A R C H I V E S O F M E T A L L U R G Y A N D M A T E R I A L S
Volume 59 2014 Issue 1
DOI: 10.2478/amm-2014-0050

W. SZYMAŃSKI*, M. BIGAJ*, M. GAWLIK*, M. MITKA*, M. SZYMANEK*

CONSOLIDATION BY CONTINUOUS ROTARY EXTRUSION OF ALUMINIUM ALLOYS CAST BY THE MELT SPINNING PROCESS

KONSOLIDACJA W PROCESIE CIĄGŁEGO WYCISKANIA NA KOLE STOPÓW Al ODLEWANYCH METODĄ MELTSPINNING

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.

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. 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).

This paper presents the results of the consolidation in the process of continuous rotary extrusion (CRE) of selected aluminum alloys with an unusually high content of alloying elements cast in the process of rapid solidification by melt spinning and crushed in a high-speed cutting mill to as ”chips”.

Keywords: aluminium alloys, continuous rotary extrusion, melt spinning process

Jednym ze sposobów otrzymywania stopów aluminium o nietypowym składzie i strukturze jest połączenie odlewania metodą szybkiej krystalizacji z przeróbką plastyczną.

W przypadku zastosowania nowoczesnej metody szybkiego chłodzenia ciekłego metalu struktura stopu krystalizuje w postaci proszków w atomizerze lub w postaci tasiemki na szybko obracającym się miedzianym kole. Jeżeli spełnione są odpowiednie warunki prowadzenia całego procesu szybkiego odlewania i konsolidacji wtedy możliwa jest kontrola paramertów struktury takich jak wielkość ziarna, wielkość wydzieleń itp. Dodatkowo wytwarzanie stopów aluminium metodą szybkiej krystalizacji umożliwia wprowadzanie składników niezgodnych zestanem równowagowym. Konsolidację materiału otrzymanego w procesie szybkiej krystalizacji przeprowadza się w procesach przeróbki plastycznej, najczęściej stosowanymi są proces wyciskania lub proces ciągłego wyciskania na kole.

W pracy przedstawiono wyniki badań dotyczących konsolidacji metodą ciągłego wyciskania na kole (CRE) wybranych stopów aluminium o nietypowo wysokiej zawartości składników stopowych odlanych metodą szybkiej krystalizacji na kole (meltspinning) i rozdrobnionych w szybkoobrotowym młynku tnącym do postaci “chipsów” (płatków).

1. Introduction

One of the methods to make aluminium alloys with customised composition and structure is by the combined process of melt spinning and plastic working.

When the advanced methods for rapid cooling of the molten metal are used, the alloy structure either crystallises in an atomiser assuming the form of powder, or it assumes the form of ribbons when solidifying on a spinning copper wheel. If the conditions necessary for an effective performance of the rapid solidification and consolidation are duly satisfied, it becomes possible to control the structure parameters such as the grain size, the size of precipitates, etc. Additionally, the manufacture of aluminium alloys by the method of melt spinning allows introducing the alloying elements that would otherwise have been incompatible with the state of equilibrium. The consolidation of material produced by the melt spinning process is carried out in the processes of plastic working, among which the most commonly used is the ordinary extrusion process and its more advanced variation known as a continuous rotary extrusion.[1-8]

This study presents the results of research on the consolidation by continuous rotary extrusion (CRE) of selected aluminium alloys cast by the melt spinning technique and “chopped” in a high-speed cutting mill to form ”chips” or flakes.

The method of continuous rotary extrusion (CRE) is becoming more and more popular as a technique for metal

* INSTITUTE OF NON-FERROUS METALS LIGHT METALS DIVISION SKAWINA, 19 PILSUDSKIEGO STR., 32-050 SKAWINA, POLAND

processing, and this is mainly due to its high speed and efficiency. Obviously, the fact that feedstock preheating is carried out no longer must have an enormous impact on the cost-effectiveness of the whole process.

By CRE, products can be extruded from solid feedstock (rods) and bulk materials (powders, flakes). It is possible to apply continuous rotary extrusion to both solid profiles and hollow products like tubes made from metal alloys and bimetals [9, 10].

