Proceedings

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✦ ***Engineering & Technology for Global Stability and Security*** ✦

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MESSAGE FROM TECHNICAL CONFERENCE CHAIRPERSON

Welcome to the Conference on Advanced Processes and Materials (CAPM) for the 4^{th} World Engineering Congress 2010 (WEC2010)! CAPM was organized to address the advancements in biochemical, chemical and food processes as well as advancements in materials and nanomaterials that are becoming an important area of research in universities and institutions worldwide. I am delighted that we have received tremendous interest and support from local and international participants with CAPM receiving the highest number of papers for WEC2010.

This proceeding is a compilation of peer-reviewed papers arising from the research and development work being carried out by researchers as well as best industrial practices. We are pleased to announce that selected papers will be published in special issues of selected citation indexed journals. I take the opportunity here to thank all of our reviewers for their contribution towards ensuring the quality of our papers.

We are honored to have the presence of two renowned professors, Professor Dr. Ng Ka Ming from Hong Kong University of Science and Technology and Professor Dr. Yoshihito Shirai from Kyushu Insitutite of Technology who will be giving keynote lectures pertaining to the areas of nanotechnology and bioprocess engineering; in line with the WEC2010 theme of 'Engineering & Technology for Global Stability and Security'. Due to the strong support from the materials engineering community we have invited plenary speakers Professor Dr. Fazal Ahmad Khalid from the GIK Institute of Engineering Science and Technology, Pakistan and Professor Dr. Hanafi Ismail from University Sains Malaysia who will talk about their research on advanced composite and nanocomposite materials.

I would like to take this opportunity to thank the CAPM technical committee members for their dedication and commitment in ensuring the success of this conference. It has been an honour to work alongside such devoted colleagues. Sincere appreciation also goes out to our national and international advisory committee for their support.

Finally I hope this conference being held in the charming city of Kuching will provide you another venue for networking, sharing of knowledge and exchanging of ideas for the continuous development of advanced processes and materials. On behalf of the organizing committee, we look forward to your participation in future WEC series.

Best wishes,

Dr. Suraya Binti Abdul Rashid
Technical Chairperson
Conference on Advance Processes and Materials

KEYNOTE SPEAKERS

Professor Dr. Ng Ka Ming is Chief Executive Officer of Nano and Advanced Materials Institute Ltd. (NAMI), Chair Professor of Chemical and Biomolecular Engineering, and Director of the Consortium of Chemical Products and Processes at the Hong Kong University of Science and Technology. He has a vast experience in the design, development and commercialization of chemical based products in particular nano and advanced materials. He serves as a consultant, technical advisor and independent non-executive director for various companies and government bodies around the world. At present he is also the Corporate Science and Technology Advisor of Mitsubishi Chemical Corp.

Professor Dr. Yoshihito Shirai is a professor in the Graduate School of Life Science and Systems Engineering, Department of Biological Functions and Engineering, Kyushu Institute of Technology (KIT), Japan and he holds a director position in the Eco-Town Research and Development Center. In 1980, Yoshihito Shirai received his B.S. in Agriculture (Food Science and Technology) from the Kyoto University, Japan. His M.S. and Ph.D. degrees in Agriculture (Food Science and Technology) were granted by the same university in 1982 and 1988, respectively. His scholarly efforts are devoted to sustainability, and his published works include several chapters in books and over 100 scholarly articles. He has lectured locally, regionally, nationally, and internationally, and frequently delivers addresses on waste treatment issues to the general public. He is currently working in collaboration with Universiti Putra Malaysia and National Institute of Advanced Industrial Science and Technology, Japan (AIST) for research and development (R&D) in the field of biomass. This collaborative team, AIST-UPM-KIT R&D team is jointly captained by Dr. Kinya Sakanishi from AIST, Dean from the Faculty of Biotechnology and Bimolecular Sciences UPM, Prof. Mohd. Ali Hassan. This research has demonstrated the links between waste and wealth issues, which has attracted considerable interest both locally and internationally.

