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Optimization of Process Parameters of Stir Casting To Maximize The Hardness of Al-Sic Composites By Taguchi Method

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Abstract

The objective of this research is to optimize the process parameters of stir casting by Taguchi method for maximizing the hardness of Al-SiC composites. Composite materials used Al-Si alloy as matrix and SiC (silicon carbide) particles of 400 mesh size as reinforcement agent. Experimental parameters were SiC content, melting temperature of the matrix, rotation speed and stirring time duration, and each parameter using 4 levels or variations. Experimental design used L_{16} orthogonal arrays of Taguchi method standards. The hardness of Al-SiC composites were tested by Brinell hardness test. The microstructures of Al-SiC composite were observed by scanning electron microscopy (SEM). Experimental results show that the optimum of process parameters of stir casting are SiC content of 15 % (wt.), melting temperature of 740 ^{o}C, rotation speed of 100 rpm (round per minute) and stirring time duration of 20 minutes. The most significant factor affected on the hardness of Al-SiC composite is SiC content with contribution of 70.72 %.

Keywords: Al-SiC composites, stir-casting, hardness, Taguchi method

Introduction

Metal Matrix Composites (MMC) are engineering materials formed by metal as matrix and metal or ceramics as reinforcement to obtain a new material which has better characteristics than that of the former materials. Compared with single materials, MMC has more advantages, which are higher hardness, better wear resistance and low thermal expansion. MMC applications on the automotive industries are used as the material of cylinder liners of engine, intake valve, exhaust valve, connecting rod, brake rotors, piston, etc [1, 2]. Al-SiC is a MMC that can be produced by stir casting process. This process is less expensive than the other method of making process and can also be used to make complex shape components [1, 3]. Stirring in semi-solid condition can break aluminum dendrite structure when it solidified, into a small or chill-type of equiaxed structure shape. Ceramic particles condition with small grain size matched with small aluminum structure can enforce Al-SiC composite [4]. Stiring can also increase distribution of SiC particles in aluminum matrix [5]. Non-uniform distribution of SiC particles on the matrix caused MMC Al-SiC mechanical properties become inferior compared with uniform distribution particles. To obtain uniform distribution, optimum stirring speeds on Al7075/SiC composite with 10 % (wt.) of SiC content is 650 rpm, but above those will cause high porosity. The stirring speeds above 650 rpm will cause turbulence on the liquid and this condition will trap the gas in the liquid to form porosity [6]. Porosity is a smooth holes defect created by gas which is trapped during mixing process with stirring and shrinkage during solidification. Porosity is also formed by interfacial reaction, oxygen and hydrogen causing the appearance of water steam on the SiC reinforcement particle surfaces [7, 8]. The coarser SiC reinforcement particle size will make the bigger Al-SiC composite porosity [9].

The aim of this research is to optimize the process parameters of stir casting by Taguchi method for maximizing the hardness of Al-SiC composites. This research also aims to analyze the effects of process parameters on the hardness of Al-SiC composites made by stir casting process.

Materials and Methods

Materials

Composite materials used Al-Si alloy as a matrix and SiC (silicon carbide) particles of 400 mesh size (32 μm) as reinforcement agent. Chemical compositions of the Al-Si alloy ingot (% wt.) were 10.516 Si, 1.715 Cu, 0.78 Fe, 0.83 Zn, 0.239 Mg, 0.15 Mn and Al balance. Morphology of SiC particle forms were angular. The Al-Si alloy materials were supplied by Pinjaya Logam, Co., Indonesia and the SiC particles were supplied by Sigma Aldrich, Co., USA. The SiC particles forms were observed by scanning electron microscope (SEM) and the result is shown in Figure 1.

