FABRICATION AND CHARACTERISATION OF IN-SITU AL-TIC COMPOSITE

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ABSTRACT

Materials are playing vital role in recent past, in-situ Al-Tic with 5% TiC composite was produced by the reaction with the halide salt \(K_2TiF_6\). SEM and EDX tests were performed on the prepared Al-TiC test specimen. As the micro hardness test was performed for the test loads of 100 grams and 300 grams. By the addition of TiC the hardness of the material was increased. There was a small variation in hardness value for 100 grams and 300 grams test load conditions.

Keywords: EDX, Halide salt, In-situ, Micro hardness and Scanning Electron Microscope

I. INTRODUCTION

There is always a scope of research in the fabrication of new materials, in the present scenario there is so much need in the development of lightweight materials with the properties like high strength, stiffness, hardness, fatigue and wear resistance. Metals are very useful in making different components and their properties can be improved by adding reinforcement like B, C, Al\(_2\)O\(_3\), TiB, BiC and TiC e.t.c. Aluminium matrix composites (AMCs) are the competent material in the industrial world [1]. The AMCs are fabricated by different methods such as stir casting, squeeze casting, spray deposition, liquid infiltration, and powder metallurgy [2]. Casting route is particularly attractive as it is economical and practical [3]. The composite prepared by ex-situ method suffers thermodynamic instability between matrix and reinforcements, thus limiting their ambient and high temperature mechanical properties [4]. Ex-situ process possesses drawbacks like agglomeration, poor
wetting and heterogeneity in microstructure [5]. Ex-situ composite fabrication method consists of many stages, like sorting, alignment, infiltration and sintering [4].

As in In-situ process the ceramic reinforcement is incorporated into the matrix by the chemical reaction of the halide salt with molten metal matrix. The in-situ formation of a ceramic second phase provides greater control of size and level of reinforcements, as well as the matrix reinforcement interface, yielding better tailorability of the composites [6]. In-situ composites are having advantages like they are more homogeneous in their microstructure and thermodynamically more stable and they also have strong interfacial bonding between the reinforcements and the matrices [4]. Applications of in-situ composites include wear parts for pumps, valves, chute liners, jet mill nozzles, heat exchangers, gun barrel liners [7]. Different reinforcements like TiB$_2$, zrB$_2$ B$_4$C and TiC can be incorporated into the matrix by In-situ reaction. As several researchers did research on In-situ composites and found that halide salts plays a major role in the development of reinforcement in the metal matrix composites.

Aluminium alloys have high strength at room temperature. The strength and other mechanical properties are reduced when the aluminium alloy is used at high temperatures. The above problem can be solved by incorporating TiC reinforcement into the aluminium matrix [8]. TiC is particularly attractive as it offers high hardness and elastic modulus, low density, good wettability yet low chemical reactivity with aluminium melts [9]. In-situ Al-TiC MMC were synthesized and properties like hardness, tensile strength and wear characteristics were studied by S. Natarajan et al. A. Mahamani et al. performed machinability study on Al-5cu-TiB$_2$ MMC.

The Al–B$_4$C composites were produced by modified stir cast route with different weight percentage of reinforcement and the microstructure, mechanical properties were evaluated by K.Kalaiselvan et al. [1]. Birol et al. [9] produced Al-TiC with different blends by varying the melt temperature and found that Al$_3$Ti particles were gradually replaced by TiC particles when the powder blend was heated above 800°C. Birol [10] performed SEM and XRD analysis and found that TiC particles apparently formed in increasing numbers with increasing reaction temperatures when Ti was introduced into molten aluminium in the form of a halide salt, together with graphite and also the particle size also get reduces with the increased temperature.

A.Mahamani [4] fabricated Al-TiB$_2$ and performed EDX analysis and micro hardness testing and stated that hardness of the aluminium is increased by adding TiB$_2$ particles. M.S.Song et al. [11] fabricated Al-TiC by self-propagating high-temperature synthesis (SHS) reaction and performed SEM analysis and stated that the size of the TiC particulates decreased with increasing Al contents in the blends. As the present work mainly focus on to fabricate Al-TiC composite by In-situ process by the reaction of K$_2$TiF$_6$ and graphite powder with the molten Aluminium. An investigation is done on the hardness by the addition of the TiC particles to the Al-6061 by using micro hardness testing. Quantitative elemental analysis is performed by EDX testing to know the presence of TiC particles and SEM is performed to know the orientation and arrangement of the TiC particles.

