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Analysis on Tensile Strength of Al/TiB_2 MMCs in FEA for Different Mould Conditions

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Abstract: *In the present work, Aluminum alloy A356-TiB_2 In-situ MMCs have been successfully synthesized and fabricated different pouring temperatures with permanent and sand mould conditions through chemical reactions between Aluminium, Titanium and Boron bearing salts and to test in terms of mechanical property (i.e. Tensile) and numerical simulation by Finite Element Analysis (FEA). The observation of SEM micrographs shows particle distribution of the TiB_2 and it appears in hexagonal shape in Al matrix. The results of X-ray Diffraction (XRD) analysis confirmed the formation of those TiB_2 particulates and the results showed TiB_2 particles are homogeneously dispersed throughout the matrix metal. The determined the experimental values of the Tensile. The experimental results were validated using FEA to simulate tensile test also developed. Tensile strength of the composites are higher in cast made in permanent mould and the best processing temperature in this study seems to be 820˚C.The predicted results were in good agreement with the experimental values.*
Keywords: *In-situ, Al/TiB_2, Finite Element Analysis, Tensile strength*

I. Introduction

Particulate reinforced metal matrix composites (PRMMCs) have been fabricated normally by conventional ex-situ research work due to their ease of fabrication, lower cost and isotropic properties [1]. The ex-situ composites are fabricated by directly adding reinforcements in to its matrix Aluminium-based reinforced TiB_2 exhibits improved mechanical and corrosion properties which find relevance in automobiles and aerospace materials for structural applications and also in naval vessels [2]. In situ Al- TiB_2 composites were synthesized successfully through the mixing salts reaction among the KBF_4, K_2TiF_6 and Al. In-situ MMCs attracted due to their advantages, such as well distributed fine reinforcement and good bonding between matrix and reinforcement [3]. Ductility to be reduced in Al/TiB_2 MMCs hence it has a higher tensile strength than pure alloy [4]. TiB_2 is particularly attractive because it exhibits high elastic modulus, hardness, high thermal conductivity and mainly TiB_2 particle do not react with molten Aluminium [5]

In Tensile test is one of the most important mechanical property evaluation tests. The resulting output from such a test is recorded as load versus displacement/elongation and can be graphically displayed as a load versus elongation curve. Load versus elongation curve is then converted to engineering-stress versus engineering-strain curve to evaluate the tensile properties of materials. The tensile properties that can be obtained from the stress-strain curves are yield strength, tensile strength, fracture strength, percent total elongation, uniform elongation, strain hardening exponent, modulus of resilience, and modulus of toughness [6, 7]. At present Finite Element Model (FEM) was used to simulate the actual process to identify the occurrence of failure, stress distribution etc, without investing much during the initial phase of the product development. Though FEM is difficult in simulating certain complex forming operations, it is essential to understand the process and reduce the tooling modification cost. The mechanical properties related to metallurgical aspects are also very important factors to be considered by the researchers. The novel finding is that it is possible to predict the tensile theoretically by FEA with a reasonable accuracy of over 90% instead of finding through laborious practical work [8, 9]. ANSYS is a complete FEA software package used by engineering like structural, electrical, mechanical and electromagnetic.

The purpose of this paper is to compare and analyse the tensile properties by UTM determined the experimental values of the Tensile. The experimental results are compared and by validated using FEA analysis in sand mould and permanent mould conditions and minimize the above defect [10].

II. Experimental Work

2.1. Materials

Aluminium (A356) was used as the base metal. Two types of salts, namely potassium Hexa Fluro Titanate (K_2TiF_6) and Potassium Tetra Fluro Borate (KBF4) were used to synthesize and to form TiB_2 reinforcement.

2.2. Processing

The Al/TiB_2 (MMCs) ingots are obtained by melting A356 Aluminium alloy and mixing calculated amounts of salts (KBF_4 and K_2TiF_6) preheated and maintained at 250 ˚C for about 30 min to yield a maximum of 6% TiB_2 reinforcements and cast at different pouring temperature (i.e. 780˚C, 790˚C, 800˚C, 810˚C, 820˚C), while maintaining the time of stirring and holding time constant.

K_2TiF_6 and KBF_4 salts were added into molten Al resulting in exothermic reaction to form In-situ TiB_2 particulates in Al. Unwanted compounds such as Al_3Ti and AlB_2 also form. Al_3Ti is a brittle compound and it degrades the mechanical properties of composites. The above In-situ based Al/TiB_2 MMCs were fabricated by sand mould and permanent mould conditions and mechanical behaviours was analyzed.

