DEVELOPMENT AND CHARACTERIZATION OF A 2024 ALUMINIUM ALLOY REINFORCED WITH TIC PARTICULATES PRODUCED BY SHS

P. Egizabal[1*], M. Merchan[1], M. Garcia de Cortazar[1], A. Torregaray[2], P. Jimbert[2]

[1]Tecnalia Research & Innovation foundation, Foundry department, Mikeletegi Pasealekua 2, Donostia-San Sebastian 20009 Spain
[2] Meatz eta Metalurgi Ing. eta Materialen Zientziaren Saila. Dept. Ing. Minera y Metalúrgica y Ciencia de los Materiales. EUITI-IITUE Bilbo. Plaza de la Casilla, 3 48012 Bilbao
**Pedro.egizabal@tecnalia.com*

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Abstract

The self propagating high temperature synthesis (SHS) process has been used to produce titanium carbide (TiC) particulates that have been subsequently mixed with a 2024 aluminium alloy through the stir casting process. The incorporation of 1 wt.% of particulates provides an increase of the tensile strength. The results obtained in the metallurgical analysis and mechanical tests confirm that the presence of TiC particulates has a positive effect on mechanical properties through different mechanisms such as grain refining and reduction of porosity.

1 Introduction

The transport sector continues demanding new light alloys with improved performance that may be used to decrease the weight of components working under abrasive or high temperature conditions. Particulate reinforced aluminium alloys are a strong candidate for the production of light components for the transport sector due to their good balance of mechanical strength and wear properties and the possibility of production at affordable costs. [1-3]

The aim of the present work is related to the development and characterization of a low cost metal matrix composite (MMC) to be applied for the production of wrought components. The production of a composite composed of the 2024 alloy and 1 wt. % titanium carbide (TiC) particulates is described and the results of mechanical and metallurgical characterization are provided.

The reinforced alloy has been produced in two stages. The first step involves the development of the production of in situ TiC particulates through the Self propagating High temperature Synthesis process. Spherical particulates with sizes ranging from 0,5 to 1,5 microns are created when Ti, Al and C powders are mixed and the reaction is activated through an initial spark that initiates an exothermic autopropagating reaction.

The particulates have been subsequently incorporated to the A2024 alloy melt through the stir casting process. [4-7]. Melt temperature and stirring conditions have been optimized in order to attain a homogeneous dispersion of the TiC particulates. Extrusion trials have been carried out in order to obtain samples that have been submitted to the T6 thermal treatment. A complete metallurgical study based on optical microscopy (OM) and scanning electronic microscopy (SEM) analysis has been carried out to validate the process and to understand the relation between the microstructure and mechanical properties. Eventually specimens for tensile and wear tests have been produced and tested. The results obtained in the metallurgical analysis and mechanical tests confirm that the presence of TiC particulates have a positive effect on properties through different strengthening mechanisms such as grain refining and the creation of obstacles for the movement of dislocations. The analysis shows that the interphase between the particulates and the matrix is clean and the microstructure is sound even though the presence of some small agglomerations is observed in the region of the aluminium grain boundaries. An increase of 10% in tensile properties without any significant decrease in the ductility has been recorded.

2 Materials and testing methods

The material developed in this work is composed of a 2024 aluminium matrix alloy reinforced with 1% wt. of TiC particulates. The preparation of the material has been carried out in two consecutive phases. The first stage TiC particulates have been synthesized through SHS. The second phase was based on the incorporation of such TiC particulates into the 2024 matrix through the stir casting process.

2.1 Production of TiC/Al powders by SHS

Ti, Al and C elemental powders were used in order to obtain the desired reinforcement. Samples of 25mm in diameter and about 30mm in height containing the required mixture of elemental Ti, Al and C were first prepared. These samples were cold pressed up to 55% of the theoretical density. Then place them into the reactor, and the reaction was ignited using a Tungsten coil.

Ti and C react very exothermically, leading to the melting of the aluminium. Eventually powder samples are obtained having TiC particles surrounded by an Aluminium matrix with a whole composition containing 70 wt. % of TiC and 30 wt.% of Al.

The XRD pattern of the obtained product revealed the formation of TiC particles and the presence of free metallic Aluminium. (see Figure 1).

