EFFECT OF POURING TEMPERATURE AND STIRRING SPEED ON MECHANICAL, MICROSTRUCTURE AND MACHINING PROPERTIES OF AL6061-CU REINFORCED SiC_P METAL MATRIX COMPOSITES

Serajul Haque[1], Akhtar Hussain Ansari[2], Prem Kumar Bharti[3]

[1]*Assistant Professor, Mechanical Engineering Department, Azad Institute of Engineering and Technology, Lucknow, India.*
[2]*Professor, Mechanical Engineering Department, Aligarh Muslim University, Aligarh, India.*
[3]*Professor, Mechanical Engineering Department, Integral University, Lucknow, India.*

Abstract

The major challenges in the fabrication of MMC are the difficulties of achieving uniform distribution of reinforcing material and possible chemical reactions between reinforcement material and matrix. Therefore, the present research was conducted to investigate the effect of stirring speed and pouring temperature on mechanical, microstructure and machining properties of Al6061-Cu reinforced SiC MMC by stir casting technique. The dependent variables are hardness, impact strength and metal removal rate of MMC by electro-discharge machining while the independent parameters are five levels of stirring speed and five levels of pouring temperature. It is observed from experimentation that with the increase in stirring speed increases the impact strength and hardness of MMC up to a certain limit after that these properties decrease drastically. The optimal value of hardness and impact strength for MMC is obtained at pouring temperature of 725˚C and 400 rpm and impact strength of MMC are least at 800 rpm and 775˚C and followed by 50 rpm and 675˚C. It is observed from an SEM study that at stirring speed 400 rpm better homogeneity can be obtained compared to 200 and 600 rpm.

***Keywords—** MMC, Stir casting, Stirring speed, Machining properties and Microstructure of Al-Cu-SiC MMC, Pouring temperature effect etc.*

---***---

1. INTRODUCTION

In spite of so many research and developments in the field of metal matrix composites (mmc) still it is not so popular due to high production cost, however, it has a lot of superior properties like their high stiffness, strength, corrosion resistance, wear resistance, non-reactivity with chemicals and so many other tailored quality which can never be obtained by alloy of metals. Mechanical properties are improved with increase in weight % of ceramics, stirring time and decrease with particle size of the reinforced ceramics [1, 2]. The pouring speed (rate) influencing the mmcs mechanical properties of Al 6061-Cu reinforced SiC metal matrix composites [4]. The process parameters are influencing the mechanical and machining properties of metal matrix composites [3, 4, 5]. A. Chennakesava Reddy and Essa Zitoun, in their rigorous experimentation, investigated the mechanical properties for different metal matrix composites produced from Al 6061, Al 6063 and Al 7072 matrices alloys reinforced with silicon carbide particulates [6]. The major hurdle in processing MMCs is achieving a homogeneous distribution of reinforcement in the matrix as it is influencing the properties and the quality of the composite [7].

2. DESIGN OF EXPERIMENT

2.1 Process Parameters

The material selection criteria involve the requirement of high strength and good corrosion resistant aluminium alloys for the matrix materials. Present work focuses on the mechanical properties of Aluminium-Copper-Silicon Carbide (Al6061-Cu-SiC) metal matrix composite casting. ANOVA were used for analysis of data. Input variables are: pouring temperature and stiring speed, the output variables are: hardness, impact strength and material removal rate. It is postulated in null hypothesis that input variables (pouring temperature and stiring speed) have no significant effect on mechanical properties (Hardness , Impact strength and material removal rate). Five levels of pouring temperature: 675^0C, 700^0C, 725^0C, 750^0C and 775^0C and 50 rpm, 200 rpm, 400 rpm, 600rpm and 800 rpm and a constant pouring speed 2.5 cm/s were considered.

2.2 Methodology

A stirring system has been developed by the motor with regulator and a cast stirrer. To ensure the proper mixing of melts, all the melting was carried out in a graphite crucible in an open hearth furnace. Billet of aluminium and copper were preheated at 450^{0}C for 40 minutes before melting and the SiC particles were preheated at 1100^{0}C for 2 hours to make their surfaces oxidized. The furnace temperature was first raised above the liquidus to melt the feed stock 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 done because difficulty in mixing by using an automatic device when the alloy was in a semi-solid state. After sufficient manual mixing, the composite slurry was reheated to a fully liquid state and then automatic mechanical mixing was carried out for about 10 minutes at five different stirring speed of 600 rpm. In the final mixing process, the furnace temperature was within 800^{0}C and the composite slurry was poured in a sand mould designed to get standard specimens.

