Hardness and impact behaviour of aluminium metal matrix composite

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Abstract - This research paper deals with the fabrication procedure and the testing process of metal matrix composite material comprising of Aluminium and Silicon Carbide in addition with Carbon Nanotubes. Aluminium composites are preferred in manufacturing of various industrial machine components and automobile parts due to their favourable properties like low density which thereby results in their light weight, high strength and superior malleability comparatively to iron carbon alloys like steel and cast iron. When Silicon Carbide is added it helps in furthering the thermal conductivity and melting point properties of Aluminium in addition to improving its hardness. The addition of Carbon Nanotubes potentially helps in further improving the tensile strength of the metal matrix composite. In this study four samples of different compositions of Silicon Carbide are prepared and studied. The fabrication process is done by Stir casting carries out by adding the required additives into the molten mixture of aluminium followed by continuous stirring. After solidification for a period of time the samples are cut according to standard dimensions for carrying out the testing procedures. The various test procedures like hardness and impact tests were conducted to study the mechanical properties of obtained metal matrix composite. The various results inferred from the tests are analysed and subjected to comparison with each other in this study.

1. Introduction

Conventional materials have drawbacks in attaining good combination of strength, stiffness, hardness and density. To come across these disadvantages composites are more promising materials of recent history. Distinct properties like high strength, damping capacity, specific modulus also good wear...
Resistance are present in metal matrix composites when compared to un-reinforced alloys. They were made by addition of reinforced material into metal matrix. The reinforcement layer is coated to prevent any chemical attack on the matrix. For example, carbon fibres are used in aluminium metal matrix to produce composites with low density and high strength.

The strength can be further increased by adding an appropriate material. High homogeneity is required to reach optimum mechanical properties for the composite material [1]. Metal-matrix composites of discrete-SiC-reinforced aluminium alloy is contrived by the method of melt-stirring. The microstructure and mechanical properties were investigated. The rise in regularity of particle scattering is the main cause for improvement in dependability resulting in hot extrusion by awell-shaped die. Young's modulus and 0.2% offset yield strength of the extruded MMCs were compared with theoretical values calculated by the Eshelby method [2]. Mechanical properties of the CNT/Al composite with the increase in Young's modulus clearly the shear lag model seems to be applicable, since the other two models are not associated with Young's modulus, but an increase in yield strength could imply the additional applicability of Orowan looping and thermal mismatch models to the composite system [3]. The tensile behaviour of a 20% SiC particle reinforced Al-Si composite with different degrees of clustering showed that an increase in particle clustering yielded a higher work hardening rate, with reduction in ductility [4]. When the percentage of the reinforcements in MMC increases, the mechanical properties such as tensile strength as well the impact strength increases the reinforcements obstructs the deformation in the composite [5]. The relation between fabrication situations and identical scattering of particles is examined for Al composites with SiCp-reinforced. By evaluating experimental results methodically, connection is among the micro-structure, the particle character, the mechanical properties and process structures for best melt-stirring with the processing of MMCs [6]. Development of carbide on the surface of CNTs and its effects on the mechanical properties of composites needs to be assessed as the load transfer ability and strength of CNTs can be improved. Further studies are required in assessing the various health and environmental hazards imposed by the CNT reinforced composites [7]. The impact behaviour of aluminium was significantly reduced by the presence of SiC particles. On the other hand, the reduction in impact strength due to aging was of no importance [8]. Al MMC has been fabricated by reinforcing with titanium di-boride (TiB2) as reinforcements by stir casting technique and the mechanical properties have been found and have been reported that the properties have been improved on adding the reinforcements [9]. Aluminium with CNT MMC are fabricated and their mechanical behaviour are studied [14,15,16]. Review on AMMC were made and found suitability of MMC for automotive applications [13,17]. Mechanical behaviours of AMMC were identified and it was concluded that reinforcement increases mechanical properties. [10,11,12,18]