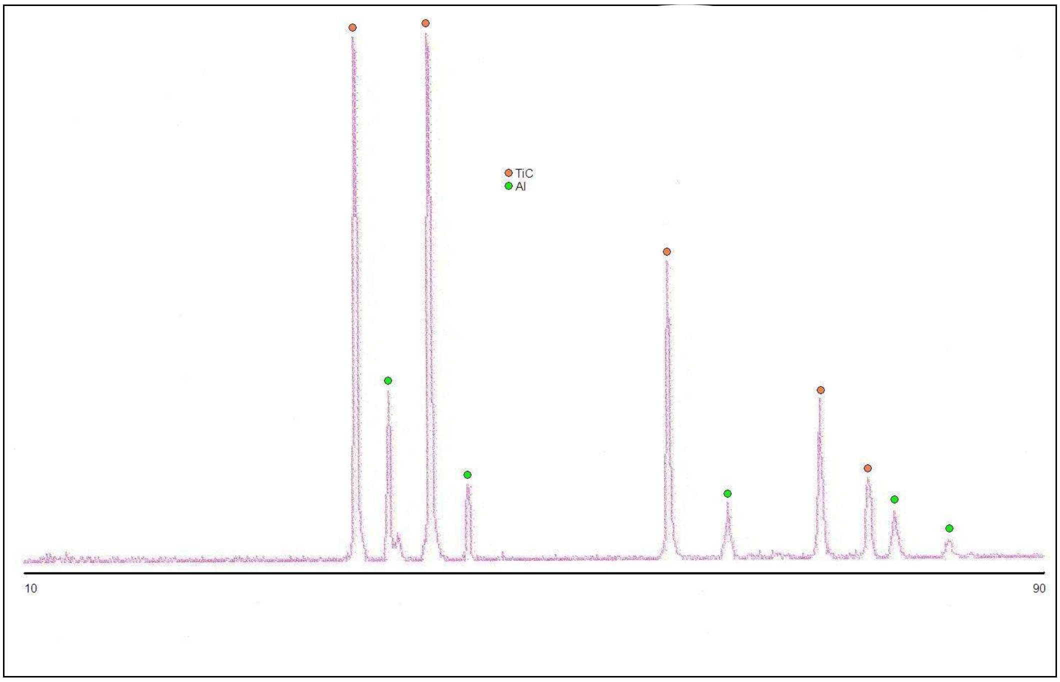

Figure 1: XRD of the TiC/Al powder obtained by SHS**.** Only TiC and Al are detected showing that no other major reaction product Is formed.

2.2 Production of the A2024/TiC 1 wt. % material

The 2024 alloy employed as the matrix presented the following composition:

Si: 0,60; Fe: 0,7; Cu: 3,5; Mn: 0,60, Mg: 0,45; Zn: 0,25; Zr + Ti; 0,,25; Cr: 0,10;Al: Bal.

The alloy was placed in a SiC crucible and heated up to 650ºC in an induction furnace. A stirring device was used to stir the melt alloy at 800-1200 rpm. The TiC particulates were incorporated keeping the stirring for 15 minutes and adding the TiC/Al powder into the vortex created by the graphite stirrer attached to the rotor. The temperature of the mixture was subsequently increased up to 730ºC and the composite was cast into a cylindrical mould with a diameter of 150 mm d and 100 mm height. The composite was afterwards extruded with a 9:1 extrusion ratio at 500ºC and at 2 mm/s speed.

Samples were subsequently machined in order to obtain cylindrical tensile specimens with 6.5 mm diameter based on ASTM A370 standard as well as specimens for microscope analysis.

3 Results and discussion

The analysis of the A2024/Tic 1wt. % has been focused on the study of the interphase between the matrix and the particulates and the possible chemical reactions between Al and TiC. No Al_4C_3 has been observed and the interphase was clean. The optical microscope analyses shows that individual TiC particulates are distributed in all the regions of the samples even though the presence of small agglomerations of 10-50 particulates with different sizes ranging from 1-10 microns can be appreciated (see figures 2-3) . There is a larger concentration of particulates in the intergranular region of the sample where other phases of the alloy appear. Porosity level was measured following Archimedes´ principle and the results were lower than 1%. Furthermore the observed pores were small and evenly distributed across the sample (see figure 3). Figure 3 shows a representative region of the samples with a higher magnification. The spherical shape of the TiC particulates produced by SHS can be clearly appreciated. Small agglomerations as well as individual particulates are mainly located in the intergranular region. Most of the particulates present a size ranging from 1 to 5 microns. Particulates seem to be well integrated in the aluminium matrix and no signs of deleterious reactions are seen.

