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Effect of dimple patterning conditions of Periodical Straining Rolling on microstructures and mechanical properties of AZ31 sheets

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ABSTRACT

Magnesium alloys are well-known for the attractive physical properties such as the lowest density among the structural metallic materials, high specific strength, high vibration absorption and so on. However, the strong (0001) basal texture of wrought magnesium alloys causes the poor plastic formability at room temperature in spite of high Lankford value. Texture and microstructure control of magnesium alloys are quite necessary to improve the cold sheet formability in order to prevail the wider application of wrought magnesium alloy products. The authors have already proposed the novel rolling process called "Periodical Straining Rolling (PSR)" using the small grooved roll to introduce periodically localized plastic strain in rolled sheet and confirmed that its effectiveness of the proposed rolling can realize the micro texture and microstructure control. This paper is aimed to discuss the effects of control of spatial strain distribution on microstructure, micro texture and mechanical properties by using various dimple patterning conditions of PSR process. The microstructure and micro texture observations of AZ31 magnesium alloy sheets PSR processed under the several dimple patterning conditions (two-sided PSR processing conditions) evince that the weak crystallographic orientations are largely prominent by changing dimple patterning conditions. As a result, the higher Erichsen values can be effectively achieved by changes in dimple patterning as compared to the conventional flat rolling process.

1. Introduction

As lightweight metallic materials, magnesium and aluminum alloys are in the widespread usage for components of automobiles, trucks and aircrafts, and recently, chassis of small electric appliances such as mobile phones, personal laptop/tablet computers, and digital cameras [1,2]. Magnesium alloys are known as the lightest among the structural metallic materials. Most of magnesium alloy products are made by die casting (rheo-casting or thixo-forming) and hot forging [3,4]. Sheet formability of magnesium alloys at room temperature is still the difficult problem that prevents the wrought magnesium alloys from prevalence of wider applications for years. Because of hexagonal closed packed crystal structure, only the basal slip system is allowed to activate at room temperature. Many researches have been conducted for improvement of sheet formability of magnesium alloys. It is reported that the utilization of the lanthanide elements, namely, cerium or gadolinium with the conventional alloying elements (zinc, zirconium etc.) is effective to weaken the (0001) basal texture and provide the non-basal texture in which prismatic slip or pyramidal slip systems are able to activate [5–9]. At the elevated temperature, more than 523 K, sheet formability of magnesium alloys is enhanced because the critical resolved shear stress for non-basal slip systems such as prismatic and pyramidal slip systems decrease [10]. Warm or hot sheet forming process is one of possible solutions for applications of wrought magnesium alloys [11,12]. Nevertheless, the high temperature forming will also bring to the complicated problems related with the die tool designs, press machine and other peripheral equipment arrangement, and the limited selection of lubricants for sheet forming. Thus the improvement of cold sheet formability of magnesium alloys is quite beneficial so that the conventional sheet forming systems for steel,

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titanium and aluminum alloy sheets can be easily diverted. It is known that the weak texture of rolled magnesium alloy sheets can be also achieved by high temperature rolling/annealing without the addition of rare earth alloying elements [13,14]. As for thermo-mechanical process, it is presumable that the plastic deformation process to introduce the change in strain path or strain distribution should be realized. Differential speed rolling, asymmetric rolling [15,16], wavy roll-forming [17], biaxial reverse corrugation [18] and groove pressing [19,20] are applied for magnesium alloys, and these plastic deformation processes have proved the feasibilities of microstructure control and enhancement of mechanical properties. We have already proposed the novel process called "Periodical Straining Rolling process" and confirmed its effectiveness on microstructure change and mechanical properties [21,22]. In our previous paper, we discussed the effect of tool designs of Periodical Straining pass on microstructure evolution and micro textures changes [22]. The proposed rolling process can be further modified as to spatial variations of microstructure and micro texture evolution by multi-pass operation or combinations of different roll profiles. Though the effect of dimple patterning conditions, for instance, wavy profile across the sheet width or along the rolling direction, on microstructural changes and mechanical properties is not cleared yet. In the present study, we investigated the microstructure and texture changes, and also mechanical properties of AZ31 sheets PSR processed by various dimple patterning conditions.

2. Scheme of Periodical Straining Rolling process

The scheme of Periodical Straining Rolling (PSR) process was already described in our previous paper [22]. Periodical Straining Rolling process possesses two deformation stages as depicted in Fig. 1. At the first pass, a sheet is rolled with a pinion-gear-like small grooved roll and a flat roll. Small rack-like dimples are formed periodically on the sheet surface. At the second pass, a rack-like sheet is flattened with conventional flat rolls. Finally, a smooth surface sheet is obtained. The roll profiles of Periodical Straining Rolling can employ such as a helical-gear-like or a worm-gear-like shapes to introduce the different spatial indentations on the sheet surface. Fig. 1(b) shows the other Periodical Straining Rolling pattern using worm-like roll profile. The grooves (or dimple patterns) are formed parallel to the rolling direction on the sheet surface. It is aimed to introduce the localized strain distribution by indentation of small grooves of Periodical Straining roll profiles, which is expected to bring the various microstructure changes along the longitudinal direction of rolled sheet. Periodical Straining Rolling process has the appropriate potential to be readily adapted in the existing strip rolling mills by replacing the ordinary work roll profiles in strip production scene. Several Periodical Straining passes that form dimple patterns on the upper and lower surfaces of sheet can be also realized to control microstructure evolution through the thickness.

