The Precipitation Of TiB_2 In Aluminum Alloy Melts From The Exothermic Reaction Of K_2TiF_6 And KBF_4 Halide Salts And Evaluation Of Its Mechanical Properties.

C.Mallikarjuna and Dr.S.M.Shashidhara

Abstract - **Aluminum alloy 2014–TiB_2 metal matrix composites have been fabricated using an exothermic reaction process at 850^0C using K_2TiF_6 and KBF_4 halide salts. The period of exothermic reaction was varied from a minimum of 15 min to a maximum of 45 min to investigate the relationship between the degree of reaction and the growth behavior of TiB_2. Micro structural observation showed a decreasing trend in grain size of the composites as the period increases. An x-ray diffractometer was used to confirm the presence of TiB_2. SEM micrographs observation revealed the hexagonal shape of the in-situ TiB_2 particles. Exothermic reaction is completed with the increase in reaction time, but the size of the in-situ TiB_2 particles was less depending on reaction time. As the period of exothermic reaction increases the weight percentage of TiB_2 increases but decrease in the grain size. Hence the yield strength, ultimate tensile strength and microhardness of the composite were increased.**

Key words: Exothermic reaction, In-situ TiB_2, Metal matrix composites.

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I. INTRODUCTION

Metal matrix composites have emerged as an important class of materials for structural, wear, thermal, electrical, automobile, aeronautical applications, primarily as a result of their ability to exhibit superior strength to weight ratio when compared to other commercial alloys. Metal matrix composites can be synthesized in a number of ways, these including liquid phase process, solid phase process and two-way processes. The composite processed using these methods suffer, in common, from matrix reinforcement interfacial thermodynamics instability, thus limiting their ambient and high temperature mechanical properties. In order to overcome this limitation, efforts have been made to synthesize Metal matrix composites in a single step from necessary raw materials to ensure good matrix to reinforcement compatibility and microstructural homogeneity. In situ processes represent one such category of techniques used to synthesize Metal matrix composites [1].

In situ processes involve the synthesis of composites such that desirable reinforcement, matrices and interfaces are formed during processing. The successful synthesis of in situ composites involves a good understanding of thermodynamics and reaction kinetics in order to obtain the desirable end product. The composites synthesized using in situ techniques exhibit the presence of a uniform distribution of reinforcement that tends to be fine and associated with a clean interface with the metallic matrix, which assists in the formation of a strong bond between the reinforcement and the metallic matrix.

Most of the studies reported so for are related to the fabrication and the mechanical properties of silicon carbide reinforced or alumina reinforced aluminum alloy composites [2]. Information related to the synthesis of composites with in situ TiB_2 reinforcement is, however very limited [3]-[5]. Accordingly, the present study focuses on the synthesis of in situ Metal matrix composites and the effects of processing parameters on the size and the weight percentage of TiB_2 reinforcement formed as a result of reaction between salts and molten aluminum.

II. EXPERIMENTAL PROCEDURE

Aluminum alloy 2014 was used as the base metal. Two types of salts, namely K_2TiF_6 and KBF_4 were used to synthesize the TiB_2 reinforcement.

Processing: Aluminum was first melted at 850^0 C, after which the two types of salts were added to the molten aluminum alloy in the atomic ratio in accordance with Ti/2B using the stirring method. The stirrer used being mild steel stirrer coated with zirconia. Coating being applied to the mild steel stirrer to avoid possible contamination of the molten metal. Chemical reaction between the two salts and the molten aluminum alloy took place to form in situ TiB_2 particulates in aluminum alloy. The period of chemical reaction was varied in steps of 15min up to 45min at 850^0 C to investigate the relationship between the degree of reaction and the growth behavior of TiB_2. After the reaction, the composite was cast into rods of 25mm diameter.

Tensile specimens having dimensions according to ASTM standard E8-03 were used for tensile testing. Tensile testing was carried out at room temperature at a constant displacement rate. Tensometre was used to carryout the tensile test. A Zwick/Roell microhardness tester was used to obtain the microhardness values of the aluminum alloy and composite samples.

III. RESULTS AND DISCURSION

A. Tensile test

Figure-I below shows comparison between the yield strength and the ultimate tensile strength for different reaction holding time of allied salts in aluminum alloy 2014, values of these mechanical properties are shown in Table-I.

