 3 Microstructure of AlSi30 alloy ribbon cast by melt spinning

Similar structure was observed in the ribbons cut into chips (Fig. 4).

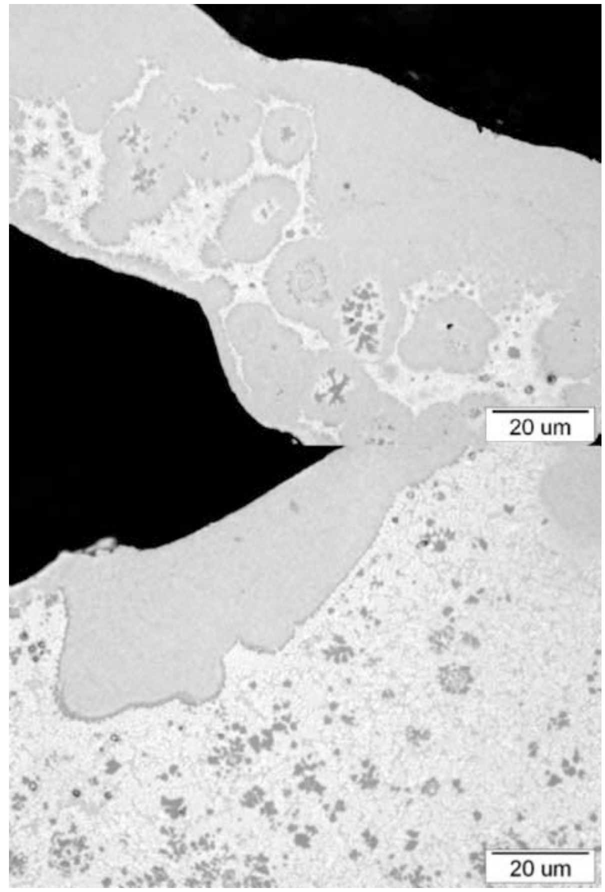

Fig.4 Microstructure of AlSi30 alloy chips

Examinations of the microstructure formed in rods obtained by direct extrusion have showed that the material consolidated by this method contained in prevailing part very fine precipitates of about 1 μm diameter (Fig. 5). On the other hand, in the material consolidated by CRE, a significant amount of precipitates with a diameter of less than 0.5 μm was found (Fig.6).

In both materials, a few areas appeared where the Si precipitates were of a size larger than 10 μm.

SEM examinations showed that the material consolidated by direct extrusion contained precipitates of two types, i.e. silicon precipitates and precipitates containing Fe, Ni and Cu (Fig. 7). The alloy matrix was mainly composed of Al with minor additions of the alloying elements. On the other hand, in practice, the material consolidated by CRE contained only the precipitates of Si, while Fe, Ni and Cu were mainly found in the matrix, where they appeared as a fine network of the spots locally enriched with these elements (Fig. 8).

