International Journal of Psychosocial Rehabilitation, Vol. 24, Issue 03, 2020
ISSN: 1475-7192

EVALUATION OF MECHANICAL PROPERTIES OF Al-SiC METAL MATRIX COMPOSITES SYNTHESIZED BY STIR CASTING METHOD

[1]A. S. HARI VIJAY , [2]K. SHANMUGANANTHAM , [3]S. SURESH KUMAR

ABSTRACT--*On account of the excellent physical and mechanical properties of composite materials, they are widely used in many engineering applications such as in tank armors and automotive disc brakes. Metal- matrix composites are a relatively new range of materials possessing several characteristics that make them useful in situations where low weight, high strength, high stiffness, and an ability to operate at elevated temperatures are required. Despite the superior mechanical and thermal properties of metal-matrix composites, their poor machinability has been the main cause to their substitution for metal parts. The hard abrasive reinforcement causes rapid tool wear during machining and, consequently, high machining costs. In this work an attempt is made to fabricate Al/SiC Metal Matrix Composite with 6.6% weight fraction constituted by SiC particles and the machinability of the fabricated specimen is evaluated by micro-drilling process on a CNC Vertical Machining Centre using 800μm diameter Tungsten Carbide tool. Design and optimization of the experiment is implemented with the help of Full factorial method. The holes are then analyzed to evaluate their surface integrity including taper and, burr formations.*

Keywords-- *Aluminum matrix composite; Microstructure; Mechanical properties; Stir casting*

I. INTRODUCTION

The objective involved in fabricating metal matrix composite materials is to combine the desirable properties of metals and ceramics. The addition of high strength, high modulus refractory particles to a ductile metal matrix produces a material whose mechanical properties are intermediate between the matrix alloy and the ceramic reinforcement. The high yield strength, high modulus of refractory and high stiffness ceramic particles, when added to a high ductility, high temperature resistance and low stiffness metals, the composite formed from mixing of them have the moderate properties that lies in between the two parent materials [1-3]. Aluminum and silicon carbide are the well-known composite as Al/SiC metal matrix composite. The mechanical properties obtained with the metal matrix composites(MMCs) along with their relatively low cost of production have made them most considerable for several applications in various fields including automotive, sports industries and aerospace

[1] *Department of Mechanical Engineering, Saveetha School of Engineering,Saveetha Institute of Medical and Techanical Sciences, Thandalam, Chennai,Tamil nadu, India 602 105, harivijayravenn@gmail.com*

[2] *Department of Mechanical Engineering, Saveetha School of Engineering,Saveetha Institute of Medical and Techanical Sciences, Thandalam, Chennai, Tamil nadu, India 602 105.*

[3] *ssureshrec@gmail.com*

Received: 03 Dec 2019 | Revised: 21 Jan 2020 | Accepted: 18 Feb 2020

[4,5,6].There are many methods available for production of MMCs like powder metallurgy, by stir casting, in situ development of reinforcements, and foil-and-fiber pressing techniques. But stir casting is best suited and economical method of production of MMCs. [7, 8]. The major challenge incorporates with the stir casting is to get homogeneous mixing of solid reinforcement particles (like SiC) into the molten phase of metal (Al) as it has a strong impact on the properties and the quality of the material [1-8]. The non-homogeneous mixing of reinforcement results into the more density distribution, directional properties, and more variations in surface hardness. The Stir casting technique is currently the most common practiced commercial method for producing MMCs. This methodology

involves mechanical mixing of the reinforcement particles into a molten metal solute bath. A basic apparatus is shown in Fig. 1, and typically is comprised of an electric furnace with heated crucible containing molten aluminum metal, with an electric motor that drives a mixing impeller or, paddle, that is submerged into the melt. To ensure a smooth and continuous feed, the reinforcement is poured into the crucible above the melt surface and at a very controlled rate.

II. PROCESS PARAMETER

For manufacturing of composite material by stir casting knowledge of its operating parameter are very essential. As there is various process parameters if they properly controlled can lead to the improved characteristic in composite material.

- Stirring speed:-

Stirring speed is the important process parameter as stirring is necessary to help in promoting weldability i.e. bonding between matrix & reinforcement. Stirring speed will directly control the flow pattern of the molten metal. Parallel flow will not promote good reinforcement mixing with the matrix. Hence flow pattern should be controlled turbulence flow. Pattern of flow from inward to outward direction is best. In our project we kept speed from 300-600 rpm. As solidifying rate is faster it will increase the percentage of weldability [8].

