TEXTURES OF ALUMINUM ALLOY THIN SHEETS FOR HEAT EXCHANGER FINS

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Abstract

Texture analysis of different sheets from Al1.5FeMnSi (AA 8006) and AlFeSi (AA 8011) alloys was carried out in order to compare textures of materials for heat exchangers fabricated by several producers and by different technologies. The textures were determined by X-ray back reflection goniometric method using SIEMENS diffractometer. A majority of samples exhibit recrystallization R-texture, remaining sheets have a cubic texture or a combination of both texture types. Several samples, fabricated by different technologies, have a texture of the same type. Consequently it is not possible to predict the type of the texture from the technology of casting and downstream processing.

Keywords

Al1.5FeMnSi alloy, AlFeSi alloy, twin-roll casting, direct-chill casting, texture analysis

1. Introduction

Fins in air-conditioners, cooling systems or car radiators are fabricated from aluminium alloy sheets 0.10 to 0.25 mm thick. Having a complex design with collars up to 12 mm high the fins are formed in several operations by deep drawing and/or ironing 1 in a step-by-step process with the tool working at a frequency of approximately 200 strokes per minute. Highly formable material is thus required and the sheets are often delivered in the O and H22 tempers. The formability of sheet materials depends on the production technology used. Highly formable sheets are produced by direct-chill (DC) casting and hot rolling. However, the technology of continuous twin-roll casting (TRC) and cold rolling offers important economical advantages - low capital investment, savings in energy and low operational costs [2]. The TRC route also offers some metallurgical advantages higher solidification rates result in a refined microstructure characterized by fine dendritic cells and smaller primary particles, in an increase in solid solubility and in the formation metastable phases [3]. Research and development are undertaken to optimize the downstream processing of the twin-roll cast material and to obtain favorable structure and properties of AA 8006 and AA 8011 thin sheets during deep drawing operations. Formability and plasticity of the material depends also on the texture. The purpose of this paper is to compare textures of the final gauge material fabricated by different technologies.

2. Materials and procedures

Al1.5FeMnSi (AA 8006) and AlFeSi (AA 8011) alloys sheets, 0.10 to 0.18 mm thick, destinated for the fabrication of the lamellae of heat exchangers, were produced mostly by twin-roll casting (TRC) and cold rolling. Nominal compositions of the alloys are in Table 1. A majority of samples were fabricated by two producers of aluminium alloy thin sheets - Aluminium Works Břidličná (AWB), Czech Republic, and ASSAN Aluminium, Tuzla-Istanbul, Turkey. Aluminium Works Břidličná uses twin-roll casters Pechiney, casting at 8.4 mm thickness, while ASSAN Aluminium uses speed twin-roll casters Fata-Hunter, where the casting thickness ranges from 6 mm down to 3 mm or less. Furthermore, two samples produced by a traditional technology of direct-chill (DC) casting and hot and cold rolling were examined as a reference material.

The textures were determined by the X-ray back reflection goniometric method on a SIEMENS texture goniometer, using Co-Kα radiation. The orientation distribution functions (ODF) were calculated from three partial pole figures {111}, {100} and {110}, with the aid of the software package POPLA [5]. The ODF functions are graphically represented in the sections of Euler space for the angle ϕ_2 = 0, 5, 10, ..., 85, 90° and also in a standard stereographic projection SP(001) [6].

ODF representation in the stereographic projection SP(001)

The ODF is calculated by the software POPLA as a function of Euler angles ϕ_2,Φ,ϕ_1 in the sampling of 5 degrees. These angles define a general ideal orientation of a monocrystal (*hkl*)[uvw]. The pole of the planes (*hkl*) is determined by the angles ϕ_2 and Φ, the pole of the direction [uvw] is situated on a corresponding grand circle determined by the angle ϕ_1. The positions of the poles (*hkl*) and [uvw] in the standard stereographic projection are calculated from the ODF function with the aid of software ODFSP1.EXE [6], and symbols corresponding to the ODF intensity are drawn in the SP(001) plot. The poles (*hkl*) represented by lozenges are situated in the quadrant IV and the

