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Characterisation of Al-Ti-B grain refiners prepared by aluminothermic reduction of TiO2 and B2O3

Mwamba, Ilunga Alain

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1. INTRODUCTION

Grain refinement by inoculation of the melt is an established industrial practice in the casting of aluminium and aluminium alloys. This is done by the introduction of nucleation sites through the addition of Al-Ti-B or Al-Ti-C master alloys shortly before pouring the molten metal in the mould. Since the pioneering work of Cibula[1] on the refinement of aluminium in the late 1940s and early 1950s, several theories have been proposed to explain the mechanism by which the grain refinement by inoculation actually takes place. Although no general agreement has been reached so far on how grain refinement occurs, it is generally observed that nucleation takes place on TiB_2 particles in alloys inoculated with Al-Ti-B master alloys[2,3] and TiC particles in alloys inoculated with Al-Ti-C master alloys[4]. In both cases excess titanium in the master alloy is necessary for good refinement[5,6]**.** Recent years have seen the use of a new grain refiner, commercially named Strobloy which combines grain refining and modification of Al-Si alloys. In this grain refiner, the inoculating particles are TiB_2 and SrB_6. Sr is known to modify the morphology of silicon particles in Al-Si castings[7,8].

Over the years, research was carried out on the different factors preventing or enhancing good grain refinement in the preparation of grain refiners and during the inoculation of the melts. In the preparation of grain refiners, processing parameters like addition temperature, sequence of addition of feed materials, holding time of the melts and pouring temperature are particularly important in influencing the grain refiner microstructure. Studies focused on the microstructure of grain refiners and its influence on the grain refining performance have been helpful for predicting the behaviour of grain refiners. In this regard, it is established that Al-Ti-B master alloys generally consist of an aluminium matrix containing blocky or needle-like $TiAl_3$ particles and fine evenly distributed TiB_2 particles[2,3]. Al-Ti-C master alloys consist of a matrix of aluminium, needle-like $TiAl_3$ and submicron titanium carbide, TiC, dispersed in the matrix[4]. In the case of Al-Ti-B grain refiners the morphology, size and size distribution of TiB_2 have been observed closely.

The nucleation rate of aluminium on TiB_2 or TiC particles, poisoning phenomena and fading effects were studied in inoculated melts. Factors like addition temperature of grain refiners, stirring of the melt, agglomeration and settling of nucleant particles and alloying elements in the melts have been at the centre of meticulous studies[9,10,11]

In recent years, theoretical models have been proposed for evaluating grain refiners by predicting their behaviour when used as inoculants in aluminium and aluminium alloys[12,13].In this regard, Maxwell and Hellawell[14] have proposed a model for nucleation and growth of α-aluminium on TiB_2 nuclei. This model, referred to as the free growth model, considered TiB_2 nuclei as

identical in respect of their potency for heterogeneous nucleation and of their size. In a recent study on the design of grain refiners, Tronche and Greer[15] modified the Maxwell and Hellawell approach by taking the initiation of free growth rather than nucleation to be the controlling step and by noting that the grain refiner particles vary in size.

Other studies showed that thermomechanical treatment also influenced the grain refining performance by changing the microstructure of the grain refiners. In particular, the breaking of $TiAl_3$ particles was found to be beneficial in improving the performance of grain refiners[16].

The aim of this work was to characterise the Al-Ti-B grain refiners produced by aluminothermic reduction of TiO_2 and B_2O_3 in respect of:

a) their microstructure

b) their grain refining potency when used as cast, after cold rolling and after cold rolling and annealing.