In continuous rotary extrusion, the processed material is introduced between the drive wheel and the extrusion deflecting element. The friction force at the material-tool interface advances the material into the deformation chamber followed by extrusion through the die orifice. Friction also causes gradual heating of feedstock, due to which the temperature proper for the extrusion process is obtained [11].

Schematic representation of the continuous rotary extrusion process is shown in Figure 1.

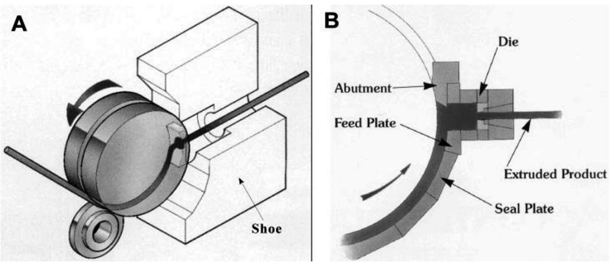

Fig. 1. The continuous rotary extrusion process CRE: A) general scheme, B) diagram of the extrusion process within the die area [2]

2. Methodology

Studies were carried out on AlZn9Cu1,8Mg2,5 (AlZn9) and AlSi30Cu1,5Mg1,2Ni1,5Fe0,8 (AlSi30) alloys cast by the melt spinning process.

The technique of melt spinning involves casting of molten metal onto a rotating copper wheel, which ensures rapid heat transfer. The result is an almost instantaneous solidification and metal leaves the wheel in the form of a thin ribbon (Fig. 2). This ribbon is then "chopped" in a special cutting mill to form fine flakes (chips) (Fig. 3).

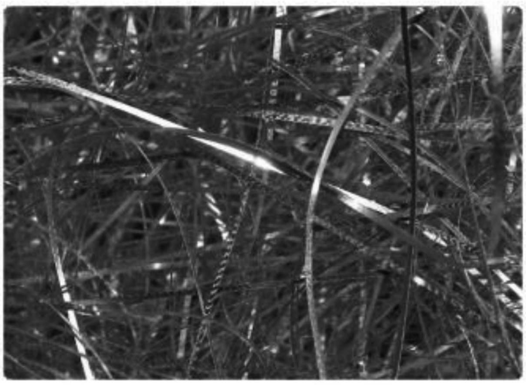

Fig. 2. Ribbon obtained by melt spinning

Fig. 3. Ribbon "chopped" into flakes in a cutting mill

Thus obtained material is next subjected to consolidation in a continuous rotary extrusion process.

The continuous rotary extrusion was carried out in an MC-260 device (Fig. 4). The die temperature was 300°C for AlZn9 alloy and 400°C for AlSi30 alloy. From both alloys, rods with a diameter of φ = 15 mm were made.

Fig. 4. View of the MC-260 device for continuous rotary extrusion made by Meltech-Confex Limited operating at IMN-OML

The extrusion process was carried out with the use of a clamping element for the pre-compaction of chips in the groove of the extrusion wheel (Fig. 5).

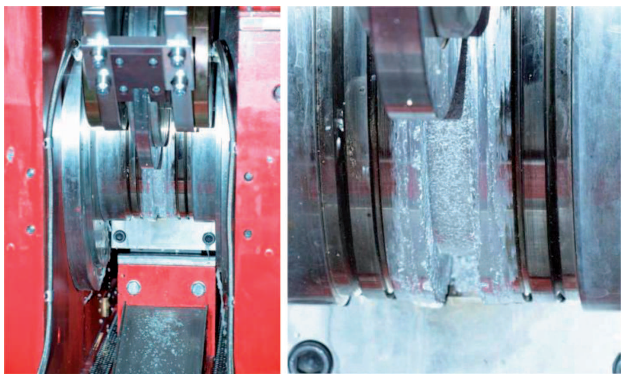

Fig. 5. Clamping element for the pre-compaction of chips in the groove of the extrusion wheel

Microstructure was examined under an Olympus GX71 light microscope and Philips XL30 scanning electron microscope with an attachment for the EDX chemical analysis in microregions.

3. Results

Microstructure examinations showed that the AlSi30 alloy ribbon had a layer of supersaturated solution of AlSi on the wheel-touching ribbon side. With the increasing distance from the wheel, the supersaturated solution was undergoing decomposition and silicon precipitates started emerging in the form of rosettes, to coagulate next and form particles of 1-3 μm size (Fig. 6).

