Effect of cooling rate and other factors on size and pattern of
distribution of TiB$_2$ particles formed during solidification of the Al-
TiB$_2$ melt for various pouring temperatures

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Abstract - In this work, A356 aluminium alloy is melt in a
graphite crucible and two salts (ie), potassium hexa fluoro
titanate and potassium tetra fluoro borate are dropped at a
slow rate and mixed with aluminium melt, with the help of a
hand held graphite stirrer. The reaction between the salts is
exothermic in nature and the temperature of the melt shoots
up very fast and that is why the salts are dropped very slowly.
TiB$_2$ particles are synthesized due to the reaction and they
grow in size with prolonged holding time at the melt
temperature. The distribution of TiB$_2$ particles and the size
vary from location to location in the casting and the reasons
are analyzed.

Key Words: Aluminium matrix composites, Titanium-di-
boride, Al/TiB$_2$ MMC, In-situ formed MMC, Particle
distribution, MMC.

1. INTRODUCTION

Aluminium based metal matrix [AlMMC]
composites are preferred because of the increased
tensile strength, hardness, fatigue strength and elastic
modulus or stiffness as compared to the base matrix
alloy.$^{[1-3]}$ These AlMMCs are fabricated by adding
ceramic reinforcement particles such as SiC, Al$_2$O$_3$, TiC,
CBN and TiB$_2$. Out of these reinforcements TiB$_2$ is
considered to be the most superior because of the
maximum tensile strength, compressive strength,
estatic modulus and hardess it possesses.$^{[4,5]}$

Al- TiB$_2$ MMCs are produced many of the times
by in-situ technique as the interface is very clean and
the size of the particles are also very fine and finer the
particles the higher will be the tensile strength,
fracture toughness and fatigue strength.$^{[6]}$

In the in-situ method of producing Al- TiB$_2$
MMCs two salts (ie) potassium hexa fluoro titanate and
potassium tetra fluoro borate are slowly mixed in the
aluminium melt and stirred to promote the reaction
between salts and the reaction is also exothermic in
nature. The mixing and stirring is carried out by a hand
held graphite rod to avoid possible reaction by the
fluron gas evolving in this method.$^{[7,8]}$ As an outcome
of this reaction, TiB$_2$ particles get synthesized and they
grow in size with prolonged holding time at the melt
temperature after mixing the salts.$^{[9,10]}$

When the MMC melt is poured into the
permanent mould because of the height of the fall
causing turbulence during filling the TiB$_2$ particles
present in the melt fragment and also the distribution
of the TiB$_2$ particles vary from location to location in
the casting and the reasons are attributed to the local
cooling rate and turbulence and fluidity of the molten
MMC.$^{[11,12]}$

The effect of the above parameters are analysed
by studying the SEM micrographs taken at six different
locations in the final cast ingot.

The purpose of the study is to analyse the
reasons as explained above on the distribution of the
TiB$_2$ particles at various locations in the cast ingot.

2. EXPERIMENTAL WORK

In this study Al-TiB$_2$ MMC is synthesized by in-
situ technique of salt metal reaction route. The melt
temperature is maintained at three different levels of
750$^\circ$ C, 780$^\circ$ C and 810$^\circ$ C and after mixing the salts in
the molten aluminium, for three different holding times
of 10 minutes, 20 minutes and 30 minutes, the MMC
melt is maintained and poured into permanent molds.
Thus nine different cast ingots were made for different
combinations of melt temperature and holding time.$^{[13]}$

After the MMC melt is ready it is poured into
the permanent mold and the size of the TiB$_2$ particle will
not be same in the casting as that present in the MMC
melt. And the reasons are attributed to parameters like
the local cooling rate, fluidity and turbulence during filling at various locations of the casting.\cite{14}

At each of the six different locations with varying local conditions explained above SEM micrographs were taken for all the nine cast ingots and the size and distribution of the TiB$_2$ particles at various locations are compared.