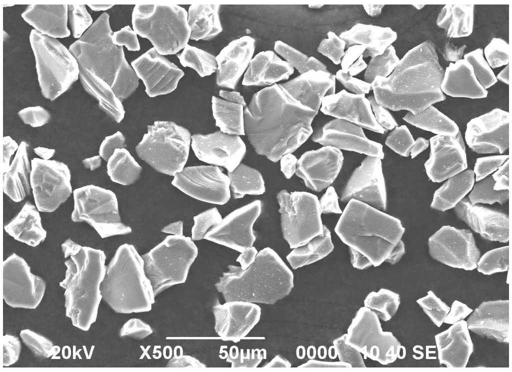


Figure 1: SEM micrograph of SiC particles

Stir Casting Process of Al-SiC Composites

The Al-Si alloy was heated up in a graphite crucible in a resistance furnace until the above melting point (above 680 °C) to make sure that the Al-Si alloy was perfectly melted, before it mixed with SiC particles. The Al-Si alloy was heated at temperature of 500 °C with holding time of 2 hours. At the same time, SiC particles were also heated up at temperature of 500 °C with holding time of 2 hours before they were mixed with Al-Si alloy to eliminate the water vapor from its surface. The melted Al-Si alloy mixed with SiC particles by stirring process. The stirring was conducted to obtain evenly distribution of SiC particles in aluminum matrix. Stirring process was conducted in two steps, which were stirring in a slurry condition (on temperature of 580 °C) for 30 minutes with rotation speed of 600 rpm and stirring on melted condition according to process parameters in Table 1. On this step, argon gas was flown into graphite crucible to push the oxygen out of the composite melted surface. Process parameters and factors used in this experiment were SiC content of 0, 5, 10, 15 % (wt.), melting temperature of 680, 700, 720, 740 °C, rotation speed of 100, 200, 300, 400 rpm and stirring duration of 10, 20, 30, 40 minutes. The Al-SiC composites molten then were poured into a steel mould which pre-heated at temperature of 200 °C. The Al-SiC composites formed in the mould were solidified and cooled for 2 hours, before taken out from the mould. Schematic diagram of Al-SiC composites stir casting process is shown in Figure 2.

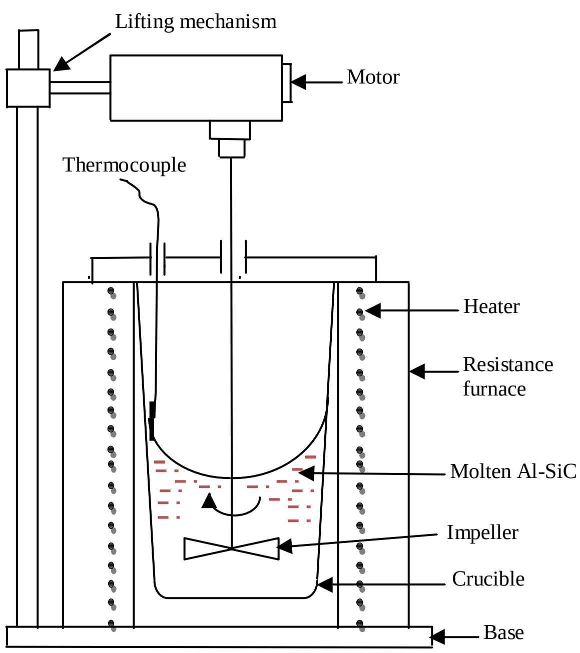


Figure 2: Schematic diagram of stir casting process

Brinell Hardness Test

Hardness of Al-SiC composite was obtained by using Brinell hardness testing machine. In this case, the specimens were pressed with 2.5 mm diameter steel ball with normal load (F) of 613 N. Specimens size for the hardness test were 50 mm length, 30 mm width and 5 mm thickness. The Brinell hardness value (HB) was determined by using the following the equation (1) [10]:

$$HB = \frac{2F}{\pi D(D - \sqrt{D^2 - d^2})} \quad (1)$$

where HB, F, D and d are Brinell hardness (kg/mm^2), test force (kg), diameter of the ball (mm), and mean diameter of the indentation (mm) respectively.

Microstructure Observation

The specimens were used in flat type with mirror smooth finish after mechanical abraded with 600, 1000, 1200 and 1500 grit silicon carbide papers, and then were polished with diamond paste, washed with alcohol and dried. The microstructures of the specimen were observed by scaning electron microscope (SEM) to observe SiC particle grain distribution in Al-Si alloy matrix.

Taguchi Experimental Design

Experimental designs used a Taguchi method standard. The factors and level or variation used in these experiments were shown in Table 1.

Table 1: Experimental factors and parameters variation

	Parameters variation			
Experimental factors	**1**	**2**	**3**	**4**
X_1 : SiC content (wt.%)	0	5	10	15
X_2 : Melting temperature (^{o}C)	680	700	720	740
X_3 : Rotation speed (rpm)	100	200	300	400
X_4 : Stirring duration (minute)	10	20	30	40

There were 4 experimental factors with each 4 level or variation, so the degree of freedom of total experiment were 12. Based on number of experimental factors, number of variation and number of degree of freedom, experimental design standard according to Taguchi method was L_{16} orthogonal arrays (in Table 2). Based on Taguchi method, Brinell hardness test data in each experiment were converted using equation 2 [11].

$$S/N\,ratio = -10\log_{10}\left[\frac{1}{n}\sum_{i=1}^{n}\frac{1}{y_i^2}\right] \quad (2)$$

where S/N ratio, n and y_i are signal to noise ratio (dB), spesimen number on each experiment and Brinell hardness of specimen to-i (kg/mm^2) respectively.

