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Formation of a single, rotated-Brass {1 1 0}⟨5 5 6⟩ texture by hot cross-rolling of an Al–Zn–Mg–Cu–Zr alloy

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The present work describes the evolution of a strong, single-component rotated-Brass ({1 1 0}⟨5 5 6⟩) texture in an Al–Zn–Mg–Cu–Zr alloy by an uneven hot cross-rolling with frequent interpass annealing. This texture development is unique because hot rolling of aluminum alloys results in orientation distribution along the "β-fibre". It has been demonstrated that the deformation by cross-rolling of a partially recrystallized grain structure having rotated-Cube and Goss orientations, and the recrystallization resistance of near-Brass-oriented elongated grains play a critical role in development of this texture.

Keywords: Aluminum alloys, Hot rolling; Crystallographic texture; X-ray diffraction (XRD)

The evolution of texture during hot deformation of aluminum alloys has been studied extensively over the past two decades with the aim of characterizing and controlling the texture components [1–3]. Depending on the alloy composition, the rolling temperature and the mode of deformation, various texture components, such as copper (Cu)-{1 1 2}⟨1 1 1⟩, Brass (Bs)-{1 1 0}⟨1 1 2⟩, S-{1 2 3}⟨6 3 4⟩, Cube-{1 0 0}⟨0 0 1⟩ and Goss (G)-{1 1 0}⟨0 0 1⟩ are formed. During hot rolling, the texture development of aluminum alloys can adequately be described by β-fibre orientation distribution spanning the four major components, namely Cu, S, {168}⟨211⟩ and Bs [3]. During hot rolling, the strength of the Bs component increases with increasing extent of deformation as well as rolling temperature [2]. In cases where dynamic recrystallization occurs during hot deformation, a Cube-{1 0 0}⟨0 0 1⟩ or its ND (rolling plane normal) rotated variations also exist. Changes in the intensities of the texture components along the β-fibre greatly influence the anisotropy of mechanical properties of the materials, and therefore a thorough understanding of such textural evolution assumes greater significance [4]. The present communication reports the formation of an unprecedented single component, i.e. "rotated Bs", in an Al–Zn–Mg–Cu–Zr alloy by an uneven hot cross-rolling schedule.

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The alloy was prepared via the conventional ingot metallurgical route and the chemical composition (in wt.%) of the alloy was found to be 6.20 Zn–2.28 Mg–1.62 Cu–0.13 Zr–0.14 Fe–0.12 Si and balance aluminum. Fe and Si associated with the primary aluminum were present as impurities. The as-cast ingot was homogenized at 465 °C for 30 h followed by air cooling. The homogenized and scalped slab of dimensions 200 mm × 150 mm × 80 mm was hot rolled to 50% reduction along the direction of casting followed by another 30% reduction in a direction normal to the former. A final thickness of 6 mm was achieved by further cross-rolling by 6% in each of the directions mentioned above. The first 80% reduction in rolling was carried out using interpass annealing at 430 °C for 20 min following every 15% reduction in thickness and the rolled plate was allowed to cool in air. After trimming the edges, a further 12% reduction was achieved after soaking the plate at 430 °C for 30 min. The deformation being a multi-step cross-rolling process, the original rolling direction and the transverse direction are designated as RD_1 and RD_2, respectively, throughout this article. The test coupons were solutionized at 465 °C for 1.5 h and quenched in water at ambient temperature.

The texture was measured at the half thickness of the sheet specimens in the as-hot-rolled and solutionized conditions by the Schultz back-reflection technique using an INEL G3000 X-ray texture goniometer [5]. Four incomplete pole figures ({1 1 1}, {2 0 0}, {2 2 0} and {3 1 1}) of the matrix phase were measured with 20 mm specimen translation, and the orientation

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distribution function (ODF) plots were calculated. Selected samples were subjected to orientation imaging microscopy using an FEI-SIRION® field emission gun scanning electron microscope with an electron backscattered diffraction (EBSD) facility.

The as-cast microstructure reveals an equiaxed, dendritic structure with solute segregation and non-equilibrium solidification products at the interdendritic channels (Figure 1a). Subsequent homogenization substantially eliminates segregation and partially dissolves the non-equilibrium solidification products, leaving behind trails of secondary phases, as shown in Figure 1b. The as-cast and homogenized materials show the presence of a very weak texture, with the latter having a weak tendency towards {0 1 3}⟨1 0 0⟩ orientation (Figure 1b, inset). Hot rolling breaks down the cast structure, resulting in an elongated grain structure. The microstructure of the solutionized sample exhibits elongated grains interspersed with recrystallized grains nucleated mostly at the coarse second-phase particles.

