



Preparation and rheocasting of semisolid slurry of 5083 Al alloy with indirect ultrasonic vibration process

Shulin Lü, Shusen Wu*, Chong Lin, Zuqi Hu, Ping An

State Key Lab of Materials Processing and Die & Mould Technology, Huazhong University of Science and Technology, Wuhan 430074, China

ARTICLE INFO

Article history:

Received 14 July 2011

Received in revised form 9 August 2011

Accepted 10 August 2011

Available online 17 August 2011

Keywords:

Indirect ultrasonic vibration

Semisolid slurry

Primary α -Al particles

Rheocasting

Mechanical properties

ABSTRACT

The indirect ultrasonic vibration (IUV) method, in which the horn was vibrated under the outside of the metallic cup containing alloy melt, was employed for preparing semisolid slurry of 5083 Al alloy in this work. The effect of IUV on the microstructure of semisolid slurry and mechanical properties of rheo-diecasting samples were studied. The results indicate that good semisolid slurry could be obtained when the melt treated by IUV for 50 s, and the average diameter and shape coefficient of primary α -Al particles were 60 μm and 0.54 respectively. Apart from preparing semisolid slurry with fine microstructure, IUV had degassing effect on semisolid slurry of 5083 Al alloy. The tensile strength and elongation of the rheo-diecasting samples were 283 MPa and 9% respectively, which were increased by 11.4% and 32.4% respectively compared to conventional liquid die-casting samples.

© 2011 Elsevier B.V. All rights reserved.

1. Introduction

Semisolid metal (SSM) processing, first developed by Flemings and his co-workers at MIT, has received considerable interest as a promising technology during the last 40 years. Thixocasting and rheocasting are the two main technologies for manufacturing semisolid metal components with high-integrity. In recent years, more and more researches have been focused on rheocasting, which possesses several technological advantages over thixocasting, such as low cost and high productivity. Rheocasting involves stirring the solidifying alloy to prepare non-dendritic semisolid slurry, then shaping the slurry directly. A number of processes have been developed to prepare semisolid slurry. Alternatively, the ultrasonic vibration process is a simple and effective process to produce semisolid slurry.

Although addition of chemical elements into Al–Si alloys is a practical way to refine grain size [1,2], it may lead to other problems associated with the formation of foreign particles and hot tearing [3]. The application of physical field such as ultrasonic vibration during solidification is another effective way to achieve microstructural refinement. In the ultrasonic vibration process, an ultrasound field is imposed to the melt resulting in grain refinement, increased homogeneity, reduced microsegregation, enhanced mechanical properties [4–9] as well as degassing [10–12]. Furthermore, this process can be categorized into direct

and indirect methods. Direct ultrasonic vibration (DUV) method, by dipping the horn into the melt, can be used to make semisolid Al alloy slurry with fine and non-dendritic microstructure [13–16], but application of this process is impeded because of the erosion problem of titanium-alloy horn by Al melt. In order to avoid this problem, the indirect ultrasonic vibration (IUV) method, in which the horn was vibrated under the outside of the metallic cup containing alloy melt, has been developed in this research.

The widely used alloys for SSM processing are cast Al alloys and certain wrought Al alloys, however, studies on SSM of 5000 series Al alloys are limited [17–19]. The 5000 Al alloys are usually used for thin-plate rolling and have been found a large variety of applications including architectural, household appliances, marine craft, and automotive body sheet due to their excellent combination of weldability and corrosion resistance [20]. Nevertheless, it is hard for traditional plastic forming technologies to produce complex-shaped components. Rheocasting process can solve this problem.

In this work, semisolid slurry of 5083 Al alloy was prepared by IUV process. The effect of IUV treatment time on the microstructure of semisolid slurry was investigated and the mechanical properties of rheo-diecasting samples were examined.

2. Experimental procedure

The schematic of IUV apparatus is shown in Fig. 1. It consists of ultrasonic generator, ultrasonic horn, heating furnace, PID temperature controller, metallic cup, pneumatic system, etc. The horn was vibrated under the outside of the metallic cup containing alloy melt. The power of the ultrasonic generator was 2.6 kW, and the

* Corresponding author. Tel.: +86 027 87556262.

E-mail address: ssw636@hust.edu.cn (S. Wu).

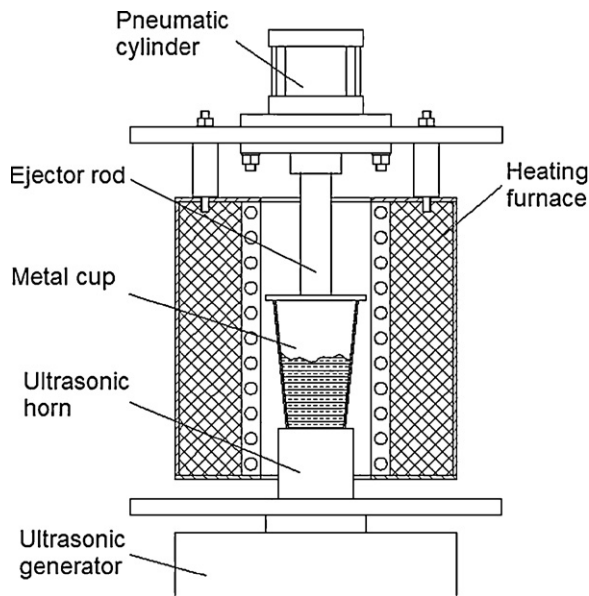


Fig. 1. Schematic of indirect ultrasonic vibration apparatus.

vibrating frequency was 20 kHz. The vibrating time and rest-work ratio could be adjusted by the ultrasonic generator. The rest-work ratio R_t of vibration was defined as the ratio of interval resting time T_r to ultrasonic time T_w in an ultrasonic vibration cycle, i.e., $R_t = T_w/T_r$. $T_r = 1.0$ s and $T_w = 1.5$ s were selected in this study. The preheating and isothermal holding temperatures of the metal cup were controlled by the PID temperature controller, and the heating furnace was driven up and down by the pneumatic system. The metallic cup, with an average diameter of 71 mm and made of stainless steel, was placed on the horn and pushed by an ejector rod to make sure its bottom contacted closely with the horn.

