TEXTURE ANALYSIS OF A COARSE GRAINED FE$_3$AL CAST ALLOY BY NEUTRON SCATTERING

MAX-PLANCK PROJECT REPORT

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INTRODUCTION

Sheet material of alloys based on the intermetallic Fe_3Al phase is promising material for high temperature application. They are produced from a cast ingot by thermomechanical processing. During the whole process the material exhibits a rather inhomogeneous microstructure and texture. The recrystallized material shows large elongated grains of rotated cube {001}<110> texture component which are surrounded by small equiaxed grains of typical recrystallized rolling texture (Kobayashi et al. Proc. ICSMA13, 2003).

The rotated cube component is inherited from the cast material because it is stable during rolling as well as during recrystallization. Controlling the crystallographic texture of the as cast Fe_3Al alloy may thus be an adequate method to optimize the microstructure and texture of the final sheet material. Due to the large grain size of Fe_3Al cast alloys conventional techniques of crystallographic texture analysis by x-ray or electron diffraction techniques show a lack of statistical confidence because of limited sample areas and small number of grains analyzed. Texture analysis by neutron scattering provides a better statistical confidence because of the high penetration power of neutrons which allows to investigate the texture of large bulk samples providing an order of magnitude higher number of analyzed grains. The texture measurements were accomplished in a cooperative work with the neutron texture diffractometer TEX-2 team at the FRG-1 neutron source of GKSS.

EXPERIMENTAL

The binary Fe_3Al alloy (26 at.% Al) was produced in a vacuum induction furnace and cast under vacuum into a cold copper mould that was placed on a massive copper base. The ingot had the dimension of 87x30x205 mm^3.

Micrographs of the sampling sites were prepared by grinding, polishing and etching to give an overview of the grain structure. Sample cubes of the dimension 10 mm^3 were cut from sites representing typical areas of the cast microstructure. The positions are indicated in Fig.1 and 2.

The texture of the samples was investigated by measuring the (111), (200) and (220) pole figures using the TEX-2 neutron diffractometer at the FRG-1 neutron source.

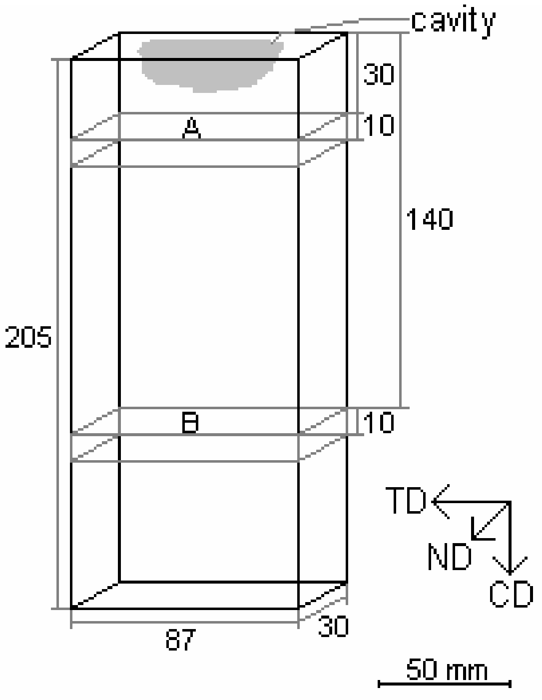

Fig. 1: Sampling sites A and B

RESULTS

The micrographs in Fig. 2 show the two sections of the ingot. The grain structure in the upper part of the ingot reveals mainly two zones with different grain morphologies: A zone of 5 to10 mm thickness built up by columnar crystallites that grew radially from the walls towards the center (a) and a large area of medium sized globular crystallites in the center (b). In the lower part this large central area does not appear. Besides small deranged areas (b) the columnar area occupies almost the whole visible sample plane.

The results of the texture analysis are also shown in Fig 2 in form of (111) and (200) pole figures. In cut A the areas 2 and 4 show clear <100> fiber textures with the fiber axes lying parallel to the long axis of the crystals in these areas. Sample A3 consisting of grains with circular intersections shows an almost random texture. However, also here a slight <100> fiber texture with the fiber axis parallel to the cast direction is visible. In the lower part of the cast block, cut B, the samples 2 and 3 show a <100> fiber textures with the fiber axis parallel to the growth direction. In contrast, sample B4 reveals a strong cube texture {001}<100>.