PLENARY SPEAKERS

Professor Dr. Fazal Ahmad Khalid has extensive experience of industry, teaching and research. His research interests are in the phase transformations, microstructure and properties of automotive and engineering materials, in the interfacial and nanostructures in composites and alloys, development of orthopedic implants and prostheses and Fe base shape memory alloys, in the deformation and mechanical behaviour of tungsten, metallic alloys and composites at high strain rate, and high temperature oxidation behaviour of stainless steels and superalloys and processing of Al-diamond, Al-C60 Cu-CNT nanocomposites and Al-TiO2 mechanically alloyed nanomaterials. Currently he is involved in R&D work related to nanomaterials and consultancy projects related to quality evaluation, and processing, properties and characterization of engineering materials and their application for wind energy and power plants.

Professor Dr. Hanafi Ismail is a professor in the Polymer Division, School of Materials & Mineral Resources Engineering, Universiti Sains Malaysia (USM). He is the President of Institute of Materials Malaysia for the northern region, Life Member of The Electron Microscopy Society Malaysia, Member of The Plastic and Rubber Institute of Malaysia and The Malaysian Counselling Association. He has published over 200 papers of national and international journals, over 200 papers in conferences/seminars and over 10 books, chapter in book and magazines/bulletin. His area of research interests includes Polymer Science and Technology (Rubber, Plastic, Rubber-Rubber Blends, Rubber-Plastic Blends, Plastic-Plastic Blends, Thermoplastic Elastomer (TPE's), Polymer Recycling and Polymer Composites). He also has reviewed over 100 papers for refereed journals. In addition, Professor Hanafi is a committee member of many society clubs at the university and is also actively involved in sports. He is the recipient of numerous awards such as the Khwarizmi International Award (Iran), Islamic Development Bank Merit Scholarship Programme Award, Japanese Society for the Promotion of Science (JSPS) Fellowship (Kyoto), and Sanggar Sanjung (Hall of Fame) Award (USM).

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MANUFACTURING AND MECHANICAL PROPERTIES OF TITANIUM CARBIDE PARTICULATE REINFORCED ALUMINIUM-11.8% SILICON ALLOY MATRIX COMPOSITE CASTINGS

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ABSTRACT

This research paper discusses on the manufacturing and mechanical properties of titanium carbide particulate reinforced aluminium-11.8% silicon alloy castings. The composite castings in the form of slab containing 0.2, 0.6, 1, and 2% weight fraction of particulate equally reinforced LM6 alloy are made by sand casting process. The results shows that tensile strength and hardness of the composites increased with increasing of titanium carbide particulate content in the matrix. Fracture surface analysis and interfacial bonding characterization has been performed to study the failure and hence to predict the presence of any interfacial reaction products formed between the particulates and the matrix.

Keywords: *titanium carbide particulate, composite castings, mechanical properties, manufacturing.*

INTRODUCTION

Particulate reinforced composites, often called as discontinuously reinforced metal matrix composites are new advanced materials. Hybrid composites are usually used when a combination of properties of different types of particulates wants to be achieved, or when longitudinal as well as lateral mechanical performances are required [1]. Aluminium oxide and silicon carbide reinforced aluminum alloy matrix composites are applied in the automotive and aircraft industries as engine pistons and cylinder heads, where the tribological properties of these materials are considered important. Therefore, the development of aluminum matrix composites is receiving considerable emphasis in meeting the requirements of various industries. Metal matrix composites are materials that are attractive for a large range of engineering applications. It has also reduced the thermal insulation requirements because of its lower thermal conductivity. Precision components in the missile guidance systems demands dimensional stability and the geometries of the components cannot change during usage [2].

Today's search is for composite materials with ever-higher service characteristics such as wear and heat resistance, high- temperature strength, antifriction, and cutting properties [3]. Different shapes of particulates are reinforced in the matrix alloy and they are characterized as acicular, irregular rod like, flake, dendritic, spherical, rounded, irregular, angular, sub angular, fibrous, granular, lamellar, nodular, crystalline and porous type. Particle shape has a major influence on processing characteristics. The shape is usually described in terms of the aspect ratio or shape factor [4]. Aspect ratio is the ratio of the largest dimension to the smallest dimension of the particle. This ratio ranges from unity, for a spherical particle to about 10 for flake like or needle like particles. Shape factor or shape index of the particulate is a measure of the ratio of the surface area of the particle to its volume, normalized by reference to a spherical particle of equivalent volume [4, 5]. The size distribution of particulates is an important consideration, because its affects the processing characteristics of the powder. Normally the fibres have a definite aspect ratio, which is defined by Length/Diameter ratio.

