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Effects of Mechanical Vibration on Gravity Die Casting of AC4C Aluminum Alloy

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Gravity die castings of AC4C aluminum alloy under mechanical vibration (0-120 Hz) were conducted using the actual casting machine. A part of mold (vibrating mold) was oscillated by a vibrator. Mechanical vibration imposed before pouring, and stopped at 40s after pouring. Columnar rod specimens (25 mm in diameter and 210 mm in length) were cast to investigate the effects of mechanical vibration on grain size, inner defect, and mechanical property. The grain size of columnar rod specimen decreased from 1800 μm (0 Hz) to 750 μm (100 Hz) by imposition of mechanical vibration. The internal defect of specimen decreased by mechanical vibration of frequency 70 Hz or less. But the vibration of 80 Hz or more led to increase of internal defect. As a result, specimens cast with the vibration of frequency 70 Hz showed higher UTS (ultimate tensile strength) compared with the specimen cast under other vibration conditions. Furthermore, the specimens vibrated at 70 Hz showed a very small scattering of UTS.

Keywords: *mechanical vibration, aluminum alloy, metallic mold, casting defect, X-ray computed tomography*

1. Introduction

Mechanical properties of castings strongly depend on its solidification structure. In general, it is known that many properties of castings such as yield point, ultimate tensile strength and elongation are improved by reduction of their grain size [1-3]. The grain refining agents are very effective to refine the grain size of castings. So, the grain refining agents are widely used in usual casting process. Titanium, boron, carbon, and mother alloys including these elements are well known as the grain refining agents for aluminum alloys [4-6]. However, in recycling, these grain refining agents are considered to be impurities. Recently, the concern for resource saving, energy saving and recycling increases rapidly. Therefore, a new grain refining process that does not use grain refining agents or other additives is required. It is well known that the vibration and agitation of melt during solidification process can refine the grain size of castings. So, many new processes using vibration and agitation have been developed and reported [7-12]. These processes are effective for refining the grain size of castings, but have been hardly put to practical use. Because, these processes need special and expensive equipments, indicating increment of product cost. Furthermore, it is difficult to fabricate the complicated and large products by these processes.

Our previous work [13] reported that reduction of the grain size, internal defect, and scattering of mechanical properties of castings was achieved by imposition of mechanical vibration on metallic mold using very simple equipments. We also investigated that the effects of mechanical vibration on cooling rate and dendrite arm spacing of castings using an actual casting machine, and it has been reported the cooling rate increased and the dendrite arm spacing decreased by addition of the mechanical vibration [14]. In present study, gravity die casting of AC4C aluminum alloy with mechanical vibration was carried out using the actual casting machine to investigate the effects of the mechanical vibration on grain size, internal defect and mechanical property.

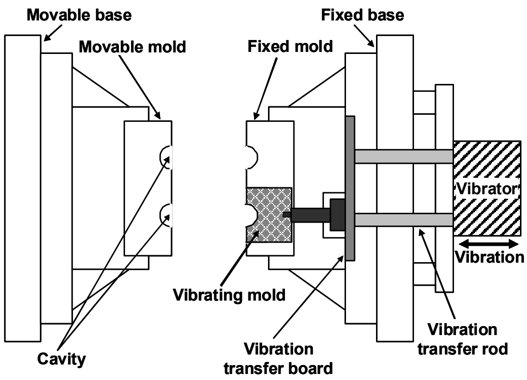

Fig.1 Schematic diagram of the experimental apparatus (top-view).