- Stirring temperature:-

It is an important process parameter. It is related to the melting temperature of matrix i.e. aluminum. Aluminum generally melts at 650

- The processing temperature

It mainly influences the viscosity of Al matrix. The change of viscosity influences the particle distribution in the matrix. The viscosity of liquid decreased when increasing processing temperature with increasing holding time stirring time [8]. It also accelerates the chemical reaction b/w matrix and reinforcement. In our project in order to promote good weldability we had kept operating temperature at 630°C which keeps Al (6061) in semisolid state.

- Reinforcement preheat temperature:-

Reinforcement was preheated at a specified 500◦C temperature 30 min in order to remove moisture or any other gases present within reinforcement. The preheating of also promotes the weldability of reinforcement with matrix [7].

- Addition of Mg:-

Addition of Magnesium enhances the weldability. However increase the content above 1wt. % increases viscosity of slurry and hence uniform particle distribution will be difficult [6].

- Stirring time:-

Stirring promotes uniform distribution of the particles in the liquid and to create perfect interface bond b/w reinforcement and matrix. The stirring time b/w matrix and reinforcement is considered as important factor in the processing of composite. For uniform distribution of reinforcement in matrix in metal flow pattern should from outward to inward.

- Blade Angle:-

The blade angle and number of blades are prominent factor which decides the flow pattern of the liquid metal at the time of stirring. The blade with angle 45° & 60° will give the uniform distribution. The number of blade should be 4. Blade should be 20mm above the bottom of the crucible [8]. Blade pattern drastically affect the flow pattern

- Inert Gas:-

As aluminum melt it start reacting with environment oxygen and will produce an oxide layer at the top. This oxide layer will avoid further oxidation but along that it will difficult to brake. So such layer will be big trouble for reinforcement mixture with metal. So in order to avoid this we had used inert gas like nitrogen.

- Preheated Temperature of Mold:-

In casting porosity is the prime defect. In order to avoid these preheating the permanent mold is good solution. It will help in removing the entrapped gases from the slurry in mold It will also enhance the mechanical properties of the cast AMC. While pouring molten metal keep the pouring rate constant to avoid bubble formation.

- Powder Feed Rate:-

To have a good quality of casting the feed rate of powder particles must be uniform. If it is non-uniform it promotes clustering of particles at some places which in turn enhances the porosity defect and inclusion defect, so the feed rate of particles must be uniform.

III. METHODOLOGY

First of all stirring system has been developed by coupling motor with gearbox and a mild steel stirrer. All the melting was carried out in a graphite crucible in an oil-fired furnace. Scraps of aluminum were preheated at 4500 C for 3 to 4 hours before melting and mixing the SiC particles were preheated at 11000C for 1 to 3 hours to make their surfaces oxidized. The furnace temperature was first raised above the liquidus to melt the alloy scraps completely and was then cooled down just below the liquidus to keep the slurry in a semi-solid state. At this stage the preheated SiC particles were added and mixed manually. Manual mixing was used because it was very difficult to mix using automatic device when the alloy was in a semi-solid state. After sufficient manual mixing was done, the composite slurry was reheated to a fully liquid state and then automatic mechanical mixing was carried out for about 10 minutes at a normal stirring rate of 600 rpm [6]. In the final mixing process, the furnace temperature was controlled within 760 ± 100C. Pouring of the composite slurry has been carried out in the sand mold prepared according to the specifications for hardness, impact and normalized displacement test specimens.

Received: 03 Dec 2019 | Revised: 21 Jan 2020 | Accepted: 18 Feb 2020

3.1 Normalized Displacement Test

Indentation was made on hardness testing machine using a 1.587 mm ball indenter and a varying load was applied for 30 seconds. Five different loads of 60, 100, 150, 187.5 and 250N have been used. The penetration depth and height of model specimen has been measured by height gauge coupled with dial indicator. The normalized displacement was calculated from following formula. The average of four readings has been reported for the results.

IV. RESULTS AND DISCUSSION

Hardness Test.

The central part of each samples was separated by tungsten carbide cutting machine. Then the surface was polished to remove course surface to prepare for hardness testing. The hardness was done by Rockwell Hardness tester. The device, which was used, for this experiment is MITITOYO, ATK-600. The ball indenter 1/16 inch in diameter and total load was selected 15 kgf .The tests carry out on different surface randomly in five different areas in each sample then by calculating the average amount for each sample .The Rockwell hardness number is gained by calculating the average amount of obtained data. The maximum hardness is achieved by adding 10 % SiC and 0.5 % Sr to aluminum.

Microstructure Analysis.