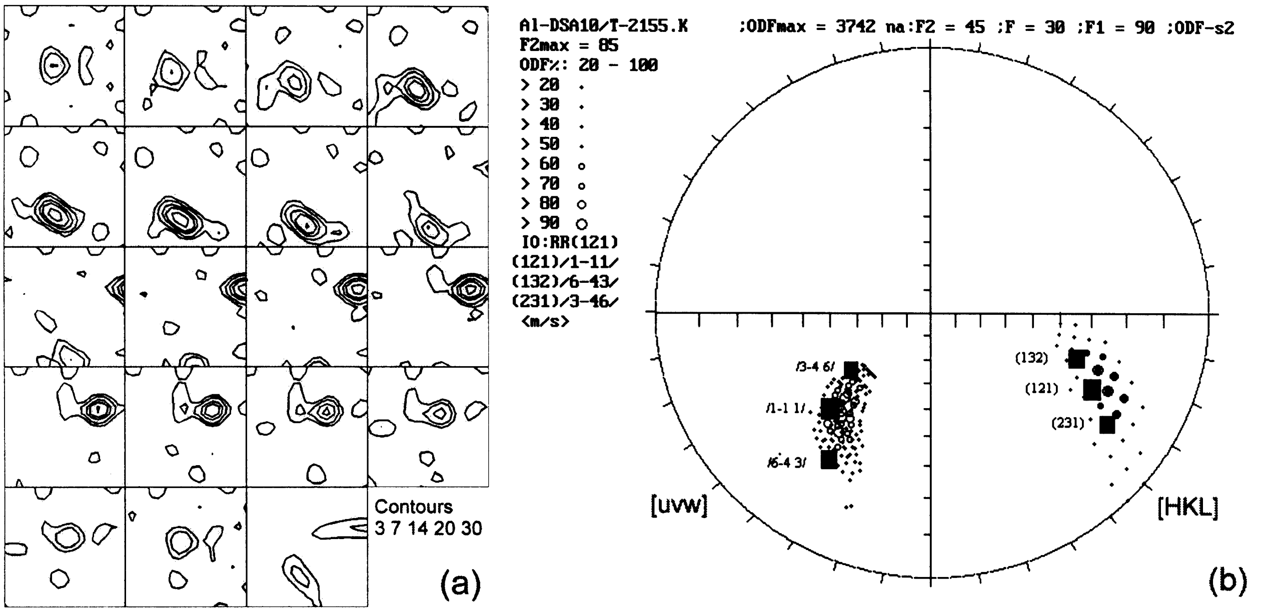

Figure 1. Typical R-texture of the sample DSA 10: (a) ODF sections in the Euler space, (b) standard stereographic projection representation.

poles [*uvw*] represented by squares are drawn in the quadrant III (Figs. 1b, 2b). The size of the symbol corresponds to the relative value of ODF intensity in %. The software enables also to superimpose an ideal orientation over the experimental ODF projection.

3. Results

Analyzed samples are listed in table 2 together with the basic material and texture characterization. According to the texture it is possible to divide samples into three groups:

i) Sheets Alcan, D215, FAF1, Z54, DSA10 and DF12 exhibit an R-texture with a similar course of the maximum intensities f(g) along β-fibre, with a dominant orientation (113)[332].

ii) Sheets DS18, DST18 and FZ018Z3 have a more or less pronounced cubic texture. The most pronounced cubic texture has the sample FZ018Z3 and the less pronounced cubic texture has the sample DST18, fabricated by ingot casting and hot and cold rolling. (See also maximum values of f(g) in table 2).

iii) Texture of the sheet F018Z3 is a combination of an R-texture and a cubic texture.

Samples DSA 10 (Fig. 1) and FZ018Z3 (Fig. 2) were selected as typical representatives of the R-texture and cubic texture, respectively. Figs. 1a and 2a show ODF plots in the sections of the Euler space, Figs. 1b and 2b give an SP(001) ODF representation. In Figs. 1a and 2a, only higher intensity contours are drawn to ensure clearness of the figure. Similarly, in Fig. 1b and 2b only intensities greater than 20% ODF_{max} are used. Smple DSA10 has a typical R-texture, in the SP(001) ODF representation it is possible to find an ideal orientation (123)[$63\bar{4}$] (R-texture) and also orientation (112)[111]. On the other hand in the sample FZ018Z3 a strong cubic texture (001)[100] with ODF_{max} = 27 predominates. Its position is in the center of the SP(001) projection. A second weaker texture with an intensity of 20 to 30% of ODF_{max} is close to the orientation (123)[$63\bar{4}$] (R-texture).

Fig. 3 compares differences in the textures of samples showing recrystallization R-texture and mixed recrystallization + cubic textures in plots of intensities f(g) along the β-fibre [8], connecting copper (112)[111] and brass (011)[211] type ideal texture orientations in Euler space [7]. The remaining sheets with cubic texture (DS18, DST18, FZ018Z3) were not included, because they do not show important values of intensity along β-fibre.

4. Discussion

An advantage of the ODF representation in a SP(001) projection is that the texture can be easily interpreted by superimposing the SP(001) projection (as overlay) with the poles of the standard stereographic projection.

Since the textures are different, a different formability and plasticity of the material could be expected. On the other hand the compared materials were fabricated by different technologies (different alloys, with and without homogenization, ingot casting - twin-roll casting - speed casting, final heat treatment to the O or H22 temper) and in many cases they have a comparable texture. So it is not possible to predict the type of the texture from the technology of casting and downstream processing. Perhaps only in the case of the materials subjected in the downstream processing to an additional recrystallization annealing (sample FZ018Z3) one can expect a cubic texture.

