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Short Communication

Effect of a two-step solution heat treatment on the microstructure and mechanical properties of 332 aluminium silicon cast alloy

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ABSTRACT

This paper investigated the effect of a two-step solution heat treatment on the mechanical properties and silicon-rich phase of 332 aluminium alloy. Traditional single-step T6 solution treatment (495 °C/6 h) increased the hardness value of the alloy by 5.96%, increased the tensile strength by 20.42% and reduced the elongation by 3.97%. Two-step solution treatment of the alloy (495 °C/2 h followed by 515 °C/4 h) increased the hardness value by 6.64%, increased the tensile strength by 16.01%, and reduced the elongation by 4.67% compared to the as-cast samples. Both solution treatments were followed by hot water quenching (75–90 °C) and artificial aging at 250 °C for 4 h. The difference in mechanical properties after heat treatment can be linked to the refinement and the spheroidisation of the silicon-rich phase in the alloy.

1. Introduction

Aluminium silicon cast alloy 332 contains mainly two types of alloying elements (approximately 9% silicon and 3% copper). The detailed chemical composition of 332 alloy is shown in Table 1 [1]. The high silicon content of this alloy makes its fluidity and castability superior to those of other materials, where fluidity refers to the ability of the liquid metal to flow through a mold without prematurely solidifying, and castability refers to the ease with which a good casting can be made from the alloy [2].

Alloy 332 is mainly used for the manufacturing of machine pistons and applications that require the ability to withstand high thermal stresses. The mechanical properties of alloy 332 can be improved by heat treatment, but the heat treatment conditions may affect the mechanical properties of alloy 332. The properties of the aluminium silicon alloys are controlled by solid-solution strengthening of the α aluminium matrix and dispersion strengthening of the β phase [2]. T6-type heat treatment processes consist of solutionising, quenching, and artificial aging and are commonly used industrially to improve the mechanical properties of aluminium silicon alloys. Heat treatment parameters such as the solutionising temperature and time, quenching temperature and cooling rate, and artificial aging temperature and time are important in controlling the mechanical properties of the alloy [3–7].

The first step in precipitation hardening is solution treatment, a heating process designed to produce a single-phase solid solution with an elevated temperature at which more solute will be dissolved into the solid solution compared to room temperature. The heating temperature should not exceed the eutectic melting temperature. The heating process should have a sufficient duration to ensure that a single phase is produced with a uniform chemistry [2]. The fact that alloy 332 contains traces of elements like Cu, Mg and others will influence the required solution temperature. The Al–Si phase diagram suggests that the eutectic temperature is 577 °C [8], but in a study conducted by Wang, the solidification sequence of A319 aluminium alloy shows that the lower melt point phases such as Al–$CuAl_2$, Al_5Mg_8 and Cu_2Si_6 have melting points in the range of 495–520 °C [5]. Therefore, the solutionising temperature during heat treatment of alloy 332 is generally kept within this limit.

The quenching process aims to retain the solute atoms in a supersaturated solid solution formed during solution heat treatment by rapidly cooling the specimens to a lower temperature, resulting in hardening by precipitation. The quenching process also maintains a certain number of vacancies in the lattice structure that tend to help the diffusion process and are necessary to form the hardening phases in the subsequent stages of age hardening [6]. Ammar compared the effect of quenching 413 aluminium alloy in hot water at 60 °C and in ambient air. The work showed that using hot water as a quenching medium markedly improved the strength and quality (but decreased ductility) because of the faster cooling rate achieved with quenching in hot water as opposed to gradual cooling in ambient air [6].

Aging is the last step of the process in which the alloy is heated within the α + β two phase region. In this stage, the β precipitate phase begins to form as finely dispersed particles. In aluminium silicon alloy, the β phase represents the silicon-rich phase. The character of the β particles and thus the strength and hardness of the alloy depend on both the precipitation temperature and the

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