

A Review on Fabrication & Characterization of Hybrid Aluminium Metal Matrix Composite

Ashish Srivastava, Prayag Garg, Avdhesh Kumar, Yamini Krishna,
Kanu Kumar Varshney

Department of Mechanical Engineering, Noida Institute of Engineering and Technology, Gr. Noida, India

Article Info

Article history:

Received 1 January 2014

Received in revised form

20 February 2014

Accepted 28 February 2014

Available online 15 March 2014

Keywords

Abstract

Necessity is the mother of research (Invention), and today's most important demand of an automobile industry is to reduce energy consumption and pollution in an automobile. This could be done in one way by increasing the efficiency. For the properties like strength, toughness, stiffness to weight ratio, good formability, good corrosion resistance and high machinability must be improved. This challenge could be accomplished by Hybrid Metal Matrix Composites. Hybrid Metal Matrix Composites (HMMCs) are one of the recent advanced materials having the properties of light weight, high specific strength, good wear resistance and low thermal expansion coefficient. These composites materials are extensively used in structural, aerospace and automotive industries. MMCs are composed of metallic base material called matrix, which is reinforced with a hard ceramic or soft reinforcement. Hybrid MMCs are obtained by reinforcing the matrix alloy with more than one type of reinforcements having different properties. For example SiC could be used as hard ceramic reinforcement and Graphite as soft reinforcement. Thus this research paper is focused on the review of the fabrication and characterization of hybrid metal matrix with summarizing the recent developments covering Aluminium used in manufacturing process.

1. Introduction

In today's world there are many challenges recognized in automotive industries such as improving fuel economy, enhancing performance, reducing vehicle emissions, maintaining safety, quality & profitability, increasing styling options, etc. Now to meet these challenges there is the need of developing new materials and new manufacturing processes. And thus MMCs are of those developed materials which give result as per the needs [1].

Metal Matrix Composites are fabricated with help of introducing ceramic/ reinforcement particles in the matrix of any metal. In common words these particles increases the properties like abrasive, hardness, wear resistance, stiffness, strength to weight ratio and many thermal properties.[2] Metal matrix composites can be designed to possess qualities such

as low coefficient of thermal expansion and high thermal conductivity which make them suitable for use in electronic packaging applications. Metal matrix composites today are extensively used in automobile and aerospace applications [3].

Hybrid metal matrix composites are unique material fabricated by reinforcements of at least two types of ceramic particles into a tough metal matrix [2]. Hybrid MMCs are one of the recent advanced materials having the properties of light weight, good wear resistance, high specific strength and low thermal expansion. Hybrid composites have great importance in automotive engineering in piston rods, piston pins, braking systems, pistons, frames, valve spring caps, disk brake caliper, brake disks, brake pads, shaft, etc [4].

2. Literature Review

A. M. S. Hamouda et.al. Presented a paper on "Processing and characterization of particulate

Corresponding Author,

E-mail address: ashish7185@gmail.com

All rights reserved: <http://www.ijari.org>

reinforced aluminium silicon matrix composite”[5] and measured the value for the quartz particulate reinforced LM6 alloy composites and it has been found that it gradually increases with increased addition of the reinforcement phase. They also found that the tensile strength of the composites decreases with the increase in addition of quartz particulate. In addition, their research article is well featured by the particulate-matrix bonding and interface studies which have been conducted to understand the processed composite materials mechanical behavior and it was well supported by the fractographs taken using the scanning electron microscope (SEM).

H. S. Arora, H. Singh & B. K. Dhindaw presented a review paper on “Composite fabrication using friction stir processing”[6] and describes the current status of the FSP technology in the field of composite fabrication with the main impetus on aluminum and magnesium alloys. He told the successful application of the FSP technique in generating surface and bulk composites firmly establishes it in the field of composite manufacturing. He also acknowledges that further efforts in this field and better understanding of the process characteristics can pave the way for the commercial success of this technology as well.