Samples of metal matrix composites and aluminum LM6 were prepared for metallographic examination. A sample size of 10*10 mm was cut from each section. Different abrasive papers were used for sample preparation 320, 400, 600, 800,1200 grit by using machine. Then they polished with same machine. For grinding, coarse polishing and lastly fine polishing suspension Buehler to the fineness of 0.05 micron was used. The available machine was Hitachi S-3400. The microstructure of casted LM6 are tested at different location on the surface of the samples. The eutectic phase of unmodified Al-Si alloy contains of silicon phase with rod-angular and flake-like morphology, which causes poor ductility and brittleness. As mentioned before modification is used to change the form of the silicon phase from flake to fibrous. Generally, modification can be attained by quick solidification (quench solidification) or chemical modification.

Tensile properties

In this study, the experimental results show that in general, the tensile strength of the MMC's produced are somewhat higher than that obtained for the non-reinforced A359 alloy It can be noted that the addition o f silicon carbide particles improved the tensile strength of the composites It is apparent that an increase in the volume fraction of SiC results in an increase in the tensile strength Figure 4 23 shows the effect of volume fraction on the tensile strength The tensile strength o f the A359 alloy in non-reinforced condition is 103.75 N/mm2, and this value increases to a maximum of 150 N/mm2, for A359/SiC/5p, which is about 65% improvement on that of the non-reinforced matrix material.

Impact Test

Charpy impact testing machine of Shimadzu Corporation, load used was 50kgf-m, Product No. is 27090247-1994-11-15 was used to check the impact strength of the composites. Standard ASTM specimens were used having notch of particular dimensions as indicated below; cross section dimensions ±1% or ±0.075mm (0.003 inches), radius of notch : ±0.025 mm (0.001 inches), depth of notch : ±0.025 mm (0.001 inches), finish requirements : 2µ, width : 10mm, depth : 10mm. Scanning electron microscopy was used for micro structural study of the

MMC.

The experimental results showed that the composition of the composite for the optimized properties ranges between 70 to 80 percent aluminum and 20 to 30 percent silicon carbide. It is quite evident that deformation in metals is because of the movement of dislocations and if we block these dislocations by some means the strength which is resistance against the applied force of the material, sufficiently increases. There are numerous ways to block these dislocations like increasing the dislocation density, alloying and making composite in such a way that the newly reinforcing phase acts like a barrier against movement of these dislocations.

For the samples, made by manual stirring, the results were not even and the samples with same

volume fractions had entirely different properties from experimentally calculated because of the aforementioned problems. The mechanical mixing process was more efficient to get the uniform results because in this case, the agitation was more uniform and steadier. The resultant composite gives better results to understand the idea of effect of volume fraction of the reinforcement phase to the Aluminum matrix. Optimum particle size distribution is considered to be very important to avoid concentration gradient of SiC in the matrix

Scope for future

In recent years, the metal matrix composites are reinforced with carbon nanotubes (CNTs) due to their strengths in excess of 100 GPa and stiffness of 1000 GPa which makes them superior to carbon fibers. Al alloy matrix and the multi-walled carbon nano tubes (MWCNTs) show excellent interfacial bonding and their thermodynamic calculations predict the type of carbide (Al4C3 or SiC) that would form at the matrix–CNT interface as a function of matrix composition and processing temperature. The amount of Al4C3 carbide formation increases with an increase in the CNT content [31, 32]. This concept of adding MWCNT can be extended to stir casting process. MWCNT will effectively transfer load to primary reinforcement (SiC) and it will act as a barrier to dislocation. Thus it will improve the fracture toughness of metal matrix composites. Since stir casting process involves a number of parameters, its effective strategy of experimentation is difficult and costly. Majority of research work carried out till date are following random selection of parameters without proper design of experiments. So incorporation of design of experiments involving all relevant parameters is expected to yield better results. Since aluminum silicon carbide metal matrix composite reaches the mushy state before solidification, it can be simulated by incorporating all relevant parameters using FLUENT software. Such a simulation will lead to an optimum result.

V. CONCLUSION

In this paper various advantages of stir casting method over other composite manufacturing methods are explained. From various recent work it is clear that clustering of reinforcement particles, wettability of reinforcement (SiC) in molten aluminum are the prime concern in the production of composites through stir casting. Further, the studies clearly show that mechanical properties of stir cast composite depend upon factors like fabrication techniques, volume fraction, shape and size of reinforcement particles and the distribution and properties of constituents. Also, it is evident that addition of reinforcement up to a particular level increases the mechanical properties. But composites fracture toughness is decreased by the addition of reinforcement. Recent studies in CNT show that it will effectively transfer load to primary reinforcement, and it will act as a barrier to dislocation thus improving the fracture toughness of composite. To improve fracture toughness it is necessary that reinforcement should be uniformly distributed. The experimental work to find out the optimum values are difficult and costly. Since stir casting process involves very high temperature, experimentation is difficult and dangerous. So proper simulations of stir casting process considering all relevant factors are necessary to yield good results, and it will help the researchers to identify strategies for experimentation.