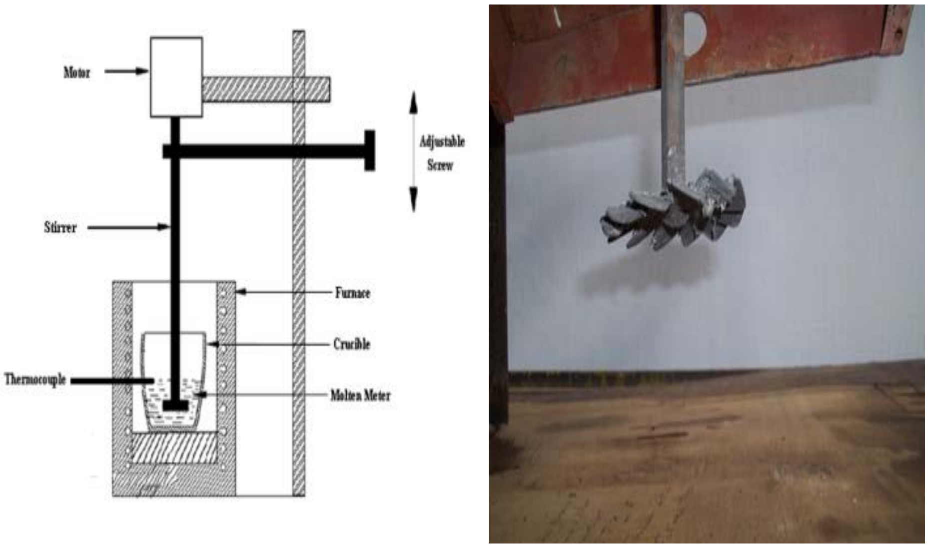

Fig1 Schematic view of Experimental setup and strirer

Table 1 Chemical compositions of Al (6061) alloy (Weight Percentage)

Mg	Si	Fe	Cu	Ti	Cr	Zn	Mn	Al
0.90	0.60	0.25	0.22	0.06	0.10	0.05	0.04	balance

2.3 Testing of Materials

1) Hardness Test : Hardness test provides an accurate, rapid and economical way to determine the material deformation. The Brinell scale characterizes the indentation hardness of materials through the scale of penetration of an indenter, loaded on a material test-piece. Hardness and impact strength were recorded and tabulated. Hardness test has been conducted on each specimen using a load of 250 N and a steel ball indenter of diameter 5 mm as indenter. The diameter of the impression made by indenter has been measured by Brinnell microscope. The corresponding values of hardness (BHN) were calculated from the standard formula.

Fig 2 Standard Specimen for Brinell hardness and Impact strength.

2) Impact Strength Test: An impact test signifies toughness of the material that is the ability of a material to absorb energy during plastic deformation. Impact strength is generally lower as compared to strength achieved under slowly applied load. Therefore the impact test measures the energy necessary to fracture a standard notch bar by applying an input load. Izod impact strength testing is a standard method of determining impact strength. The Izod impact test was conducted on notched sample. Standard square impact test specimen of dimension 75mm x 10mm x 10mm with notch depth of 2mm and a notch of an angle of 45^0 were prepared by casting. The machine could provide a range of impact energies from 0 to 164J. The mass of the hammer was 22 kg.

3) Material Removal Rate (MRR) by Electro-Discharge-Machining (EDM) : The advantage of EDM process is its capability to machine difficult to machine materials with desired shape and size with a required dimensional accuracy and productivity. Melting and vaporization of matrix material from the plasma channel in EDM but the reinforced ceramic particle SiC are unmelted and collected on cutting edge as the debris. This machining mechanism has confirmed with the earlier research [8]. Velmurugan et al., research on Al 6061 hybrid metal matrix composite advocated the optimal parameter for better MRR by EDM are current 15 Amps, voltage 30 volts , pulse on time 600 µs and 5 psi [9]. In this research above process parameters are adopted as base metal and reinforced ceramic are same for obtaining maximum material removal by EDM. Material for research is Al 6061-4%Cu-5%SiC metal matrix composite.