2. Experimental Procedure

2.1. Stir casting process

Stir casting is a good economical process for producing composite material and best suited for Aluminium-Silicon carbide combination. The process is simple where molten aluminium is stirred continuously with addition of reinforcements in appropriate proportions. During the process particles tend to form agglomerates that can only dissolved by vigorous stirring at high temperature. This process is chosen mainly due to both flexibility and feasibility that it offers as shown in Figure 1. It is very economical, simple, effective and adaptive. The chance of controlling the matrix structure is easy by using different stirrer blades and cooling times. The whirlpool technique provides high strength and homogenous set of aluminium composites.
2.2 Fabrication process
The foremost part of stir casting is preheating the materials to be casted. In this case the aluminium rod weighing 1.5kg approximately is taken in a graphite crucible and the reinforcements in suitable proportions are mixed in another crucible. Both of them are heated separately for around 3-4hrs at different temperatures ~900°C and ~400°C respectively. After the preheating process both the crucible are taken out and the reinforcement materials are added to the molten aluminium. De-gasser and Dust remover are added to remove any gasses and impurities present in the mixture. This whole mixture in the crucible is again left to the furnace for further heating do that the aluminium alloy completely fuses with the powders of CNT and silicon carbide. The furnace is then taken out after 2hrs of heating is introduced to the stirring machine where vigorous stirring is done by the rotating blades of the motor at 550 rpm. Constant stirring is done for about 6-10 min the matrix structure began to form while stirring and the mixture begins to solidify, ensuring that the mixture is thoroughly mixed it is then poured in preheated die to the temperature of 550°C to take the shape of the die.

3. Results and Discussion
The tested result for compression and hardness tests performed on the metal matrix composites are as follows.

| Samples | Composition        | Impact load (Joules) | Hardness in HBW |
|---------|--------------------|----------------------|-----------------|
| 1       | Sample 1 Al+2%SiC  | 8                    | 55.4            |
| 2       | Sample 2 Al+2%SiC+0.2%CNT | 6         | 55.2            |
| 3       | Sample 3 Al+3%SiC+0.2%CNT | 10        | 47.5            |
| 4       | Sample 4 Al+4%SiC+0.2%CNT | 8         | 54.9            |
4. Conclusion

It is found that the composition Al+3%SiC+0.2%CNT withstands more impact load compared to other compositions but at the same time there's a huge drop in the hardness of that material which may be due to its plasticity. There's a stable increase in hardness upon the addition of silicon carbide but if the same is added more, hardness decreases gradually after attaining a peak value. Discussing the load withstanding capability, it's also starts to decrease after attaining a limiting value. Thus we infer with optimum addition of silicon carbide and carbon nanotubes in their corresponding ratios to the base metal aluminium yields a metal matrix composite that have a superior balance between high hardness and prevail against exceptional impact load.
References

[1] Brian Ralph, H.C. Yuen, W.B. Lee, The processing of metal matrix composites — an overview, Journal of Materials Processing Technology, Volume 63, Issues 1–3, January 1997, Pages 339-353, ISSN 0924-0136.

[2] Y.H. Seo, C.G. Kang, Effects of hot extrusion through a curved die on the mechanical properties of SiCp/Al composites fabricated by melt-stirring, Composites Science and Technology, Volume 59, Issue 5, April 1999, Pages 643-654, ISSN 0266-3538.

[3] George, R., et al. "Strengthening in carbon nanotube/aluminium (CNT/Al) composites." Scripta Materialia 53.10 (2005): 1159-1163.

[4] Deng X, Chawla N. Modelling the effect of particle clustering on the mechanical behaviour of SiC particle reinforced Al matrix composites. J Mater Sci 2006; 41:5731–4.