### 2.2 FINITE ELEMENT ANALYSIS

The simulation model and mesh diagrams of the ingot are shown in figure (1a to 1b). At 24 different locations of each ingot temperature vs time curves were obtained using ESI ProCAST simulation casting software. Out of the 24 locations six locations were short listed and at these six locations the local conditions of cooling rate, turbulence and fluidity found to drastically vary.

![ProCAST Simulation model](image1)

**Figure. (1a): ProCAST Simulation model**

![ProCAST model mesh diagram](image2)

**Figure. (1b): ProCAST model mesh diagram**

At these selected six different locations temperature vs time curves are found to be as shown in figures below figure 2(a) to figure 2(f).

![Temperature – time curve for 750°C pouring temperature at location – 1.](image3)

**Figure. (2a): Temperature – time curve for 750°C pouring temperature at location – 1.**

![Temperature – time curve for 780°C pouring temperature at location – 4.](image4)

**Figure. (2b): Temperature – time curve for 780°C pouring temperature at location – 4.**

![Temperature – time curve for 780°C pouring temperature at location – 7.](image5)

**Figure. (2c): Temperature – time curve for 780°C pouring temperature at location – 7.**
3. RESULTS AND DISCUSSION

Out of the 24 locations of the cast ingot the location – 23 is found to have the combination of maximum cooling rate, turbulence while filling. The fluidity of the liquid metal is found to be maximum at the maximum melt and pouring temperature.

At location – 23 the fluidity is maximum at 810°C and the cooling rate is also found to be the maximum. Because of this and as the fall through height of the liquid metal while filling is maximum for location – 23 the turbulence will be maximum and because of this the TiB₂ particles will fragment and the circulation will be maximum due to maximum fluidity at 810°C and as cooling rate is maximum the fragmented TiB₂ particles will get entrapped in the quickly freezing casting at this location – 23.[15]

Because of the above mentioned reason at location – 23 corresponding to 810°C the presence of TiB₂ particles is found to be the maximum at location – 23 and the area occupied by the TiB₂ particles in the various clusters observed in the location – 23 is as high as 70% – 80%.

At location – 1 where the cooling rate is minimum and the fall through height is minimum due to which the turbulence also is minimum and as more number of TiB₂ particles have already got trapped in the bottom most point, the TiB₂ particles observed in the location – 1 are less and the area occupied by the TiB₂ particles at this location for 810°C is found as 40% – 50% in the SEM micrograph.

At lower melt and pouring temperatures and lower holding times the size and distribution of particles in the clusters at all the locations are found to be lower as shown in the table (1).

<table>
<thead>
<tr>
<th>Location</th>
<th>Temperature in °C</th>
<th>% Relative area of reinforcements</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>10 minutes</td>
</tr>
<tr>
<td>1</td>
<td>750</td>
<td>10 - 20</td>
</tr>
<tr>
<td></td>
<td>780</td>
<td>20 - 30</td>
</tr>
<tr>
<td></td>
<td>810</td>
<td>20 - 30</td>
</tr>
<tr>
<td>4</td>
<td>750</td>
<td>30 - 35</td>
</tr>
<tr>
<td></td>
<td>780</td>
<td>20 - 30</td>
</tr>
<tr>
<td></td>
<td>810</td>
<td>25 - 30</td>
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<td>7</td>
<td>750</td>
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<tr>
<td></td>
<td>780</td>
<td>35 - 40</td>
</tr>
<tr>
<td></td>
<td>810</td>
<td>40 - 50</td>
</tr>
</tbody>
</table>

Table (1): Percentage TiB₂ particles in six locations of ingot from SEM micrographs.
4. CONCLUSIONS

1. When the cooling rate and local turbulence are very high at a particular location of the casting the presence of the TiB₂ particles are also found to be more.

2. When fluidity is more the circulation will be more and at the same time if the cooling rate is very high more number of TiB₂ particles will be trapped and observed in that location.

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REFERENCES


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