3. RESULTS

From the surface micrographs (SEM) study it is observed that with the increase in pouring speed up to certain limit increases the homogeneity in mixing of SiC_p ceramic in matrix alloy but after that SiC_p is separated from metal alloys. At pouring speed 200 rpm insufficient mixing of alloy metal and SiC ceramic [figure 3 (a)], at pouring speed of 400 rpm having homogenous mixing is achieved [figure 3 (b)] and at pouring rate 800 rpm the clouting of SiC are observed again [figure 3 (c)].

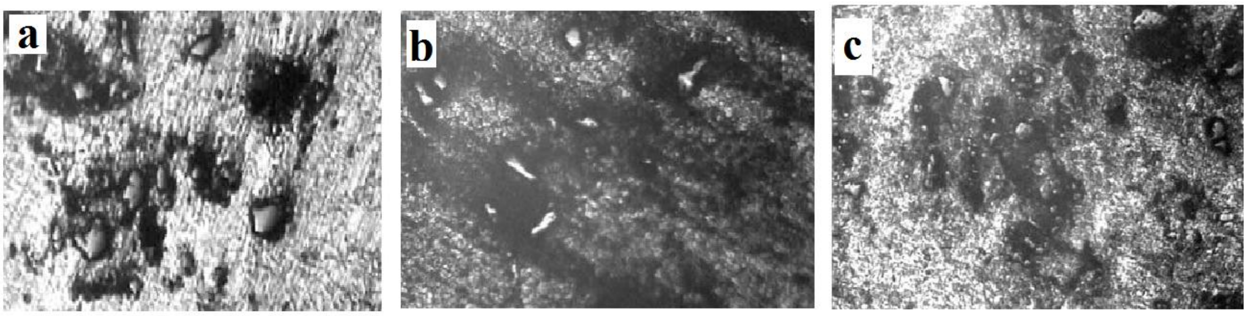

Fig 3 Micrograph of Al6061+4% Cu and 5% SiC Composite at different stirring speed.

Statistical analysis was performed using SPSS (version-17.0). The result of Multivariable Analysis of Variance (MANOVA) to see the effect of input variables stirring speed and pouring temperature on output properties such as hardness, impact strength and material removal rate. It is obtained from MANOVA (table-1), the effect of pouring temperature and stirring speed are highly significant for the output variables (hardness, impact strength and material removal rate). However the interaction of Material Type and pouring rate on output variables are not found significant. The above analyses were done for 95% confidence level.

Table-2: Summary of Result Analyzed by MANOVA

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	Dof	Mean Square	F	Sig.
Corrected Model	Hardness	13623.653[a]	24	567.652	41.903	.000
	Impactstrength	3475.013[b]	24	144.792	47.839	.000
	MaterialRemovalRate	163448.187[c]	24	6810.341	47.255	.000
Intercept	Hardness	320264.013	1	320264.013	23641.536	.000
	Impactstrength	151245.653	1	151245.653	49971.031	.000
	MaterialRemovalRate	7281468.813	1	7281468.813	50523.653	.000
Stirspeed	Hardness	11225.920	4	2806.480	207.171	.000
	Impactstrength	2158.347	4	539.587	178.278	.000
	MaterialRemovalRate	145236.720	4	36309.180	251.937	.000
Pouringtemp	Hardness	1569.120	4	392.280	28.958	.000
	Impactstrength	1203.413	4	300.853	99.401	.000

	MaterialRemovalRate	13799.920	4	3449.980	23.938	.000
Stirspeed * Pouringtemp	Hardness	828.613	16	51.788	3.823	.000
	Impactstrength	113.253	16	7.078	2.339	.011
	MaterialRemovalRate	4411.547	16	275.722	1.913	.041
Error	Hardness	677.333	50	13.547		
	Impactstrength	151.333	50	3.027		
	MaterialRemovalRate	7206.000	50	144.120		
Total	Hardness	334565.000	75			
	Impactstrength	154872.000	75			
	MaterialRemovalRate	7452123.000	75			
Corrected Total	Hardness	14300.987	74			
	Impactstrength	3626.347	74			
	MaterialRemovalRate	170654.187	74			

a. R Squared = .953 (Adjusted R Squared = .930)

b. R Squared = .958 (Adjusted R Squared = .938)

c. R Squared = .958 (Adjusted R Squared = .938)