Composite materials have found increasingly wider applications in aircraft, space vehicles, offshore structures, piping, electronic, automobiles, boats and sporting good. On a weight adjusted basis, many aluminium and aluminium alloy based composite materials can outperform the conventional ferrous and non-ferrous materials like cast iron, steel, aluminum, magnesium and virtually any other reinforced metal or alloy in a wide variety of applications [6,7]. Hence, probably, metal matrix composites will replace the conventional materials in many commercial and industrial applications in the near future. Special interest on particulate-reinforced metal matrix composites is due to the several merits offered by them.

The interface between the matrix and the reinforcement plays an important role for deciding and explaining the toughening mechanism in the metal matrix composites. The interface between the matrix and the reinforcement should be organized in such a way that the bond in between the interface and the matrix should not be either strong or weak. While the load is acting on the composite, it has been distributed to the matrix and the reinforcement phase through the matrix interface. The reinforcement is effective in strengthening the matrix only if a strong interfacial bond exists between them [8]. The interfacial properties also influence the resistance to crack propagation in a composite and therefore its fracture toughness. The two most important energy-absorbing failure mechanisms in a composite are debonding and particle pull out at the particle matrix interface. If the interface between the matrix and reinforcement debonds, then the crack propagation is interrupted by the debonding process and instead of moving through the particle, the crack move along the particle surface allowing the particle to carry higher load.

MATERIALS AND METHODS

MATERIAL SELECTION

The materials selected in this research work are aluminium-11.8% silicon alloy containing 85.99% of aluminium, 11-13% of silicon for the matrix and titanium carbide as a particulate reinforcement phase. For preparing the composite, aluminium-11.8% silicon alloy is used because it has excellent castability and fluidity. Titanium carbide is used as second phase reinforcement in the alloy matrix with different percentages added on it by weight fraction basis.

METHOD

Titanium Carbide Particulate Reinforced LM6 Alloy Composite Preparation

Only one type of pattern is used in this research work and the procedure for making the pattern involves the preparation of drawing, selection of pattern material, and making the mold. Carbon dioxide moulding process was used to prepare the specimens as per the standard moulding procedure. Titanium carbide-particulate reinforced MMCs were fabricated by sand casting technique. Four different weight fractions of TiC particle in the range from 0.2%, 0.6%, 1%, 2% were added in the matrix. An induction melting furnace was used to melt the aluminium alloy at 800^0C and TiC was mixed in it after the alloy attains the liquid state. The main concern was to maintain the temperature while transferring the molten metal to the mould and hence to ensure the quality of the cast product. The metal handling equipment used to transfer the molten metal also depends on the mould size and quality of cast being cast. Figure 1 and 2 shows the casting processing steps.

Tensile Test

Tensile test specimens were made as per ASTM standards; B557 M-94 specifications as shown in Figure 3. Fracture surface analysis by using SEM was conducted after tensile testing. Tensile tests were carried out by using a universal testing machine to determine the tensile properties of the material such as ultimate tensile strength.

Figure 1. Casting process

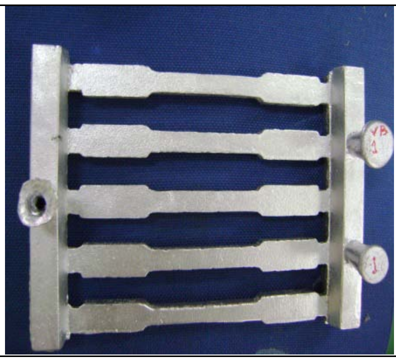

Figure 2. Composite casting with runner system

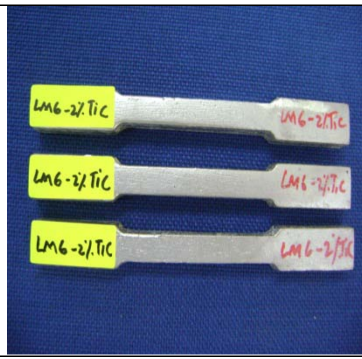

Figure 3. Specimens after removed from the runner system

Hardness measurement

The hardness testing was done on a Rockwell Hardness Tester. The hardness of composites were tested by using MITUTOYO ATK-600 MODEL hardness testing machine. For each sample, ten hardness readings were taken randomly from surface of the samples. Hardness values of different types of the processed composites are determined for different weight fraction % of titanium carbide particulate containing aluminium-11.8% silicon alloy and graphs are plotted between the hardness value and the corresponding type of particulate addition on weight fraction basis.