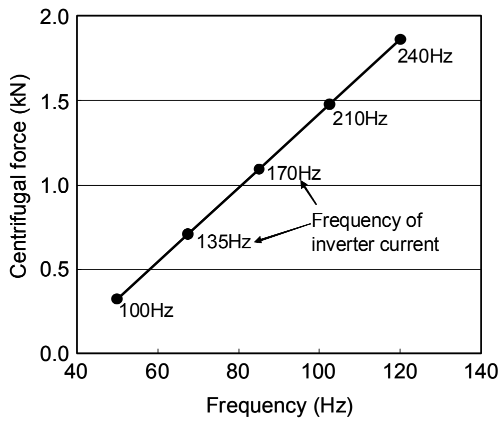

Fig.2 Relationship between inverter frequency and vibration properties.

2. Experimental procedure

The schematic of the experimental apparatus of vibration casting is shown in Fig. 1. A vibrator (HKM154VS; EXEN, Tokyo, Japan) was placed at the fixed base. The vibration generated by the vibrator was transmitted to a part of fixed mold (Vibrating mold) through transfer rods and a transfer board. This vibrator generates the vibration by the high speed rotation of eccentric pendulum. Thus, the vibration frequency and centrifugal force of the vibrator could be easily controlled by changing the frequency of the inverter current supplied (Fig. 2).

Table 1 Chemical composition of AC4C aluminum alloy

(mass%)

Si	Mg	Ti	Fe	Ni	Cu	Zn	Al
6.67	0.200	0.005	0.052	0.003	0.000	0.014	Bal.

The commercially available AC4C aluminum alloy was used in the test. The chemical composition of this material determined by emission spectrometric analysis is shown in Table 1. The liquidus temperature of this material was 888 K.

Figure 3 shows the shape of castings fabricated by mechanical vibration casting. Columnar rod specimens (25 mm in diameter and 210 mm in length) were cast using bottom gate plan. In this figure, the direction of the mold vibration is a vertical to the plane of this paper. Mechanical vibration casting was carried out at 1003 K of the melt temperature and 633-693 K of the metallic mold temperature. The imposition of mechanical vibration (0-120 Hz) started before pouring, and stopped at 40s after pouring.

Macrostructure and inner defect of the as-cast specimens was observed by an optical microscope (OM) and an X-ray CT system (SMX-225CT; Shimadzu, Kyoto, Japan). Tensile test specimens (14 mm in gauge diameter and 60 mm in gauge length) were machined from as-cast columnar rod specimens. Tensile tests were carried out at room temperature at a constant crosshead speed of 1 mm/min.

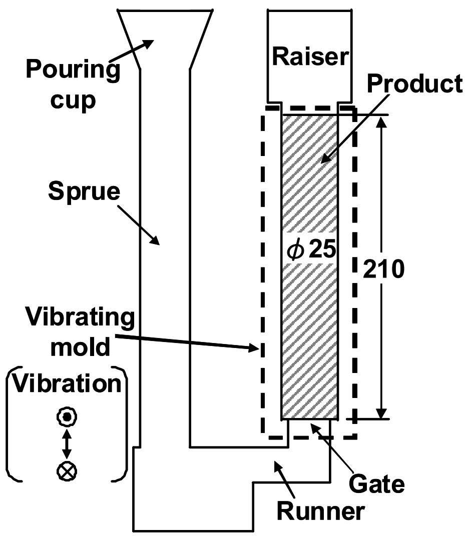

Fig.3 Schematic drawing of castings.