The graphical analysis of the effect of the input variables on output characteristics is shown in figure -4 , figure-5 and figure -6 (for, Hardness, impact strength and metal removal rate). The graph of figure 4 (a) shows that the hardness value initially increases with the stirring speed up to 400 rpm, thereafter it falls sharply with the increase in stirring speed at 600 rpm and 800 rpm. For the stirring speed range of 200 rpm to 600 rpm the optimum value of hardness was obtained at all pouring temperature levels(i.e., 675˚C,700˚C,725˚C, 750˚C and 775˚C) but at 400 rpm stirring speed the hardness values are maximum for all level of pouring temperature. The graph of figure-4 (b) inferred that at 400 rpm the variation of value of hardness are linear for pouring temperature 700˚C,725˚C and 750˚C means the hardness values more stable and constant at 400 rpm but for other stirring speed variation of hardness values are observed. At 800 rpm and 50rpm of stirring speed the least hardness value of MMC were observed also it can be concluded from the graphs that at high (i.e., at 800 rpm) the hardness of surface of MMC were defoliated. Moreover at 675˚C and 775˚C hardness values are comparatively substandard.

The graph of impact strength for five levels of stirring speed and five level of pouring temperature are represented by figure 5(a) and figure 5(b). The graph shows that superior value of impact strength pouring temperature of 725˚C and 400 rpm and impact strength of MMC are least at 800 rpm and 775˚C and followed by 50 rpm and 675˚C. The graph of figure-6 (a) and (b) shows that the material removal rate were high at 725^{0}C compared to other pouring temperature and 400 rpm have good impact strength compared to other stirring speed. But at other stirring speed little variation in impact strength were obtained.

