Effect of TiB2 particles and Precipitation of hardening response of A356 alloy

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Abstract: A356-TiB_2 in situ composites have been successfully prepared by the reaction of mixture of K_2TiF_6 and KBF_4 with molten A356 alloy. A reaction temperature of 850°C and a reaction time of 60 min were adopted in stir caster. A continuous increase in the yield strength and ultimate tensile strength without any significant loss in ductility has been observed with increase in the amount of TiB2 in both as-cast and peak-aged conditions. TiB_2 particles enhance the aging kinetics and the time to peak aging at the aging temperature of 170°C comes down from 6h when the TiB_2 amount is increased.

Index Terms **– In situ process, Al-TiB_2 composites, Precipitation of hardening, Aging kinetices.**

I. Introduction.

The difficulties in the development of ex situ particulate metal matrix composites such as poor wettability, inhomogeneous distribution of reinforcement particles, formation of unwanted reaction products at the interface between the matrix and reinforcement, etc. have led to the attempts to synthesize new generation in situ composites. Among the in situ composites, A356-TiB_2 composites have become popular in recent years.[1–8].Different sources of Ti and B such as K_2TiF_6 and KBF_4 salts [1,2,6] used for the synthesis of TiB_2 reinforced A356 matrix in situ composites. There have also been efforts to synthesize in situ composites with fine TiB_2 dispersions in A356 matrix [1,3,4,7,9]. However, in all the investigations employing the salt route, the formation of brittle intermetallic A356-Ti, which deteriorates the mechanical properties of the final composite. Significantly, could not be completely avoided. Thus, the formation of only TiB_2 particles with A356 alloy as matrix has not been reported so far.

Bartels et al.[2] have observed significant enhancement in the aging kinetics of A356 alloy due to the presence of TiB_2 particles. Salazar and Barrena [11] have observed similar increase in the aging kinetics of A356 alloy in presence of Al_2O_3 dispersoids. In contrast, Lu et al. [1] have not found any significant difference in the peak aging duration between the unreinforced alloy and the reinforced composites. The present paper reports the synthesis of high strength in situ composites with TiB2 particles alone, by completely suppressing the formation of Al_3Ti particles in the A356 matrix by the mixed salt route (K_2TiF_6 and KBF_4). The paper also demonstrates the influence of TiB_2 reinforcement on the aging behavior of the A356 matrix and the mechanical properties.

II. Experimental Work.

In this study A356 and TiB_2 composites were prepared via in situ route by melting together in appropriate amount of fresh A356 and allowing the melt to react with K_2TiF_6 and KBF_4 salts till furnace reaches up to 850°C. After that the molten metal going to under process of stirring for 10 min once. The melt put in to furnace for 60 min after getting 850°C again in the furnace. With the help of using preheated die we cast the composites sample. The composites have been characterized by XRD test. The TiB_2 particles were extracted from the composite by NaOH solution and the particles of TiB_2 were characterized by XRD.

The precipitation of hardening of the composites were studied by the solutionising the samples at 501°C for 60 min followed by quenching in regular water for 2 hours and aging at 175°C for 6 hr. Their tensile properties were evaluated using an electronic tensometer. The sample were machined as per ASTM E8 specification. The tensile properties reported are an average of two test at each conditions.

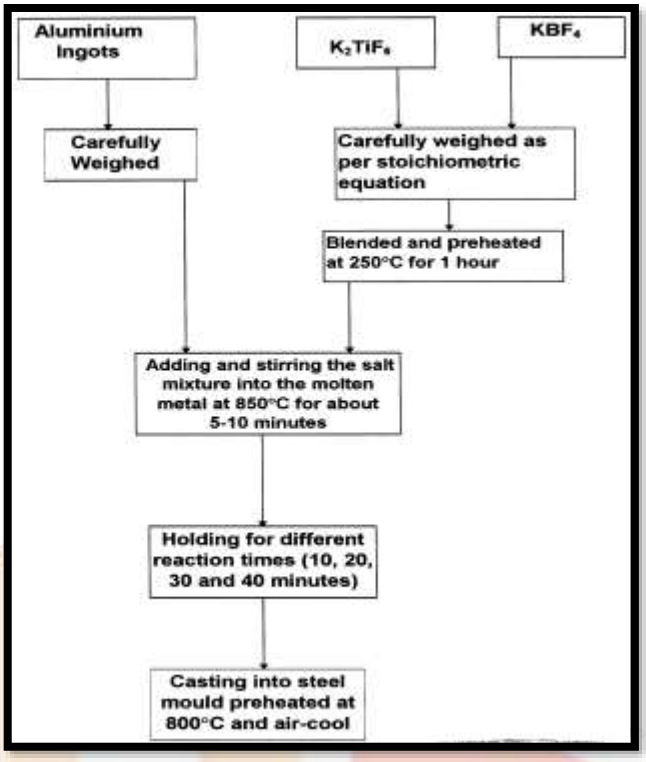
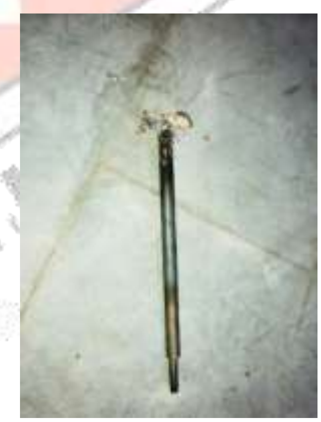