3. Results and discussion

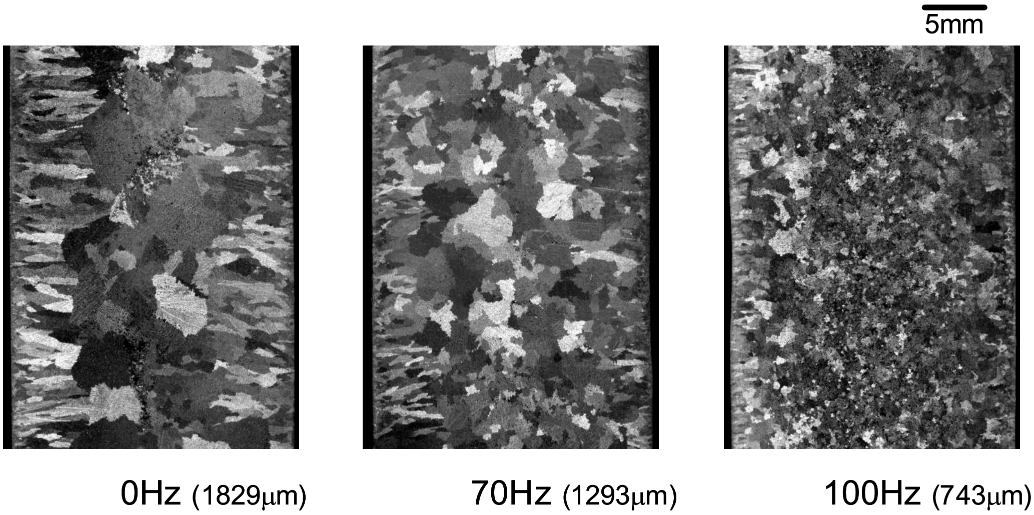

Fig.4 Effect of vibration frequency on the macrostructure of AC4C specimen cast at the mold temperature of 663K.

Figure 4 shows typical macrostructure of castings fabricated at mold temperature of 663K. In the specimen cast without mechanical vibration (Fig. 4(a)), columnar structure and granular structure are observed in their outer region and inner region respectively. A mean grain size of granular structure is about 1800 μm. By imposition of the mechanical vibration, the region of granular structure expands and the mean grain size of granular structure decreases from 1800 μm (0 Hz) to 750 μm (100 Hz), though the columnar structure is still observed in their outer region.

The X-ray CT images of specimens cast at mold temperature of 633-693K with and without mechanical vibration are shown in Fig. 5-7. These images express the vertical section of specimen including the diameter. In the X-ray CT image, the area of high X-ray absorption capacity is indicated in white, while the area of low X-ray absorption capacity is presented in black. Therefore, in this

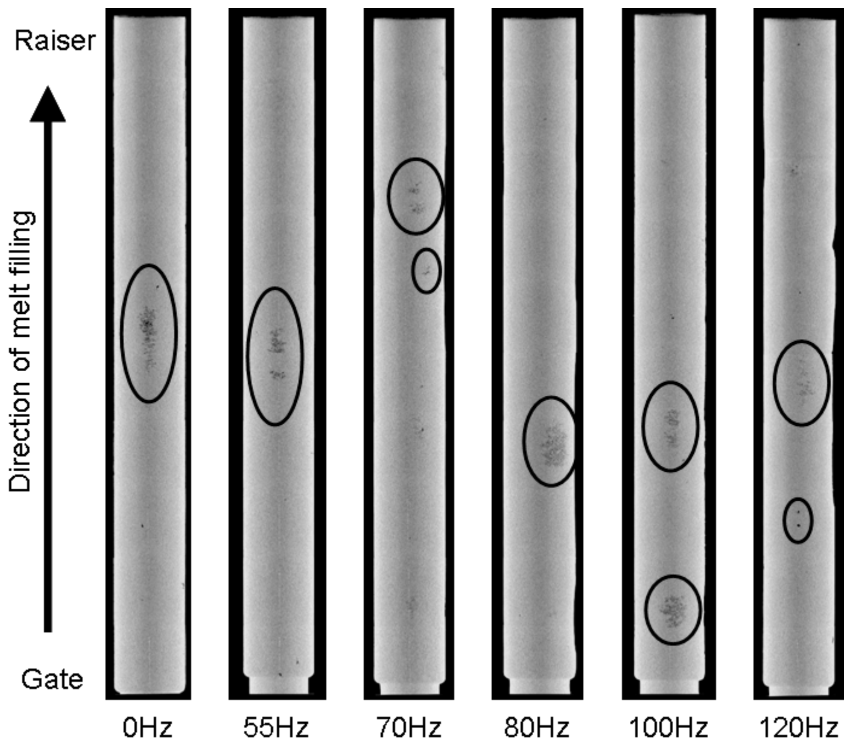

Fig.5 Effect of vibration frequency on the internal defect of specimen cast at the mold temperature of 633K.

