Applied Mechanics and Materials Vols 66-68 (2011) pp 1207-1212
© (2011) Trans Tech Publications, Switzerland
doi:10.4028/www.scientific.net/AMM.66-68.1207
Online: 2011-07-04

Influence of Mechanical Vibration Moulding Process on the Tensile Properties of TiC Reinforced LM6 Alloy Composite Castings

Sayuti, M[1a], S. Sulaiman[1b], B.T.H.T, Baharudin [1c], M.K.A, Arifin[1d], Vijayaram.T.R[2e], and Suraya, S[1f]

[1]Department of Mechanical and Manufacturing Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia.

[2]Faculty of Engineering and Technology (FET) Multimedia University, Jalan Ayer Keroh Lama, Bukit Beruang, 75450, Melaka. Malaysia.

[a]tgk_sayuti@yahoo.co.uk, [b]suddin@eng.upm.edu.my, [c]tuah@eng.upm.edu.my, [d]khairol@eng.upm.edu.my, [e]vijayaram1@gmail.com, [f]sue_bahira@yahoo.com

Keywords: Mechanical vibration moulding process, TiC particulate, LM6 alloy, Metal Matrix Composite , tensile properties, modulus of elasticity

Abstract. Vibrational moulding process has a remarkable effect on the properties of castings during solidification processing of metals, alloys, and composites. This research paper discusses on the investigation of mechanical vibration mould effects on the tensile properties of titanium carbide particulate reinforced LM6 aluminium alloy composites processed with the frequencies of 10.2 Hz, 12 Hz and 14 Hz. In this experimental work, titanium carbide particulate reinforced LM6 composites were fabricated by carbon dioxide sand moulding process. The quantities of titanium carbide particulate added as reinforcement in the LM6 alloy matrix were varied from 0.2% to 2% by weight fraction. Samples taken from the castings and tensile tests were conducted to determine the tensile strength and modulus of elasticity. The results showed that tensile strength of the composites increased with an increase in the frequency of vibration and increasing titanium carbide particulate reinforcement in the LM6 alloy matrix. .

Introduction

Composite material is a combination of two or more chemically distinct and insoluble phases with its properties and structural performance superior to those of the constituents acting independently. Composites by definition, being a combination of different materials, offer a particular challenge when preparing it by liquid metal processing method such as SiC, TiC and SiO_2 [1, 2]. Composite are considered as an important class of materials that have numerous attractive properties. Metal matrix composites often consist of a soft aluminum alloy matrix with brittle particles of, for example, tungsten carbide, titanium carbide, aluminium silicate or quartz [3]. These particles can vary in size, distribution and concentration in the matrix. One of the advantages of composite materials is that they can be engineered for specific applications[4]. Applying mechanical vibration during the solidification process is a simple technique that requires neither complicated procedure nor expensive setup. It can be applied to the existing processes and does not require extensive modifications on the equipments. It requires less energy as compared to electromagnetic vibration and semisolid processes and less expensive. The low energy required the most environmentally friendly process compare to other grain refinement methods. There are three practicable methods of application of vibration; one is applying vibration to the entire mould, another method is applying vibration to the molten metal, and lastly by means of electromagnetic induction [5]. Abu Dheir et have also reported that certain mechanical properties were affected by the vibration which includes 19% to 68% increase in elongation with a slight increase (3%) in ultimate tensile strength [6]. However, the literature review reveals that the application of mechanical, sonic and ultrasonic vibration has a number of notable effects such as grain refinement, increased density, degassing, shrinkage, and the shape, size and distribution of the second phase. Vibration energy has been used in many processes within the metallurgical and engineering fields [7, 8]. In this research work, MMC consisting of aluminum reinforced Titanium Carbide (TiC) particles were produced by sand casting using mechanical vibration mould during solidification process. Tensile testing was employed to evaluate tensile strength of TiC-particulate reinforced LM6 alloy composites.

Experimental

Material Preparation. The materials used in this work were Aluminium LM6 alloy as the matrix and TiC as reinforcement particulates with different percentages. Sodium silicate and CO_2 gas was used to produce CO_2 sand mould for processing composite casting. The aluminium alloy used was BS 1490-1988 LM6. The chemical composition of LM6 alloy is shown below in Table 1.

Table 1. Chemical composition of LM6.

Element	Al	Cu	Fe	Mg	Mn	Ni	Pb	Si	Sn	Ti	Zn
wt %	85.95	0.1	0.6	0.1	0.5	0.1	0.1	11.8	0.05	0.2	0.1

Vibration table set up. A mechanical vibration moulding set up is used to conduct the experiment and the vibration specifications in terms of frequency and amplitude are shown in Table 2..

Table 2. Specification mechanical vibration

Frequency (Hz)	Amplitude (mm)
10.2	0.120
12	0.160
14	0.207

Furthermore, an accelerometer with a panel meter was used to measure the vibration parameters. An insulating plate was sandwiched between the table surfaces to protect the vibration table from the head. Figure 1a shows the vibrational moulding set up.