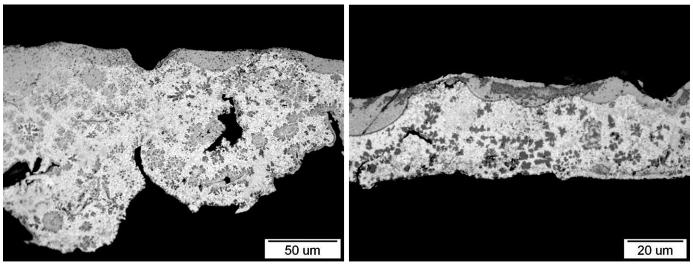

Fig. 6. Microstructure of a ribbon made from the AlSi30 alloy cast by melt spinning

A similar structure was observed in the ribbons "chopped" into flakes (chips) (Fig. 7).

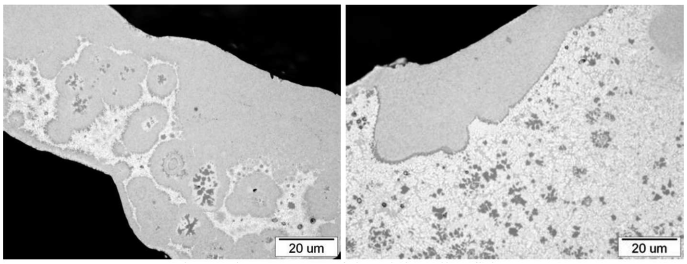

Fig. 7. Microstructure of the AlSi30 alloy flakes

On the other hand, detailed examinations of ribbons and flakes made from the AlZn9 alloy showed the presence of small amounts of the very fine precipitates (Figs. 8 and 9).

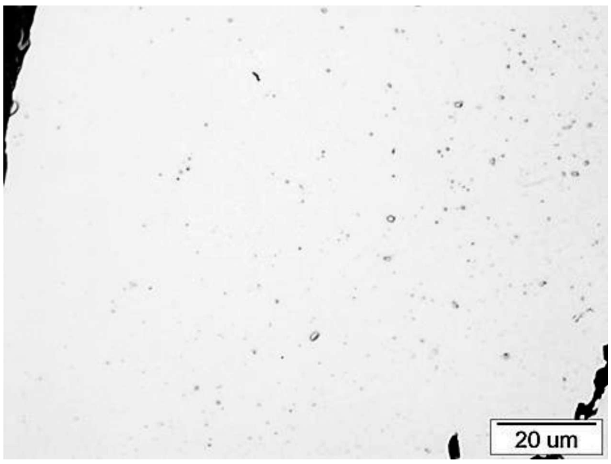

Fig. 8. Microstructure of a ribbon made from the AlZn9 alloy cast by melt spinning

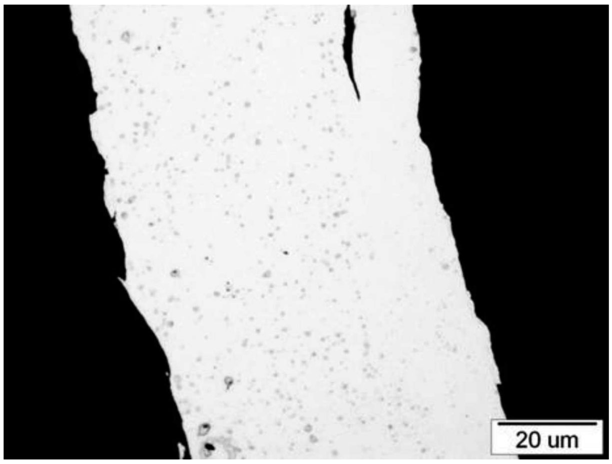

Fig. 9. Microstructure of the AlZn9 alloy flakes

Examinations of microstructure of the AlSi30 alloy rods consolidated by CRE showed the presence of Si precipitates with a diameter of less than 0.5 μm; scarce areas were also noted where the Si precipitates had the size larger than 10 μm (Fig. 10). The examinations by scanning electron microscopy showed only the presence of Si precipitates. The precipitates of Fe, Ni and Cu were mainly found in the matrix, where they were forming a fine network of spots rich in these elements (Fig. 11).

