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 fluro titanate and potassium tetra fluro 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 and 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_2O_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, elastic modulus and hardness 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 fluro titanate and potassium tetra fluro 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 750^0 C, 780^0 C and 810^0 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.[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 have the local conditions of cooling rate, turbulence and fluidity found to drastically vary.

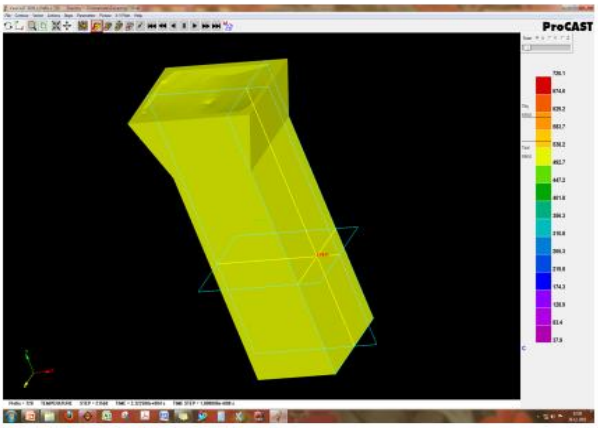

Figure. (1a): ProCAST Simulation model

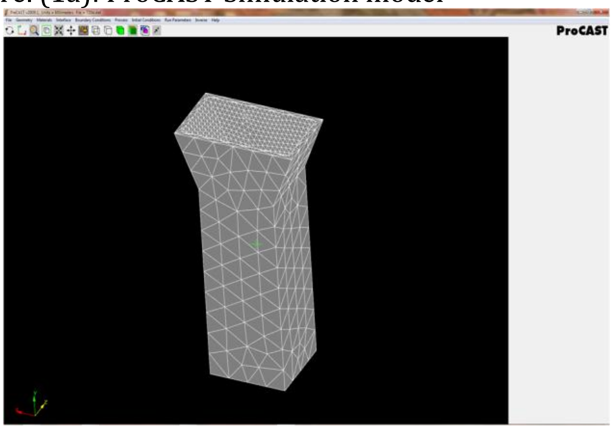

Figure. (1b): ProCAST model mesh diagram

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).

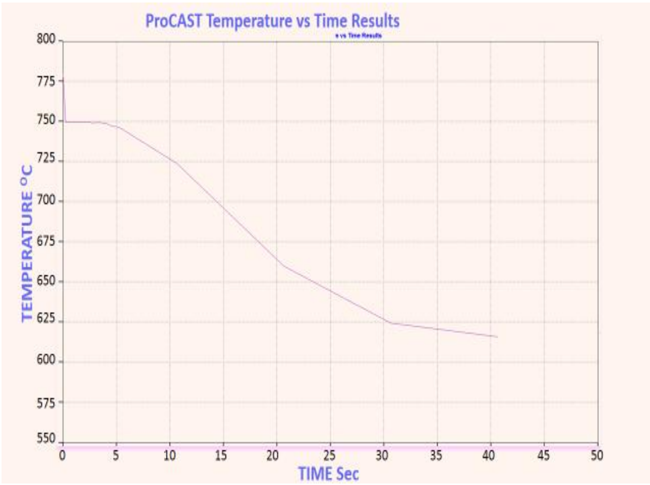

Figure. (2a): Temperature – time curve for 750^0 C pouring temperature at location – 1.

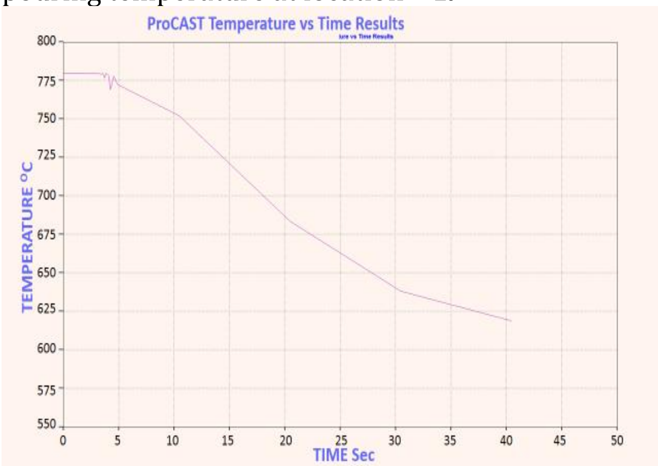

Figure (2b): Temperature – time curve for 780^0 C pouring temperature at location – 4.

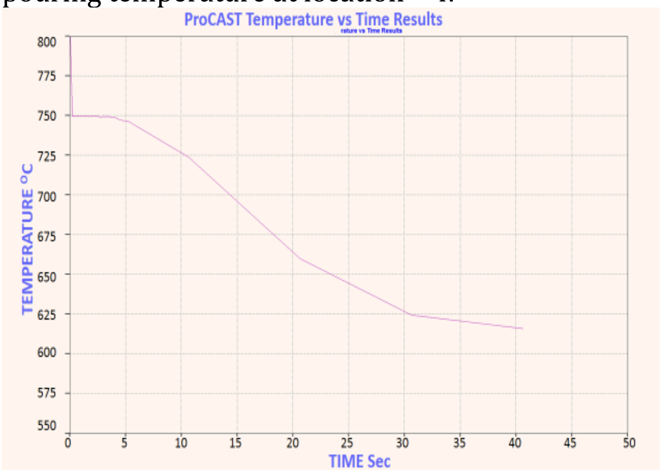

Figure (2c): Temperature – time curve for 780^0 C pouring temperature at location – 7.