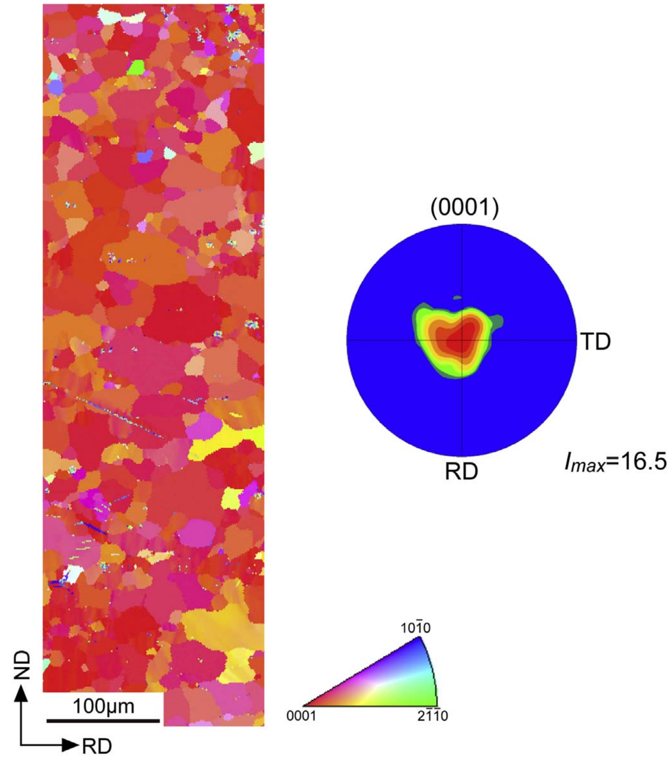

Fig. 2. OIM images and (0001) pole figures of hot rolled AZ31 sheet as the starting material.

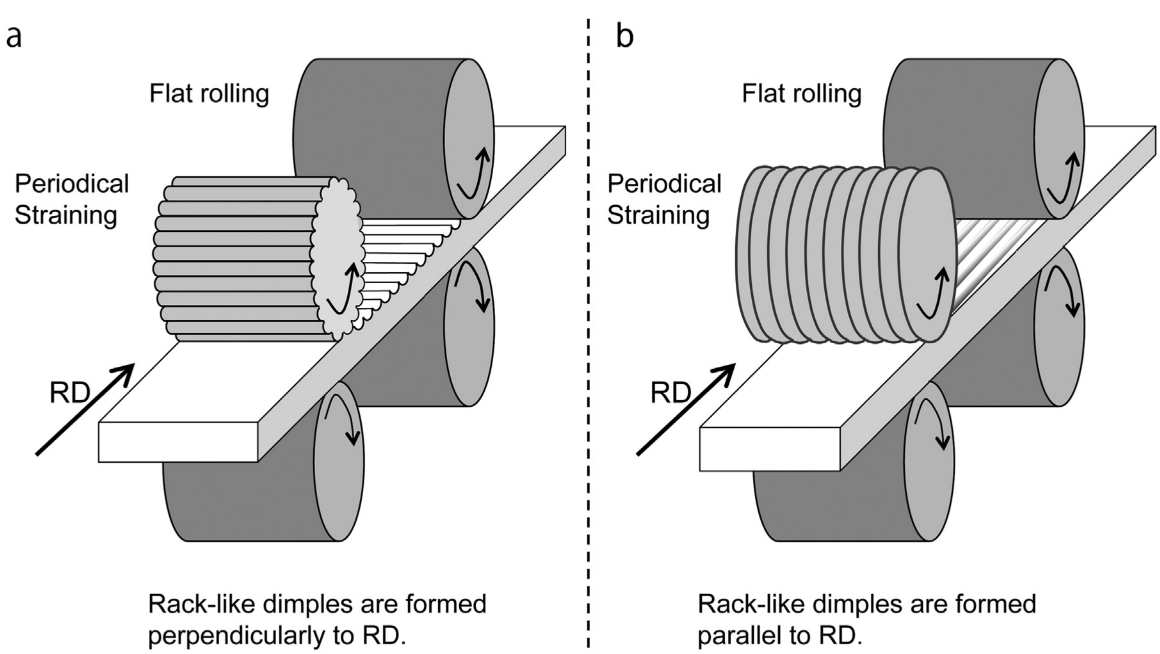

Fig. 1. Schematic illustrations of Periodical Straining Rolling (PSR) process.