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Texture balancing in a fcc/bcc multilayered composite produced by accumulative roll bonding

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ABSTRACT

The high strain deformation and recrystallization behaviour of a Fe/Ni multilayered composite sheet fabricated by accumulative roll bonding has been investigated. The comparable initial hardness and subsequent strain hardening behaviour of the Ni and Fe layers reduces the flow compatibility related challenges at the bonding interfaces, thereby generating parallel layers of uniform thickness during rolling to true strains up to 4.18. Typical body centred cubic (α- and γ-fibres) and face centred cubic (β-fibre) rolling textures were generated in the Fe and Ni layers, respectively. During annealing at 700 °C, recrystallization takes place homogenously in the Ni layers but commences initially by particle stimulated nucleation at oxide debris present at the interface of adjacent Fe layers. After recrystallization, the texture of the Ni layers is similar to the starting material prior to ARB, but considerable texture modification occurs in the Fe layers. For both metals, oriented growth of nucleated grains has the greatest influence on the final annealing textures, which generates the classic Cube texture in Ni and a {511}<1 5 10> texture in Fe. While these final textures of the individual Fe and Ni layers are not conducive to good formability, texture-based Schmidt factor calculations of the combined layers show an overall balance in texture components that points to a reduction in planar anisotropy. The ability to fabricate multilayered textured sheets by this route is a promising way of controlling the anisotropy of both strength and ductility.

1. Introduction

Accumulative roll bonding (ARB) is a thermomechanical processing (TMP) route that has two exciting capabilities: (a) a conventional metal can processed to very high strains and strengthened considerably via the creation of a nanostructure within the original grains [1–10], and (b) multilayered composite structures are achievable via the combination of different metals [11–17]. ARB was demonstrated originally by Saito et al. [18,19] for a number of commercially significant alloys. Here, two metal sheets of similar dimensions are cleaned, brushed and stacked together then roll bonded by ~50% reduction in thickness in a single pass, with the process repeated continually by restacking and rolling the processed sheet [18]. The overall process is capable of generating very large true strains ($\varepsilon > 10$) without significantly reducing the original sheet thickness; such large strains also cause a considerable refinement of the initial microstructure. ARB is also capable of generating multilayered composite structures based on similar or dissimilar metals such as Al/Ni [11], Al/Mg [12], Cu/Al [13] and Cu/Nb [14]. However, ARB of dissimilar metals is challenging due to their different initial strengths and subsequent strain hardening behaviour. Strain-induced incompatibilities in the form of wavy layers are often generated at the bonding line of the metals, whereby the harder sheet material experiences sequential necking along its length when viewed in the section perpendicular to the transverse direction (TD). Quadir et al. [20] showed that such plastic instability can be controlled by selecting metals of comparable initial strength and work hardening behaviour together with an appropriate choice of TMP parameters (temperature, rolling speed, roll diameter etc).

The ability to fabricate multilayered composite sheets containing a tailored combination of two or more different alloys can be exploited for improving a specific property as well as controlling