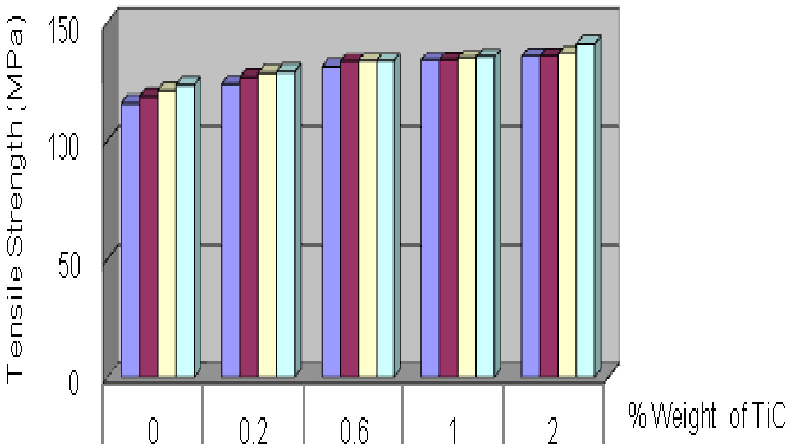
Titanium Carbide particulate reinforced composite casting processing. Only one type of pattern was used in this research work and the procedure for making the pattern involves the preparation of drawing, selection of pattern material. Carbon dioxide moulding process was used to process the cast specimens as per the standard moulding procedure. Four different weight fractions of TiC particle in the range from 0.2%, 0.6%, 1%, 2% were added in the LM6 alloy matrix. An induction furnace was used to melt the aluminium alloy at 750^{o}C and the particulates are preheated to 200 ^{o}C in a heat treatment muffle furnace for 2 hours, which is transferred immediately in the crucible containing liquid LM6 alloy for mixing by an impeller blade of the vortex-stirring machine. The main concern was to maintain the temperature while transferring the molten metal to the mould and to ensure the quality of the cast product. Figure 1b shows the raw specimens before post processing.

Tensile Testing. Tensile test was conducted to determine the mechanical properties of the processed TiC particulate reinforced LM6 alloy composites. The dimensions of the test samples were designed according to B557 M-94 and Figure 1c shows the test specimens. A 100 KN servo hydraulic INSTRON 8500 UTM was used to conduct the tensile tests. The test samples were subjected to a tensile load and the mechanical properties were determined. The tensile strength and Young's modulus values were calculated after the testing.

Figure 1 Vibration table setup (a), Specimens with the uncut gating system (b), Test specimens (c).

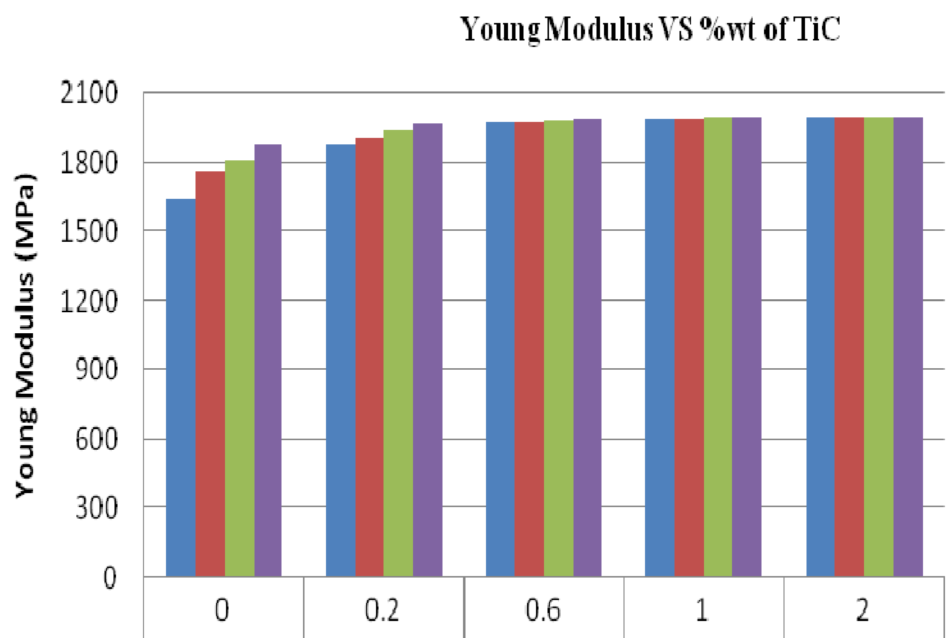
Results and Discussion

Tensile testing was performed on the specimens according to the ASTM standards. The crosshead speed was 2.00 mm/minute and at temperature 24^{o}C. The tensile properties of the LM6/TiC MMC for different weight fractions at ambient temperature reveals an increases in tensile strength and Young's modulus with increase in reinforcement content in the LM6 alloy matrix. Figure 2 shows the tensile strength results while Figure 3 shows the Young's modulus results of 0Hz, 10.2Hz, 12Hz and 15Hz of frequency. From the test results, the mechanical properties of the composites with vibration are better than the cast samples without vibration effect. The increase in tensile strength and Young's modulus results were well supported by the literature citations [9-12]. There are two main causes of strengthening, firstly, due to the direct strengthening and secondly due to the indirect strengthening [13, 14]. The explanations on the direct composite strengthening are based on load transfer from the matrix to the higher stiffness reinforcement particles. The indirect strengthening results from the changes in the matrix microstructure that takes place due to the presence of reinforcement particles. Mechanical vibration makes the solidified microstructure of aluminum matrix finer and homogeneous and decreased the amount of defects such as shrinkage cavity and inclusions. The densities of these thermally induced dislocations were also increased with an increasing weight fraction of TiC [15, 16], so the indirect strengthening contribution increases with increasing TiC content.



