SUPERPLASTICITY OF 1N90 PURE ALUMINUM BASED COMPOSITES AND THE THERMOMECHANICAL PROCESSING

Sumito KOJIMA*, Daming JIANG, Tsunemichi IMAI***, Jianfu Mao**, Gilles L'ESPERANCE****, and Bande Hong******

* Nagoya Municipal Industrial Research Institute,3-4-41 Rokuban-cho, Atsuta-ku, Nagoya 456, Japan
** Harbin Institute of Technology, Harbin 150001, China
***National Industrial Research Institute of Nagoya, 1 Hirate-cho, Kita-ku, Nagoya 462, Japan
****Ecole Polytechnique de Montreal,P.O.Box 6079,Station"A", Montreal(Quebec)H3C 3A7,Canada

ABSTRACT: High Strain Rate Superplastic characteristics(HSRS) of 1N90 PM pure aluminum, TiC/1N90 pure aluminum composites and the microstructure evolution during the superplastic deformation are investigated in order to reveal the deformation mechanism. The 1N90 PM pure aluminum exhibits the m value of 0.3~0.47 and the total elongation of about 500% at the strain rate of $1x10^{-2}s^{-1}$ and at 893~913K. The TiC/1N90 pure aluminum composite indicates the m value of 0.3 and the total elongation of 200% at the strain rate of about $2x10^{-1}s^{-1}$ and at 913K. The optimum strain rate at which the maximum total elongation is obtained is higher by ten times than that of the 1N90 PM pure aluminum. The TiC/1N90 composite consists of TiC particles dispersed homogeneously and pure aluminum matrix with the subgrains of 0.2~1.0 μm. This results indicate that fine grains and subgrains which are built during the thermomechanical processing , including hot extrusion and hot rolling, could provide HSRS to the composites.

Keywords: superplasticity, pure aluminum, composite, thermomechanical processing

1. INTRODUCTION

Ceramic whisker or particulate reinforced aluminum alloy composites are attractive for application to automobile engineering components, aerospace structures, semi-conductor packaging since these composites exhibit excellent mechanical, physical and thermal properties and also superplasticity could produce at high strain rate such as 0.1~10 s^{-1}, which is expected to build a near-net shape forming[1~7].

And since the optimum strain rate at which a maximum elongation is obtained is higher by 10~100 times than that of conventional superplastic aluminum alloys, the deformation mechanism of the composites is thought to be different from that of conventional superplasticity. It has been pointed out that the primary deformation mechanism of the HSRS materials is grain boundary sliding, as the HSRS materials have fine grain size less than 3μm and strain rate sensitivity of m=0.3~0.5[1~7]. But since the HSRS behavior is affected by chemical and structure's changes in components such as matrix, reinforment and interface in aluminum matrix composites during fabrication and thermomechanical processing and superplastic deformation, the deformation mechanism has not yet been understood entirely. It is, therefore, important to investigate simple superplastic characteristics of pure aluminum composites in order to reveal the deformation mechanism of the HSRS.

The purpose of this work is to develop a thermomechanical processing route to build fine microstructure and to produce the HSRS in TiC particulates reinforced pure aluminum composites and 1N90 pure Al. In addition, the superplastic characteristics of the compsites and of 1N90 pure aluminum will also be discussed.

2. EXPERIMENTAL PROCEDURES

TiC with an average particle size of 1 μm was used as reinforcement material. **Table 1** show chemical composition of 1N90 pure aluminum(the particle size is under 45 μm). 1N90 pure Al and TiC/1N90 pure Al composites(Vf= 0.15) were fabricated by powder metallurgy method. Mixed powders were sintered at 773 K in vacuum under the pressure of 200 MPa for 20 minutes. The as-hot pressed billet was reforged at 773 K in air under the pressure of 495 MPa for 20 minutes. Thermomechanical processing used to produce superplasticity in these materials was (1)hot extrusion only and (2)hot rolling after hot extrusion. The hot extrusion was performed with the extrusion ratio of 44 at 773 K and 873K. The hot rolling was carried out at 903K . The strain in each rolling pass was less than 0.1 and the reheating time between passes was 5 minutes. The final thickness of hot-rolled mateirals became less than 0.75mm. Materials after hot rolling after extrusion was cut to a tensile specimen with 4mm width and about 5.5mm gage length, and a as-exturded mateirla was cut to a cylindrical specimen with 2.5mm diameter and about 20mm gage length. Specimens were pulled at 873~923 K in the strain rate range from $1x10^{-3}$ to about $1.5s^{-1}$. Microstructures of these superplastic materials were observed by optical, TEM and SEM.