The chemical compositions of the 5083 Al alloy are Mg 4.5%, Mn 0.44%, Cr 0.15%, Si 0.4%, Fe 0.41% (mass%) and Al balance. The liquidus and the solidus temperatures of this alloy are 630.6 °C and 570.6 °C, respectively, determined by differential scanning calorimetry (DSC) method. The alloy was melted in a resistance furnace at 740–750 °C, and then degassed for 10 min with argon gas through a graphite lance. The melt was cooled to a pouring temperature of 650–660 °C after degassing and the metallic cup was preheated to 570 °C simultaneously. Subsequently, about 450 g of melt was poured into the metallic cup, followed by application of IUV at 632 °C. In order to prevent the melt from oxidation, argon gas was introduced as the protective atmosphere during the slurry preparation process. The melt cooled down from the liquidus temperature at a rate of about 6 °C/min. After vibrated for 20, 30, 40, 50, 60 and 70 s, some slurry was extracted out by a quartz tube with an inner diameter of 6 mm and quenched in water immediately. The remaining slurry treated by IUV for 30 s, 50 s and 70 s was poured into a ceramic mould made of Al_2O_3 and solidified as ingots for measuring density. For comparison, some slurry without IUV treatment was poured into the ceramic mould at 626 °C. The shape and dimensions of the ceramic mould are shown in Fig. 2.

Some additional semisolid slurry treated by IUV for 50 s was poured into the shot chamber of the cold-chamber diecasting machine (HPDC) to produce standard tensile test samples. The injection speed of die-casting was 4 m/s, and the specific pressure of injection was 40 MPa. The die was preheated to 200 °C before processing. Conventional liquid die-casting samples were also made without IUV under a pouring temperature of 730 °C. The shape and dimensions of tensile test samples are shown in Fig. 3. Tensile tests were performed using an universal materials testing machine at a

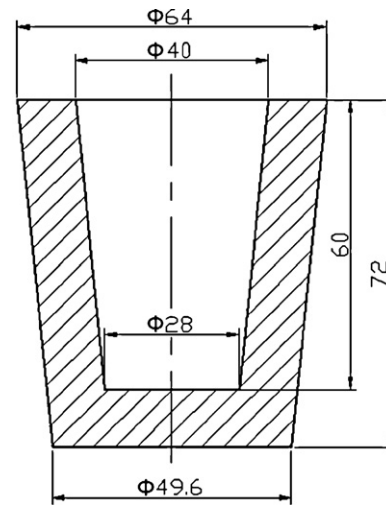


Fig. 2. Schematic of the ceramic mould (unit: mm).

strain rate of 1.25 mm/min. Densities of the ingots and tensile test samples were measured by using Archimedes' method.

Specimens for the metallographic examination were cut from the quenched rods and the ends of tensile test samples, then polished and etched by solution with 1% HF, 1.5% HCl and 2.5% HNO_3 . The microstructures were examined using an optical microscope and micrographs of the samples were analyzed by a quantitative metallographic analysis software. The size of the primary α -Al particles is characterized by average particles diameter (APD). The shape coefficient of a primary α -Al particle in this study was defined as:

$$S_F = \frac{4\pi A}{L_p^2}$$

where A is the sectional area of a particle in a micrograph, and L_p is the circumference. S_F varies from 0 to 1, and when the value of S_F is close to 1, the sectional shape of the particle approaches to a circle. The average shape coefficient $\bar{S}_F$ is based on counting all primary α -Al particles in a photograph. Fracture surfaces of the tensile test samples were examined by a Quanta 200 environmental scanning electron microscope (SEM).

3. Results and discussion

3.1. Preparation of semisolid slurry of 5083 Al alloy by IUV

Fig. 4 shows the microstructure of the semisolid slurry without IUV treatment quenched at 626 °C. Typical dendritic primary α -Al particles with length of more than 1000 μ m are observed.

Fig. 5 shows the microstructures of the semisolid slurry treated by IUV for different times. It is clear that non-dendritic primary α -Al particles are dispersed uniformly in the matrix. The size and morphology of primary α -Al particles are influenced significantly by IUV treatment time. When treated for 20 s (ended at 630 °C), Fig. 5a,

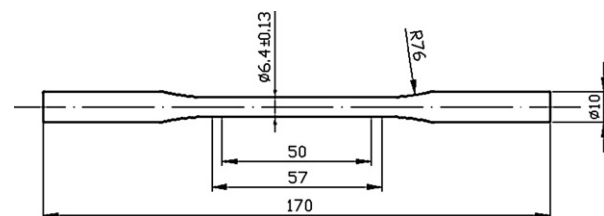


Fig. 3. Schematic of tensile samples made by die-casting (unit: mm).

Download English Version:

<https://daneshyari.com/en/article/1578093>

Download Persian Version:

<https://daneshyari.com/article/1578093>

[Daneshyari.com](https://daneshyari.com)