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Microstructural evolution in Al−Zn eutectoid alloy by hot-rolling

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Abstract: The Al−Zn eutectoid alloy has been widely known as a typical superplastic metallic material, where fine-grained microstructure is usually obtained by heat treatment. Recently, thermo-mechanical controlled process has also been reported to provide a fine-grained microstructure. In the present study, Al−Zn alloy ingots of 20 mm in thickness were homogenized and hot-rolled to a thickness of 2 mm under three processes: 1) the specimen was air-cooled after homogenization and hot-rolled; 2) the specimen was water-quenched after homogenization and hot-rolled; 3) the specimen was immediately hot-rolled after homogenization. Microstructural observation showed that, in processes 1 and 3, lamellar microstructure was formed after homogenization, and became fragmented to fine-grained microstructure as the hot rolling process proceeded. In process 2, fine-grained microstructure without lamellar microstructure was attained throughout the hot-rolling process. A minimum grain size of 1.6 μm was obtained in process 3. Tensile tests at room temperature showed that the elongation to failure was the largest in process 3.

Key words: aluminum−zinc alloy; eutectoid; microstructure control; hot-rolling; superplastic material

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1 Introduction

The Al−Zn eutectoid alloy has been known to exhibit superplasticity at high testing temperatures, where fine-grained microstructure is usually obtained by solution treatment, water-quenching and subsequent aging at elevated temperatures [1]. This alloy had been used as cases of a printer and a ticket machine produced by superplastic forming [2]. Recently, severe plastic deformation, such as equal channel angular extrusion (ECAE) and high pressure torsion (HTP), has been reported to provide ultrafine-grained microstructure in this alloy [3−6]. Thermo-mechanical controlled process (TMCP), where hot-rolling is conducted by controlling temperature, cooling way, etc, has also been reported to provide a fine-grained microstructure. The microstructure in the Al−Zn alloy rolled by TMCP was reported to provide a grain size of about 1 μm with a nanocrystalline substructure, and the alloy was reported to exhibit superplastic behavior at room temperature [7−9]. Since the critical cooling rate in TMCP is slower than that in the above-mentioned traditional process, it can be applied to thick-gage components. In Japan, plates produced by TMCP have been used as a seismic damper in high-rise buildings and wooden detached houses for the protection against earthquakes [10−12]. However, condition to obtain fine-grained microstructure in TMCP and its mechanism have not been elucidated yet.

Therefore, in the present study, control conditions in hot rolling such as cooling way after homogenization, rolling timing have been investigated in an Al−Zn eutectoid alloy to obtain fine-grained microstructures by hot-rolling. Also, tensile tests were performed at room temperature to assess the mechanical properties.

2 Experimental

The material used in the present study was an Al−Zn eutectoid alloy. The composition of the alloy is shown in Table 1. This alloy exists as a solid solution α' phase above eutectoid temperature (275 °C). The α' phase decomposes into two phases, α and β, where α is Al-rich, FCC structure and β is Zn-rich, HCP structure below eutectoid temperature. Pure Al (99.99%), pure Zn (99.99%) and Al−40%Cu alloy were melted in a graphite

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Table 1 Chemical composition of specimen (mass fraction, %)

Al	Cu	Zn
22	0.15	Bal.

crucible and then cast into ingots of 27 mm in thickness, 32 mm in width and 200 mm in height. Three different ingots, air-cooled or water-quenched after homogenization at 350 °C for 5 h and as-cast were cut and scalped into specimens with 20 mm in thickness, 30 mm in width and 60 mm in length.

Conventional rolling mill without a heating device was used for hot-rolling. In order to obtain the final sheet of 2 mm in thickness from a 20 mm-thick ingot, i.e. a total rolling reduction of 90%, the hot rolling process was conducted under conditions shown in Fig. 1. In process 1, the specimen was air-cooled after homogenization, and heated to 250 °C in 30 min, hot-rolled to underlined thickness, re-heated to 250 °C in 10 min and then subjected to repetitive hot rolling and re-heating steps. In process 2, the specimen was water-quenched after homogenization, heated to 250 °C in 30 min, hot-rolled to underlined thickness, water-quenched, re-heated to 250 °C in 30 min and then subjected to repetitive hot rolling and re-heating steps. In process 3, the specimen was immediately hot-rolled after homogenization to underlined thickness, re-heated to 250 °C in 10 min and then subjected to repetitive hot rolling and re-heating steps. Specimen measured with a thermocouple until it broke during hot rolling process is shown in Fig. 2.