R. Ramesh, N. Murugan presented a paper on “Microstructure and Metallurgical Properties of Aluminium 7075 – T651 Alloy / B4c 4 % Vol. Surface Composite by Friction Stir Processing”[7] and finds that the surface composite fabricated with the rotational speed of 500 rpm, traverse speed of 60 mm/min using three passes produced a good processed surface composite. In addition, for a given traverse speed, the grain size in the nugget zone is reduced with increasing the rotational speed. He also found that the average hardness of friction stir processed surface composite was 1.5 times higher than that of the base metal aluminum 7075 – T651.

K.L. Meena et al. presented a paper on “An Analysis of Mechanical Properties of the Developed Al/SiC-MMCs”[8] and finds that Optical micrographs shows reasonably uniform distribution of SiC particles. Tensile strength increases with the increase in reinforced particulate size and weight fraction of SiC particles. Also % Elongation and % Reduction in area decreases with the increase in reinforced particulate size and weight fraction of SiC particles. Hardness (HRB) and Density increases with the increase in reinforced particulate size and weight fraction of SiC particles. Impact Strength decreases with the increase in reinforced particulate size and increases with the increase in weight fraction of SiC particles.

N. Altinkok, Ozsert & F. Findik presented a paper on “Dry sliding wear behavior of Al_2O_3 /sic particle reinforced aluminium based MMCs fabricated by stir casting method”[9] and found that hybrid and bimodal particle reinforcement decreased weight loss especially when SiC powder with larger grain size was used. His, microstructural examination showed that besides occurring coarse SiC particle reinforcement, a fine alumina particle reinforcement phase was observed within the aluminium matrix (A332). Furthermore he also told that the incorporation of hybrid and bimodal particles increased hardness of the composites with respect to the composite with fully small sized particles.

Dharmal Deepak, Ripandeep Singh Sidhu, V.K Gupta presented a paper on “Preparation of 5083 Al-SiC surface composite by friction stir processing and its mechanical characterization”[10] in which they reveals that the doping of 5083Al with hard SiC particles through FSP leads to significant increase in hardness of the surface composite produced on FSPed sample layer. The wear resistance of FSPed sample is inferior to that observed for 5083Al in spite of its higher hardness. It may be attributed to high coefficient of friction and higher friction force observed during the wear testing of FSPed sample.

M. L. Ted Guo & C.Y.A.Tsao presented a paper on “Tribological behavior of self-lubricating aluminium/SiC/graphite hybrid composites synthesized by the semi-solid powder-densification method” [11] reveals that hardness decreases with the amount of the graphite addition fracture energy decreases monotonously as the amount of graphite addition increases. Friction co-eff. decreases as the % of graphite addition increases. Amount of graphite released on the wear surface increases as the % of graphite addition increases. Graphite released from the composites did bond on the wear surfaces on the counter parts however the amount bonded is small, and there is no significant difference in the amount bonded for different Graphite additions.

M. Asif, K. Chandra & P.S. Misra presented a paper on “Development of Aluminium Based Hybrid Metal Matrix Composites for Heavy Duty Applications”[12] and investigates the dry sliding wear behavior of aluminium alloy based composites, reinforced with silicon carbide particles and graphite. The results reveal that wear rate of hybrid composite is lower than that of binary composite. The wear rate decreased with the increasing load and increasing speed. He also compares the results of the proposed composites with iron based metal matrix composites at corresponding values of test parameters. The comparative study reveals that the proposed composites have lower friction coefficient, less

temperature rise and low noise level; however they have little higher wear rate.

Farshad Akhlaghi, S.Mahdavi presented a paper on "Effect of the SiC Content on the Tribological Properties of Hybrid Al/Gr./SiC Composites Processed by In Situ Powder Metallurgy (IPM) Method"[13] in which graphite acts as a solid lubricating agent and lowers the friction coefficient. However, it reduces the mechanical properties of the composite. The presence of hard SiC particles in these hybrid composites increases the hardness and strength and compensates for the weakening effects of graphite. Powder metallurgy (P/M) is an important processing technique for processing of these MMCs but requires a relatively long mixing time for obtaining a uniform distribution of graphite and SiC particles in the matrix alloy. The Al/Gr/SiC compacts were prepared by cold pressing of different powder mixtures and after sintering, the effects of SiC content on the density, microstructure, hardness and wear properties of the resultant hybrid composites was investigated.