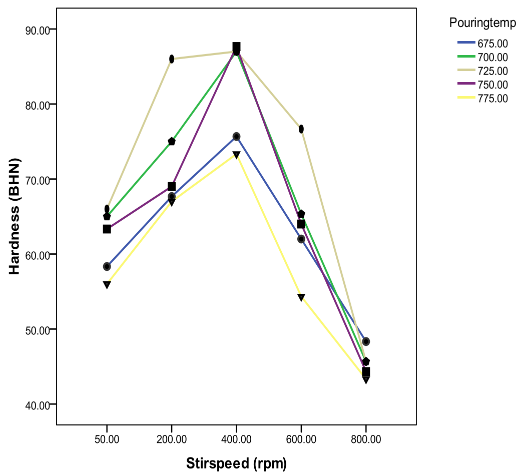

Fig 4. (a) Stirring Speed Vs Hardness

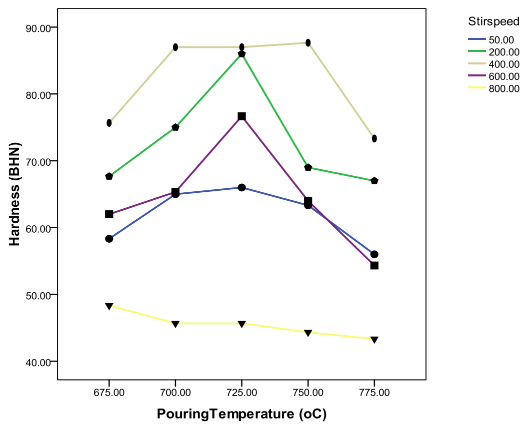

Fig 4 (b) Pouring Temperature Vs Hardness

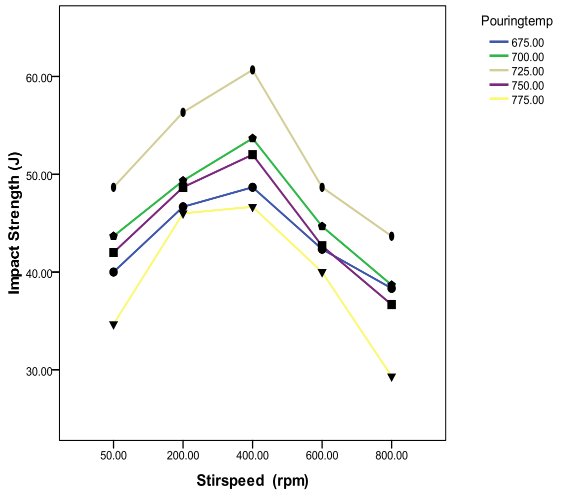

Fig 5. (a) Stirring Speed Vs Impact Strength

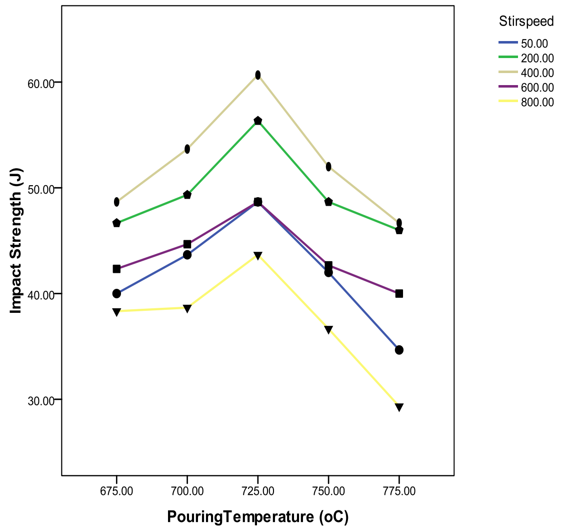

Fig 5. (b) Pouring Temperature Vs Impact Strength

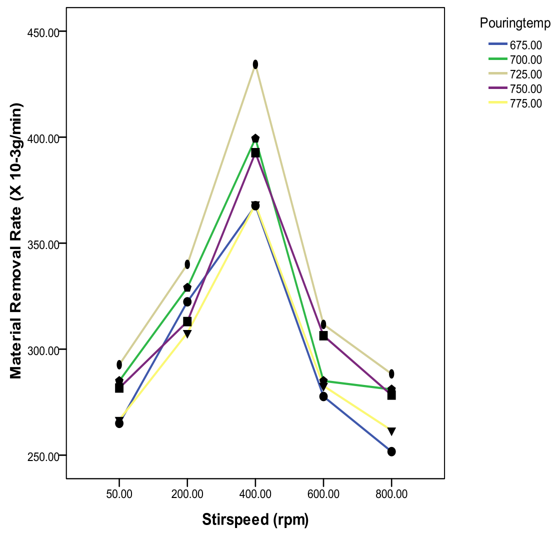

Fig 6 (a) Stirring Speed Vs Material Removal Rate

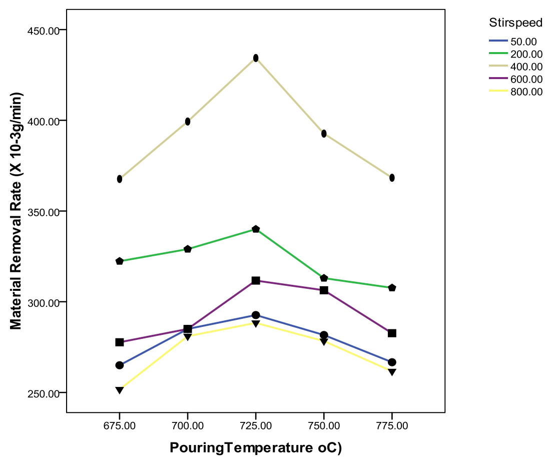

Fig 6 (b) Pouring Temperature Vs Material Removal Rate

4. DISCUSSION

It is inferred from experimental results that variables (stirring speed and pouring temperature) have a significant effect on output variables such as hardness and impact strength. From the figure 4 & 5, it is clear that the pouring temperature ranges from 700^{o}C to 750^{o}C gives the optimum value of hardness and impact strength for all stirring speed, when the pouring speed were kept constant at 2.5 cm/s.

No significant work has been found in literature survey on the effect of pouring temperature and stiring speed on Al6061+4%Cu + reinforced 5% SiC particulate MMC.

The result is partially supported by the study of Manoj et al., Which suggest that with the increase in the composition of SiC, increases the hardness and impact strength, also the study suggest that homogenous dispersion of SiC particles in the Al matrix shows an increasing trend in mechanical properties [10]. The result of Prabu et.al., the study conclude that at 600 rpm for Al-10 % SiC MMC has superior value of hardness, the reason of a better result in the context of better value of hardness of MMC at 400 rpm instead of 600 rpm, may be the homogeneous dispersion of SiC particles due to stir casting technique and the addition of 4% Cu also in present experimentation 5% SiC is considered instead of 10% SiC [11] .