REFERENCE

1. Skibo DM, Schuster DM, Jolla L Process for preparation of composite materials containing nonmetallic particles in a metallic matrix and composite materials, 1998.
2. Kalaiselvan K, Murugan N, Parameswaran S. Production and characterization of AA6061-B4C stir cast composite. Materials and Design, 2011.
3. Nikhilesh Chawla, and Yu-Lin Shen, Mechanical Behavior of Particle Reinforced Metal Matrix Composites", Advanced engineering materials, 2001.
4. Kumar B, Murugan N, Metallurgical and Mechanical Characterization of Stir Cast AA6061-t6-AINp Composite, 2011.
5. Richard AMA, Fennessy K, Hay RA, Aluminum Silicon Carbide (AlSiC) for Advanced Microelectronic Packages, 1998.
6. Surappa.M. K., Surappa, JMaterProcess Technol, 1997
7. K. L. Meena, Dr. A. Manna, Dr. S. S. Banwait, Dr. Jaswanti, An Analysis of Mechanical Properties of the Developed Al-SiC-MMC's, 2013,
8. A. Chennakesava Reddy and Essa Zitoun,. "Matrix Al-alloys for Silicon Carbide Particle Reinforced Metal Matrix Composites, 2010.
9. Law E, Pang SD, Quck ST, Discrete dislocation analysis of the mechanical reponse of silicon carbide reinforced aluminum nanocomposite, 2011.
10. Hashim J, Looney L, Metal matrix composites,production by the stir casting method., 1999.
11. Davidson, David L, Computational Study of Crack Growth in SiC-A1 Composites, 2005.
12. Olivier B, Metal Matrix Composites (MMCs) from Space to Earth,2013
13. Luan BF, Hansen N, Godfrey A, Wu GH, Liu Q High strength Al–Al2O3p composites. Optim Extrusion Parameters, 2011
14. Bolu CA, Babalola PO, Inegbenebor, Influence of the Grit size of Silicon Carbide Particles on the Mechanical and Electrical properties of Stir Casting Aluminum Matrix Composite Material, 2015.
15. Pranav Wagh, Abhinav Paliwal ,Aluminum Metal Matrix Composite Fabrication Using Stir Casting: A Review , 2018.
16. P.B. Pawar, Abhay A, etal. Development of aluminum matrix composites, 2014
17. Manoj singh, Singala Dwivedi DD, Development of aluminum based silicon carbide particulate metal matrix composite, 2009.

18. G. G. Sozhamannan, S. Balasivanandha prabhu, R. Paskaramoorthy, Failure Analysis of Particle Reinforced Metal Matrix Composites by Microstructure Based Models, 2010.
19. W. Zhou, Z.M. Xu, Casting of SiC Reinforced Metal Matrix Composites, 1997.
20. M. Yilmaz, S. Altintas, Properties of Al-Mg-SiC Composites Produced by a Modified Compo Casting Technique, 1994.
21. Sijo M T , K R Jayadevan, Analysis of stir casting aluminum metal matric composites, a comprehensive review, 2015
22. Mohit kumar sahu , Raj kumar sahu, Fabrication of aluminum stir casting metal matrix composites by stir casting technique and stirring process parameters optimization,
23. A.O. Inegbenbor, Aluminum silicon carbide particulate metal matrix composite development via stir casting process, 2016.
24. Dhruv kumar, Sonu kumar, Aluminum compositiies materials using stir casting process challenges and opportunities, 2015
25. Jayashree P.K, Gowri Shankar M.C, Achutha kini, Review on effect of silicon carbide (SiC) on stir casting aluminum metal matrix composites, 2018.
26. Sijo M T , K R Jayadevan, Analysis of stir casting aluminum metal matric composites, a comprehensive review, 2015
27. Mohit kumar sahu , Raj kumar sahu, Fabrication of aluminum stir casting metal matrix composites by stir casting technique and stirring process parameters optimization,
28. A.O. Inegbenbor, Aluminum silicon carbide particulate metal matrix composite development via stir casting process, 2016.
29. Dhruv kumar, Sonu kumar, Aluminum compositiies materials using stir casting process challenges and opportunities, 2015
30. Jayashree P.K, Gowri Shankar M.C, Achutha kini, Review on effect of silicon carbide (SiC) on stir casting aluminum metal matrix composites, 2018.