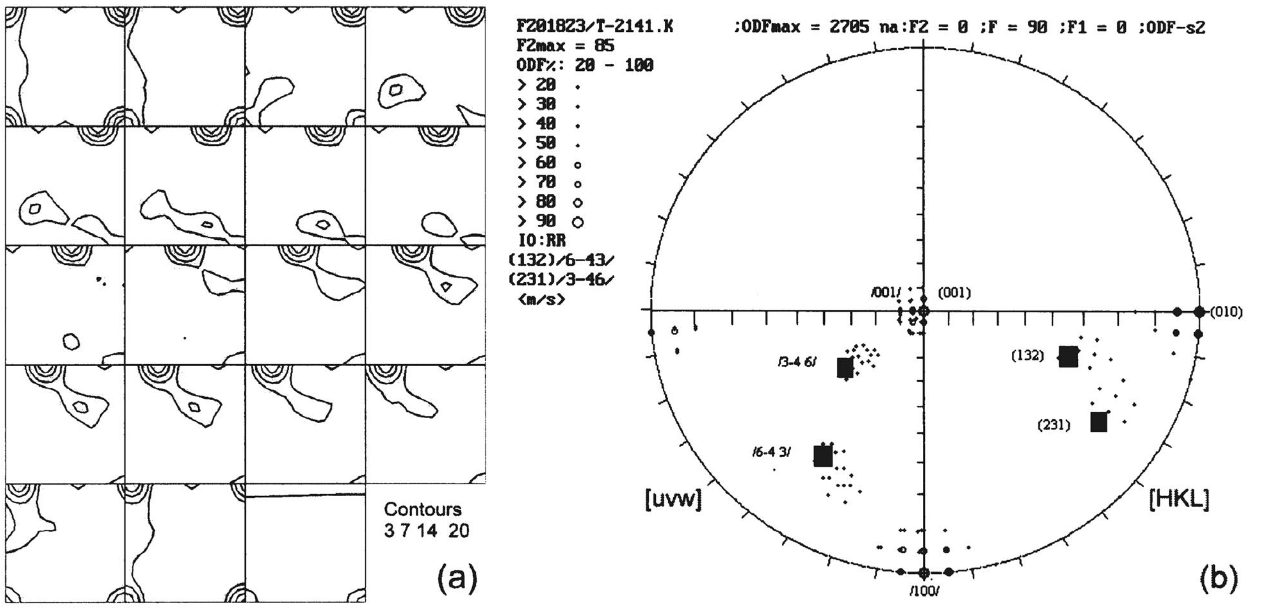

Figure 2. Typical cubic texture of the sample FZ018Z3; (a) ODF sections in the Euler space, (b) standard stereographic projection presentations.

One of the samples fabricated by DC casting and hot and cold rolling exhibits an R-texture, the other one a combination of a cubic and a Goss texture.

5. Conclusion

1) A majority of thin sheets from AA 8006 and AA 8001 aluminium alloys exhibit R-texture, remaining materials have a cubic texture or a combination of both texture types.

2) In many cases materials produced by different technologies exhibit a comparable texture. Consequently is not possible to predict the type of the texture from the technology of casting and downstream processing.

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Table 1. Nominal chemical composition of studied alloys (wt%) [4].

	Fe	Mn	Si	other	Al
AA 8006	1.40 - 1.60	0.35 - 0.40	0.15 - 0.20	< 0.04	balance
AA 8011	0.65 - 0.86	-	0.62 - 0.67	< 0.05	balance

Table 2. List of analysed samples with their basic structure and texture characterization.

* ingot cast + hot + cold rolled material, O – soft temper, H22 – quarter-hard temper, R-texture – recrystallization texture $(123)[63\bar{4}]$, G-texture – Goss texture (110)[001], RG-texture – rotated Goss texture $(011)[01\bar{1}]$

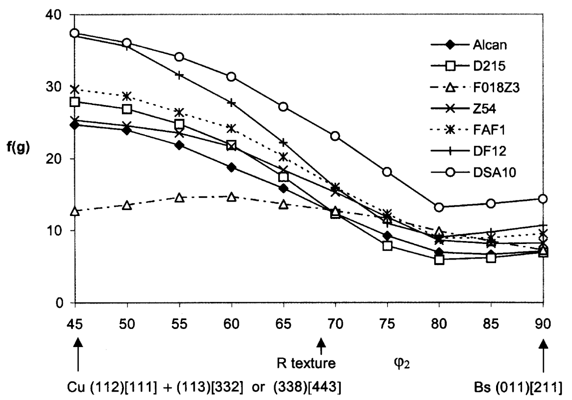

Figure 3. Comparison of the maximum intensity f(g) along β-fibre for the sheets with *R*-texture