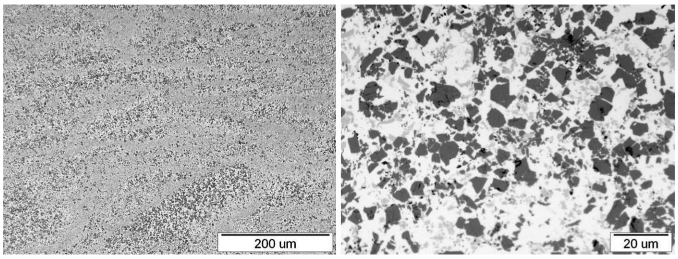

Fig. 10. Microstructure of the AlSi30 alloy rod consolidated by CRE

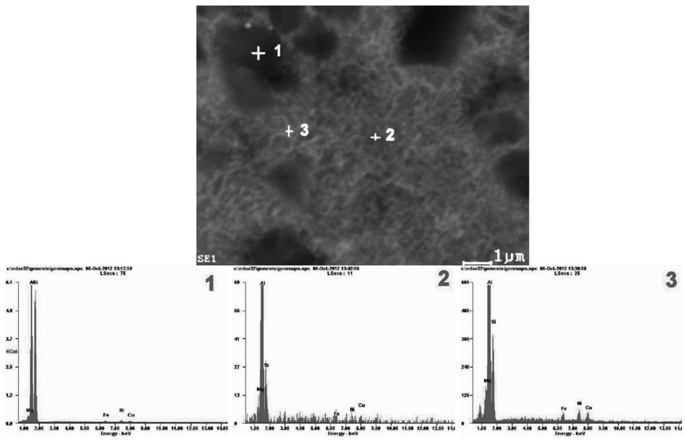

Fig. 11. Microstructure of the AlSi30 alloy rod consolidated by CRE and chemical analysis of the precipitates

Examinations of the microstructure of rods made from the AlZn9 alloy showed only a fine network of the precipitates and some spots where the remaining flake boundaries with the oxidised surfaces were visible (Fig. 12).

Observations by scanning electron microscopy revealed the presence of Zn, Mg and Cu in the precipitates (Figs. 13 and 14).

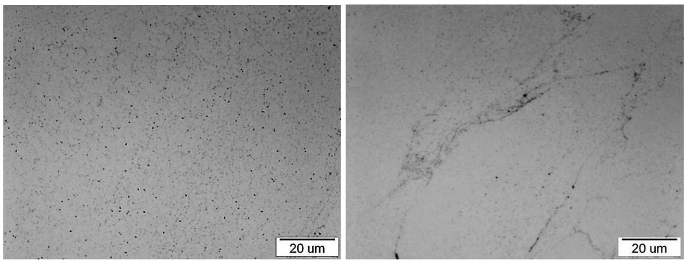

Fig. 12. Microstructure of the AlZn9 alloy rod consolidated by CRE

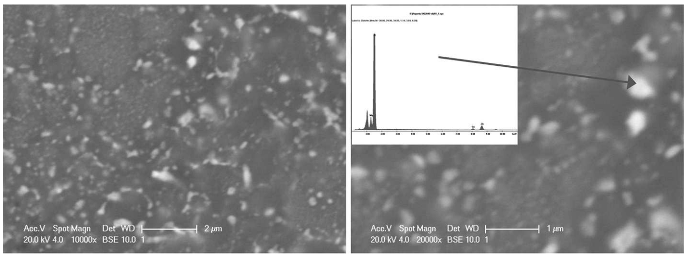

Fig. 13. Microstructure of the AlZn9 alloy rod consolidated by CRE and chemical analysis of the precipitates