J.Jenix Rino, D.Chandramohan, K.S.Sucitharan presented a paper on "An Overview on Development of Aluminium Metal Matrix Composites with Hybrid Reinforcement"[14] in which they reveals that aluminium alloy matrix composites reinforced with Hybrid can be successfully synthesized by the stir casting method. For synthesizing & Characterizing of hybrid composite by stir casting process, stirrer design and position, stirring speed and time, melting and pouring temperature, particle-preheating temperature, particle incorporation rate, mould type and size, and reinforcement particle size and amount are the important process parameters. With the addition of hybrid reinforcement instead of single reinforcement the hardness, toughness, strength, corrosive and wear resistance of the composite will be further increased.

Gopi K. R, Mohandas K. N, Reddappa H. N & M. R. Ramesh presented a paper on "Characterization of As Cast and Heat Treated Aluminium 6061/Zircon sand/Graphite Particulate Hybrid Composites" [15] which indicates that there is a considerable improvement in the hardness values, microstructure and resistance for wear. Hardness gets improved with addition of zircon and graphite and along with heat treatment. There was a considerable improvement in the resistance for wear with addition of zircon and graphite and along with and T6 heat treatment. In the as-cast specimen coarse acicular intermetallic particles is seen and it is distributed along primary aluminum dendrite boundaries.

Arun. L. R, Saddam Hussain B., Suneel Kumar, N. Kulkarni presented a paper on "Dynamic

behaviour of hybrid aluminium6061 metal matrix reinforced with sic and fly ash particulates"[16] and concluded that the ultimate tensile strength has enhanced with increase in Fly Ash weight percentage and compared to base metal it has increased by 23.26%. The fatigue life has also been increased with the increase in weight percentage of fly ash and it can be seen from S- N curve that SiC 6% give better results when compared to monolithic alloy.

Gheorghe Iacob, Gabriela, Mihai. Presented a paper on "Studies Regarding Technological Properties Of Al/Al₂O₃/Gr. Hybrid Composites"[17] in which two different Al/Al₂O₃/Gr composites were obtained. Al/15%Al₂O₃/1%Gr & Al/15%Al₂O₃/3%Gr on different milling time (2 and 4 hours) Apparent and tap densities of composite powders increase with increasing Gr content in the mixture, and with increasing the milling time. Using zinc stearate as PCA we prevent the excessive cold welding of powder particles amongst themselves, onto the walls of the vial, and to the surface of the grinding balls during milling. Density of green compacts and sintered billet is lower for small amount of graphite after 2 and 4 hour of milling. Introducing graphite in the powder mixture has led to the reduced density of composite material. Sintered density is lower than green density and increase with graphite content and milling time. Al/15wt.%Al₂O₃/3wt%Gr milled 4 h has the highest green density. There was no contamination of milled powders that was confirmed by EDS analysis. Aluminum matrix composites reinforced with ceramic particles have a weak relation between weight and volume, but high wear resistance, thermal conductivity and diffusivity, properties that are used in automotive and aerospace industry.

Satyappa Basavarajappa & Govindarajulu Chandramohan presented a paper on "Dry Sliding Wear Behavior of Hybrid Metal Matrix Composites"[18] and concluded that SiC particles can be used as both reinforcement material to improve the properties and as a carrier for introducing the Graphite particles in Al2219 alloy. He also told that wear rates of the Graphitic composite is lower than that of the matrix alloy and SiCp reinforced composite. The wear rate has been increased with the increasing load and decreased with increasing speed up to 4.6 m/s and then increased.

M.V. Achutha, B.K. Sridhara, Abdul Budan did an investigation "Fatigue Life Estimation Of Hybrid Aluminium Matrix Composites" [19] and finds that hybrid materials show improvement in fatigue life. He fabricates Aluminum (LM 25)-SiC-Gr composite with help of gravity die casting technique. And as they show scatter behavior therefore large no. of experiments have to be performed.

Mahendra Boopathi, et al. focuses on fabricating a material of better strength and toughness in his research paper "Evaluation of Mechanical Properties of Aluminium Alloy 2024 Reinforced With Silicon Carbide and Fly Ash Hybrid Metal Matrix Composites"[20] In his research paper he also analyzed various mechanical properties like density, tensile strength, yield strength and elongation.