Table 1 Chemical composition of 1N90 pure aluminum

Material	Fe	Cu	Si	Zn	Mn	Mg	Ti	Ni	Al
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	wt%
1N90	43	6	41	17	5	3	2	3	99.99

3. EXPERIMENTAL RESULTS AND DISCUSSION

3.1 HSRS of TiC/1N90 aluminum composite

The effect of hot rolling on superplastic characteristics of TiC/1N90 aluminum composite extruded is shown in **Fig.1(a) and (b)**. Testing temperature was 893 and 913K for the TiC/1N90 hot-rolled after extrusion and 913K for the TiC/1N90 extruded only that is below the melting point of pure aluminum. The TiC/1N90 hot- rolled after hot extrusion indicates the total elongation of 200% and the m value of 0.34 at the strain rate of about $2x10^{-1}$ s^{-1} at 913K, although the TiC/1N90 extruded only shows only total elongation of 100% at the strain rate of about $1x10^{-1}$ s at 913K and the m value of about 0.2.

The SEM microstructures of TiC/1N90 aluminum composite extruded only and hot-rolled after extrusion are shown in **Fig.2** (a) and (b), respectivelly.

Although reinforcement free zone presents in the as-extruded TiC/1N90 (Fig.2(a)), TiC particles were dispersed homogeneously in the hot-rolled composite (Fig.2(b)). Since a reinforcement free zone might be dominant sites for fracture initiation and propagation during deformation of the HSRS, it is thought that the microstructural homogeneity during hot rolling could improve superplastic characteristics of the TiC/1N90 [8].**Fig.3** shows TEM microstructures of the TiC/1N90 hot-rolled at 903K after being extruded at 773K. The composite includes fine grains less than 2μm and subgrains of 0.2~0.5 μm and also TiC particles were dispersed homogeneously. High density dislocations at an interface between TiC particle and aluminum matrix also could be observed. It is thought, therefore, that during hot rolling, dynamic recrystallization could occur so as to make fine grain with high angle boundary improve.

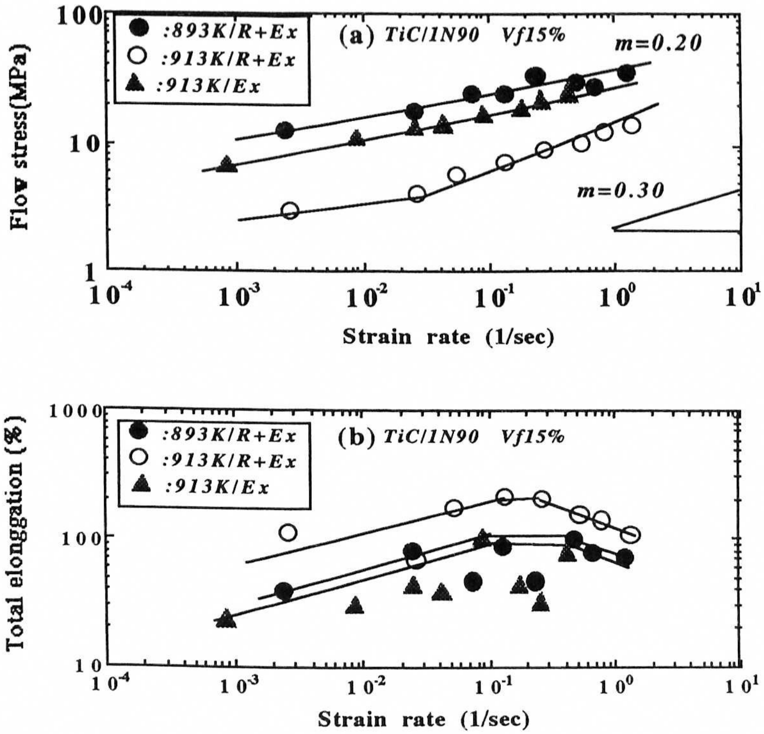


Fig.1 Effect of hot rolling on superplastic characteristics of the TiC/1N90 pure aluminum composite

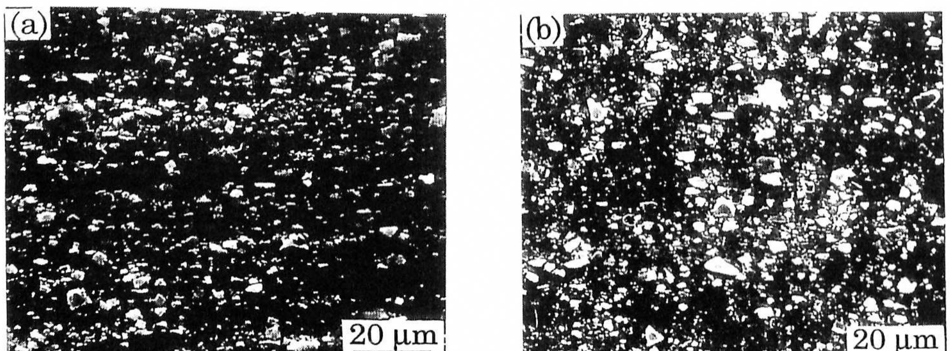


Fig.2 SEM microstructures of the TiC/1N90 aluminum comosite (a) hot-extruded at 873K (b) hot-rolled at 903K after the extrusion