5. CONCLUSIONS

A. Reinforcement of SiCp increases the Impact strength , Hardness and also material removal rate.
B. Increased material removal rate due to the addition of SiC particulates are concluded as better machinability of MMC as compared to base alloy.
C. Increase in stirring speed increases the impact strength and hardness of material up to a certain limit after that these properties decrease drastically.
D. The optimal value of hardness and impact strength for MMC is obtained at stirring speed 400 rpm.
E. It is observed from an SEM study that at stirring speed 400 rpm better homogeneity can be obtained compared to 200 and 600 rpm.

F. The material removal rate is high in MMC at 400 rpm and 725^{o}C means better machining property is obtained compared to other stirring speed and pouring temperature.
G. The postulation of null hypothesis failed so the alternative hypothesis is "the input variables stirring speed and pouring temperature have a significant effect on hardness, impact strength and material removal rate at the constant pouring speed of 2.5 cm/s".

REFERENCES

[1] Lakhvir Singh, Baljinder Ram and Amandeep Singh "Optimization Of Process Parameter for Stir Casted Aluminium Metal matrix Composite Using Taguchi Method" International Journal of Research in Engineering and Technology, Volume: 02 Issue: 08 , pp 375-383, Aug-2013.

[2] Manoj Singla, D. Deepak Dwivedi, Lakhvir Singh, Vikas .C.,(2009),Development of Aluminium Based Silicon Carbide Particulate Metal Matrix Composite, Journal of Minerals & Materials Characterization & Engineering, Vol. 8, No.6, pp 455-467.

[3] T.V. Christy, N. Murugan and S. Kumar,A Comparative Study on the Microstructures and Mechanical Properties of Al 6061 Alloy and the MMC Al 6061/TiB2/12P, Journal of Minerals & Materials Characterization & Engineering, vol. 9, No.1, pp.57-65, 2010.

[4] Serajul Haque, Prem Kumar Bharti and Akhtar Hussain Ansari, Mechanical and Machining Properties Analysis of Al 6061-Cu-Reinforced SiC_P Metal Matrix Composite, Journal of Minerals & Materials Characterization & Engineering, vol. 2, No.1, pp.54-60, 2014.

[5] Serajul Haque, Prem Kumar Bharti and Akhtar Hussain Ansari, Study of Process Parameters on Mechanical Properties and Microstructure of Al-Cu and SiC_P Reinforced Metal Matrix Composite ,International Journal of Engineering and Technology, vol. 4, No.6, pp.427-431, 2013.

[6] A. Chennakesava .R, Essa Z., Matrix Al-alloys for silicon carbide particle reinforced metal matrix composites, Indian Journal of Science and Technology, Vol. 3 No. 12 ,pp.1184-1187,2011.

[7] Naher S, Brabazon D, Looney L., , Development and assessment of a new quick quench stir caster design for the production of metal matrix composites. Journal of Material Process Technology, vol.166(3),pp.430–439, 2005.

[8] Ponappa K. Aravindan S. Rao P.V. Ramkumar J. and Gupta M. . The effect of process parameters on machining of magnesium nano alumina composites through EDM. International Journal of Advanced Manufacturing Technology,Vol. 46, pp.1035-1042, 2010.

[9] C. Velmurugan, R.Subramanian, S.Thirugnanam, B.Ananadavel, Experimental investigations on machining characteristics of Al 6061 hybrid metal matrix composites processed by electrical discharge machining, International Journal of Engineering Science and Technology, Vol. 3, No. 8, pp. 87-101, 2011.

[10] Manoj Singla, D. Deepak Dwivedi, Lakhvir Singh, Vikas .C., Development of Aluminium Based Silicon Carbide Particulate Metal Matrix Composite, Journal of Minerals & Materials Characterization & Engineering, vol. 8, No.6, pp 455-467, 2009.

[11] S. Balasivanandha Prabu, L. Karunamoorthy , S. Kathiresan , B. Mohan, Influence of stirring speed and stirring time on distribution of particles in cast metal matrix composite, Journal of Materials Processing Technology, Vol. 171, pp. 268–273, 2006.