DISCUSSION

The observed textures can be assigned to the respective grain morphologies. The longitudinal axis of the columnar grains correspond in all cases to the <100> fiber axis of the texture. Columnar grains emerge from the sites of preferred nucleation at the cold mould walls and grow into the direction of the highest temperature gradient. The fact that this preferred growth direction coincides with the <100> direction of the crystals shows that <100> is the direction of highest growth rate in this material. The texture can thus be interpreted in terms of a growth selection process: Random nucleation takes place at the mould walls. This is visible from the high number of smaller grains immediately at the walls. During the subsequent solidification a selective growth of grains having their <100> crystal direction parallel to the highest temperature gradient occurs. In the lower part of the cast block the heat flux is sufficient for an almost complete directional solidification. In the case of sample B4 the heat flux from both sides superimposes thus creating two preferred growth directions resulting in the cube texture of this sample. For the upper part the resulting cooling rate is lower and parts of the melt in the centre of the mould crystallize by nucleation in the melt and grow almost undirected. However, the slight <100> fiber texture indicates that also here a preferred temperature gradient exists in casting direction. The cooling conditions generated by casting into a cold copper mould lead to an inhomogeneous grain structure and a pronounced crystallographic texture. The microstructure and texture is governed by preferred <100> crystal growth into the directions of highest heat flux at different positions in the mould. If the cast material is subsequently rolled in casting direction the solidification texture provides a strong rotated cube component for the start material which is inherited through the different process steps all the way into the final material.

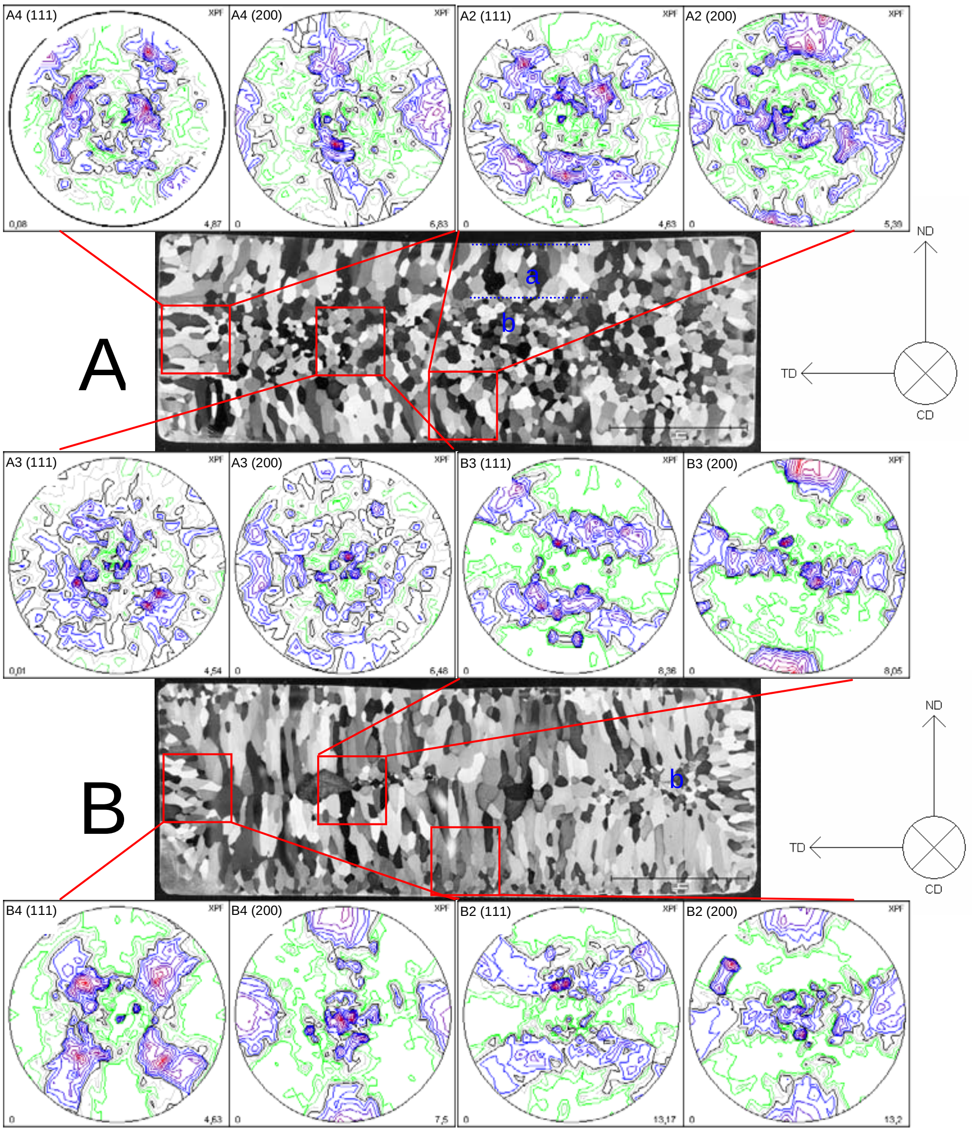

Fig. 2: pole figures and corresponding micrographs of the sample sites (samples are 1 cm³ cubes)