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Effect of microstructure on hot tensile deformation behavior of 7075 alloy sheet fabricated by twin roll casting

Lei Wang [a,b], Huashun Yu [a], Yun-Soo Lee [b], Min-Seok Kim [b], Hyoung-Wook Kim [b,*]

[a] Key Laboratory for Liquid–Solid Structural Evolution and Processing of Materials (Ministry of Education), School of Materials Science and Engineering, Shandong University, Jinan 250061, China
[b] Metallic Materials Division, Korea Institute of Materials Science, Changwon 642-831, Republic of Korea

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ABSTRACT

7075 aluminum alloy sheet with a thickness of 1 mm was successfully fabricated by twin roll casting and subsequent rolling process. The hot tensile deformation behavior of 7075 alloy was evaluated and large elongation over 200% was obtained at 450 °C under the high strain rate of 1×10^{-1} s^{-1}. In order to clarify the reason for the large elongation obtained at high strain rate, the effects of microstructure on hot tensile deformation behavior were investigated. The results show that high solidification rate during TRC casting process induced small particles (~1 μm) in homogeneous distribution. The relatively high fraction of particles over 1 μm in size attributed the homogeneous recrystallized microstructure with fine grains induced by particle simulated nucleation (PSN). This fully recrystallized fine-grained microstructure of TRC alloy sheet contributed to high ductility and formability of 7075 alloy sheet under high strain rate.

1. Introduction

There has been recently a growing demand for producing lightweight vehicles in order to reduce the energy consumption and CO_2 emission. High strength-weight ratio, good formability, good corrosion resistance are considered as general characteristics of aluminum alloys applied to automotive industry [1]. Although, 5XXX and 6XXX series aluminum alloys have been widely used for automobile application, more high strength aluminum alloys are required for light weight of automobile body structure. Nowadays, 7XXX series of alloys which have been developed for aircraft and space applications [2] are considered as a good candidate for the automobile body structure.

Twin roll casting process (TRC) is considered as a cost-efficient process to fabricate aluminum alloy sheets with good mechanical properties, wherein molten metal is fed onto water-cooled rolls and solidifies with a high cooling rate [3]. Due to the high solidification rate achieved in twin roll casting, the microstructure of TRC alloys differs significantly from that of conventional casting alloys. Traditional twin roll casting process is difficult to produce high strength aluminum alloy strip, because of thermal fragmentation and segregation induced by high contents of alloying elements [4]. However, we successfully fabricated 7075 alloy sheets by twin roll casting and subsequent rolling process, the sheets showed good tensile properties for automobile body application [3]. Moreover, it presented large elongation over 200% when deformed at elevated temperature under high strain rate [5]. Small and homogeneous particles were induced during TRC process, which was considered to have a great effect on the alloy formability [6].

It is reported that micro-cracks were easily initiated by the debonding of the interface between matrix and particles [7] or by inner fracture of large particles [8,9]. Tewari et al. [6] reported the influence of the particle distribution of 5754 aluminum alloys on their localization in uniaxial strain. It is presented that large particles lowered the localization strain.

In this study, the effect of particles on the microstructural evolution was investigated to clarify the reason for large elongation obtained at high strain rate. For comparison of different particle distribution, the alloy sheet fabricated by permanent mold casting (PMC) process was also prepared.

2. Experimental procedures

The material in the present study is 7075 aluminum alloy. The chemical composition is Al–5.2Zn–2.3Mg–1.5Cu (wt%) shown in Table 1. For comparison of different particle distribution, test samples are produced by two different casting processes; twin roll casting (TRC) and permanent mold casting (PMC).

* Corresponding author.
E-mail address: hwkim@kims.re.kr (H.-W. Kim).

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Table 1
Chemical composition of the alloys studied (wt%).

Alloy	Zn	Mg	Cu	Mn	Cr	Fe	Si	Ti	Al
7075	5.18	2.27	1.49	0.045	0.22	0.23	0.11	0.05	Bal.

The TRC sample with 4.5 mm in thickness was fabricated by a horizontal type twin roll caster with water-cooled Cu–Cr rolls with the diameter of 300 mm [3,5]. At this time, the molten alloy heated up to 680 °C was transferred into the preheated tundish and nozzle. The roll gap was 4 mm and casting roll speed was 5-6 rpm. The PMC sample was made by pouring the molten alloy heated to 680 °C into a rectangular block steel mold in the size of 195 × 180 × 25 mm^3. The cast ingot (t=25 mm) was homogenizing treated at 465 °C for 24 h followed by hot rolling at 460 °C to 4.5 mm in thickness. As-cast TRC alloy sheet (t=4.5 mm) and hot rolled PMC alloy sheet (t=4.5 mm) were annealed at 400 °C for 1 h followed by warm rolling at 250 °C to 2.5 mm in thickness. After re-annealed, the sheets were finally rolled to the thickness of 1 mm at ambient temperature.