2.3. Tensile test

The extracted tensile specimens of permanent mould and sand mould test conditions are shown in Fig. 1.a & b. Tensile specimens were prepared to evaluate the tensile properties as per the ASTM E8M-04 specifications. Tensile tests were carried out in a 100 KN, electro-mechanical controlled universal testing machine. In each casting two samples were tested. The average results were obtained for final value.

Fig.1.a**.** Permanent mould specimens after testing conditions

Fig.1.b. Sand mould specimens after testing conditions

III. Finite Element Analysis

FEA simulations of deformation during tensile was used in ANSYS program. Taking into consideration that real model is symmetric and model made in Ansys is ½ of real model.

3.1. ANSYS Work Methodology

- Apply Material Properties
- Create the model as per the practical experimentation
- Meshing is carried out as per the size control
- Define the condition of specimen
- Define load
- Solve
- Plot Results

Finite Element model is created by using ANSYS 13.0 software. The specimen is meshed with the plane 182 element obtained with 1526 elements and 1616 nodes. The geometrical data input to the computer is taken from the tensile test configuration according to ASTM E8M-04 standards. One end of the specimen is fully restrained and the other end is constrained to have translations along the principal material direction. The computer simulations are performed by applying the load 100 kN and boundary conditions are shown in Fig.2.a. & b.

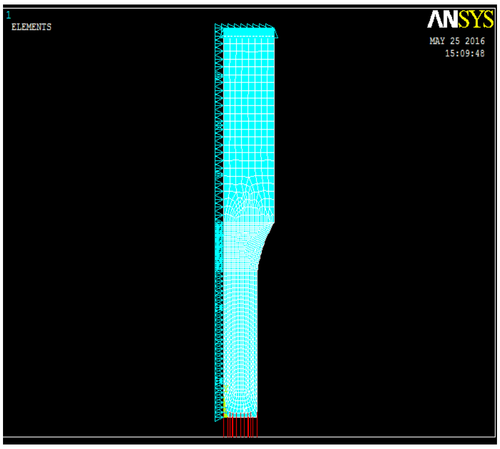

Fig.2.a. Tensile test specimen with loading and boundary condition.

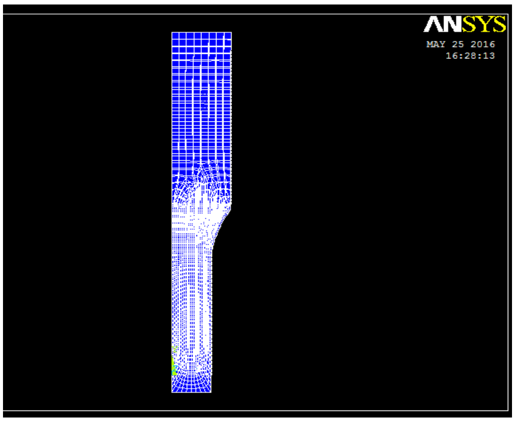

Fig.2.b. Deformation of tensile test specimen

IV. Results And Discussion

4.1. Phase formation of in-situ particles.

In this process TiB_2 has not formed directly. Exothermic reaction starts first with the reduction of K_2TiF_6 and KBF_4 salts as they decompose in the presence of A356 Al melt and KF liquid, titanium Fluoride and boron fluoride gases form as the results. Then Ti and B ions are diffused into liquid Al through the aluminothermic reduction. Fig.3.a & b shows the presence of TiB_2 and Al_3Ti formation in sand mould and permanent mould with XRD result at different pouring temperatures.