Metallography

Metallography is the study of internal physical structure in metals and alloys. The surface of metallographic samples of the composites is prepared in accordance with standard procedures used for metallographic analysis. This involved coarse polishing of the samples using 300, 600 and 1000-grit silicon carbide impregnated emery paper followed by fine polishing using 0.05µm colloidal silica as the lubricant. The as-cast composite samples were etched with Keller's reagent containing 95% distilled water, 1.5ml hydrochloric acid, 1.5% hydrofluoric acid and 2.5% nitric acid. It is used to reveal the phases present in the composites. The specimens are shown in Figure 4 and the polishing machine is also shown in Figure 5.

Figure 4. Specimens after mounting

Figure 5. Polishing process

With the aid of a metallurgical microscope, investigation has been performed. The sample of size 10mm x 10mm was cut from each specimen after tensile testing to fit in the specimen chamber for Scanning electron microscopy (SEM) test. SEM was used to study the fracture surface of the reinforced LM6 alloy composites. The SEM test is performed by the HITACHI S-3400N variable pressure microscope with Inca 300 Energy Dispersive X-ray (EDX). The fracture surfaces of the tensile tested samples are observed at higher magnifications to characterize the features of the failure and the type of failure. Then further studies on the interphase and bonding are performed to observe the formation of any interfacial reaction products and hence to predict the type of bonding between the particulate surface and the matrix surface.

RESULTS AND DISCUSSION

Results and data are obtained from the tested samples taken from the titanium carbide reinforced LM6 alloy slab composite castings made in sand molds. The values are reported for the mechanical properties, hardness and microstructural features of titanium carbide particulate distribution for each weight fraction percentage addition to the LM6 alloy matrix are explained. In this section, the above mentioned composites are analyzed and the results are presented in the corresponding graphs that are shown in Figure-6 and Figure-7.

Tensile Test

The tensile strength of titanium carbide particulate composites are determined. The tensile strength of 2% and 0.2% weight fraction of the above combined particulate composite is 135.8325 MPa and 116.0743 MPa respectively. From this, it is clear that the tensile strength value increase with the increase on the weight fraction % of titanium carbide in the alloy matrix. The tensile strength value decreased gradually when above combination of particulate weight fraction addition of LM6 alloy matrix is increased and it is shown in the graph as Figure 6.

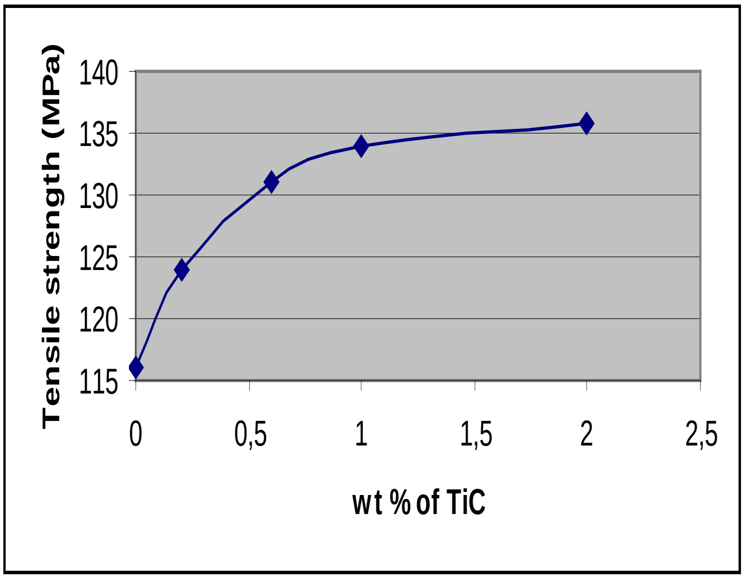

Figure 6. Average tensile strength versus weight fraction of TiC

Hardness measurement

Data on the hardness of combined particulate reinforced composites made in sand mold is analyzed. It is found that the hardness value increases gradually with the increased addition % by weight and it is shown below in the graph as Figure 6. The maximum hardness value based Rockwell superficial 15N-S scale is 85.88 for 2% weight fraction addition.