Fig. 2.1 Flow process chart for manufacturing of composite

2.2 Fresh ingot of A356

2.3 K_2TiF_6 and KBF_4



2.4 Mechanical Stirer

The chemical reaction between the two salts and the molten A356 took place to form in situ TiB_2 particulates in A356. The period of chemical reaction or the reaction holding time (RHT) was fixed 30 min as per literature review. The overall reaction showing the formation of TiB_2 can be written as:

$$K_2TiF_6\ (1) + KBF_4\ (1) + Al\ (1) \longrightarrow TiB_2\ (\text{in alloy}) + KFAlF_3\ (1) + KF\ (1) + AlF_3\ (1)$$

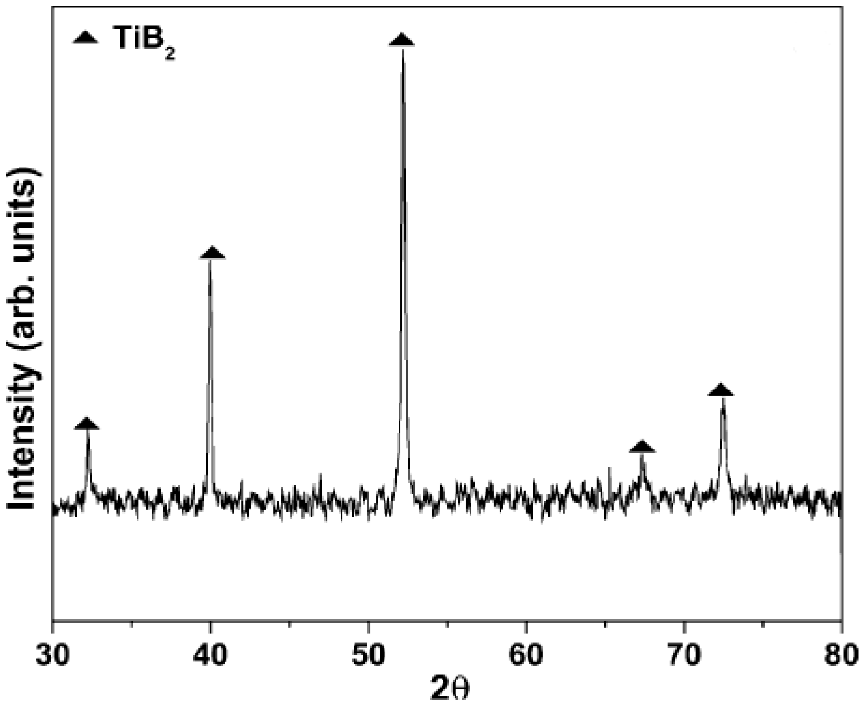
2.5 A356 casted sample

2.6 Composite casted sample

2.7 Dog-bone specimen

III. Results and discussion

In figure 3.1 shows the XRD results of in situ composites. As per figure it clearly shown the present of TiB_2 at pecks. An increase in the peak intensity of TiB_2 is evident with the increase in the TiB_2, as expected. A gradual marginal shift in the A356 peaks to higher angles with an increase in the weight fraction of the reinforcement is evident, which indicates a decrease in the lattice parameter of A356. This may be attributed to solution of Ti in A356 alloy. No evidence of the formation of the brittle intermetallic, Al_3Ti have been observed from figure which shows only TiB_2 peaks. This was further confirmed by the XRD studies on the extracted TiB_2 particles as seen in figure. It is important to note that the complete elimination of Al_3Ti particles during the synthesis of A356-TiB_2 composites has not been reported so far, and the present work is the about report in this direction. This was achieved in the present study by the careful control of the reaction parameters, such as reaction temperature and reaction time, and regular stirring of the melt.



3.1 XRD Patterns of A356-TiB_2 composite

The tensile properties and the hardness of the as-cast and peak-aged composites are compared with those of the base alloy in below table. Considerable increase in tensile properties is evident in the peak-aged condition in comparison to as-cast condition, as expected. The increase in the yield strength (YS) and ultimate tensile strength (UTS) on peak aging is 100 and 136% for the A356 alloy. However, the increase in the YS and UTS of the composite reinforced with TiB_2 particles is much higher respectively, in the peak-aged condition. Interestingly, the ductility is only marginally affected in presence of the reinforcement. The increase in YS of the composites can be attributed to the decrease in the grain size and hardening due to TiB_2 particles. Following table also gives the tensile properties of the A356-TiB_2 composites synthesized by the other investigators. It is very clear that the composites prepared in the present study have better YS, UTS and %elongation than the earlier reported values for similar amounts of the reinforcement. This could be attributed to the complete suppression of the formation of brittle Al_3Ti phase in the present study, which could not be achieved in the earlier studies. In addition, the presence of fine TiB_2 particles with coherent and semi-coherent precipitates throughout the matrix and grain refinement of composites could be the causes for improvement in ductility of the composites.

	A356	A356 + Precipitation of Hardening	Composite	Composite + Precipitation of Hardening
0.2% proof load (N)	4920	6540	8566	9356
Ultimate load (N)	7850	15320	18566	20443
0.2% proof stress (N/mm^2)	92.00	152.00	95.00	88.00
Ultimate Tensile Strength (N/mm^2)	175.00	247.50	155.57	160.89
% elongation	1.79	2.3	5.11	10.3

IV. Conclusion.

1. In A356-TiB_2 composites with high strength and ductility have been successfully synthesized by proper reaction of molten A356 with K_2TiF_6 and KBF_4 for noticeable time period.
2. The formation of TiB_2 is completely achieved.
3. TiB_2 particles accelerate the precipitation of hardening process in the A356 alloy.
4. The rate of hardening on peck aging increases with respect to amount of TiB_2 .

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