Table-I: Values of Yield Strength and Ultimate Tensile Strength with respect to Reaction Holding Time of allied salts in aluminum alloy 2014.

RHT (min)	YS (M.Pa)	UTS (M.Pa)
0	94	184
15	113	189
30	123	194
45	121	192

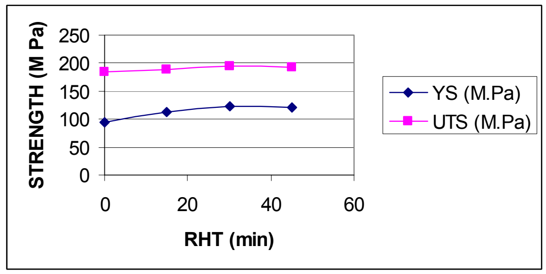


Figure-I: Graph of Strength Vs Reaction Holding Time of allied salts in aluminum alloy 2014

The yield strength and ultimate tensile strength of TiB_2 reinforced Aluminum alloy 2014 samples are compared with results of Aluminum alloy 2014 samples in Figure 3.1, as a function of the reaction holding time of allied salts in aluminum alloy 2014. The stress values increase with the reaction holding time of allied salts in aluminum alloy 2014 from 0 min to 30 min then slightly decreases. This reveals that the optimum level of reaction holding time of allied salts in aluminum alloy 2014 is 30 min.

B. Percentage elongation

Figure-II below shows the percentage elongation of the composite specimen tested for different reaction holding time of allied salts in aluminum alloy 2014. The values of percentage elongation for different specimens are shown in Table-II.

Table-II: Values of Percentage Elongation with respect to Reaction Holding Time of allied salts in aluminum alloy 2014.

RHT (min)	% EL
0	17.74
15	22.58
30	24.19
45	23.81

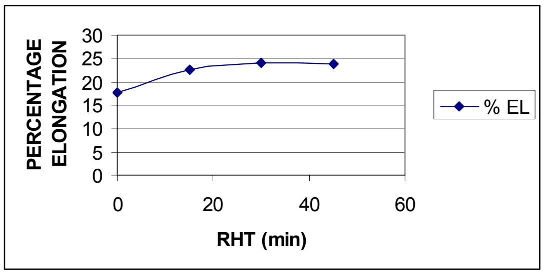
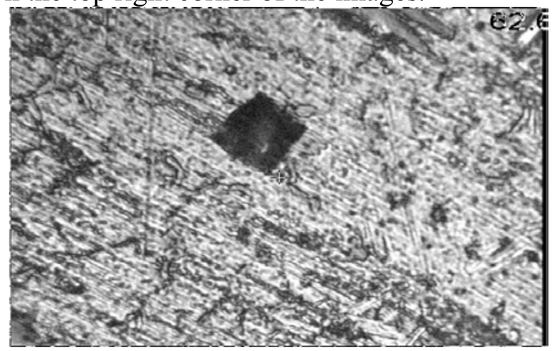


Figure-II: Graph of Percentage Elongation Vs Reaction Holding Time of allied salts in aluminum alloy 2014

The percentage elongation of TiB_2 reinforced Aluminum alloy 2014 samples are compared with results of Aluminum alloy 2014 sample in Figure 3.2, as a function of the reaction holding time of allied salts in aluminum alloy 2014. The percentage elongation values increase with the reaction holding time of allied salts in aluminum alloy 2014 from 0 min to 30 min then slightly decreases. This reveals that the optimum level of reaction holding time of allied salts in aluminum alloy 2014 is 30 min.

C. Microhardness

In this study the micro hardness test is conducted on the different specimens containing different reaction holding time of allied salts in aluminum alloy 2014 from 0 min to 45 min. We used Zwick/Roell microhardness tester to conduct these tests. Specifications of the tests are given below. Load = 25 gm, Time of loading = 10 sec, Magnification = 400 X. The results of the test are as shown in Figure-III in the form of four images corresponding to different reaction holding time of allied salts in aluminum alloy 2014. The Vickers hardness numbers for these specimens as given by the machine is depicted on the top right corner of the images.