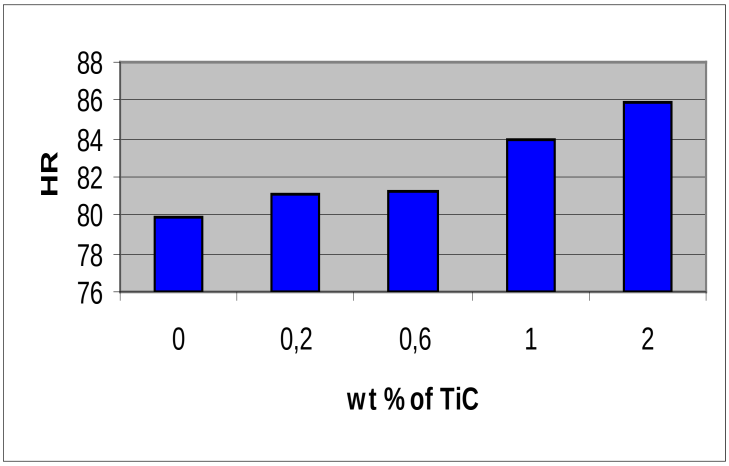

Figure. 7 Average hardness Rockwell versus weight fraction of TiC

Based on the above figure, variation in hardness value of the composites corresponding to the variation in weight fraction of titanium carbide particulate can be known. It is clear in this figure that the hardness value of the processed composites increases with the increase in addition of titanium carbide particulate by weight fraction %.

Metallography of titanium carbide particulate reinforced LM6 alloy composites

The samples are viewed at different magnifications and photomicrographs are captured to predict the confirmation of the presence of the particulates in the alloy matrix. Then, it is further studied to identify the particulate distribution. From the in-depth research on this, it is confirmed the presence and distribution of embedded particulates in the matrix is uniform. The alloy matrix grains are finer and the bonding between particulate surface and the matrix material is satisfactory. It is found that, the morphological distribution of combined particulate for every weight fraction % addition increases. In this section, a number of captured photomicrographs are shown in the Figure-8 to 12 for better understanding.

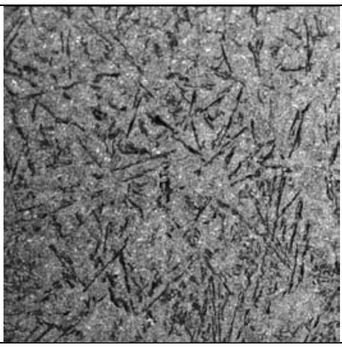	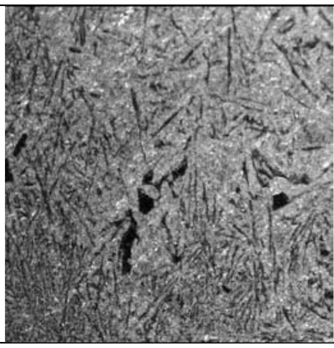	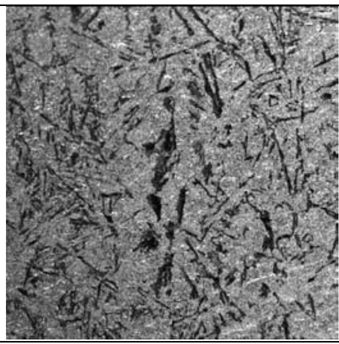
Figure 8. Microstructure of LM6 alloy magnified at 100x	Figure 9. Microstructure of composite with 0.2% wt of TiC (100x)	Figure 10. Microstructure of composite with 0.6% wt of TiC (100x)

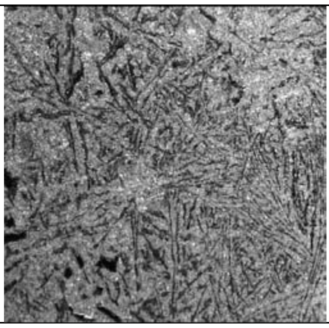	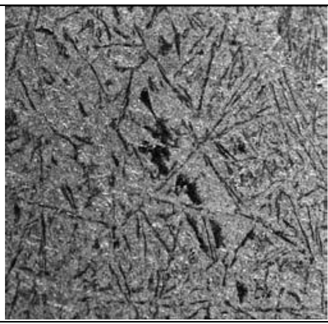
Figure 11. Microstructure of composite with 1% wt of TiC (100x)	Figure 12. Microstructure of composite with 2% wt of TiC (100x)