The as-rolled and solutionized samples exhibit moderate strength of texture, as shown in Figure 2a and b, respectively. The texture development can exclusively be described by a strong rotated-Bs component in both the cases. However, considerable texture strengthening occurs in the solutionized sample. Such an increase in intensity is related to the substantial recovery processes occurring during solution treatment, leading to a less strained matrix [1]. In the case of the as-rolled sample, the maximum intensity of the ODF is found to be near the two twin orientations {1 0 2}⟨4 3 2⟩ split by about 8° away from the Bs component in the $\varphi_2 = 0^{\circ}$ section. Around the split orientation, a trail of orientations towards the Bs component originating close to the RD-rotated Cube components can also be seen. This orientation spread encompasses components such as {2 0 3}⟨3 0 2⟩ and {0 1 2}⟨4 2 1⟩. The presence of either Cu or S components has not been detected in the as-rolled sample. A minor component {1 1 4}⟨2 6 1⟩ with $f(g) = 2.0$ times random is observed in the $\varphi_2 = 45^{\circ}$ section of the ODF. On the other hand, the solutionized sample displays only one prominent rotated Bs-{1 1 0}⟨5 5 6⟩ component that is about 15° away from the ideal Bs orientation in the $\varphi_2 = 45°$ section.

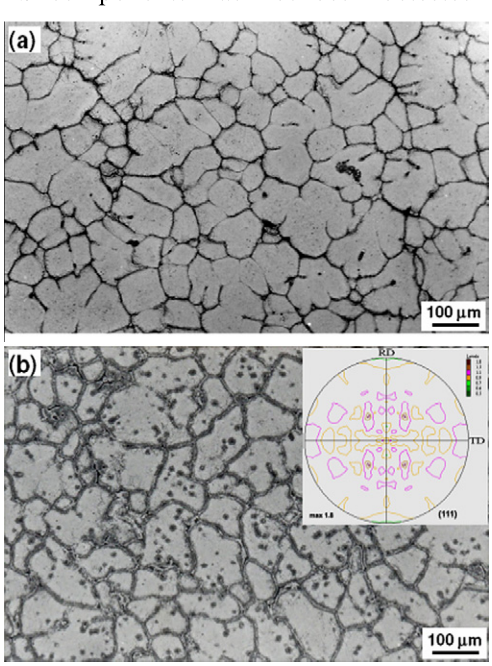

Figure 1. Optical microstructure of (a) as-cast, and (b) homogenized alloy. Inset: {1 1 1} pole figure of the homogenized alloy.

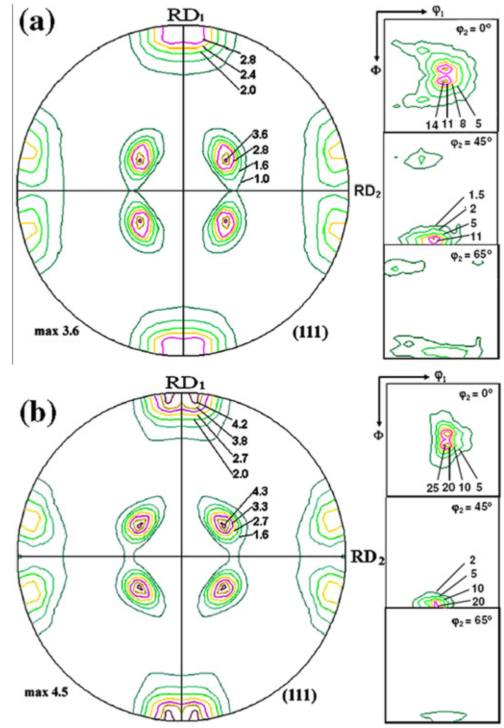

Figure 2. {1 1 1} Pole figures along with $\varphi_2 = 0°$, 45° and 65° ODF sections of the (a) as-hot rolled sample, and (b) the solutionized sample.

The present results clearly indicate that a strong, single-component rotated-Bs texture observed in the as-rolled sample is retained in the solutionized condition even though the microstructure is partially recrystallized. Although the retention of the as-rolled texture after solution treatment has been observed previously [1,6], the formation of a single Bs component has yet not been reported. Table 1 compares the texture development in various aluminum alloys where a Bs/rotated Bs component was found to be the major texture component. It may be noted that the strong Bs texture associated with β-fibre orientations is the characteristic feature of hot deformation of aluminum alloys in particular 7xxx series [6,7], and rotation of Bs around the ND is often observed after cross-rolling [8,9].

In the present study, the evolution of this unique texture is discussed in terms of the effects of initial texture, mode of rolling and interpass annealings. As mentioned in the preceding experimental results, the texture of the starting homogenized material has a weak rotated Cube-{0 1 3}⟨1 0 0⟩ component. This component, being highly unstable under unidirectional hot-rolling conditions [10], is expected to rotate to Bs orientations via α-fibre according to the rate- sensitive crystal plasticity model [11]. Thus, after completion of the first 50% reduction by unidirectional rolling, a β-fibre texture with stronger intensities towards Bs orientation is expected to develop. However, under the cross-rolling condition (i.e. the rolling direction is rotated 90°), the β-fibre orientations