After hot rolling process, L−LT, L−ST and LT−ST sections (perpendicular to the ST (short transverse), LT (long transverse) and L (longitudinal) directions, respectively) were cut from final and intermediate sheets. Microstructural observation was conducted on mirror-finished samples by a HITACHI S−2150 scanning electron microscope (SEM) at an accelerating voltage of 20 kV. Degree of grain refinement was evaluated with average grain size l.

$$l=1.75d \tag{1}$$

where d is the linear intercept length and averaged in two directions for the three sections [1].

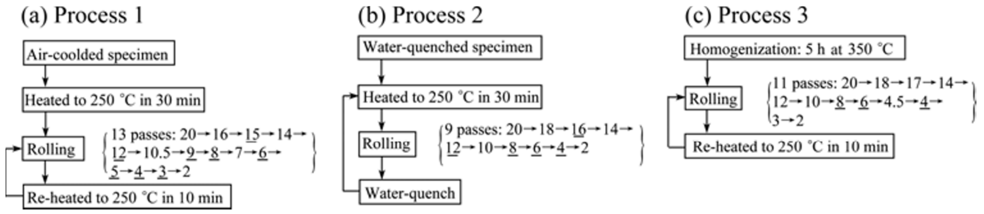

Fig. 1 Three kinds of hot-rolling process

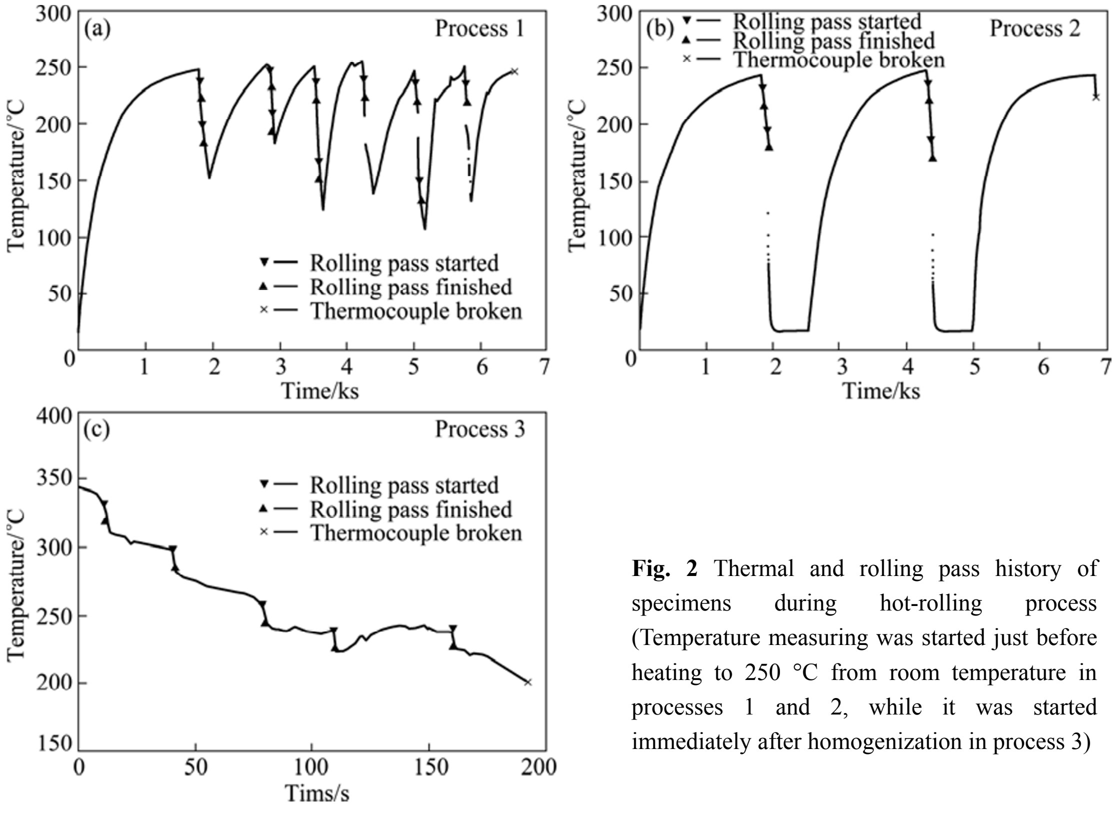

Fig. 2 Thermal and rolling pass history of specimens during hot-rolling process (Temperature measuring was started just before heating to 250 °C from room temperature in processes 1 and 2, while it was started immediately after homogenization in process 3)