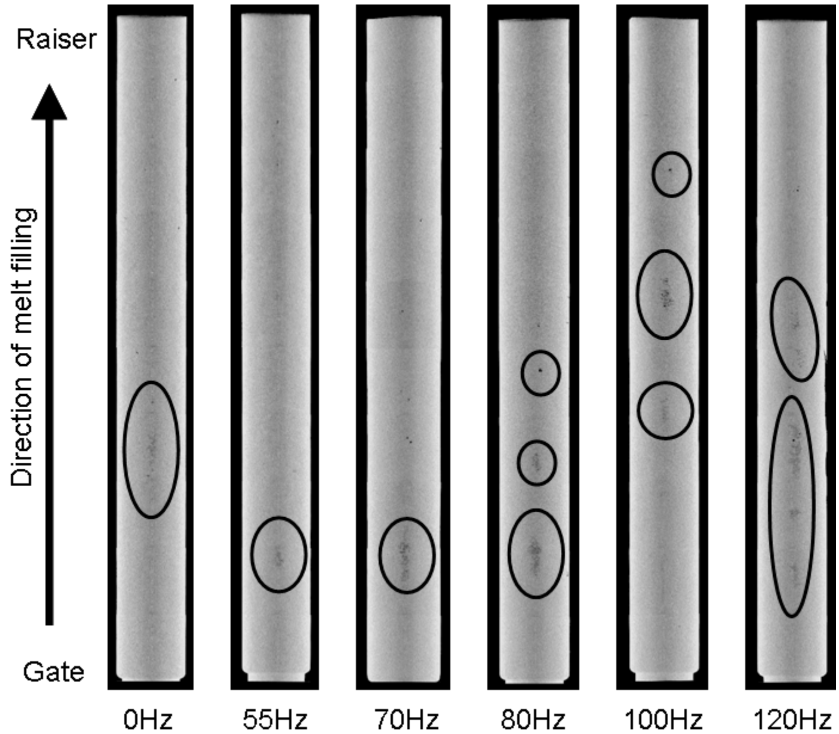

Fig.6 Effect of vibration frequency on the internal defect of specimen cast at the mold temperature of 663K