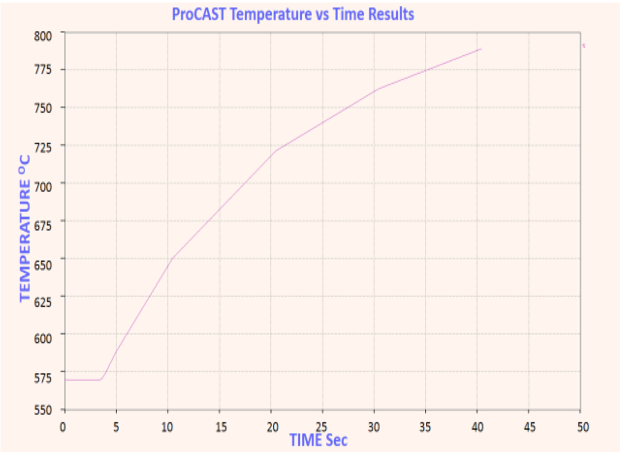

Figure (2d): Temperature – time curve for 780⁰ C pouring temperature at location – 19.

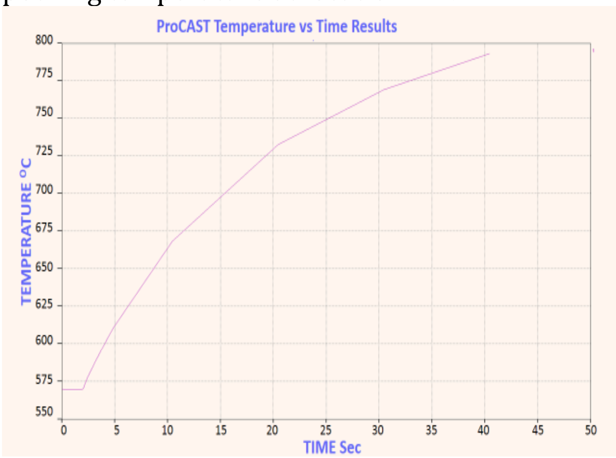

Figure (2e): Temperature – time curve for 780⁰ C pouring temperature at location – 21.

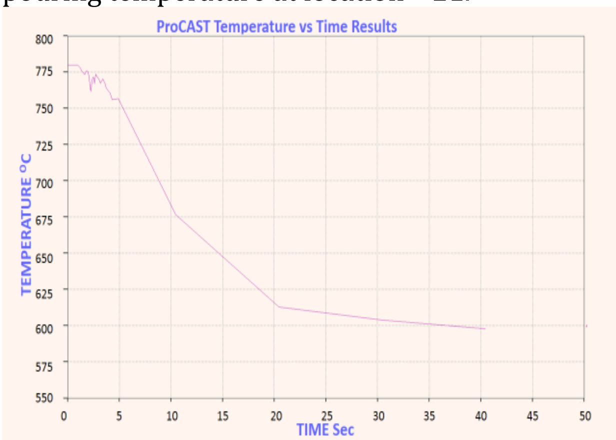

Figure (2f): Temperature – time curve for 780⁰ C pouring temperature at location – 23.

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 810⁰ 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 TiB_2 particles will fragment and the circulation will be maximum due to maximum fluidity at 810⁰ C and as cooling rate is maximum the fragmented TiB_2 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 810⁰ C the presence of TiB_2 particles is found to be the maximum at location – 23 and the area occupied by the TiB_2 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 TiB_2 particles have already got trapped in the bottom most point, the TiB_2 particles observed in the location – 1 are less and the area occupied by the TiB_2 particles at this location for 810⁰ 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).

Location	Temperature in ⁰C	% Relative area of reinforcements		
		10 minutes	20 minutes	30 minutes
1	750	10 - 20	30 - 40	35 - 40
	780	20 – 30	30 - 40	35 - 40
	810	20 - 30	30 - 40	40 - 50
4	750	30 - 35	30 - 35	35 - 40
	780	20 – 30	25 - 35	30 - 40
	810	25 - 30	30 - 35	40 - 50
7	750	10 - 20	30 - 40	25 - 35
	780	20 – 30	35 - 45	40 - 50
	810	20 – 30	40 - 50	60 - 70
19	750	20 – 30	20 – 30	30 - 40
	780	20 – 30	40 - 50	40 - 50
	810	20 – 30	50 - 60	50 - 60
21	750	30 - 40	20 – 30	40 - 50
	780	10 - 20	30 - 40	30 - 40
	810	30 - 40	50 - 60	60 - 70
23	750	30 - 35	35 - 40	40 - 50
	780	35 - 40	45 - 50	50 - 60
	810	40 - 50	60 - 70	70 - 80

Table (1): Percentage TiB_2 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 TiB_2 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 TiB_2 particles will be trapped and observed in that location.

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