ARTICLE IN PRESS

Available online at www.sciencedirect.com

ScienceDirect

Progress in Natural Science: Materials International ▮ (▮▮▮▮) ▮▮▮–▮▮▮

Progress in Natural Science Materials International

www.elsevier.com/locate/pnsmi
www.sciencedirect.com

Original Research

Modification performance on 4032 Al alloy by using Al–10Sr master alloys manufactured from different processes

Chengwei Liao[a], Jianchun Chen[b], Yunlong Li[b], Huan Chen[b], Chunxu Pan[a,*]

[a]School of Physics and Technology, Center for Electron Microscopy, Wuhan University, Wuhan 430072, China
[b]Hunan Jinlianxing Special Materials Technology Co., Ltd., Yueyang 414005, China

Received 20 August 2013; accepted 30 December 2013

Abstract

The microstructures and modification performance on 4032 aluminum alloy of the Al–10Sr master alloy wire prepared from "direct reaction-hot extrusion" and the trapezoidal block from "direct reaction" were systemically studied by using optical metallurgical microscope, XRD and SEM. It was found that the preparation processes exhibited a significant effect on the microstructures of the Al–10Sr, which thereby influenced its modification performance. It has been found that when the Al–10Sr alloy wire was used, a desirable modification was obtained after 2 min and reached to the best performance at 60 min, and the optimum Sr addition amount was 0.04–0.06 wt%, and the good modification performance was kept even after 300 min. However, when the Al–10Sr alloy trapezoidal block was used, a desirable modification was started after 30 min and reached to the best performance as long as 120 min, and the optimum Sr addition amount was 0.06–0.08 wt%, and the effective modification period was only 180 min. Therefore, comparing with the Al–10Sr alloy trapezoidal block, the Al–10Sr alloy wire had better modification efficiency, which not only reduced the Sr addition amount of about 30%, but also greatly decreased the incubation time and improved the ability of anti-fading.

Keywords: Al–10Sr master alloy; 4032 Al alloy; Sr; Modification; Addition amount; Holding time

1. Introduction

As structural materials Al–Si alloys are the most important and widely used Al alloys in the foundry industry due to their specific characteristics, such as light weight, good corrosion resistance, low coefficient of thermal expansion, high strength at high temperature, favorable mechanical properties, and excellent castability, etc. [1–3]. Of various Al–Si alloys, 4032 Al alloy has attracted more attention due to its good casting and wrought performances, and has been widely applied in the areas of automobile part manufacturing industry, such as forgings, diesel locomotive pistons and other high temperature components. However, due to its high Si content (11.0–13.5 wt%) in 4032 Al alloy, located in the eutectic point of Al–Si phase diagram [4], the casting microstructures prior to the modification treatment consist of the coarse blocks and acicular/flakes primary Si and eutectic Si phase, respectively. In general, these coarse Si phases are easy to arouse the stress centralization and cause micro-cracks during deformation process, which will seriously deteriorate the mechanical properties and processability of the alloys, especially the ductility [5,6]. Therefore, in order to improve the mechanical properties of Al–Si casting alloys, the structural refinement of Si phases has been a basic practice in applications, by changing the morphology, size and distribution of the Si phases to weaken its effect on α-Al matrix [6–9].

Many techniques have been proposed for refinement of Si phases in Al–Si alloys, such as mechanical/electromagnetic stirring treatment [10–12], chemical treatment by modifiers [13,14], rapid solidification [15] and ultrasonic treatment [16] etc.. In general, adding modification elements, such as Na, Sb,

*Corresponding author. Tel.: +86 27 68752481x8168; fax: +86 27 6875 2003.
E-mail address: cxpan@whu.edu.cn (C. Pan).
Peer review under responsibility of Chinese Materials Research Society.

Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.pnsc.2014.03.002
1002-0071/

alkaline earth metals (Sr, Ca, Ba) [17], and rare earth metals (La, Ce, Pr, Eu, Yb) [18,19] in the form of Al-based master alloys are the most simple and efficient processes and have been widely used in industry. Na is the first element used to modify Al–Si alloys commercially. However, due to its very low solubility in Al melts, the recovery of Na is very poor (10–50%). In addition, Na oxidizes quickly and the modification performance fades fast. Element Sb reduces the mechanical properties, particularly in the slower solidifying regions of a casting, and it also has reaction with element Sr or Na to reduce the effectiveness of these modifiers. Element Sr not only has a high recovery rate (80–90%), good modification performance and long modification period, but also has no environmental problems. Therefore, the use of Al–Sr master alloys for modification has been an established practice in Al–Si foundries [20–23].

