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The microstructure and refinement performance of Al-Ti-C master alloy smelted via improved SHS-approach

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The reduction of TiC-containing refiners smelting temperature below 1250 °C inevitably leads to the deterioration of their performance. In this work, an improved combustion route is used to prepare Al-5Ti-0.2C master alloy. The separate smelting of Al-10TiC and Al-Ti followed by the intermixing enabled to better kinetic conditions and accelerate the formation of TiC phase. As a result, the smelting temperature was decreased down to 1050 °C while the refinement efficacy of the alloy was improved. Comparative analysis of the master alloy microstructure is given with relation to the results of refinement tests.

Keywords: *Al-Ti-C master alloy: SHS-approach; Grain refinement; Smelting Temperature.*

1. Introduction

Chemical inoculation of aluminium-based alloys has been widely used industrial practice for decades. The master alloys of Al-Ti-C system possess several advantages compare to refiners of other systems. However, difficulties related to the high production temperatures and consequent high energy and cost consumption have always led to the restriction in extending their usage scope [1, 2].

The Self-propagating High-temperature Synthesis (SHS) is considered the most promising in terms of energy consumption and cost reduction [3]. With great potency of the SHS-approach to facilitate the TiC formation at lower temperature, it is of special importance to adapt the smelting process and utilize maximum benefits from the combustion reaction. Thus, the production route for Al-Ti-C refiners may be improved and production expenses may be reduced.

2. Experimental procedures

Starting materials for master alloy preparation: commercial purity Al (99.8%, hereafter – CPAl) and elemental powders of Al (99 % purity), Ti (99 % purity) and graphite (99% purity). All compositions quoted in this work are in wt.% unless otherwise stated. The Al-5Ti-0.2C master alloy was smelted in a resistance furnace at 1050 °C and 1250 °C.

The main feature of the SHS approach presented in this work resides in the separation of raw materials before the master alloy smelting. In this case, the Al-10TiC was smelted first, and then mixed with Al-Ti to obtain Al-Ti-C master alloy of desired composition. The holding conditions for Al-10TiC smelting and following Al-10TiC and Al-Ti mixing are 10 min and 20 min, respectively.

The Al-5Ti-0.2C master alloy was also smelted via conventional combustion approach, i.e. a green preform of Al, Ti and C powders was inserted into molten Al and then it was held for 30 min at the experimental temperature.

A Zeiss Supra55 FE-SEM was used for the master alloy microstructure observation and analysis. Refinement tests were performed by addition of 0.25% Al-5Ti-0.2C master alloy into CPAl melt at 740 °C and subsequent holding for 5 min. The mean linear intercept method was applied to determine the average grain size of CPAl.

3 Results and Discussion

The macrostructures of CPAl in initial and refined with 0.25% Al-5Ti-0.2C master alloy conditions are presented in Fig. 1. Although the master alloy smelted via conventional SHS method at 1250 °C refines CPAl effiently and the grain size decreases from 2380 µm (Fig. 1a) to 370 µm (Fig. 1b), its refinement efficiency deteriorates significantly when the master alloy smelting temperature is 1050 °C (Fig. 1c). In contrast, the performance of refiner smelted via improved method is superior even at 1050 °C smelting temperature (Fig. 1d), the CPAl grain size is 330 µm.

In Al-Ti-C master alloys designed to refine aluminium, the main phases are TiC and Al_3Ti. The TiC particles are considered to provide nucleation sites for Al grains, while the Al_3Ti phase dissolves fast into the Al melt and supplies it with solute Ti.

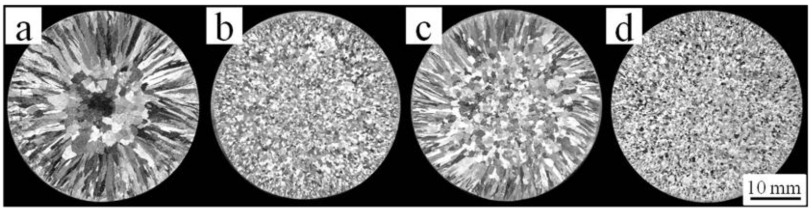

Fig. 1 Macrostructure of CPAl without (a) and with (b-d) addition 0.25% Al-5Ti-0.2C master alloy; b) SHS$_{conv.}$, 1250 °C; c) SHS$_{conv.}$, 1050 °C; d) SHS$_{impr.}$, 1050 °C

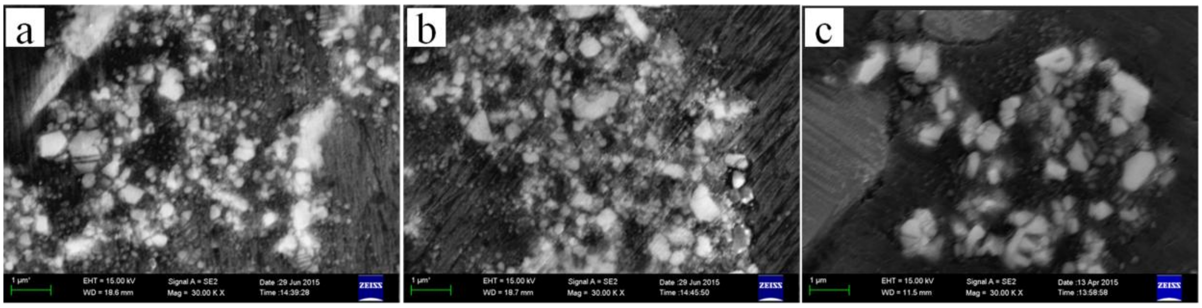

Fig. 2 SEM micrographs of Al-5Ti-0.2C master alloy smelted via conventional (a, b) and improved (c) SHS approach; a) 1250 °C; b), c) 1050 °C; × 30000

One of the factors affecting the performance of refiner is the size of particles which are claimed to act as heterogeneous nuclei [4]. Fig. 2 represents the TiC-rich region in the microstructure of Al-5Ti-0.2C master alloy smelted via conventional (Fig. 2a, b) and improved (Fig. 2c) SHS approach. In the case of conventional smelting (SHS$_{conv.}$), the average TiC particle size decreases from 0.35 µm to 0.27 µm at 1250 °C and 1050 °C, respectively. Separation of raw materials appears to accelerate the growth of carbide particles even at lower temperature (0.45 µm). Moreover, the master alloy smelted by SHS$_{conv.}$ method possess TiC particles of inconsistent size (Fig. 2a, b) compare to the one smelted by SHS$_{impr.}$ method (Fig. 2c).

The application of SHS-approach to the preparation of different materials is caused by the potential of combustion phenomena to accelerate considerably the interaction between system constituents. However, low content of TiC in Al-5Ti-0.2C master alloy is suggested to impede utilization of benefits provided by combustion wave during the SHS-reaction. Diffusion processes during the holding rather than combustion itself, appear to dominate the formation of TiC [5]. Therefore, the smelting temperature above 1200 °C is required to ensure the satisfactory performance of Al-5Ti-0.2C master alloy. The separation of raw materials during the smelting leads to an improvement in kinetic conditions, thus accelerating the formation of desired TiC phase even at lower temperature.

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