J. Grassi, et al. Submitted their research paper "Ablation of Hybrid metal Matrix Composites" [21] in which they did an successful research on Ablation process to get better solidification rates and mechanical properties. They find that there is an increase in yield strength and better solidification rates.

Babic Miroslav, Stojanovic Blaza, Mitrovic Slobodan, Bobic Ilija, Miloradovic Nenad, Pantic Marko, Dzunic Dragan did an research "Wear Properties Of A356/10SiC/1Gr Hybrid Composites In Lubricated Sliding Conditions"[22] to check the tribological properties in conditions with lubrication. The tests were done on an advance & computer supported Tribometer with block on disc contact pair. It was observed that wear rate was lesser than 3/9 times than base metal.

Edson Cocchieri Botelho, Rogerio Almeida Silva, Luiz Claudio Pardini, Mirabel Cerqueira Rezende did a research "A Review on the Development and Properties of Continuous Fiber/epoxy/aluminum Hybrid Composites for Aircraft Structures"[23] to improve damage tolerance characteristics & Weight reduction. Many companies such as Embraer, Aerospacia, Boeing, Airbus, and so one, starting to work with this kind of materials

3. Methodology

Various researchers have used different methods for fabrication of hybrid composites, each having its own advantages and disadvantages. Like H. S. Arora, H. Singh, B. K. Dhindaw R. Ramesh, N. Murugan etc uses the friction stir casting (FSP) method and finds that due to better homogeneity this process produces good processed surface with better hardness at

Reference

- [1] John E. Allison, S. Gerald Cole: metal- matrix composites in the automotive industry
- [2] S. Vignesh., C. Sanjeev, Investigation on Surface Quality in Machining of Hybrid Metal Matrix Composite (Al-SiC B4C)
- [3] S. R. Bakshi, D. Lahiri, A. Agarwal, Carbon nanotube reinforced metal matrix composites
- [4] S. Gopalakannan, T. Senthivelan, S. Ranganathan, Stastical optimization of EDM parameters on

surface. This method is of mainly two types on the basis of power input that is Mechanical FSP and Electrical FSP. [6, 7]

M. V. Achutha, B. K. Sridhara etc used Gravity die casting technique to improve fatigue life, surface texture etc. It is a simple method which utilizes metallic moulds for simple shapes and is best for light alloys like aluminium. [19]

Farshad Akhlaghi, S.Mahdavi etc. used the in-situ powder metallurgy method for the fabrication of HMMC. This process is the combination of stir casting and powder metallurgy. First molten metal are mixed and cooled in form of powder then cold pressing of those powder followed by sintering. Consolidated composites with high contents of well-distributed reinforcing particles could be fabricated by this method [13].

M. L. Ted Guo, C. Y. A. Tsao, M. Ravichandran etc uses the Powder metallurgy method (powder densification). In this process first the powder is pressed in the die of desired shape followed by sintering. This method could be used for much wider range of product. Main advantage is materials with large variety of composition and high melting point could be easily fabricated [11].

4. Conclusion

1. It could be seen that HMMCs fabricated by FSP is simple and shows high surface hardness and homogeneity. Thus most of the researchers have used this method. But leads to inferior wear resistance.
2. It is also observed that SiC & Graphite are the most used refractory materials. Where SiC is used as hardening material and to improve mechanical properties also increasing the wear rate while Graphite is used as for softening and even wear rate is reduced.
3. Powder metallurgy (P/M) is an important processing technique for processing of these MMCs but requires a relatively long mixing time for obtaining a uniform distribution of graphite and SiC particles

machining of aluminium hybrid metal matrix composite by applying Taguchi based Grey analysis

- [5] A. M. S. Hamouda, S. Sulaiman, T. R Vijayaram, M. Sayuti, M. H. M. Ahmad, "Processing and characterisation of particulate reinforced aluminium silicon matrix composite" journal of Achievements in Materials and Manufacturing Engineering, 25(2), 2007