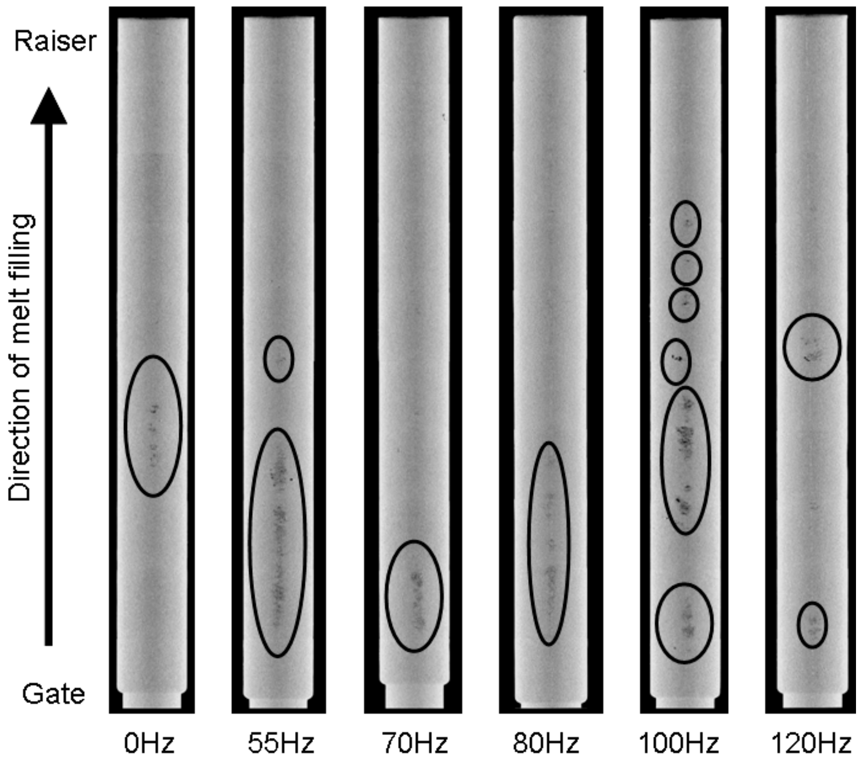

Fig.7 Effect of vibration frequency on the internal defect of specimen cast at the mold temperature of 693K

study, the specimen (aluminum) area is expressed in white, and internal defect such as pore is drawn in black. When the mold temperature is 633K, as shown in Fig. 5, some internal defect is observed in the middle area of specimen cast without vibration (0 Hz). The internal defect decreases by the

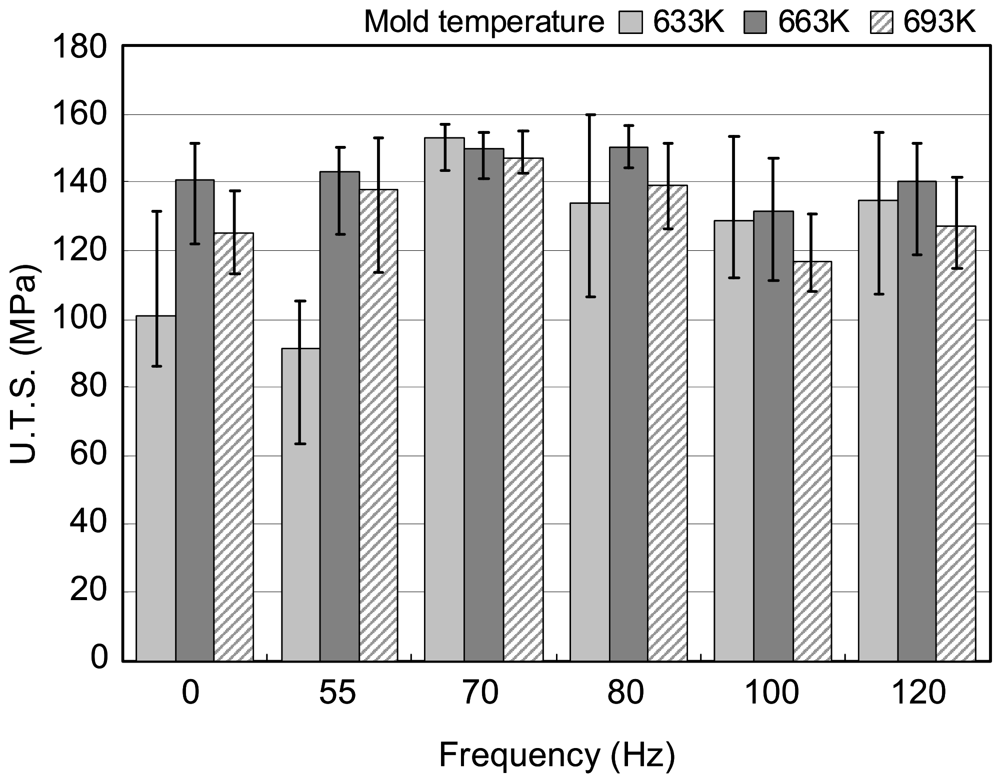

Fig.8 Ultimate tensile strength of as-cast specimens as a function of the vibration frequency.

