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Influence of filling parameters on fatigue properties of A357 alloy produced by counter pressure plaster mold casting

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Abstract: The influence of filling parameters including pouring temperature, filling speed, boost pressure and synchronous pressure on the fatigue of A357 alloy produced by counter pressure plaster casting was studied. The Taguchi method was used to investigate the relationship between the fatigue performance and filling parameters. The results show that filling speed is the most significant factor among the four parameters. Synchronous pressures is less influential on the fatigue life when the value of synchronous pressure is from 400 kPa to 600 kPa.
Key words: counter pressure casting; A357 alloy; filing parameters; fatigue properties

1 Introduction

Porosity has significant influence on the fatigue performance of cast Al−Si alloys. Numerous studies [1−8] have proven that fatigue strength is decreased due to the presence of porosity. To reduce or eliminate porosity is the only way to increase the fatigue performance of cast Al−Si alloys. Counter pressure casting (CPC) is a good way to reduce porosity for cast Al alloys.

CPC is one of counter gravity casting methods, such as low pressure casting and vacuum-assisted pressure-adjusted casting. It overcomes many casting problems compared with gravity casting, such as low turbulence or turbulence-free filling, controlled and directional solidification, and elimination in oxide and porosity formation [9]. KATZAROV et al [10] proposed a method for simultaneous treatment of heat and mass transfer processes and porosity formation of casting produced by CPC method, and it was reported that differential pressure (here is called synchronous pressure) was valuable during the process of crystallization. MA et al [11] and MI et al [12] studied the effect of cooling rate on the microstructure and mechanical properties of A357 alloy produced by CPC method. Besides the cooling rate and differential pressure, there are many process parameters in CPC that are very important to casting quality, such as pouring temperature, filling speed, and boost pressure. In this work, the influence of filling parameters including pouring temperature, filling speed, boost pressure and synchronous pressure on the fatigue strength was investigated.

2 Experimental

2.1 CPC process

The CPC equipment used in the present study is shown in Fig. 1. It includes an upper and a lower can (an airtight pressure container). Meanwhile, a mold was placed in the upper can and a holding furnace was kept inside the lower can. The whole counter-pressure casting process can be divided into five stages, i.e., 1) synchronous pressurizing, 2) filling mold, 3) boosting pressure, 4) holding pressure and 5) releasing pressure, as shown in Fig. 2. It should be noted that the upper can and lower can were pressurized with equal pressures until the pressure reached the set-up value (synchronous pressure). Then the pressure in upper can decreased under control while the pressure in the lower can maintained. This allowed metal to rise in the riser-tube, and into the mold at a controlled and tranquil rate, under a countering pressure.

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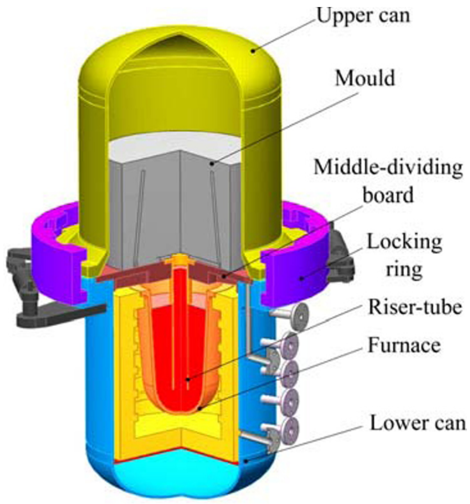

