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Effect of Vibration Conditions and Shear Rate on the Shape of Solid Particles in JIS AC4CH Aluminum Alloy Slurry Made by Applying Mechanical Vibration

Yuichiro Murakami[1], Kenji Miwa[2], Masayuki Kito[3], Takashi Honda[3] and Shuji Tada[1]

[1] National Institute of Advanced Industrial Science and Technology, 2266-98, Anagahora, Shimo-Shidami, Moriyama-ku Nagoya, Japan
[2] Aichi Science and Technology Foundation, 1-157-1, Onda-cho, Kariya, Aichi, Japan
[3] Aisan Industry Co., Ltd. 1-1-1, Kyowa-cho, Obu, Aichi, Japan

The shape of solid particles affects on fluidity in the semi-solid die-casting process, so to clarify the effects of shear stress and initial shape of solid particles on deformation are an important issue. The slurry made by applying mechanical vibration under different acceleration amplitude was injected into the spiral shape cavity with different shear rate at the gate. The solid particles became fine and globular in the case of the high acceleration amplitude and high shear rate. Moreover, at the high acceleration amplitude slurry, fraction solid after the injection process became higher than low acceleration amplitude. This result suggested that the slurry made with high acceleration amplitude can be formed stably and high fluidity.

Keywords: *Semi-solid slurry, high pressure die-casting, mechanical vibration, shear stress, solid particle*

1. Introduction

Semi-solid process is a method of forming at the solid-liquid coexistence phase. The semi-solid metal has a higher viscosity and lower solidification shrinkage ratio than the liquid metal, so the casting defects caused by air entrainment or shrinkage porosity are expected to be decreased. However, the semi-solid process has the disadvantages of formability in low fluidity, and a difficulty of temperature control to make a semi-solid slurry.

We have developed the method to prepare the slurry by applying mechanical vibration during cooling from liquid to semi-solid temperature [1]. The fluidity of the slurry could be improved by applying shear stress to the slurry at the gate of mold. In this method, the solid particles in the slurry were deformed to fine and globular by applying shear stress, and fluidity of slurry was increased with fine and globular solid particles [2-4]. Therefore, deformation of solid particles is thought to have effects on the fluidity.

In this study, to clarify the effect of the shear stress and the initial shape of solid particles on deformation, the fluidity tests for the semi-solid slurry made by applying various mechanical vibration conditions were carried out.

2. Experimental procedure

The slurry was prepared as follows [1]. In this study, an Al–7wt%Si–0.3wt%Mg alloy (AC4CH in the JIS, equivalent to A356 in the ASTM standard) was used. The molten AC4CH alloy at 650 °C was poured into the horizontal vibrating a stainless steel container at the room temperature. The vibration was applied for 20 s. The frequency of vibration was constant at 50 Hz, and the acceleration amplitude was varied as 117.6 m/s^2 (12 G), 147.0 m/s^2 (15 G) and 166.7 m/s^2 (17 G).

The slurry was injected into the spiral shape cavity (Fig. 1) by high pressure die-casting machine. Moreover, to vary the shear rate on the slurry, the thickness of the gate at the entrance of the cavity was set at 1.0 mm or 4.0 mm. The shear rate γ is 7.5×10^5 /s or 4.7×10^4 /s, respectively. The specimens were cut, and polished, then were subsequently etched with 0.5% HF solution. Then the microstructure at vertical section to flow direction was observed.

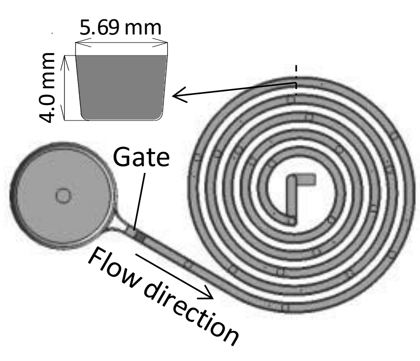

Fig. 1 Schematic illustration of fluidity test sample

3. Results and discussion

Fig. 2 shows the microstructure of the specimens. The mean particle diameter and roundness were calculated by these microphotographs, and then the effect of the acceleration amplitude on both these values was shown in Fig. 3. The roundness was defined as the ratio of measured circumference and equivalent circle circumference [3]. Therefore, if roundness is 1, the particle has the true circle shape, and this value increases if the particle deviates from the circle. The solid particles became fine and globular by increasing the acceleration amplitude of the mechanical vibration before injection. Moreover, the solid particles became finer and more globular after injection. Meanwhile, at low acceleration amplitude, the coarse solid particles could be seen. Fig. 4 shows the relation between acceleration amplitude and fraction solid. The fraction solid was decreased after injection in low acceleration amplitude. By the