	0	0.2	0.6	1	2
0 Hz	116.074	123.902	130.934	133.948	135.832
10.2 Hz	118.68	126.662	133.308	134.029	135.845
12 Hz	121.290	128.450	133.606	134.856	136.893
15 Hz	123.561	128.945	133.609	135.329	141.125

Fig. 4. Average of tensile strength vs wt.% of TiC



	0	0.2	0.6	1	2
0 Hz	1638.3156	1881.24634	1972.14165	1990.31387	1998.423
10.2 Hz	1762.25636	1909.28863	1974.83204	1990.54294	1998.513
12 Hz	1812.01761	1935.58255	1980.79374	1994.221	1998.768
15 Hz	1876.22305	1969.60661	1986.76819	1995.678	1998.771

Fig. 4. Average of Young's modulus vs wt.% of TiC

For a given reinforcement weight percentage, the Young's modulus of the composite can be controlled by regulating the degree of particulate alignment. The contribution of particle alignment has a more significant effect at higher weight fractions. This is due to the contribution of the particle to the overall modulus of the composite increases with the increasing of weight fraction particularly when the particle has higher Young's modulus than the matrix, as in this case are Titanium carbide and aluminum.

Summary

The tensile strength and Young's modulus of elasticity were increased gradually as the TiC content in the composite increased from 0.2, 0.6, 1 and 2% by percentage weight fraction. The tensile behavior of the processed composites had strong dependence on the weight fraction addition of the second phase reinforcement particulate on the alloy matrix and various vibration frequencies during solidification processing.

Acknowledgement

The authors of this research paper express their deep gratitude to the staff and laboratory technicians of the Department of Mechanical and Manufacturing, Universiti Putra Malaysia for their help during the conducting of the experiments.

References

[1] Warren H. Hunt, J : Materials Science Forum, 2000. **331-337**: p. 71-74.

[2] Sulaiman, S., M. Sayuti, and R. Samin : Journal of Materials Processing Technology, 2008. **201**(1-3): p. 731-735.

[3] Tottle, C.R., *An Encyclopaedia of Metallurgy and Materials*. 1985, : The Institute of Metals, Macdonald & Evans Ltd, Plymouth, UK.

[4] A.Taha, M :Journal of Material and Design, 2001. **22**(431-441).

[5] Kocatepe, K. and C.F. Burdett : Journal of Materials Science, 2000. **35**(13): p. 3327-3335.

[6] Abu-Dheir, N., Khraisheh, M., Saito, K., and Male, A. : Materials Science and Engineering A, 2005. **393**(1-2): p. 109-117.

[7] Kocatepe, K : Materials & Design, 2007. **28**(6): p. 1767-1775.

[8] Limmaneevichitr, C., S. Pongananpanya, and J. Kajornchaiyakul : Materials & Design, 2009. **30**(9): p. 3925-3930.

[9] Chirita, G., Stefanescu, I., Soares, D., and Silva, F. S : Materials & Design, 2009. **30**(5): p. 1575-1580.

[10] Gao, D., Li, Z., Han, Q., and Zhai, Q : Materials Science and Engineering: A, 2009. **502**(1-2): p. 2-5.

[11] Karantzalis, A.E., S. Wyatt, and A.R. Kennedy : Materials Science and Engineering A, 1997. **237**(2): p. 200-206.

[12] Selcuk, C. and A.R. Kennedy : Materials Letters, 2006. **60**(28): p. 3364-3366.

[13] Miller, W.S. and F.J. Humphreys : Scripta Metallurgica et Materialia, 1991. **25**(11): p. 2623-2626.

[14] Miller, W.S. and F.J. Humphreys : Scripta Metallurgica et Materialia, 1991. **25**(1): p. 33-38.

[15] Sayuti, M., S. Sulaiman., B.T.H.T. Baharudin., M.K.A. Arifin., Suraya. S., Gholamreza Esmaeilian : Key Engineering Materials, 2011. **471--472**: p. 721-726.

[16] Shyu, R.F. and C.T. Ho : Journal of Materials Processing Technology, 2006. **171**(3): p. 411-416.

Mechanical, Materials and Manufacturing Engineering
10.4028/www.scientific.net/AMM.66-68

Influence of Mechanical Vibration Moulding Process on the Tensile Properties of TiC Reinforced LM6 Alloy Composite Castings
10.4028/www.scientific.net/AMM.66-68.1207