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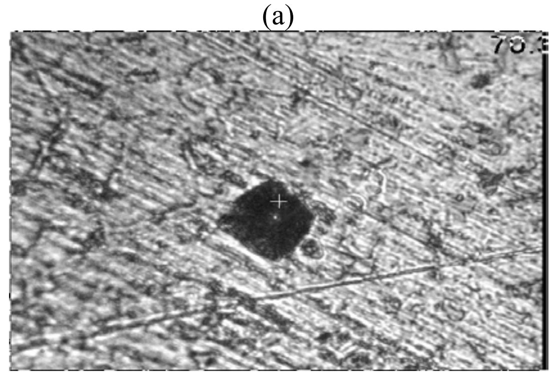

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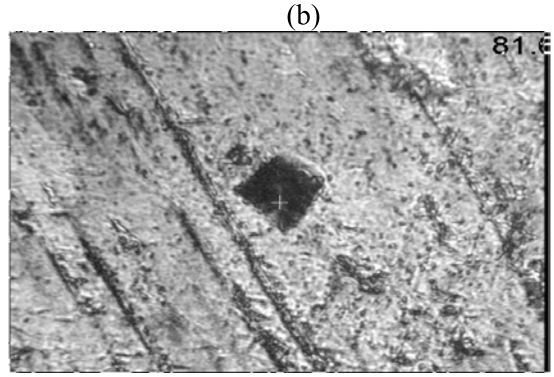

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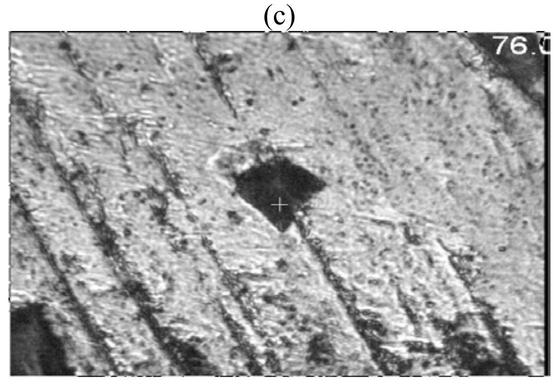


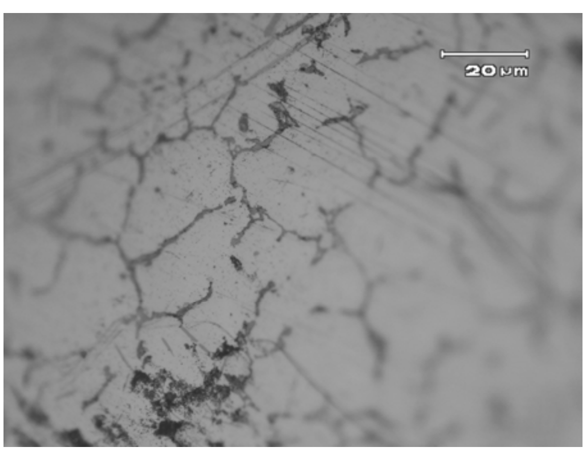
(d)

Figure-III: Micro hardness structure of (a) Aluminum alloy 2014, (b) Aluminum alloy-TiB_2 composite produced in situ with reaction holding time of 15min, (c) 30min and (d) 45min.

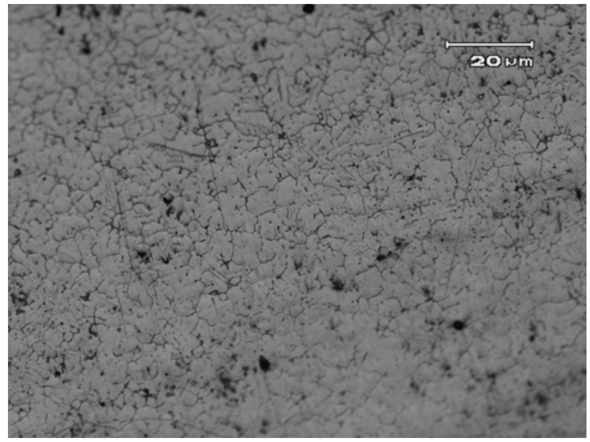
It can be seen from these images that as the microhardness values increases with the reaction holding time of allied salts in aluminum alloy 2014, up to 30 min then slightly decrease. This reveals that the optimum level of reaction holding time of allied salts in aluminum alloy 2014 is 30 min.

