# Development of Heat- and Creep-resistant Fine-grained Rapidly Solidified P/M Aluminum Alloy

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**Abstract**

*The new alloy[1)] is made from rapidly solidified Al-Ni-Zr-Ce aluminum alloy powder, and has the following unique mechanical characteristics:(1) The stress-strain curve shows a yield point; (2) The alloy shows high heat resistance; (3) Although the alloy is submicron particle diameter, it shows excellent creep resistance. We observed the micro structures of this new alloy, and it is thought that is based on the following reasons:(1) The dislocation strongly adheres to the alloy's many crystal boundaries;(2) The added alloying elements have a small diffusion coefficient in aluminum;(3) The tiny inter-metallic compound particles crystallizing at the grain boundary.*

**Keywords : Aluminum, rapidly solidified powder, heat resistance, creep**

## 1. Introduction

In recent years the need for solutions to worldwide environmental conservation and energy problems has increased the demand for developing new functional lightweight alloys that make it possible to the fuel consumption and increase the output of machines and transport vehicles, particularly automobiles.

In the field of aluminum alloys, there is a large need for higher heat-resistance and creep-resistance. In an effort to develop a new solidification method and a new alloy to meet this need on a comprehensive basis, we developed an aluminum alloy, which has an unprecedented hyperfine structure made up of crystalline grains on the order of several hundred nanometers in size. This report introduces the properties of the new alloy and the reasons why the new alloy shows these properties.

## 2. Experimental and Results

$Al_{95}Zr_1Ce_1$ (atomic%) powder was cold compacted and hot extruded at 400 degree C. After extrusion, consolidate was in the shape of a bar, 20mm in diameter was machined. The mechanical properties and the microstructures were observed.

(1) Tensile properties

Fig.1 shows the stress-strain curve of the new alloy. The curve shows a yield point which is not shown with conventional aluminum alloy.

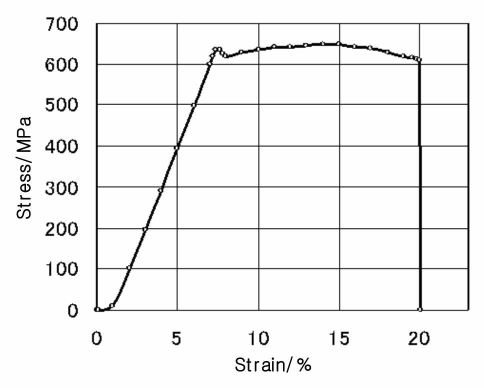



**Fig. 1. Stress strain curve of the new alloy at room temperature.**

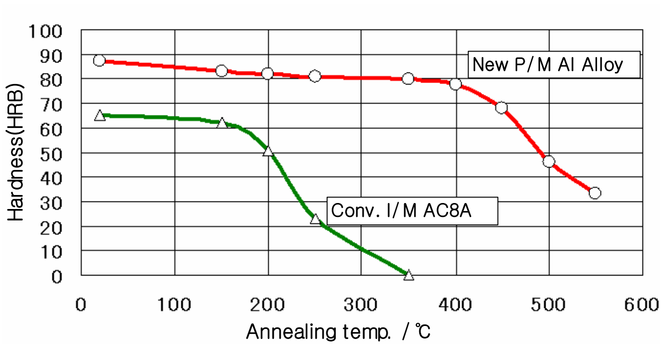



**Fig. 2. Anneal softening curve of the new alloy for 24 hours**

(2) Heat resistance

Fig. 2 shows the change in hardness measured after annealing at a high temperature for 24 hours and then cooling to room temperature compared with the conventional I/M AC8A alloy. The new alloy shows high heat resistance. The hardness of the alloy does not deteriorate until the annealing temperature reaches roughly 400 degrees C.

(3) Creep behavior

Fig. 3 shows a plot of strain versus time for an applied stress of 137 MPa at a temperature of 250℃. For comparison, the figure includes plots for an existing powder aluminum alloy and cast Al-12Si (mass%) (AC8A). Although the new alloy is submicron particle diameter, it shows excellent creep resistance.

