Development of P/M Aluminum Alloy with Fine Microstructure

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Abstract

We successfully developed Al -Si -Transition Metal (TM) -Rare Earth (RE) Powder Metallurgy (P/M) alloy with fine microstructure, which has high strength at high temperature. This material was compacted rapidly solidified powder and directly consolidated by hot extruding or forging. Before consolidating, rapid heating was performed on powder compaction in order to keep the fine microstructure in powder state. We have also investigated the processing conditions of this new alloy by computing simulations and experiments.

Keywords : Aluminum alloy, rapidly solidified powder, extruding, forging

1. Introduction

Aluminum alloy made with P/M processing using rapid solidification process shows superior mechanical characteristics compared to Aluminum alloy made by conventional cast processing. To successfully apply powder metallurgy Aluminum alloy to components, a process that generates shearing stress to break down oxide film on the surface of each alloy particle enabling the powder to bond is required. We have developed a P/M Aluminum alloy with heat-resisting properties, Al -Si -TM -RE alloy. We have also investigated the processing conditions of this new alloy by computing simulations and experiments.

2. Experimental and Results

Alloy powder consisting of Al17 Si2 Fe1.5 Ni1.5 and Misch Metal 5 (numbers are mass %) prepared by an air atomizing process was formed into a green compact with diameter of 85 mm, height of 50 mm and relative density of 80%. The green compact sample was then heated to 773K by an induction furnace. The heating rate was 2 to 3 K/s. Hot forging was then performed on the sample at a compacting pressure of 800 MPa resulting in a cup-shaped. The forged sample prepared was cut, polished and its material structure was observed at the position shown in Fig. 1. The polished surface was etched, and the profiles of alloy powder contained in the sample were observed at the arbitrary positions and their shapes measured. The major (a) and minor (b) axes of the original alloy particles were measured, with the aspect ratio determined by a/b and used as an indicator of plastic deformation at the time of forging. The aspect ratio of raw material particles was about 2.

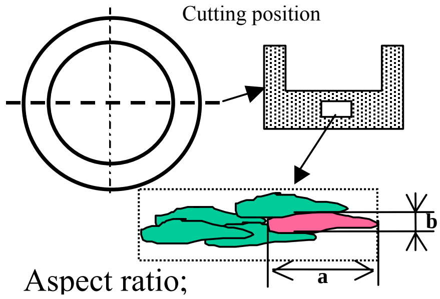

Fig. 1. Evaluation of the amount of plastic deformation about alloy powder

For finite element analysis, Deform-2D<TM> simulation software for deformation processing by Scientific Forming Technologies Corporation was used. The model was performed on a half-sized rigid-plastic model, with the number of elements between 1030 and 1050. The mold was rigid and the coefficient of friction was 0.3 for contact between the base of the work and the mold. The sample was also examined using other forging conditions. Based on this simulation, the changes in the distribution of plastic deformation could be investigated by varying the amount of upper punch penetration.

Fig. 2 show contour maps for estimated plastic strain based on FEM simulation. Fig. 3 shows some examples of observed material structure the same as the model in Fig. 2. Depending on the measurement position, aspect ratio of powder varies greatly, and the same as simulation estimates, there is large plastic deformation in the corner position of the cup inner wall and a small amount of plastic deformation in the center of the upper punch around the mold.

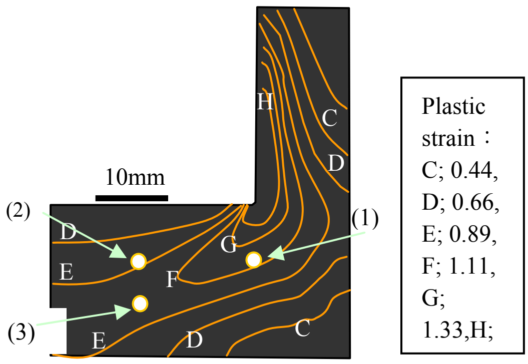

Fig. 2. Prediction of the amount of plastic deformation by FEM

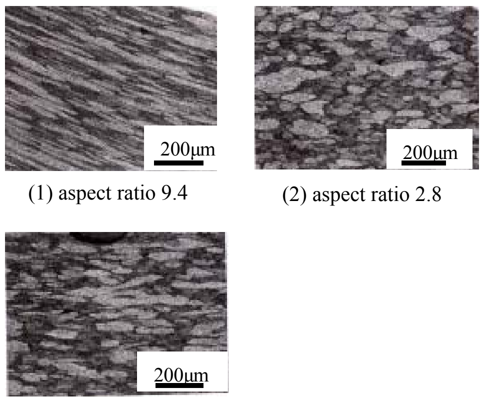

Fig. 3. Plastic deformation of alloy powder in consolidated material (The number in this figure corresponds to Fig.2)

Fig. 4. shows the correlation between predicted values for plastic strain based on FEM simulation using arbitrary positions and the aspect ratio of actual alloy powder. It is thought that a linear correlation exists between two values where an alloy powder has aspect ratio of 3 or greater. From the FEM simulation results it is possible to predict the plastic deformation of a forged body at each position.

Fig.5. shows the correlation between test results for tensile test pieces cut from a forged sample and the aspect ratio (a/b) of alloy powder inside the test piece. For tensile strength it can be seen that a stable value can be reached once the aspect ratio exceeds 3.

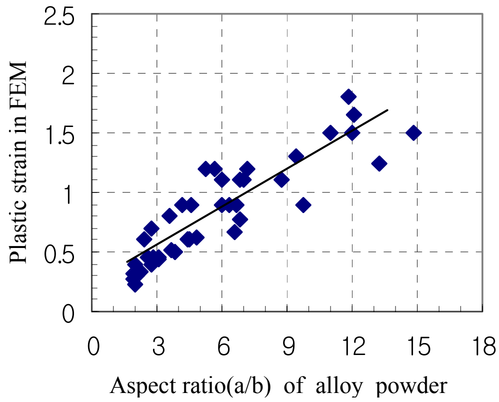

Fig. 4. the relation between the amount of plastic deformation by FEM and aspect ratio of powder in consolidated material

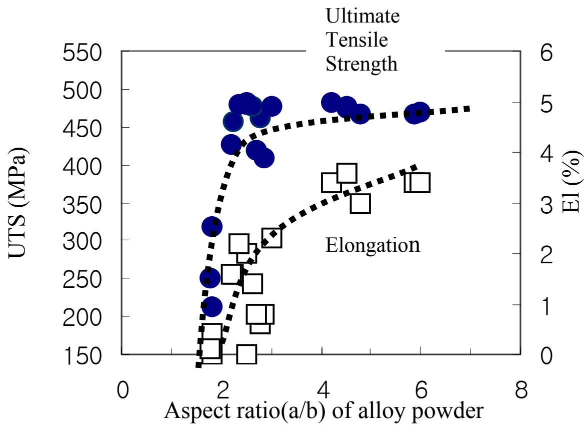

Fig. 5. Relation between Ultimate Tensile strength or Elongation at Room Temperature and aspect ratio of alloy powder in consolidated material

3. Summary

a) There is a linear correlation between the aspect ratio of alloy powder observed in the material structure and plastic strain based on FEM simulation when the aspect ratio is in an area above 3.

b) There is also a correlation between the aspect ratio of alloy powder and mechanical characteristics.

4. References

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