Fig. 1 3D cutaway view of main machine

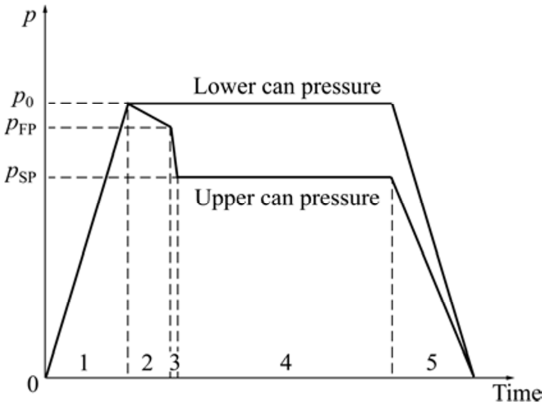

Fig. 2 Technical process curves of counter pressure casting

2.2 Design of experiments

The experiments were designed to establish the effects of filling parameters on fatigue strength in A357 aluminum alloy produced by counter pressure plaster casting with Taguchi method. Four filling parameters and their levels are given in Table 1.

Table 1 Filling parameters and levels

No.	Factor	Level 1	Level 2	Level 3
1	Pouring temperature (PT)/°C	690	710	730
2	Filling speed (FS)/(mm·s^{-1})	40	60	80
3	Boost pressure (BP)/kPa	10	20	40
4	Synchronous pressure (SP)/kPa	400	500	600

The common principle of Taguchi method is to develop an understanding of the individual and combined effects of a variety of parameters from a minimum number of experiments. A generic signal to noise (S/N) ratio is used to quantify the present variation. There are several S/N ratios available depending on the type of characteristics, including "Larger is better", "Nominal is best", and "Smaller is better". Because the value of fatigue strength is vital in this test, the S/N ratio for "Larger is better" is related to the present study which is given by [13]

$$R_{S/N} = -10\times\lg\left(1/n\left(\sum_{i=1}^{n} 1/y_i^2\right)\right) \quad (1)$$

where n is the number of repetition in a trial under the same design condition, y_i represent the measured values, and subscript i indicates the number of design parameters in the orthogonal array.

2.3 Materials

Commercial igots of alloy A357 were supplied by Shenyang Research Institute of Foundry (SRIF), which contain 7.29% Si, 0.6% Mg, 0.042% Be, 0.17% Ti, 0.023% Fe and balance Al. Eutectic Si modification was accomplished by sodium; grain refinement and degasing were achieved by adding a commercial agent. Figure 3(a) illustrates the plaster casting obtained in the present work. The gauge section of the round bars is of diameter D=10 mm and length 90 mm. There were 9 casting conditions varied with filling parameters according to the Taguchi method, and each condition had 4 specimens for fatigue test. All the specimens were subjected to T6 heat treatment: solution treating at 540 °C for 4 h in an heat treatment resistance furnace, water quenching at room temperature, and then artificial aging at 165 °C for 6 h. The specimen geometry used for the fatigue test is shown in Fig. 3(b).

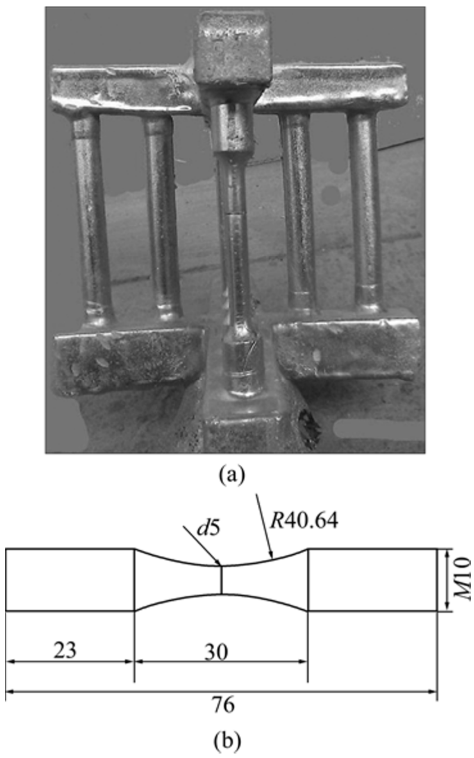

Fig. 3 Plaster casting (a) and specimen geometry for fatigue test (b) (Unit: mm)