mechanical vibration, and decreases with the increase of the vibration frequency. However, by addition of the vibration of frequency 80 Hz or more, the internal defect slightly increases. As a result, the specimen vibrated at 70 Hz shows the least internal defect. In the case of mold temperature 663K, as shown in Fig. 6, a little internal defect is observed in the specimen cast without vibration. So it is not clearly seen that the internal defect decreases by imposition of the vibration. When the vibration frequency is 80 Hz or more, the internal defect increases as well as the mold temperature 633K (Fig. 5). In the case of mold temperature 693k, the internal defect shows similar tendency, in a word, the internal defect is minimized at the vibration frequency of 70 Hz, and increased by the imposition of mechanical vibration of frequency 80 Hz or more. These results indicate that the optimum condition of mechanical vibration that minimizes the internal defect is independent of the mold temperature, and is 70 Hz in this casting plan.

Figure 8 represents the ultimate tensile strength (UTS) of as-cast specimen cast at various mold temperatures and vibration conditions. When the vibration frequency is 0 Hz and 55 Hz, the UTS is low and scatters widely. Especially the specimens cast at low mold temperature (=633K) show very low and scattering UTS. By addition of the vibration of frequency 70 Hz, the UTS increases to about 150 MPa. The UTS of these specimens is independent of the mold temperature, and hardly scatters. Vibrations of frequency 80 Hz or more lead to decrease and scatter in UTS.

4. Conclusions

Gravity die casting of AC4C aluminum alloys with mechanical vibration was carried out to investigate the effects of vibration on the macrostructures, internal defect and mechanical property. The area of columnar structure expanded and the grain size of columnar structure decreased by the addition of the vibration. The internal defect of specimen reduced at the vibration frequency of 70Hz or less. However, the internal defect increased when the vibration frequency was 80 Hz or more. The specimens cast at vibration frequency of 70 Hz showed higher and less scattered UTS compared with the specimens cast at other vibration conditions. Furthermore, the UTS of specimen vibrated at 70 Hz was independent of the mold temperature.

References

[1] N. J. Petch: Iron Steel Inst. 174 (1953) 25-28.
[2] C. H. Caceres, C. J. Davidson, J. R. Griffiths and C. L. Newton: Mater. Sci. Eng. A325 (2002) 344-355
[3] S. A. Kori, B. S. Murty and M. Chakraborty: Mater. Sci. Eng. A283 (2000) 94-104.
[4] Y. C. Lee, A. K. Dahle, D. H. StJohn and J. E. C. Hutt: Mater. Sci. Eng. A259 (1999) 43-52.
[5] T. Sritharan and H. Li: J. Mater. Proc. Tech. 63 (1997) 585-589.
[6] C. T. Lee and S. W. Chen: Mater. Sci. Eng. A325 (2002) 242-248.
[7] Y. Osawa and A. Sato: J. JFS 72 (2000) 733-738. [in Japanese]
[8] O. V. Abramov: Ultrasonics 25 (1987) 73-82.
[9] J. Dong, J. Cui, X. Zeng and W. Ding: Mater. Lett. 59 (2005) 1502-1506.
[10] B. Zhang, J. Cui and G. Lu: Mater. Sci. Eng. A355 (2003) 325-330.
[11] Y. Mizutani, S. Kawai, K. Miwa, K. Yasue, T. Tamura and Y. Sakaguchi: Mater. Trans. 45 (2004) 1939-1943.
[12] Y. Mizutani, Y. Ohura, K. Miwa, K. Yasue, T. Tamura and Y. Sakaguchi: Mater. Trans. 45 (2004) 1944-1948.
[13] N. Omura, Y. Murakami, M. Li, T. Tamura. K. Miwa, H. Furukawa, M. Harada and M. Yokoi: Mater. Trans. 50 (2009) 2578-2583.
[14] N. Omura, Y. Murakami, M. Li, T. Tamura. K. Miwa, H. Furukawa and M. Harada: Mater. Trans. 50 (2009) 2604-2608.