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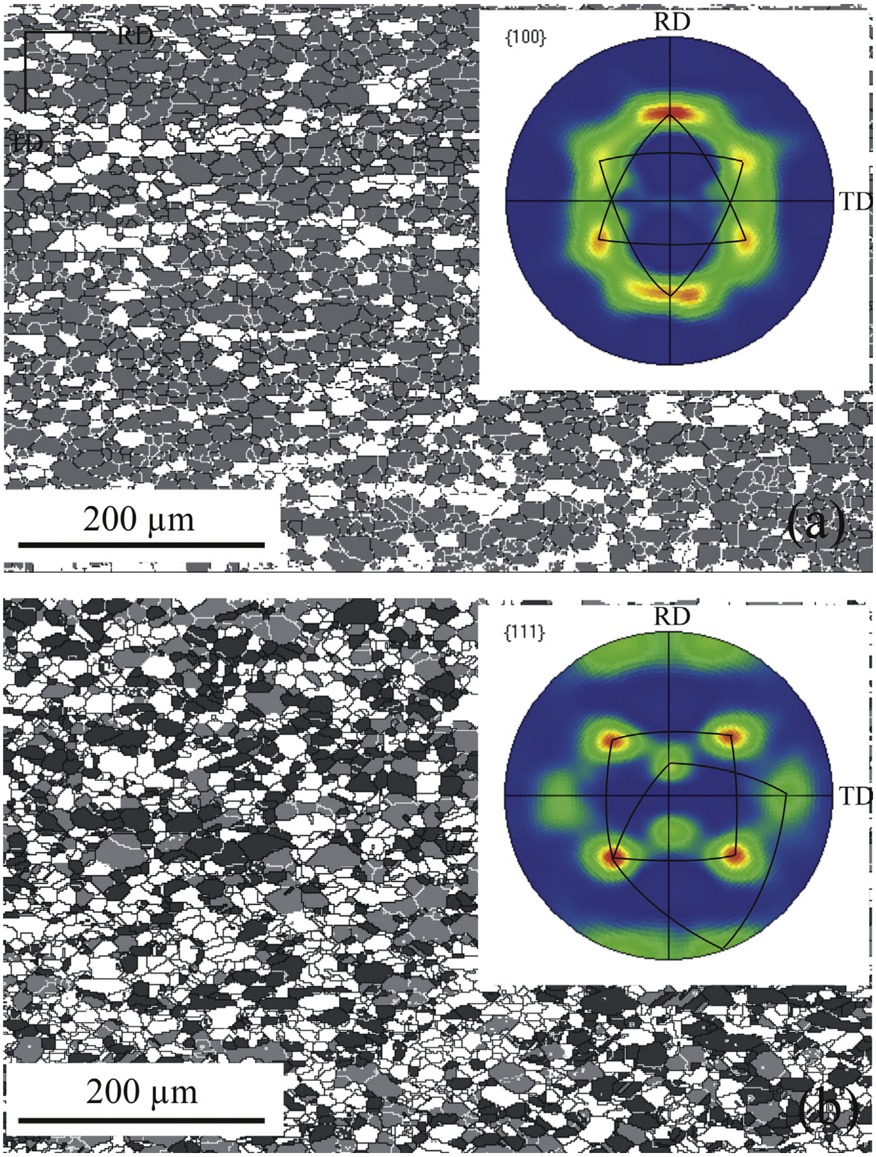

Fig. 1. EBSD maps showing the textures and grain size distributions of the (a) Fe and (b) Ni starting materials. In (a) the γ-fibre grains are shown in gray and the overall texture is shown in a contoured {200} pole figure. In (b) the S- and Cube-oriented grains are shown in dark and light gray, respectively, and the overall texture is shown in a contoured {111} pole figure.

the anisotropy of that given property. For example, combining a highly formable sheet material with one that is less formable has the ability to improve the performance of the latter, if this is the key material to be targeted for a certain application. For example, fcc metal sheets have poor deep drawability due to the persistent formation of the {100}<001> (Cube) texture after TMP [21]. Hence, the usual attempts at improving the formability of fcc metals is to generate a near random texture or a balance of different texture components such that their individual affect on drawability is nullified [22]. Conversely, bcc metal sheets can be produced readily with textures that are highly favourable for deep drawing. If these different materials with their characteristic textures can be tailored in the form of a multilayered composite, the resultant mechanical properties affecting sheet formability can be better controlled. In this investigation, a multilayered fcc/bcc composite with a specific property profile was designed by combining the desirable individual properties of Ni and Fe and fabricating by ARB.

2. Materials and methods

Ti-containing interstitial free (IF) steel (hereafter termed Fe) and high purity Ni sheets were used for fabricating a multilayered hybrid sheet composite by ARB. The steel slab was hot and cold rolled and annealed to generate 0.5 mm thick sheet with a recrystallized grain size of 25 ± 10 μm and a well-developed {111}//<*uvw*> (γ-fibre) texture, whereby over 90% of the grains were oriented within 15° of this orientation fibre. In Fig. 1a, these γ-fibre grains are shown in gray with other orientations shown as white grains. The inset shows the overall texture in the form of a contoured <200> pole figure, whereby the peak intensities on the γ-fibre are located at the {111}<112> complementary positions (marked). Similarly, a Ni sheet was thermomechanically processed to a similar starting thickness as the Fe sheet to generate a recrystallized grain size of 30 ± 16 μm and a texture comprising mainly of the {123}<634> (S) and Cube orientations. Grains within 15° of the ideal S and Cube orientations are shown in Fig. 1b as dark