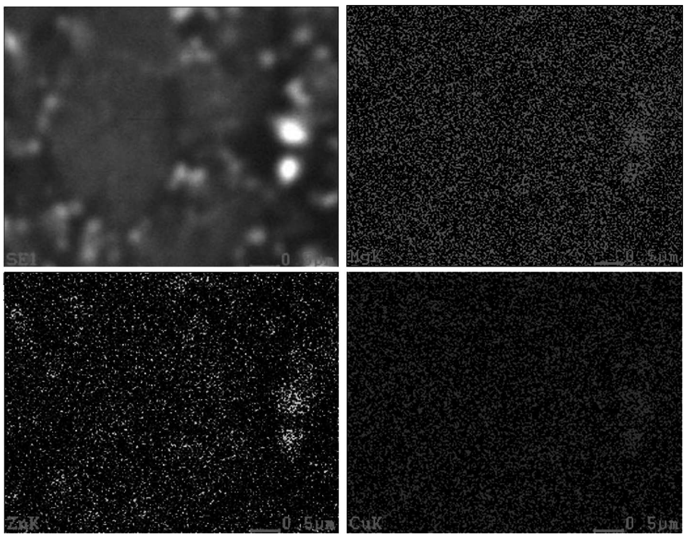

Fig. 14. Surface distribution of Mg, Zn, and Cu in the AlZn9 alloy rod consolidated by CRE

4. Summary

The process of continuous rotary extrusion allows a relatively rapid consolidation of materials in powder form. Compared to the consolidation by traditional extrusion process, it enables effective elimination of such process steps as pre-consolidation (densification) and preheating of the feedstock.

Alloys obtained by the melt spinning process with the following consolidation in the process of continuous rotary extrusion have fine-grained structure with a characteristic network of small-size precipitates inside the grains. This proves that the time of the exposure of the processed material to the effect of high temperature during the consolidation process has been considerably reduced. Absence of large silicon precipitates in the structure of AlSi30 alloy allows further mechanical processing of this alloy, e.g. by forging, whereas the uniform distribution of the alloying elements in grains, assuming the form of spots with a high content of these elements, promises satisfactory results during heat treatment.

Material of this composition and structure can not be obtained by the common process of casting and plastic working. [10, 11]

REFERENCES

[1] L. Katgerman, F. Dom, Rapidly solidified aluminium alloys by meltspinning, Mat. Sc. Eng **A375-377**, 1212-1216 (2004).

[2] Grant EP/E040608/1 "Development of Bulk Nanostructured Aluminium Alloys for High Strength Applications" (University of Oxford) Ol. Juli 2007- 31 December 2010.

[3] B. Pucun, Microstructure and mechanical properties of a large billet of spray formed AlZnMgCu alloy with high Zn content Mat. Sc. Eng 2009.

[4] F. Palm, Hypereutectic high Strength AlMgSc profile materials Melt- spun Scalmalloy- a new family of weldable and corrosion free Al alloys with 500- 850 MPa strength Aeromat 2006 15-18 th of May 2006. Seattle. Washington. USA.

[5] A.J. Bosch, R. Senden, W. Etelmann, F. Palm, Nanostructured and High Strength Alloys: Scamalloy- a Unique High Strength and Corrosion Insensitive AlMgScZn Material Concept Aluminium Alloys Their Physical and Mechanical Properties, Vol 1 Edited by Jürgen Hirsch Wiley- VCH 2008.

[6] F. Wang, B. Xiong, Y. Zhang, Microstructure and mechanical properties of spray-deposited Al-Zn-Mg-Cu alloy Materials dand Design **28**, 1154-1158 (2007).

[7] A. Inoue, H. Kimura, Fabrication and mechanical properties of bulk amorphous, nanocrystaline, anaoquasicrystalline alloys in aluminium-based system, Journal of Light Metals **1**, 31-41 (2001).

[8] P.M. Thomas, Conform- the use of alternative feedstock materials, APT Aluminium September 2004.

[9] M. Szymanek, W. Szymański, B. Augustyn, D. Kapinos, The production of wrought AlSi30Cul.5Mgl.2Nil.5Fe0.8 alloy with ultrafine structure, Light Metals, pp. 521-527 (2013).

[10] W. Szymański, M. Szymanek, J. Żelechowski, M. Bigaj, M. Gawlik, B. Płonka, Alloy AlSi30 cast in the process of rapid solidification and consolidated in the process of plastic forming, Light Metals, pp. 333-337 (2013).

[11] M. Mitka, W. Szymański, Próba ciągłego wyciskania na kole materiałów litych i sypkich, Rudy i Metale Nieżelazne **56**, 405-411 (2011).

Received: 10 May 2013.