[5] J. Jeykrishnan, B. VijayaRammath, X. Hervin Savariraj, R. David Prakash, V. R. Dhinesh Rajan and D. Dinesh Kumar. Investigation on Tensile and Impact Behaviour of Aluminium Base Silicon Carbide Metal Matrix Composites. Indian Journal of Science and Technology, Vol 9(37), DOI: 10.17485/ijst/2016/v9i37/101979, October 2016

[6] Young HS, Chung GK. The effect of applied pressure on particle-dispersion characteristics and mechanical properties in melt-stirring squeeze-cast SiC/Al composites. J Mater Process Technol 1995;55:370–9.

[7] Ramnath, B. V., Parswajinan, C., Elanchezhian, C., Pragadeesh, S. V., Ramkishore, P. R., Sabarish, V. (2014). A Review on CNT Reinforced Aluminium and Magnesium Matrix Composites. In Applied Mechanics and Materials (Vol. 591, pp. 120-123). Trans Tech Publications.

[8] Ozden S, Ekici R, Nair F. Investigation of impact behaviour of aluminium based SiC particle reinforced metal–matrix composites. Composites: Part A, Applied Science and Manufacturing. 2007 Feb; 38(2):484-94.

[9] J.Jeykrishnan, S.Jayanthi Nathan, M.R.Karthik. Fabrication and characterization of aluminium titanium di-boride metal matrix composites using stir casting technique. International journal of mechanical engineering and technology. Vol. 8(4). 2017.

[10] B.Vijaya Rammath, C. Elanchezhian, M.Jaivignesh, S. Rajesh, C. Parswajinan, A. Siddique Ahmed Ghias, “Evaluation of Mechanical Properties of Aluminium Alloy-Alumina-Boron Carbide Metal Matrix Composites”, Materials and design, Volume 58, June 2014, Pages 332-338.

[11] Siddique Ahmed Ghias B.Vijaya Rammath, ‘Investigation of Tensile Property of Aluminium SiC Metal Matrix’, International Journal Applied Mechanics and Materials, Volume 766-767, 2015, Pages 252-256.

[12] P.Subramaniya Reddy, R.Kesavan, and B.Vijaya Rammath, “Investigation of Mechanical Properties of Aluminium6061-Silicon Carbide, Boron Carbide Metal Matrix Composite, DOI: 10.1007/s12633-016-9479-8 2016, Silicon

[13] C.Elanchezhian, B.VijayaRammath, G.Ramakrishnan, K.N.SripadaRaghavendra, MithunMuralidharan, V.Kishore, “Review on metal matrix composites for marine
applications”. Accepted for publication in Elsevier – Materials Today Proceedings, 5(1), PP.1211-1218

[14] Parswajinan C, Vijaya Ramnath B, Syed Mohammed Buhari A. S. A., Muthukumaaran C and Riyaz Ahmed A, “Investigations of mechanical properties of Aluminium Matrix Composite reinforced with B4C and MWCNT”, Advanced Science, Engineering and Medicine, Vol. 10, 2018, 1–3

[15] C. Parswajinan, B.Vijaya Ramnath, N. Sai Prasath, S. Kuralamudhan and S. Balaji, “Mechanical investigation of Aluminum hybrid Composite Reinforced with CNT and Aluminum oxide (Al2O3)”, Advanced Science, Engineering and Medicine, Vol. 10, 2018, 1–3

[16] C. Parswajinan, B. Vijaya Ramnath, M. Vetrivel, M. Aswin, and B. Mohana Vignesh, “Mechanical Behavior of Aluminium Metal Matrix Composite”, Advanced Science, Engineering and Medicine, Vol. 10, 2018, 1–3

[17] G. Ramakrishnan , Vijaya Ramnath B, Naveen E, Gowtham S, Arun Kumar A, Muthuvel M.S and Akil R,” A review on aluminium metal matrix composites”, Advanced Science, Engineering and Medicine Volume 10, 2018, Pages 1-4

[18] Shreyas P, Shriramkumar, Sruthisagar R, Vijaya Ramanath B and Elanchezhian C,”Studies on Mechanical Behaviour of Aluminium-Silicon Carbide-Copper Metal Matrix Composite”, MATEC Web of Conferences 166, 01001 (2018).