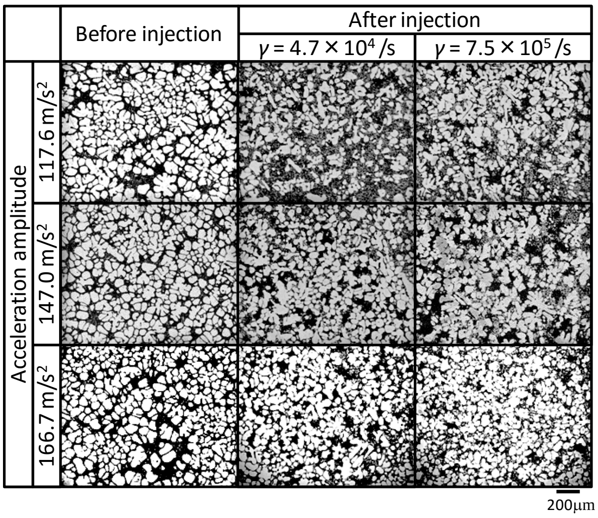

Fig. 2 Microstructure of specimens

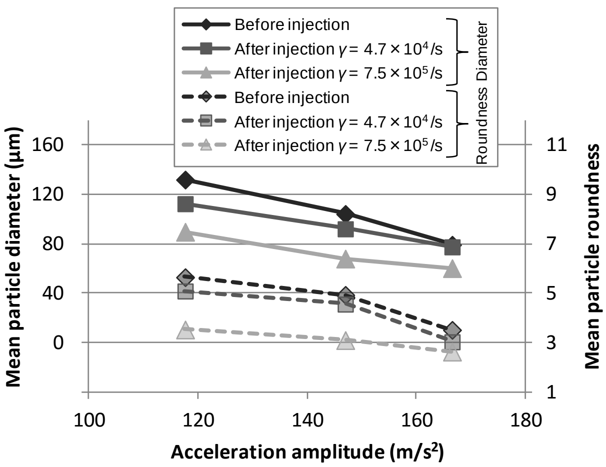

Fig. 3 Effect of acceleration amplitude on the shape on solid particles.

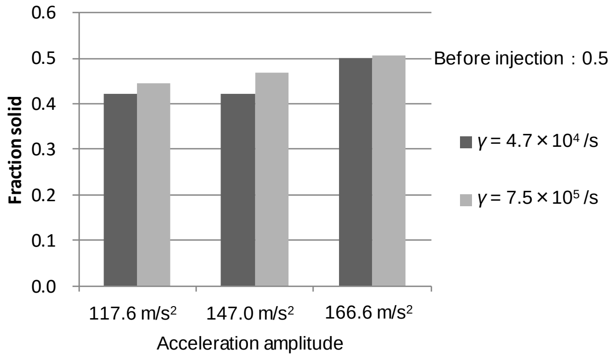

Fig. 4 Effect of acceleration amplitude on the fraction solid after injection process

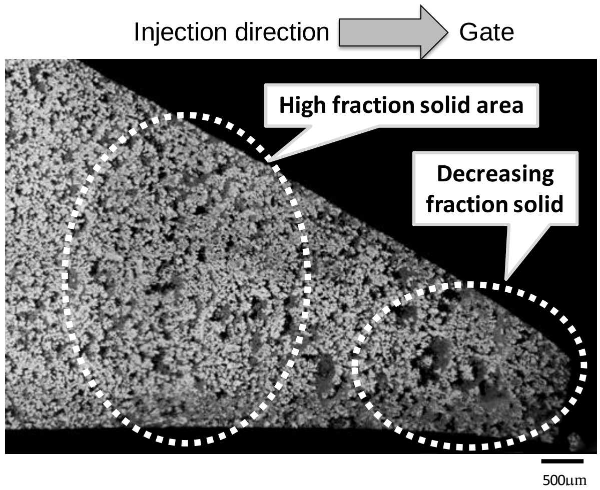

Fig. 5 Microstructure at the gate (acceleration amplitude 117.6 m/s^2, $\gamma = 7.5\times10^5$ /s)

observation of the microstructure at the gate (Fig. 5), the high fraction solid area was seen. Then the gate was considered to be clogged in low acceleration amplitude. This is considered as the cause of the decreasing of fraction solid. This phenomenon is also thought to be the reason for the high ratio of refinement, because coarse solid particles could not flow into the cavity by clogging. Meanwhile, the fraction solid after injection was same as before the injection at high acceleration amplitude. Therefore, the slurry made with high acceleration amplitude is expected to be formed stably.

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