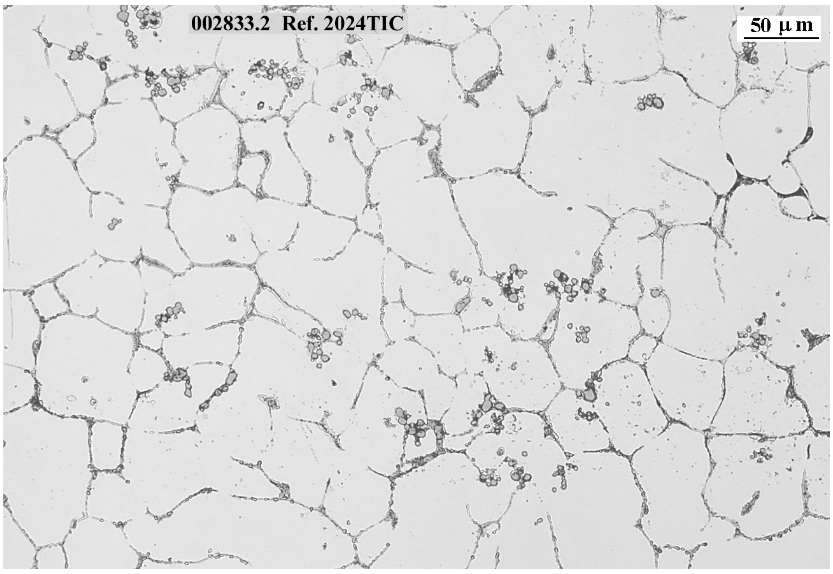

Figure 2: General aspect of the A2024/TiC 1wt. % samples after the extrusion stage. Particulates can be seen forming both small agglomerates as well as individually isolated.

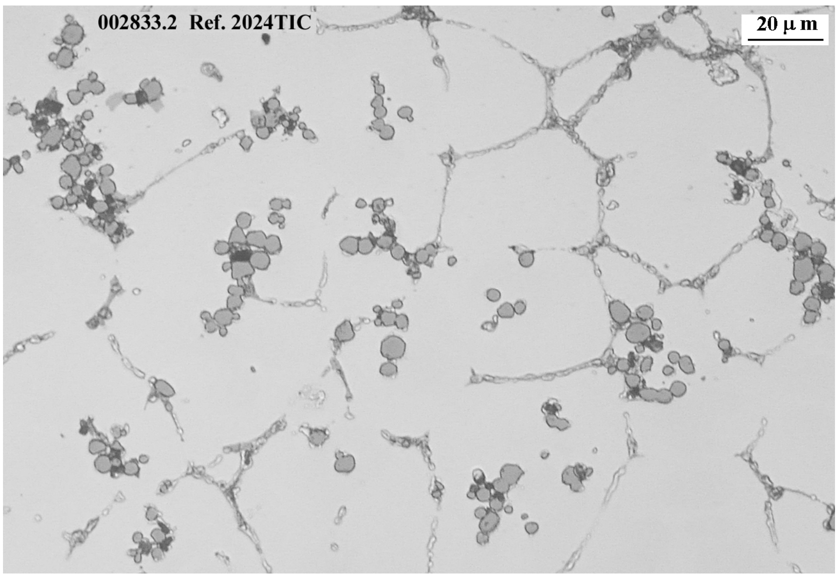

Figure 3: Detail of a region of the extruded sample

Figures 4-5 present the microstructure of the samples by SEM at different augmentations. In figure 4 particulates can be seen forming small agglomerations and surrounded by other typical phases of the alloys such as Al_2Cu, Al_2CuMg and Al-Fe-Cu, Mn, Si phases.