- [6] H. S. Arora, H. Singh, B. K. Dhindaw, Composite fabrication using friction stir processing - a review, *International Journal of Advance Manufacturing Technology*
- [7] R. Ramesh, N. Murugan, "Microstructure and Metallurgical Properties of Aluminium 7075 – T651 Alloy / B4c 4 % Vol. Surface Composite by Friction Stir Processing" *International Journal of Advanced materials manufacturing and characterization*, 2012
- [8] K. L. Meena, A. Manna, S. S. Banwait, Jaswanti, "An Analysis of Mechanical Properties of the Developed Al/SiC-MMC's" *Science and education publishing*, 2013
- [9] N. Altinkok, I. Ozsert, F. Findik, Dry sliding wear behavior of al₂o₃/sic particle reinforced aluminium based MMCs fabricated by stir casting method" *International Journal of Science and Advanced Technology*, 2012
- [10] Ripandeep Singh Sidhu, Dharpal Deepak, V. K Gupta, Preparation of 5083 Al-SiC surface composite by friction stir processing and its mechanical characterization" in *International Journal of Mechanical Engineering*, 3(1), 2013
- [11] M. L. Ted Guo, C. Y. A. Tsao, Tribological behavior of self-lubricating aluminium/SiC/graphite hybrid composites synthesized by the semi-solid powder-densification method." *Research gate*, 2000
- [12] M. Asif, K. Chandra, P. S. Misra, Development of Aluminium Based Hybrid Metal Matrix Composites for Heavy Duty Applications " *Journal of Minerals & Materials Characterization & Engineering*, 10(14), 2011
- [13] Farshad Akhlaghi, S. Mahdavi, Effect of the SiC Content on the Tribological Properties of Hybrid Al/Gr./SiC Composites Processed by In Situ Powder Metallurgy (IPM) Method, *Advanced Materials Research*, 2011
- [14] J. Jenix Rino, D. Chandramohan, K. S. Sucitharan, An Overview on Development of Aluminium Metal Matrix Composites with Hybrid Reinforcement" *International Journal of Science and Research (IJSR)*, 2012
- [15] K. R Gopi, K. N. Mohandas, H. N Reddappa, M. R. Ramesh, Characterization of As Cast and Heat Treated Aluminium Technology (*IJEAT*), 2(5), 2013
- [16] L. R Arun, Saddam Hussain. B, Suneel Kumar, N. Kulkarni, Dynamic behaviour of hybrid aluminium6061 metal matrix reinforced with sic and fly ash particulates". *International Journal of Innovative Research in Science, Engineering and Technology*, 2013
- [17] Gheorghe, Gabriela, Mihai, Studies Regarding Technological Properties of Al/Al₂o₃/Gr. Hybrid Composites" *U. P. B. Sci. Bull., Series B*, 75(2), 2013
- [18] Satyappa Basavarajappa, Govindarajulu Chandramohan, Dry Sliding Wear Behaviour of Hybrid Metal Matrix Composites, *Materials science (Medziagotyra)*, 11, 2005
- [19] M. V. Achutha, B. K. Sridhara, Abdul Budan, Fatigue life Estimation of Hybrid aluminium matrix composites" *International Journal on Design and Manufacturing Technologies*, 2, 2008
- [20] Mahendra Boopathi, M. K. P. Arulshri, N. Iyandurai, Evaluation of Mechanical Properties of Aluminium Alloy 2024 Reinforced With Silicon Carbide and Fly Ash Hybrid Metal Matrix Composites" *American Journal of Applied Sciences*, 2013
- [21] J. Grassi, D. Weiss, B. Schultz, P. Rohatgi, Ablation of Hybrid metal Matrix Composites *American Foundry Society*, 2011
- [22] Babic Miroslav, Stojanovic Blaza, Mitrovic Slobodan, Bobic Ilija, Miloradovic Nenad, Pantic Marko, Dzunic Dragan, Wear Properties of A356/10SiC/1Gr Hybrid Composites In Lubricated Sliding Conditions" *Serbian Tribology Society*, 2013
- [23] Edson Cocchieri Botelho, Rogerio Almeida Silva, Luiz Claudio Pardini, Mirabel Cerqueira Rezende, A Review on the Development and Properties of Continuous Fiber/epoxy/aluminum Hybrid Compositesfor Aircraft Structures" *Materials Research*, 9, 3, 2006
- [24] 6061/Zircon sand/Graphite Particulate Hybrid Composites, *International Journal of Engineering and Advanced*