Up to now, there has been a great deal of researches on the 4032 Al alloy. For example, Rogante et al. [24] studied the microstructural evolution of precipitates in 4032 Al alloy car engine pistons by small angle neutron scattering technique. Yang et al. [25] discussed the effects of high temperature diffusion treatment on the microstructures, mechanical properties, thermal extension and conduction of the 4032 Al alloy. Fang et al. [26] exhibited the thermal formability of 4032 Al alloy. Zhan et al. [27] investigated the deformation behaviors of porous 4032 Al alloy during hot rolling. However, it is very few on the systematic study of modification performance of Al–Sr master alloy on the microstructures of 4032 Al alloy. In fact, the modification performance is closely related to the microstructural characteristics of the Al_4Sr phase. That is to say, different microstructures of Al–Sr master alloy with the same composition will exhibit different modification performance on Al–Si alloys [23,28].

In the present work, we comparatively investigated the influence of manufacturing methods, "direct reaction" and "direct reaction-hot extrusion", on the microstructural variations including morphologies and sizes of the Al_4Sr in two kinds of Al–10Sr master alloys. Furthermore, the effects of the microstructures on the modification performance of 4032 Al alloy were studied according to the addition amount and holding time. It is expected to demonstrate that relationship among modification performance – microstructure – manufacturing method, which will propose a novel stratagem for improving casting quality of Al–Si alloys.

2. Experimental procedure

Two modifiers were used in this work, i.e. the Al–10Sr master alloy wire (∅ 9.5 mm, Fig. 1a) prepared by "direct reaction-hot extrusion" process, and Al–10Sr alloy trapezoidal block (Topline = 15 mm, Baseline = 30 mm, Fig. 1b) prepared by "direct reaction" process. The details of the processes had been reported elsewhere [20,28]. The chemical compositions were quantified by using a direct reading spectrometer (SPECTROMAXx). The metallurgical specimens which cut along the transverse direction were mechanically polished, and then etched in a 0.5% HF aqueous solution at room temperature for 5 s according to the test standards ASTM E3-11 2011 and ASTM E407-07e1. The microstructures of the specimens were characterized by using an optical metallurgical microscope (BX51F, Olympus, Japan), and the size of Al_4Sr phase was statistically measured by using image analysis software of Image-Pro Plus 6.0.

The 4032 Al alloy was mainly composed of Al, Si, Mg, Ni and Cu, and the chemical compositions used in this work were listed in Table 1. The 4032 alloy was placed into a graphite clay crucible and brought to 760 °C using a high-frequency induction electric furnace (YG) to facilitate fast heating. Then the melt was stabilized at 730 ± 5 °C for 5 min followed by

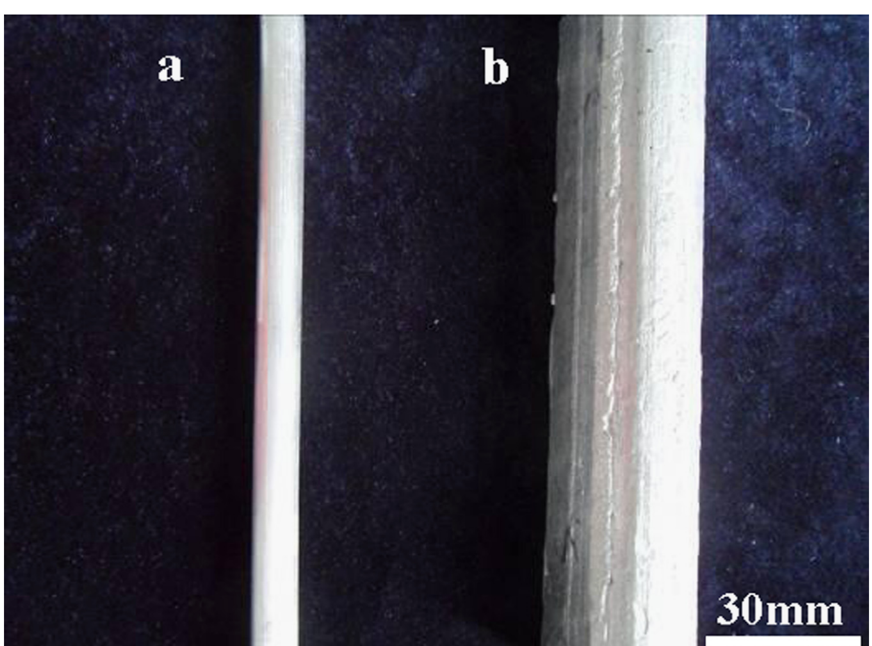

Fig. 1. Al–10Sr master alloys manufactured by (a) "direct reaction-hot extrusion" and (b) "direct reaction".