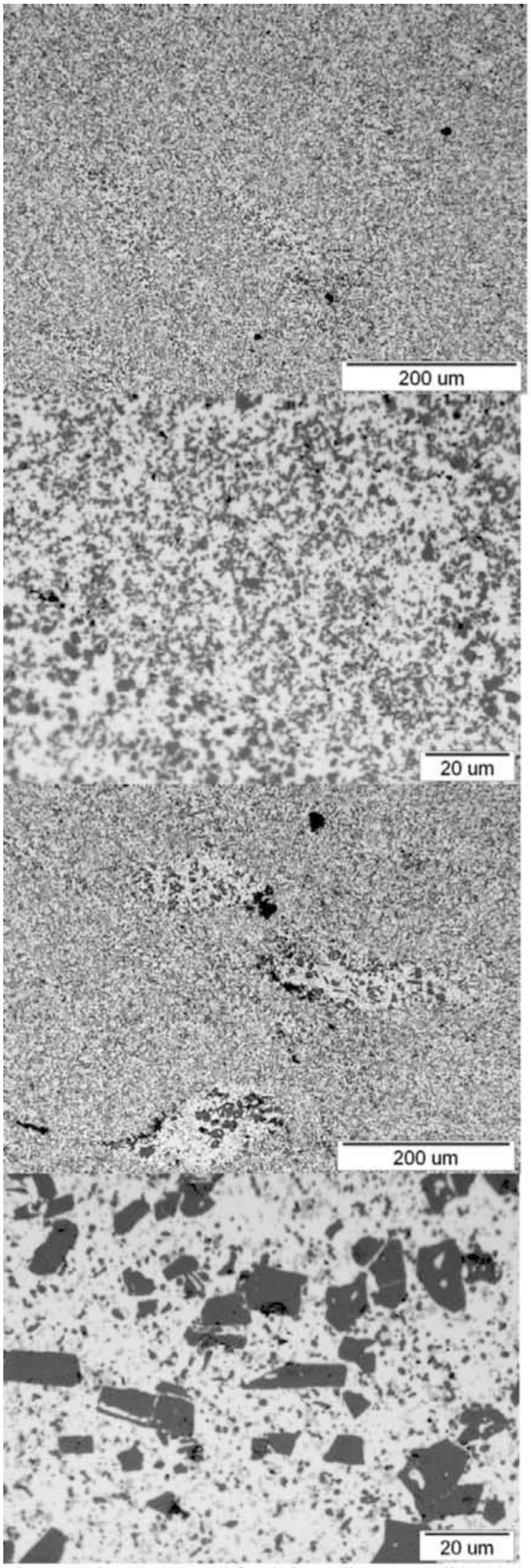

Fig. 5 Microstructure of AlSi30 alloy consolidated by direct extrusion

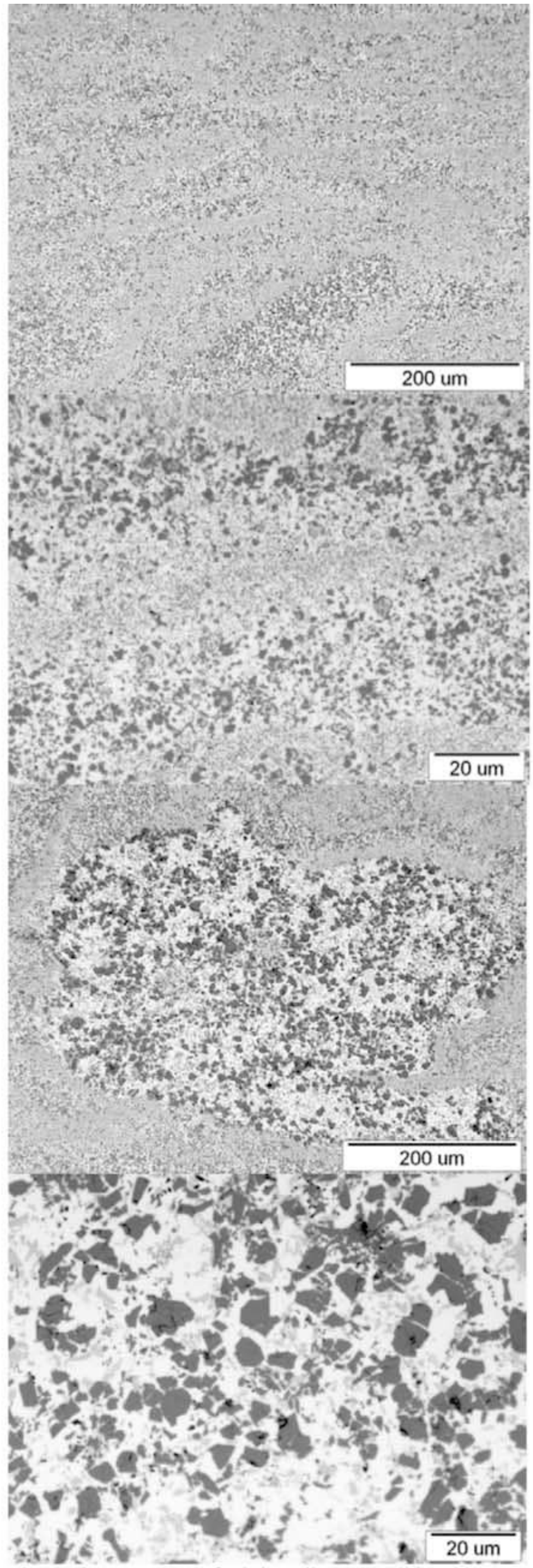

Fig.6 Microstructure of AlSi30 alloy consolidated by CRE

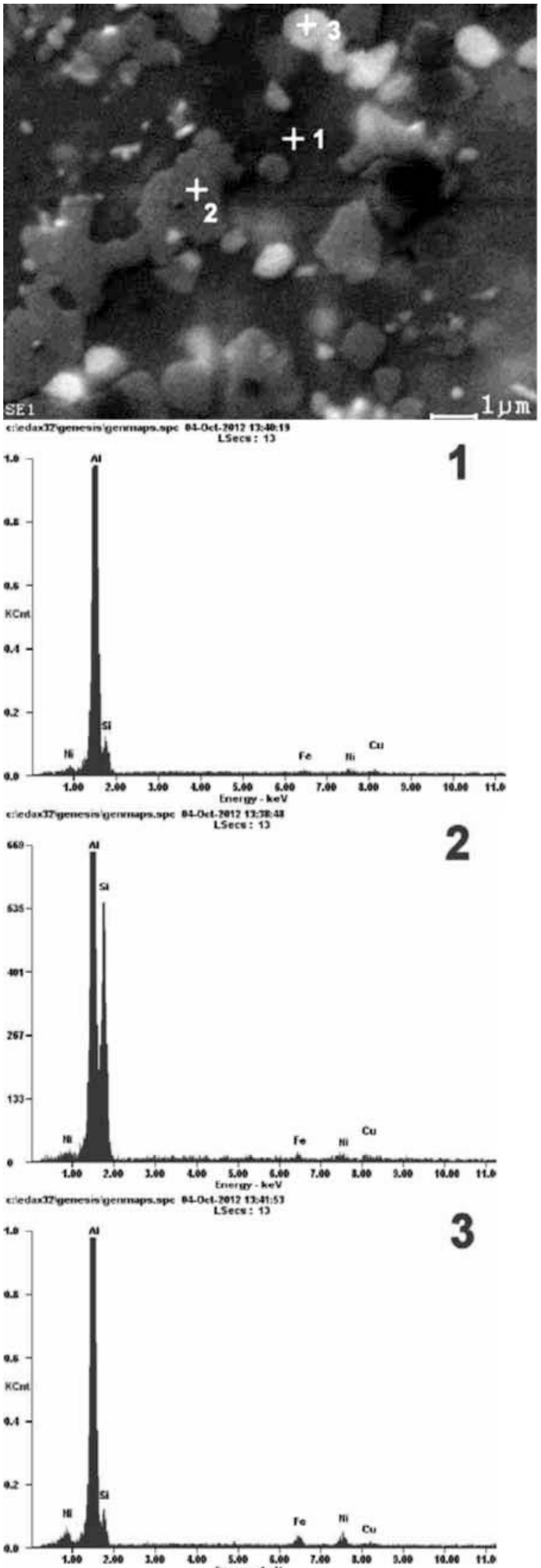

Fig.7 Microstructure of AlSi30 alloy after consolidation by direct extrusion with chemical analysis of the precipitates

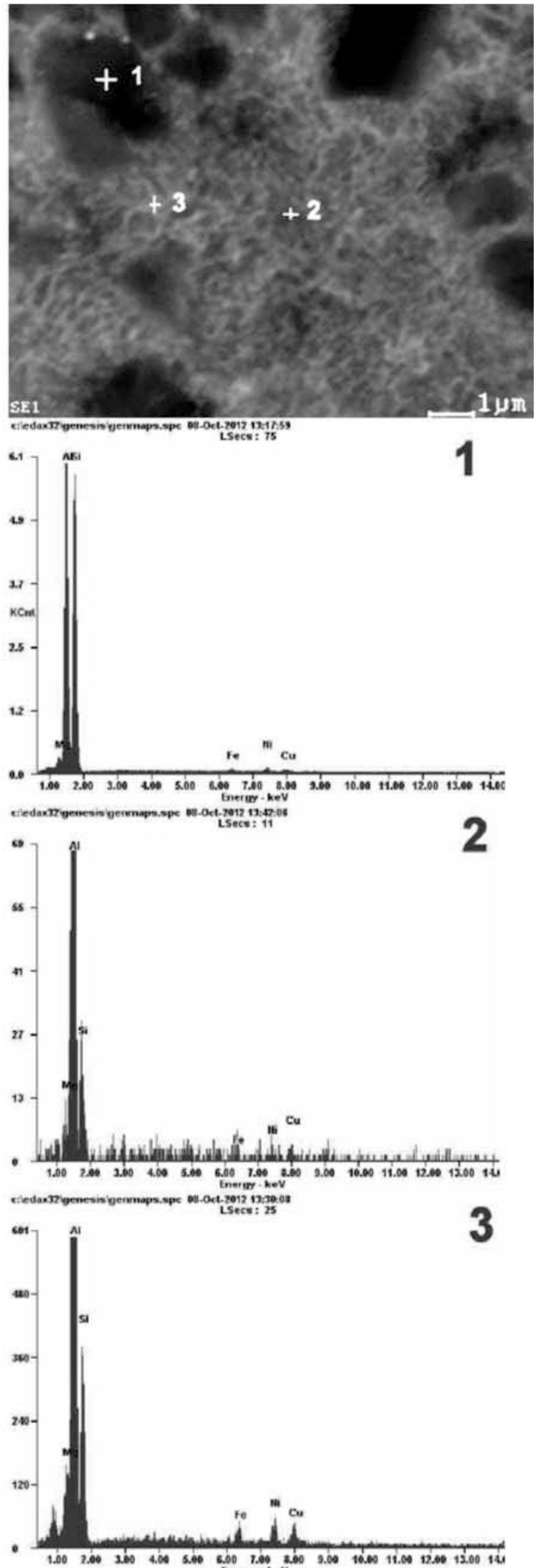

Fig.8 Microstructure of AlSi30 alloy after consolidation by CRE with chemical analysis of the precipitates.

The results of the measurements of the size of the crystallites done by Sherrer method are shown in Table 2.

Table 2 The results of the measurement of the size of crystallites

Material	Size of crystallites [μm]
Ribbons	1.233
Chips	1.346
Direct extrusion	6.273
CRE	0.808

Summary

The method of melt spinning applied to produce an AlSi30 alloy subjected next to the process of consolidation by direct extrusion or continuous rotary extrusion has yielded the material with fine Si precipitates of an average size of about 1 μm uniformly distributed in the matrix. The consolidation by CRE introduced only minor changes to the alloy microstructure compared with the consolidation by hot extrusion process. There was no formation of the precipitates of the phases containing Fe, Ni and Cu; only a network of areas enriched with these elements existed in the matrix. The crystallites did not grow in size, either. The reason was most probably the time of exposure to the effect of elevated temperatures, too short in the case of the material that did not have to be pre-heated for the CRE process, just opposite as it happened in the direct extrusion.

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