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Improving single pass reduction during cold rolling by controlling initial texture of AZ31 magnesium alloy sheet

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Abstract: The AZ31 magnesium alloy sheets obtained by multi-pass hot rolling were applied to cold rolling and the maximum single pass cold rolling reduction prior to failure of AZ31 magnesium alloy was enhanced to 41%. Larger single pass rolling reduction led to weaker texture during the multi-pass hot rolling procedure. The sheet obtained showed weak basal texture, while the value was only 1/3−1/2 that of general as-rolled AZ31 Mg alloy sheets. It was beneficial for the enhancement of further cold rolling formability despite of the coarser grain size. The deformation mechanism for the formation of texture in AZ31 magnesium alloy sheet was also analyzed in detail.

Key words: AZ31 magnesium alloy; texture control; cold formability; work hardening

1 Introduction

Magnesium alloy sheets have attractive interests due to their excellent properties, as low density and high specific strength, making them potentially suitable candidates in automotive, aerospace and electronic industries [1]. Unfortunately, magnesium sheets usually exhibit poor ductility at room temperature [2] and the sheets must be rolled at elevated temperatures to avoid cracking which adds considerable cost of magnesium sheet products and is a significant impediment to their acceptance in industrial applications [3].

The poor cold rolling response of Mg is generally ascribed to its hexagonal crystallography and the associated lack of sufficient independent slip systems [4]. Usually, the single rolling pass reduction is less than 5% and the accumulative reduction of a rolling procedure is no more than 25% [5]. BARNETT et al [3] examined the cold rolling procedure of AZ31 magnesium alloy and the maximum cold rolling reduction achievable prior to failure was ~15%. CHANG et al [4] researched the texture and microstructure evolution of AZ31 Mg alloy, and the crack appeared when the cold rolling reduction reached 22%. These studies relied heavily on microstructure and texture of sheets after cold rolling. As known, the cold rolling capacity of magnesium alloys closely depends on alloy composition, hot rolling technology and sheet microstructure. The maximum cold rolling reductions achievable of pure Mg, Mg−0.2Ce and Mg−3Al−1Zn prior to failure were ~30%, >90% and 15%, respectively [3]. However, practically no studies in the literature have focused on the influence of hot rolling technology and sheet microstructure on the further cold formability of AZ31 magnesium alloy sheets. In the present work, we emphasize texture control before cold rolling and its influence on cold formability. Therefore, the aim of the present work is to improve plastic deformation ability of initial cold rolling sheet by designing a reasonable hot rolling technology, so as to enhance the cold formability of AZ31 magnesium alloys.

2 Experimental

As-cast AZ31 magnesium alloy (Mg−2.85%Al−0.95%Zn) ingots with 26 mm in thickness were rolled to 2 mm in thickness through different rolling passes at a given reduction of ~15% (15 passes) or ~30% (7 passes) per pass by multi-pass hot rolling, and the obtained as-rolled sheets were named as sample A and sample B, respectively. The microstructure and room-temperature stress−strain curve of the initial ingot are shown in Fig. 1,

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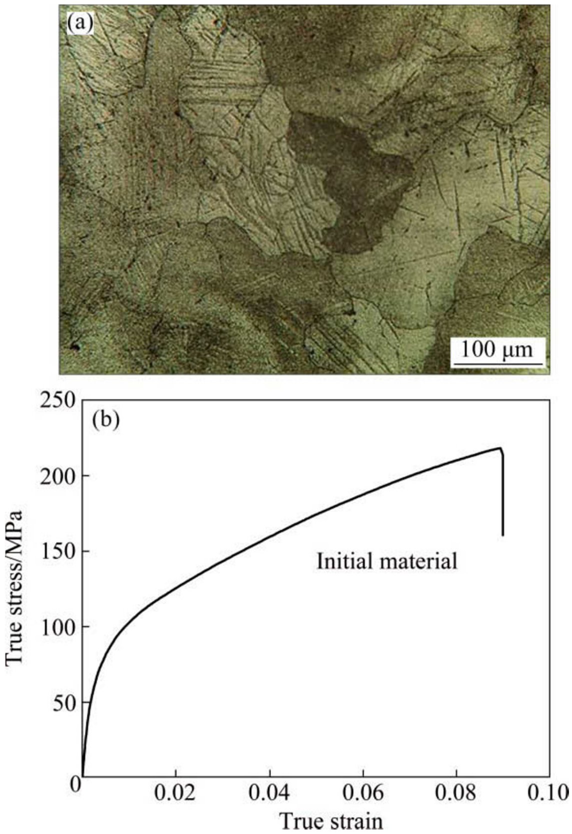

Fig. 1 Microstructure (a) and room-temperature stress−strain curve (b) of initial material [6]

Table 1 Sheet thickness of each pass at single pass reduction of 15% and 30% in experimental procedure

Procedure	Pass	Thickness/mm	
		15% reduction	30% reduction
Multi-pass hot rolling	Initial	26	26
	1	22.1	18.2
	2	18.8	12.7
	3	16	8.9
	4	13.6	6.2
	5	11.6	4.3
	6	9.9	3
	7	8.4	2 (Sample B)
	8	7.1	
	9	6	
	10	5.1	
	11	4.3	
	12	3.7	
	13	2.6	
	14	2.2	
	15	2 (Sample A)	
Single-pass cold rolling	1	1.84	1.18

which were described in previous work [6].

The sheet thickness of each pass at the single pass reduction of 15% and 30% in the experimental procedure is shown in Table 1. In multi-pass hot rolling procedure, the starting temperatures of the sheets and rollers both were 400 °C. The temperature of the rollers was maintained at 400 °C using internal electric heaters and the sheets were no longer heated between passes. The temperature drop of the sheet between passes was kept at 15 °C. To implement the accurate control of rolling temperature, the time interval between passes was strictly controlled. The temperatures of the sheets before and after rolling were measured and recorded immediately at each pass. The samples were air cooled to room temperature and then applied to cold rolling. Cold rolling of the AZ31 magnesium alloy sheets was carried on the mill with a roll diameter of 190 mm and the rolling speed was 2 m/min. No heating was carried out during the cold rolling procedure. The specimens were cold rolled to different thickness reductions. The surface of the as-rolled sheets began to form cracks with the increasing of rolling reduction.

The microstructure and texture of the samples were identified using electron backscattered diffraction (EBSD) performed on a scanning electron microscope (SEM, Quanta 200 FEG-SEM) equipped with an EBSD detector and OIM 6.14 analysis system. Surface preparation of the samples consisted of grinding with SiC emery papers of #200, #600, #800 and electrolytically polishing with solution of phosphoric acid and ethanol with a volume ratio of 3:5.

Tensile specimens with a gauge length of 25 mm and width of 6 mm were machined out of the samples along both RD and TD, where RD and TD are the rolling direction and transverse direction, respectively. Tensile tests were performed at room temperature using Instron 5569 testing machine at an initial strain rate of 1.0×10^{-3} s^{-1}. To check the repeatability of the results, three experiments were conducted under each set of conditions.

3 Results and discussion

The schematic diagrams of rolling technology and stress analysis are shown in Fig. 2. During the rolling deformation, the sheet was mainly subjected to friction force (T) along the rolling surface and the radial force (N) perpendicular to rolling surface. Due to small contact arc and in order to analyze conveniently, the contact arc can approximately take as a plane, n-plane, seen in Fig. 2(b). In general, a variation in the rolling reduction has a significant influence on the bite angle α, which is described as the central angle corresponding to the arc of the sheet contacting with the roller.