3.2 HSRS of 1N90 pure aluminum

It is important to investigate superplastic characteristics of 1N90 pure Al alone in order to understand deformation behavior of the HSRS. The effect of thermo-mechanical processing on superplastic characteristics of the 1N90 is shown in **Fig.4**. Superplastic characteristics of the 1N90's extruded only at 773 and 873K and hot-rolled after extrusion are compared at testing temperature of 913K, because the temperature is equal to the optimum temperature at which the maximum elongation of 200% is obtained in the TiC/1N90. The 1N90 hot-rolled at 903K after being extruded at 773K indicates the maximum total elongation more than 300% and the m value of 0.5 at the strain rate of about $2x10^{-2}s^{-1}$ and at 913K. But the optimum strain rate in the 1N90's extruded only at 773 and 873K at which the maximum total elongation of 200% and the m value of 0.3 at 913K are obtained is the lower strain rate of $7x10^{-3}s^{-1}$.

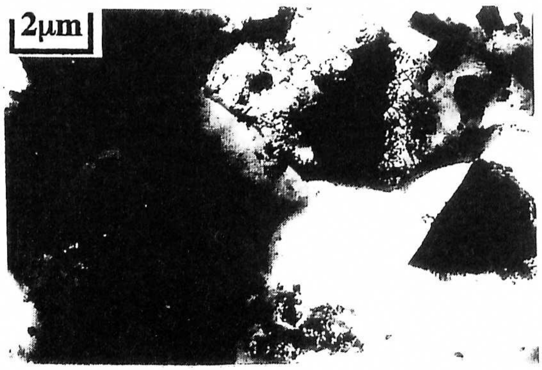


Fig.3 TEM microstrucres of the TiC/1N90 aluminum composite

Fig.5 (a) and (b) shows optical microstructure of 1N90 heated and holded for 5 minutes at the testing temperature of 913K, after being hot-rolled after extrusion and being extruded, respectively. The optical microstructures of the 1N90 hot-rolled after extrusion has so eqiaxial and fine grain as to produce the HSRS(Fig.5(a)) even though the 1N90 is without reinforcement. On the other hand, in the as-extruded 1N90, unrecrystallized zone such as elongated grains in extruded direction and uncrear grain boundary is observed(Fig.5(b)). **Fig.6** shows TEM microstructure of 1N90 pure Al hot-rolled before superplastic deformation . Since the misorientation angles were between 0~11 degrees, the 1N90 pure aluminum consists of fine subgrains of 0.6~1.0μm inside the grains of 10~20 μm.

4. CONCLUSION

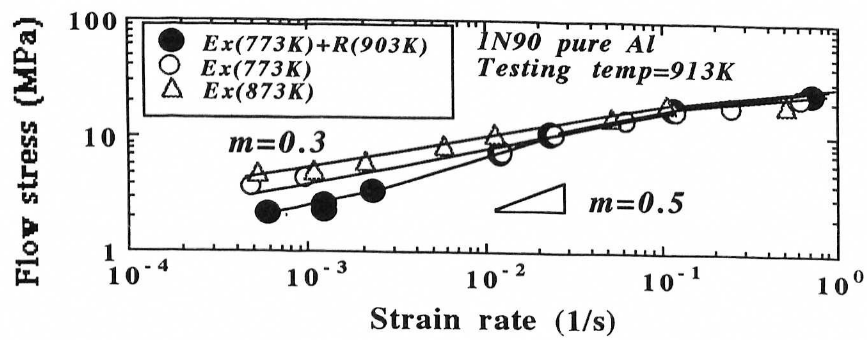
The effect of thermomechanical processing on superplastic characteristics of TiC/1N90 pure Al composite and 1N90 pure aluminum alone were investigated. The following results were obtained:

(1) Hot rolling could improve the microstructural homogeneity in TiC/1N90 pure Al composites and 1N90 pure Al alone.

(2) TiC/1N90 pure Al composite hot-rolled after hot extrusion indicates the maximum total elongation of 200% and the m value of 0.34 at the strain rate of about $2x10^{-1}$ s^{-1} at 913K.