The tensile test samples measuring 5 mm × 1 mm in cross section with a gauge length of 10 mm were machined from the final cold-rolled sheets parallel to the rolling direction. Hot tensile tests were performed on a tensile machine with a three-zone temperature-controlled furnace at a constant crosshead speed. Uniaxial tensile tests were conducted at initial strain rates of 0.001, 0.005, 0.01 and 0.1 s^{-1} and deformation temperatures of 300, 350, 400 and 450 °C, respectively. The samples were held at desired temperature for 10 min before tensile loading to ensure a homogeneous temperature distribution through the samples. Microstructural observation was carried out using an optical microscope (OM, ECLPPSE MA200) and electron back-scattered diffraction (EBSD) technique. Samples for optical microscopy were etched by 5% fluoroboric acid (HBF_4) for 120 s. Particle observation was performed by scanning electron microscopy (SEM, JSM-6610LV) and transmission electron microscope (TEM, JEM-2100F). Energy dispersive spectroscopy (EDS) was used to obtain the composition of the particles. Samples for TEM observation were mechanically ground to a thickness of 80-100 μm and followed by twin-jet electropolishing operated at 20.5 V and −20 °C using a 25% nitric acid and 75% methanol solution. The texture and orientation distribution functions (ODFs) were determined using TSL OIM Analysis software.

3. Results

3.1. Initial microstructure

Fig. 1 shows the microstructure of TRC and PMC alloys. The grain structures in as-cast alloys (Fig. 1(a) and (c)) were mostly equiaxed. The grain sizes were ~40 μm and ~41 μm, respectively, for as-cast TRC and PMC alloys. Moreover, TRC sample exhibited very fine second dendrite arm spacing (DAS) around 6 μm due to the high cooling rate during casting process. It is seen that cold-rolled TRC and PMC samples had a deformation structure, where band-liked structures were observed along the rolling direction (Fig. 1(b) and (d)). As to whole thickness reduction from 25 mm to 1 mm during thermo-mechanical process (TMP) for PMC samples,

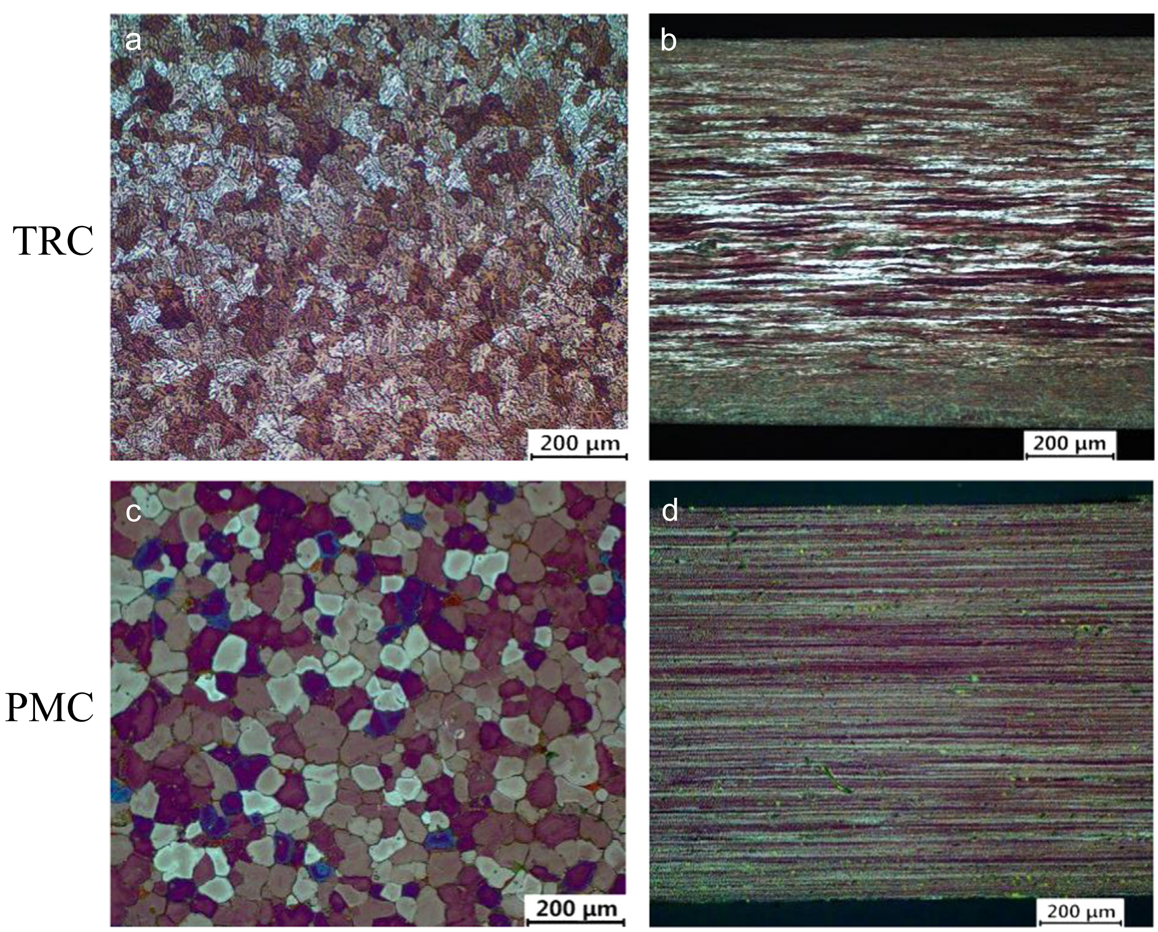

Fig. 1. Optical micrographs of (a) and (c) as-cast alloys and (b) and (d) cold-rolled sheets, respectively, for TRC and PMC alloys.