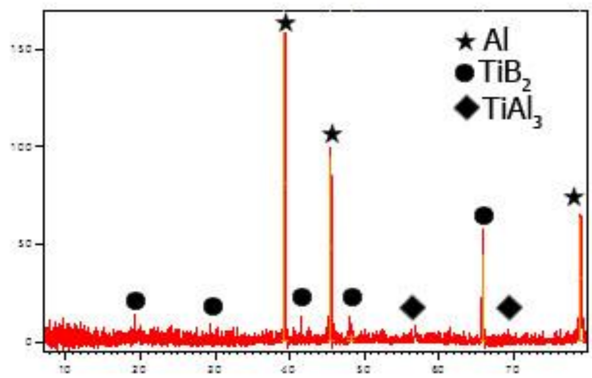

Fig.3.a. XRD graphs show the permanent mould in 820˚C

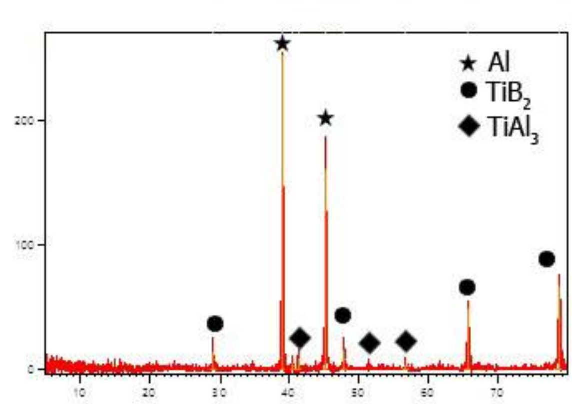

Fig.3.b. XRD graphs show the sand mould in 820˚C

4.2. Microstructure

Fig.4.a shows SEM Micrographs of Al- 6 wt % TiB_2 composites (permanent mould) with different temperature. The TiB_2 particles were homogenously dispersed and uniform distribution of reinforcement particles in the matrix phase is observed from these SEM micrographs. There is good bonding between the matrix and reinforcement phases present in white and dark colure of TiB_2 and Aluminium respectively. In compared to different levels of temperature particularly the casting were produced at 820˚C temperature more number of TiB_2 particles were dispersed, with the reduced common defects such as porosity, fluidity and agglomeration. Similarly Fig.4.b shows sand mould casting SEM micrographs. After the pouring the cooling rate is low the growth of TiB_2 particles in size high affecting the mechanical properties.

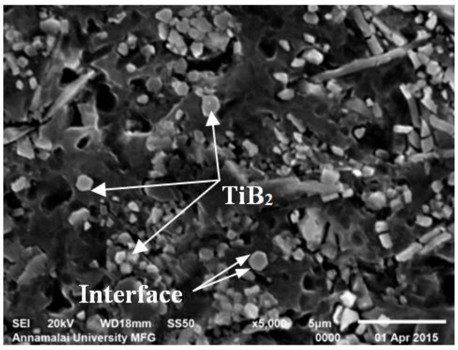

Fig.4.a. SEM show the permanent mould in 820˚C

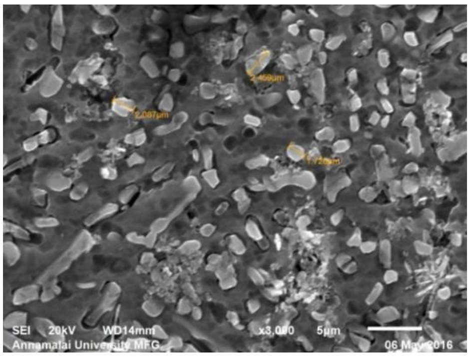

Fig.4.b. SEM show the sand mould in 820˚C

4.3. Tensile strength

The tensile strength of the Al 6% wt of TiB_2 while pouring temperature to the Aluminum the tensile strength is increases from 118 MPa to 171 MPa. Fig.5. shows the comparison of UTS bar graph values with permanent mould and sand mould conditioned. In permanent mould casting have more UTS with higher temperature as the cooling rate is high and TiB_2 particles formed is are finer.

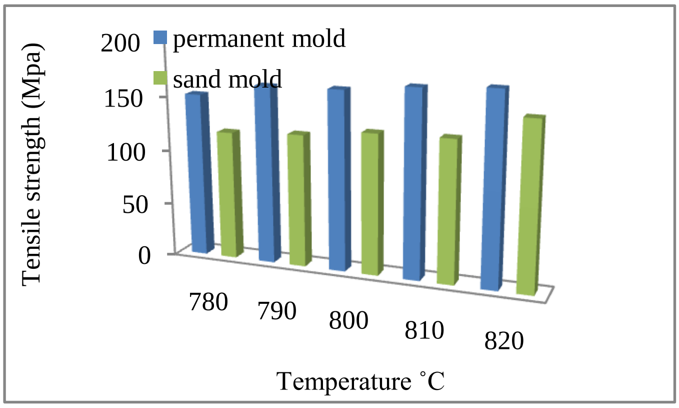

Fig.5. shows the comparison of UTS bar graph values with permanent mould and sand mould conditioned samples.