Table 2: L_{16} orthogonal array design

Experiments	Experimental factors and parameter variation			
	X_1	X_2	X_3	X_4
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	1	4	4	4
5	2	1	2	3
6	2	2	1	4
7	2	3	4	1
8	2	4	3	2
9	3	1	3	4
10	3	2	4	3
11	3	3	1	2
12	3	4	2	1
13	4	1	4	2
14	4	2	3	1
15	4	3	2	4
16	4	4	1	3

Results And Discussion

Brinell Hardness

The result of the Brinell hardness test and the S/N ratio for each experimental are shown in Table 3.

Table 3: Experimental condition and results

Experiments	Experiment factors and parameter variation				Brinell hardness average (kg/mm^2)	S/N ratios (dB)
	X_1	X_2	X_3	X_4		
1	0	680	100	10	82.344	38.254
2	0	700	200	20	83.621	38.419
3	0	720	300	30	85.683	38.606
4	0	740	400	40	82.534	38.284
5	5	680	200	30	82.985	38.335
6	5	700	100	40	92.978	39.328
7	5	720	400	10	90.131	39.082
8	5	740	300	20	95.594	39.558
9	10	680	300	40	90.894	39.109
10	10	700	400	30	96.968	39.699

11	10	720	100	20	95.388	39.525
12	10	740	200	10	97.616	39.748
13	15	680	400	20	95.509	39.567
14	15	700	300	10	94.399	39.403
15	15	720	200	40	98.717	39.864
16	15	740	100	30	102.187	40.156

Response data of Brinell hardness test were calculated to make Brinell hardness response and S/N ratio tables. Data calculations used MINITAB 16 and excel software. The results of experiment data calculations were shown in Table 4 and Table 5.

Table 4: Response of Brinell hardness average

Factors	**Variation and Brinell hardness average (kg/mm^2)**				**Delta**	**Rank**
	1	2	3	4		
X_1	83.55	90.42	95.22	97.70	14.16	1
X_2	87.93	91.99	92.48	94.48	6.55	2
X_3	93.22	90.73	91.64	91.29	2.49	3
X_4	91.12	92.53	91.96	91.28	1.41	4

Table 5: Response of S/N ratios-larger is better

Factors	**Variation and S/N ratios-larger is better (dB)**				**Delta**	**Rank**
	1	**2**	**3**	**4**		
X_1	38.39	39.08	39.52	39.75	1.36	1
X_2	38.82	39.21	39.27	39.44	0.62	2
X_3	39.32	39.09	39.17	39.16	0.22	3
X_4	39.12	39.27	39.20	39.15	0.15	4

Rank order of factors affecting Brinell hardness of Al-SiC composites were SiC content, melting temperature, rotation speed and stirring duration (Table 4 and 5). ANOVA (Analysis of variance) as shown in Table 6, Table 7 and Table 8 indicated that the most significant factor affected on the Brinell hardness is SiC content with probability value of P = 0.05 for level of confidence 95 %.

Table 6: Analysis of variance of Brinell hardness average

Factors	**DF**	**Adj SS**	**Adj MS**	**F**	**P**	**Contribution (%)**
X_1	3	466.12	155.37	9.16	0.05	66.67
X_2	3	90.50	30.17	1.78	0.32	5.86
X_3	3	13.71	4.57	0.27	0.85	-6.07
X_4	3	5.03	1.68	0.10	0.96	-7.39

Residual Error	3	50.87	16.96			40.93
Total	15	626.24				100

where DF, Adj SS, Adj MS, F and P are degrees of freedom, the sum of squares, the mean sum of squares, the F-ratio and factor probability respectively. Contribution (%) is percentage contributions of factor on the Brinell hardness of Al-SiC composite.