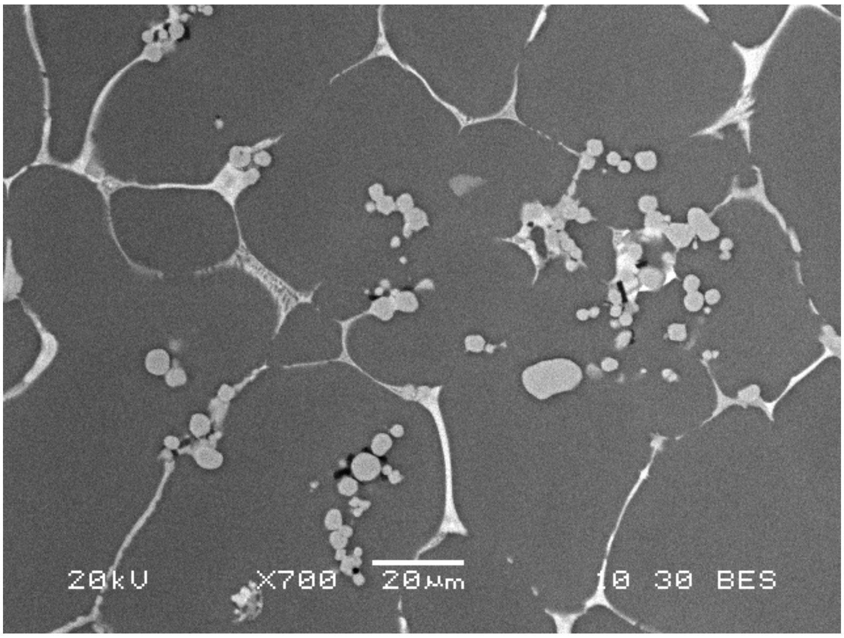

Figure 4: The microstructure of the A2024/TiC alloy shows that most of the particulates are located in the region between aluminium grains. Al2Cu phase can be seen as the brightest white phase at the right angle superior corner of the micrograph that are usually connected to grey Al_2CuMg phases.

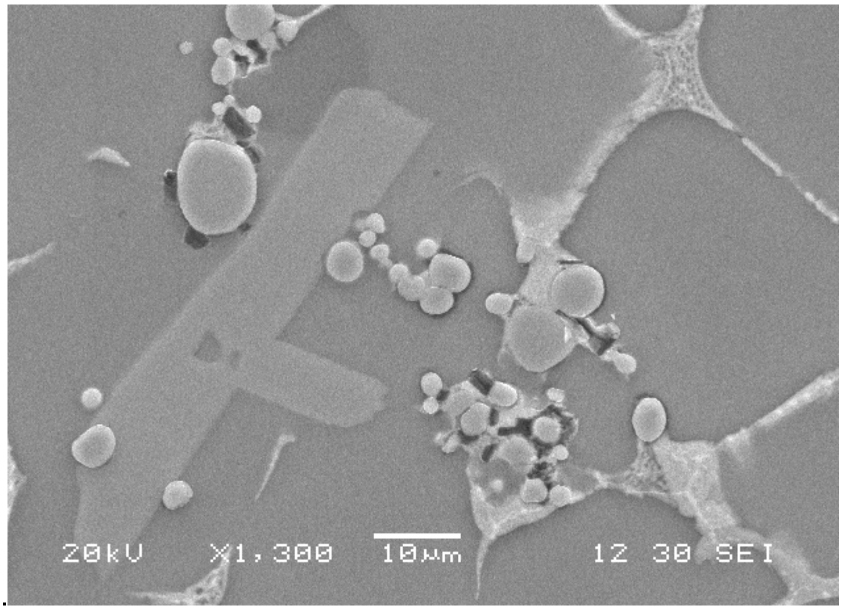

Figure 5. Detail of a TiC cluster within the A2024-6%TiC composite.

Table 1 presents the results of the tensile tests carried out on cylindrical specimens machined from the samples after the T6 heat treatment. The A2024/TiC 1 wt. % alloy presents an increase in the ultimate tensile strength and yield stress of almost 10% together with a decrease in elongation values. These results follow the general trend of aluminium based composites reinforced with particulates. The presence of TiC particulates seems to have a grain refining effect on this alloy. Porosity of the reinforced alloy is also lower than that of the unreinforced matrix,

	σ_y (Mpa)	σ_{UTS} (Mpa)	Elongation (%)
A2024/TiC 1 wt.%	468	514	6.7
A2024	414	483	10

Table 1: Tensile properties of the developed A2024/TiC 1 wt.% alloy compared with the unreinforced matrix.

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