### II. EXPERIMENTAL PROCEDURE

The matrix used for fabrication of the Al-TiC composite was Al6061, for 5% TiC reinforcement 1500 grams of Al6061, 300.9 grams of K$_2$TiF$_6$ (Potassium hexafluorotitanate) and 19.5 grams of graphite powder was used. The schematic representation of the composite processing [12] was shown in Figure. 1.
The Al6061 was melted in crucible and premixed K₂TiF₆ and graphite powder of measured quantity were added to the molten aluminium and melt temperature was maintained as 900°C. The molten material was held for 20 minutes and for the proper mixing the molten metal was stirred with a graphite rod during this exothermal reaction will take place between the molten aluminium and halide salt K₂TiF₆. After 20 minutes the slag is removed from the molten mix and the molten mix is poured into the mould. Figure 2 shows fabricated composite rod.

III. CHARACTERISATION OF AL-5% TIC COMPOSITE

The fabricated composite was subjected to EDX, SEM and hardness test to know the characterisation. EDX and SEM tests were performed on FEI Quanta FEG 200 - High Resolution Scanning Electron Microscope. Micro hardness test was performed on Vickers hardness testing machine. The test specimen prepared for SEM and EDX testing were shown in Figure 3, as the test specimen is circular in shape and the dimensions are 5mm in diameter and 5 mm in thickness. The test specimen is well polished by using belt grinder and disc
polisher. Fabricated composite was examined under scanning electron microscopy (SEM) to ascertain the formation of TiC particles and their distribution. Figure 4 shows scanning electron micrograph of the fabricated Al-5% TiC composite material. The SEM image discovers the presence of TiC particles in the aluminium matrix and the TiC particles are distributed homogeneously in the matrix. The size of the reinforcement particles are less than 1µm.

Figure 3: Test specimen for SEM and EDX

Figure 4: SEM Image of Al-TiC 5%

Quantitative elemental analysis is performed by EDX testing to know the presence of TiC particles. Figure 5 shows EDX spectrum of the Al-TiC 5% composite.

Figure 5: EDX analysis of Al-5% TiC

In EDX analysis[14] Y-axis represents the counts that is number of X rays received and processed by the detector and X- axis represents energy level of those no of counts. Moseley’s Law is basis for the EDX analysis. Moseley’s Law was shown in the equation 1.

\[ E = C_1 (Z - C_2)^2 \]  "equation 1"

Where E= energy of the emission line
Z= atomic number of the emitter
C_1 and C_2 are constants
If the energy of the respected X-ray is determined then the atomic number of the element producing the line can be determined. Figure.5 shows the presence of Ti and C particles in the fabricated Al-TiC composite. To know the improvement of hardness in the fabricated Al-5% TiC composite micro hardness test was performed at a load of 100 gram and 300 gram with 15 seconds dwell time and the specimen prepared for micro-hardness was shown in Figure.6. The shape of the specimen is cube 10mm side. The test specimen was well polished before performing micro hardness test by using belt grinder and disc polisher.

**Figure.6:** Test Specimen prepared for Testing Micro Hardness (Al-TiC 5%) 

The average hardness of the aluminium 6061 was 51 HV as specified by the supplier, by the addition of the TiC reinforcement to the matrix the average hardness of Al-5% TiC was increased to 55.4 HV at 300 gram test load. Hardness value of the fabricated Al-5% TiC composite for 100 gram and 300 gram test load are given in Table.1

<table>
<thead>
<tr>
<th>Test load</th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
<th>Average Hardness</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 gram</td>
<td>71.3</td>
<td>68.5</td>
<td>71.2</td>
<td>70.33</td>
</tr>
<tr>
<td>300 gram</td>
<td>56.7</td>
<td>52.7</td>
<td>57.0</td>
<td>55.46</td>
</tr>
</tbody>
</table>

In Vickers micro hardness test the hardness is calculated by using the equation 2.

\[ HV = \frac{1854(F/d^2)}{''equation 2''} \]

Where

- \( HV \) = Vickers hardness value
- \( F \) = Indentation load in grams
- \( d \) = Diagonal of the indentation in µm

The hardness value increases with the decrease in the test load. As the test load increases the indentation size increases [13] and which will affect the hardness value. Depending upon material, type of indenter and size of indentation a proper test load can be selected.

**IV. CONCLUSION**

Fabrication of Al-5% TiC MMC was successfully done by in-situ process by the reaction of the halide salt \( K_2TiF_6 \). Scanning electron microscopy (SEM) was performed on the fabricated composite material and it shows that TiC reinforcement is properly distributed over that matrix and size of the reinforcement was less than 1µm. Energy – dispersive X-ray spectroscopy (EDS) was done on the fabricated composite and investigated the presence Ti and C elements in the Al-5% TiC composite material. Vicker’s micro hardness test was conducted and it reveals that by the addition of TiC reinforcement to the Al6061 matrix the hardness value was increased.
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