D. Grain refinement

The results of the present study indicate a decrease in grain size up to a reaction holding time of 30 min, followed by a significant increase up to a reaction holding time of 45 min as shown in Figure-IV. This can be related to the coupled effect of the weight percentage of TiB_2 in aluminum alloy matrix. For a given particulate size an increase in weight percentage will increase the number of particulates and similarly for a given weight percentage a decrease in particulate size will increase the number of particulates. Thus, it is related to the decrease in grain size up to a reaction holding time of 30 min is due to the coupled effects of increase in the weight percentage of TiB_2 in the aluminum alloy matrix and the decrease in the size of the TiB_2. However, a significant increase in the grain size for a reaction holding time of 45 minute may be attributed to the coupled effect of a decrease in the weight percentage of TiB_2 in the aluminum alloy matrix and increase in the size of TiB_2 particulates. The grain refinement of aluminum alloy 2014 by addition of titanium and boron via reagent salts K_2TiF_6 and KBF_4 has been studied extensively by many researchers [6], [7].



(a)



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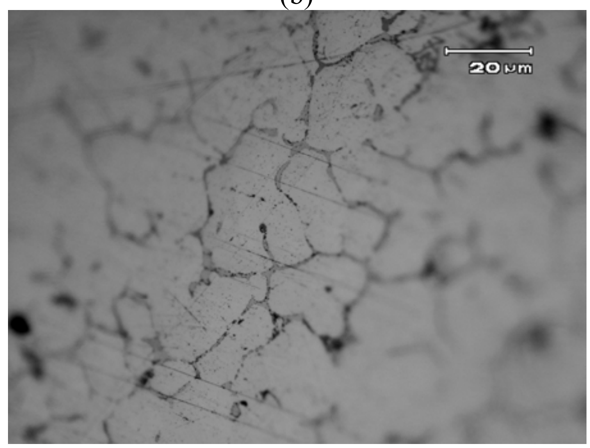


(c)

Figure-IV: Grain structure of Aluminum alloy-TiB_2 composite produced in situ with reaction holding time of (a) 15min, (b) 30min and (c) 45min.

E. X-ray diffraction analysis

XRD pattern of MMC formed by in situ is shown in Figure-V. The presence of TiB_2 peaks in the XRD pattern confirms the formation of TiB_2.

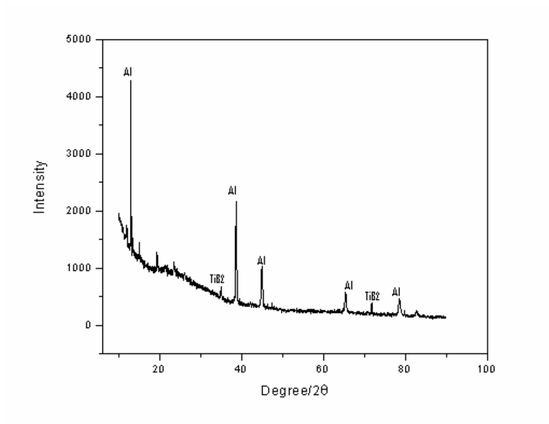
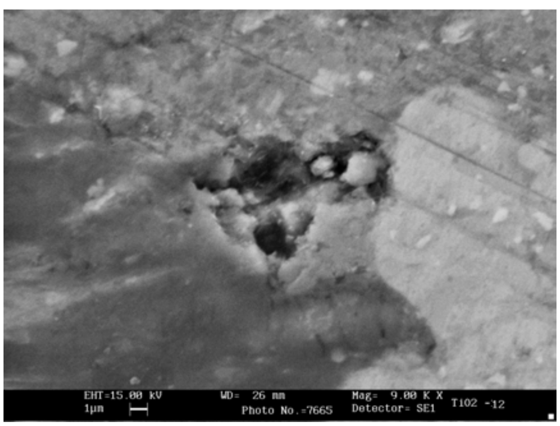