Table 7: Pooled analysis of variance of Brinell hardness

Factors	**DF**	**Adj SS**	**Adj MS**	**F**	**P**	**Contribution (%)**
X_1	3	466.12	155.37	9.16	0.05	70.72
X_2	3	90.50	30.17	1.78	0.32	10.74
X_3	(3)	(13.71)	Pooled			
X_4	(3)	(5.03)	Pooled			
Residual Error	9	69.62	7.74			18.54
Total	15	626.24				100

Table 8: Analysis of variance of S/N ratios

Factors	**DF**	**Adj SS**	**Adj MS**	**F**	**P**
X_1	3	4.31	1.44	9.14	0.05
X_2	3	0.81	0.27	1.72	0.33
X_3	3	0.12	0.04	0.26	0.85
X_4	3	0.05	0.02	0.10	0.96
Residual Error	3	0.47	0.16		
Total	15	5.75			

Effect of Process Parameters on Brinell Hardness

Effect of SiC content on Brinell hardness

The effect of SiC content on Brinell hardness and S/N ratio are shown in Figure 3. In Figure 3, it is shown clearly that the increasing of SiC content parameter from 0 to 15 % (wt.) on Al-SiC composite produced by stir casting technique is able to increase the average Brinell hardness of 16.94 %. Brinell hardness of Al-SiC composite increases from 83.55 to 97.7 kg/mm^2. The highest S/N ratio is on variation 4 (39.75 dB) with SiC content of 15 % (wt.). And so the optimum Brinell hardness of Al-SiC composite is obtained on parameter condition of SiC content of 15 % (wt.).

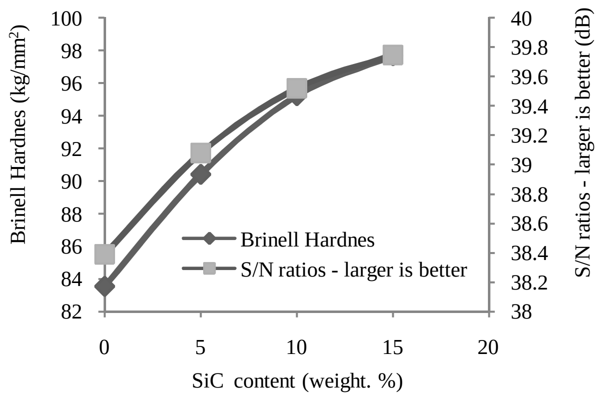


Figure 3: Effect of SiC content on Brinell hardness and S/N ratios-larger is better

The composite Brinell hardness increases because the addition of SiC particles which were spread on the aluminum matrix. The hardness of SiC particles is higher than the hardness of aluminum matrix, therefore the increasing of SiC particles content on aluminum matrix produces the increasing of composite hardness. This result (Figure 3) is consistent with the studies conducted by Kayal et al [12] and Behera et al [13], their study results stated that the Brinell hardness of Al-SiC composite increased by increasing of SiC content on the matrix of aluminum alloy LM6 (Al-10-13 % Si, in weight %). Our result is also consistent with the studies conducted by Tofigh et al [14] and Vanarotti et al [15], their results also stated that the Brinell hardness of Al-SiC composite increased by the increasing SiC content on the matrix of aluminum alloy A356 (Al-7,5 % Si, in weight %). Above results show the same phenomenon that increasing SiC particles content on Al-Si alloy matrix can increase the Al-SiC composite hardness.

Effect of melting temperature on Brinell hardness

The effect of parameter variation of melting temperature factor on Al-SiC composite hardness is shown in Figure 4. Based on Figure 4, it is shown clearly that increasing melting temperature from 680 to 740 ^{o}C is able to increase Brinell hardness of Al-SiC composite of 7.45 %. Brinell hardness of Al-SiC composite increase from 87.93 to 94.48 kg/mm^2. The highest effect of melting temperature on S/N ratio is on fourth variation (39.44 dB), so optimum of melting temperature parameter which affecting Brinell hardness composite is 740 ^{o}C.

The increasing of composite Brinell hardness due to increasing of melting temperature would make the aluminum perfectly melted and evenly spreading on the SiC particles surface when it was stired. Evenly spreading of the molten aluminum on the SiC particles surface produced the stronger interfacial bond between aluminum matrix and SiC particles, it caused the Al-SiC composite becomes harder than less evenly. In this study, the melting temperature of 740^{o}C could result the pouring temperature on the mould become higher than pouring temperature on the melting temperature of 680, 700 and 720°C. The increasing of the pouring temperature caused the composite hardness increase [16].