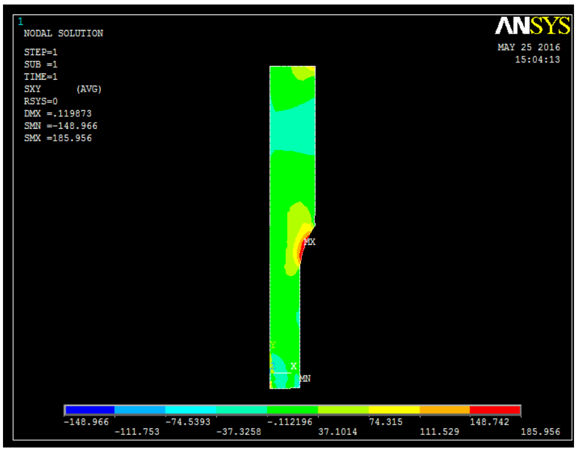

Fig: 6.a. Tensile strength distribution of permanent mould inMPa

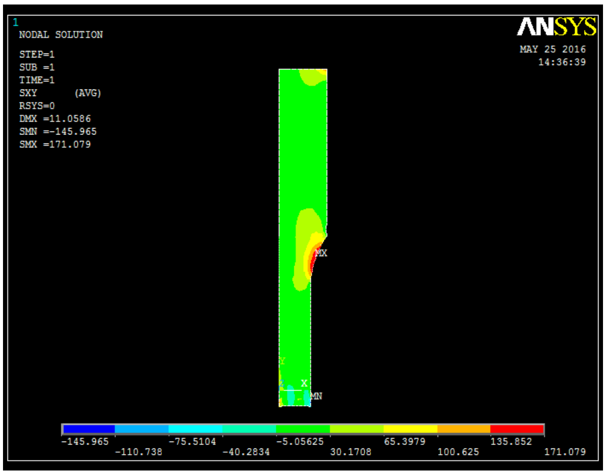

Fig: 6.b. Tensile strength distribution Sand mould in MPa

The tensile strength distribution for the specimens of permanent mould and sand mould is shown in Fig.6.a & b. The tensile strength obtained for specimen from this analysis is 185 MPa & 171 Mpa. Its experimental value is observed permanent mould and sand mould to be 175 MPa & 152 MPa. The experimental and FEA results are noticed to be 10 %. Hence the results arrived at experimentally are almost matching the theoretically predicated tensile value. The results obtained in ANSYS exhibit a good agreement with the experimental finding as shown in Fig. 7.

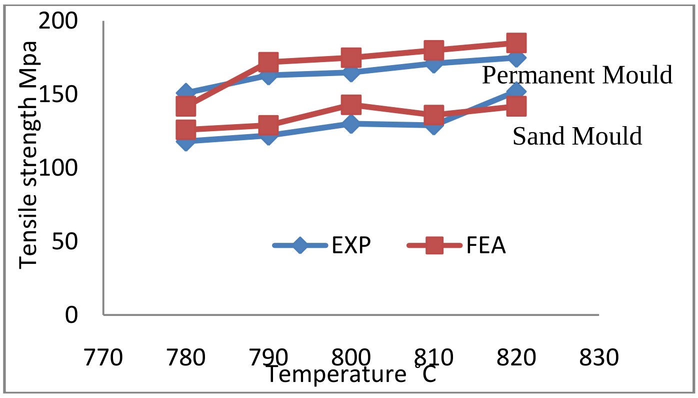

Fig.7. Effect of processing temperature on tensile strength of composite on FEA and Experimental results.

V. Conclusion

- Aluminium (A356) with salts K_2TiF_6 and KBF_4 were synthesized to get Al/TiB_2 MMCs. It is concluded finally that the permanent mould casting are more suitable for Al/TiB_2 composite fabrication as compared with sand mould.
- XRD patterns confirmed the presence TiB_2phase. The SEM analysis of composite material produced by stir casting technique shows genuinely uniform dispersion of TiB_2 phase in the Al metal matrix.
- Tensile strengths were compared in sand and permanent mould conditions. The tensile strength of the Al 6% wt while the temperature poring temperature increase tensile strength is also increase. Show significant improvements of tensile strength in permanent mould condition than sand mould condition.
- The ANSYS model programmed with use of finite elements method permits to analyze the mechanical (tensile) properties, what makes plausible its application for computation of the tensile. The results obtained in ANSYS exhibit a good agreement with the experimental results.

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