(3) The optimum strain rate at which maximum total elongation is obtained in TiC/1N90 Al composite is higher by ten times than that of the 1N90 pure Al alone.

(4) The TiC/1N90 composite includes fine grains less than 2μm and subgrains of 0.2~0.5μm



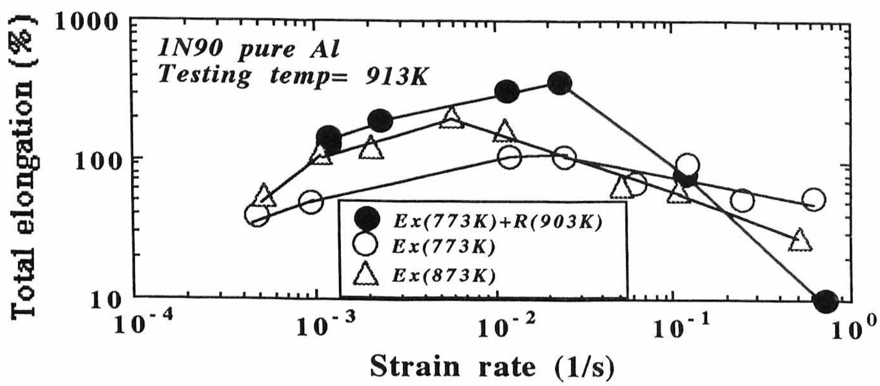


Fig.4 Effect of thermomechanical processing on superplastic characteristics of 1N90 pure aluminum.

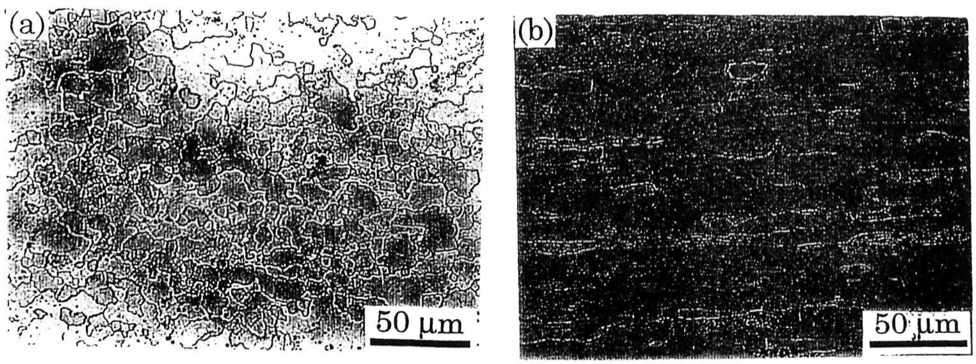


Fig.5 (a) and (b) Optical microstructure of 1N90 hot-rolled after extrusion and extruded only

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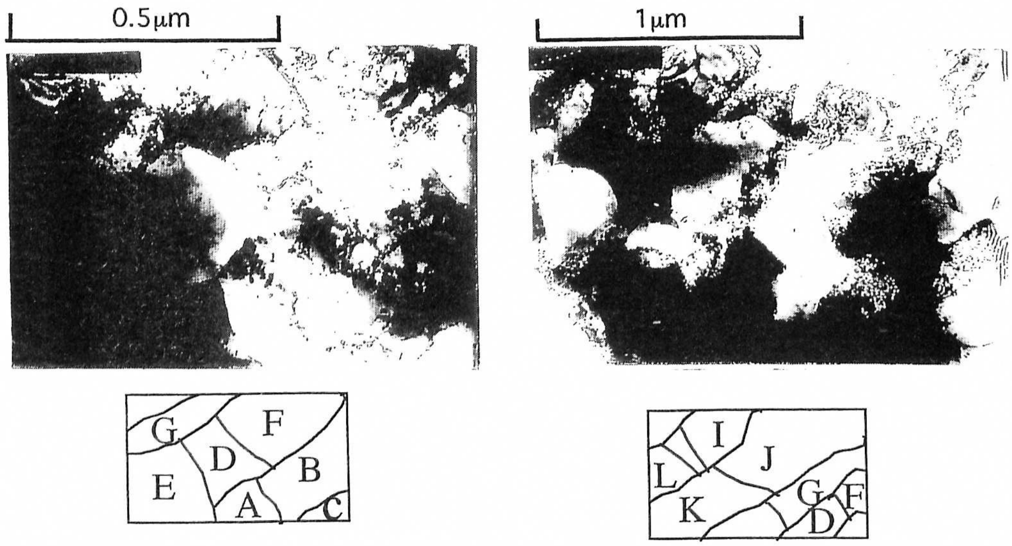

Fig.6 Misorientation angle at grain boundaries in 1N90 pure aluminum.