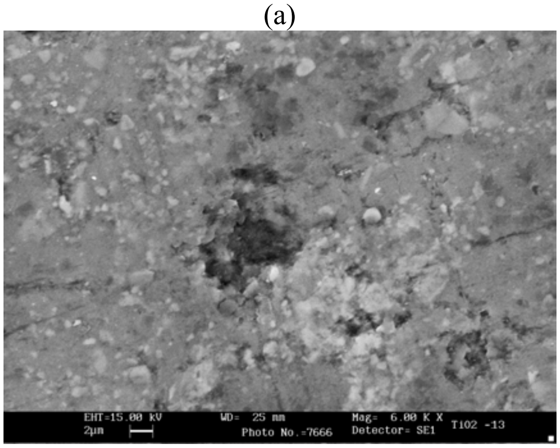
Figure-V: XRD pattern of aluminum alloy-TiB_2 composite produced by in situ with optimum reaction holding time of 30min.

F. Microstructure

SEM micrographs, showing the general micro structural features of composite samples prepared with reaction holding times of 15, 30 and 45 min are shown in Figure-VI.



(a)



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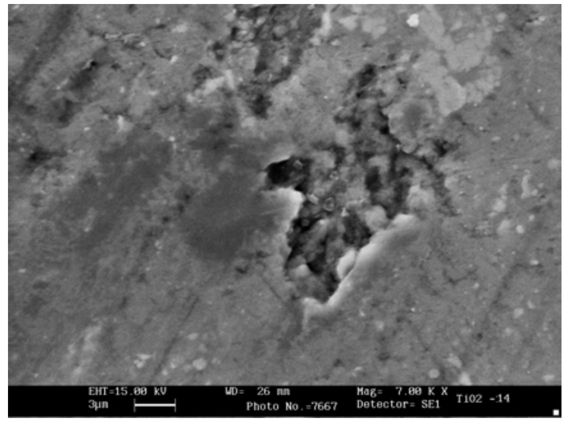

(c)

Figure-VI: SEM microstructure of Aluminum alloy-TiB_2 composite produced in situ with reaction holding time of (a) 15min, (b) 30min and (c) 45min.

It was observed that hexagonal shape TiB_2 particulates were formed even for 15 min of chemical reaction time. Because of short reaction time, complete reaction was not achieved therefore residual salts could still be found after casting.

IV. CONCLUSIONS

1. By exothermic reaction between K_2TiF_6 and KBF_4 salts in aluminum alloy 2014, in-situ aluminum alloy-TiB_2 composites were synthesized successfully.

2. XRD studies conforms the formation of TiB_2 particulates.

3. TiB_2 particulates were made clean interface with aluminum alloy 2014, because of in-situ synthesis method.

4. Variation in the weight percentage of TiB_2 will take place because of change in the volume of cryolite slag.

5. Volume of cryolite slag increases with reaction holding time.

6. The tensile strength varies with the reaction holding time. Initially tensile strength was increased up to 30 min, followed by a significant decrease over the next 15 min. This phenomenon can be related to the effect of the weight percentage of TiB_2 in the aluminum alloy matrix.

7. In situ processed aluminum alloy-TiB_2 composites showed similar trend in micro hardness and tensile properties.

8. The micro-hardness and ductility of the in situ processed aluminum alloy-TiB_2 composites increased significantly up to 30 min, followed by a significant decrease over the next 15 min.

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REFERENCES

1. M. K. Aghajanian, M. A. Rocazella, J. T. Burke, S. D. Burke, S. D. Keck, J. Mater. Sci. 26 (1991) 447.

2. P. Davies, J. L. F. Kellie, J. V. Wood, Key Eng. Mater. 357 (1993) 77-78.

3. J. V. Wood, P. Davies, J. L. F. Kellie, Mater. Sci. Technol. 9 (1993) 833.

4. I. Gotman, M. J. Koczak, Mater.Sci. Eng. 187A (1994) 189.

5. W. O. Soboyejo, R. J. Lederich, S. M. L. Sastry, Acta Metall. 42 (1994) 2579.

6. S. Mohanty, E. Gruzleski, Acta Metall. 43 (5) (1995) 2001.

7. C. D. Mayes, D. G. Mc Cartney, G. J. Tatlock, Mater. Sci. Technol. 9 (1993) 97.