Fractography

Fracture surface investigation of composite samples is performed by using HITACHI S-3400N variable pressure microscope with Inca 300 Energy Dispersive X-ray (EDX). By using it, fracture surfaces of the tensile tested samples are observed at higher magnifications to characterize the type of failure. Then, studies on the interphase and bonding are performed to observe the formation of interfacial reaction products and to predict the type of bonding between the particulate surface and the matrix surface. The examined fracture surface of an LM6 matrix composite surfaces exhibit a brittle cleavage fracture mechanism. The fracture surface of the grain refined composite showed broken Aluminium and TiC particles (Figure 13 to Figure-17) and well-attached particles within the dimples, indicating rather good interface cohesion between matrix and reinforcing particles.

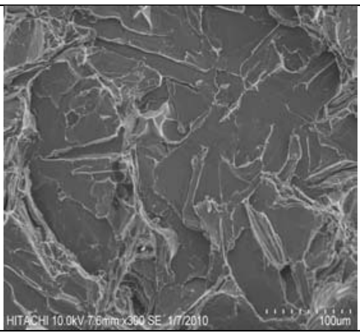	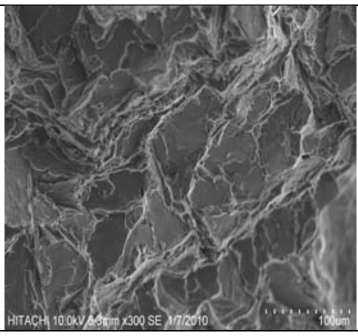	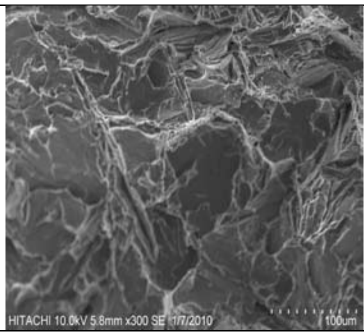
Figure 13. Fractograph of LM6 at 300X magnification	Figure 14. Fractograph of 0.2% TiC particulate at 300X	Figure 15. Fractograph of 0.6% TiC particulate at 300X

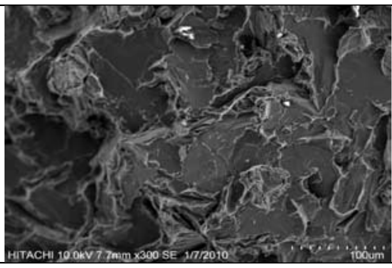	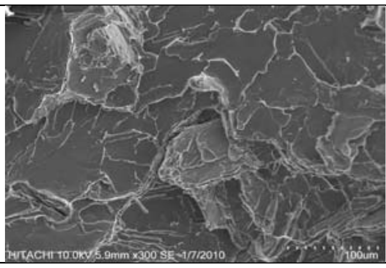
Figure 16. Fractograph of 1% TiC particulate at 300X	Figure 17. Fractograph of 2% TiC particulate at 300X

The above displayed fractographs are the fracture surfaces of titanium carbide particulate composites after tensile testing. The failure mechanism consists of titanium carbide particulate cleavage, interfacial decohesion, and cleavage of the aluminium-silicon alloy matrix. The addition of titanium carbide toughens the matrix, the crack propagates by the toughening mechanism by the deflection of crack, and it is supported from the literature citation [9].

CONCLUSIONS

The split tensile strength and hardness values increased gradually as the TiC content in the composite increased from 0.2%, 0.6, 1% and to 2% by percentage weight fraction. The tensile behavior of the processed composite had a strong dependence on the weight fraction addition of the second phase reinforcement particulate on the alloy matrix. The reason for this tensile behavior is due to the dominating nature of the compressive strength of the TiC particulate reinforced in the LM6 alloy matrix. Particle cracking of the reinforcement particulate was seen on both MMC fracture faces under tensile test, implying that there is sufficient interfacial bonding between the reinforcement particles and LM6 alloy matrix.

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