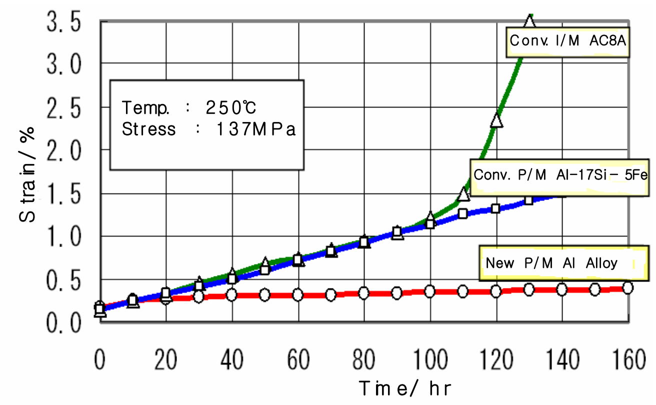



**Fig. 3. Creep curves of Aluminum alloys**

We observed the micro structures of this new alloy, and it is thought to base on the following reasons:

(1) The reason of the yield point

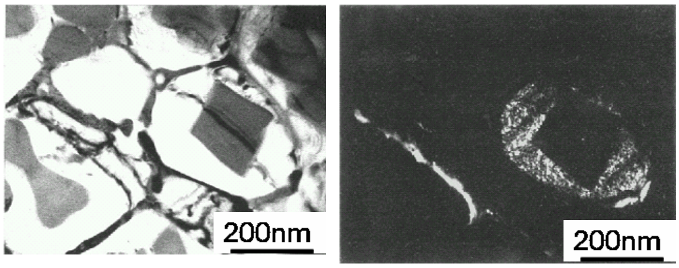
The yield point is considered to be a result of the fact that the dislocation strongly adheres to the alloy's many crystal boundaries. Fig.4 shows the TEM structures of the alloy. The dark field image shows the submicron grains.

(2) The reason of the high heat resistance

Fig. 5 shows SEM images of the structure at different stages during the heating process. No change in structure is observed up to 400 ℃. At 500 ℃, IMC begins to condense at the grain boundaries of the fine aluminum crystalline structure. The $Al_3Zr$ in the center of the aluminum crystal grains does not change. This is considered to be possible because the added alloying elements have a small diffusion coefficient in aluminum.

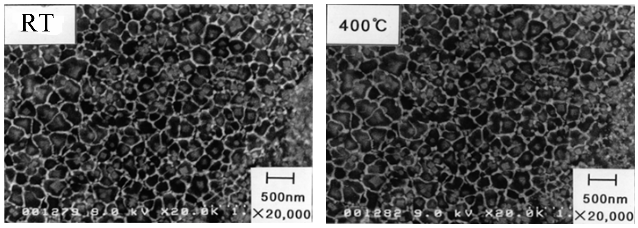
(3) The reason of the high creep resistance

The strong creep resistance is thought to result from the tiny inter-metallic compound particle (approximately 100 to 200 nm) of this alloy crystallizing at the grain boundary, thus inhibiting the grain-boundary slip.




(a) (b)

**Fig. 4. TEM structure of the new alloy.**
**(a) Bright field image. (b) Dark field image.**



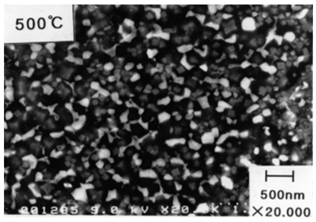




**Fig. 5. In situ SEM observations of the heating $Al_{95}Zr_1Ce_1$ alloy.**

## 3. Summary

Rapidly solidified $Al_{98}Zr_1Ce_1$ alloy has high heat- and creep- resistance thanks to IMCs containing rare earth and transition metals, which are highly heat resistant. Furthermore, this new alloy shows unique yield strength that is not seen in conventional aluminum alloys.

## 4. Reference


1. T. Kaji, H. hattori, M. hashikura, T. Tokuoka, T. Takikawa, A. Yamakawa and Y. Takeda : SEI Technical Review, 51(2001), 114.