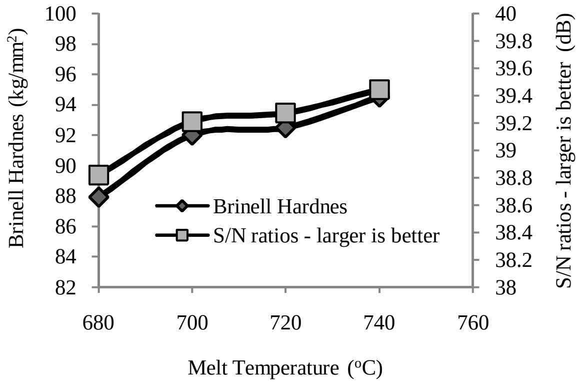


Figure 4: Effect of melting temperature on Brinell hardness and S/N ratios-larger is better

Laurent et al [17], Hashim et al [18] and Jayashree et al [19] stated that the increasing of the melting temperature will decrease the contact angle between the melt aluminum on the SiC particles surface. The smaller contact angle produced better wettability of the melt aluminum on the SiC particles, but increasing the melting temperature will lower the melt aluminum viscosity which causes SiC particles easily precipitate at the bottom of the crucible. Muttharasan et al [20] reported also that the increase the melting temperature of the composite matrix above 700°C will increase Si content in the interface and increase their micro hardness.

Effect of rotation speed on Brinell hardness

The effect of rotation speed factor on Al-SiC composite hardness is shown in Figure 5. Based on Figure 5, it is shown that increasing rotation speed from 100 to 200 rpm, Brinell hardness of Al-SiC composite decrease from 93.22 to 90.73 kg/mm^2, and then it increase back to 91.64 kg/mm^2 on rotation speed of 300 rpm. On rotation speed of 400 rpm, the Brinell hardness of Al-SiC composite decrease back to 91.29 kg/mm^2. Overall increasing rotation speed parameters from 100 to 400 rpm tend to decrease the hardness of Al-SiC composite. Composite hardness decrease about 2.07 % when rotation speed is raised from 100 rpm to 400 rpm. The highest S/N ratio happened in the first variation or level (39.32 dB) with rotation speed of 100 rpm, so the optimum Brinell hardness of Al-SiC composit is obtained on rotation speed parameter condition of 100 rpm.

Increasing the stirring rotation speed will increase centrifugal force which moves SiC particles in the aluminum melt from the center to the periphery crucible. However SiC particles movement will be stopped by the liquid aluminum. Centrifugal force of the liquid aluminum is smaller than centrifugal force of the SiC particles because density of SiC particles is bigger than density of aluminum. Centrifugal force value can be determined using the following equation: $\mathbf{F = m \times \omega^2 \times r}$, where **m** is the mass of the SiC particle, **ω** is the rotating angular speed of the SiC particle and **r** is distance of SiC particle from the central axis of the crucible [21]. Increasing the stirring rotation speed will make the more evenly distribution of SiC particles on the composite matrix [21, 22, 23]. High stirring rotation speed will cause gas bubbles were trapped on composite melt and formed the porosity. However, too high stirring speed would result in the high porosity and gas on the molten absorption of composites [24].

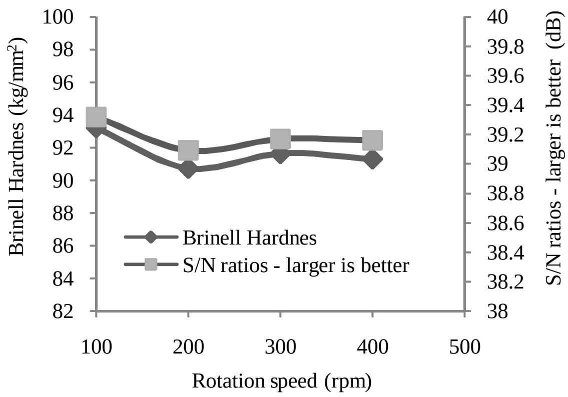


Figure 5: Effect of rotation speed on Brinell hardness and S/N ratios-larger is better.

Effect of stirring duration on Brinell Hardness

The effect of stirring time duration on Brinell hardness of Al-SiC composite is shown in Figure 6.

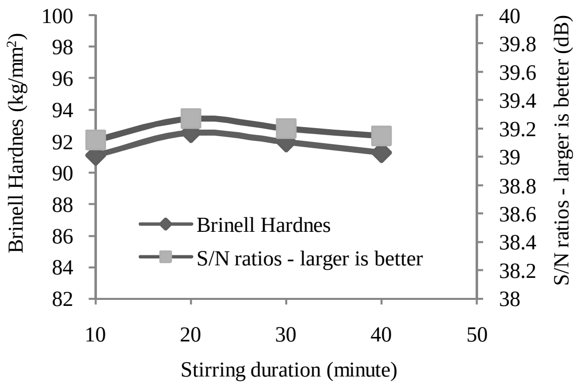


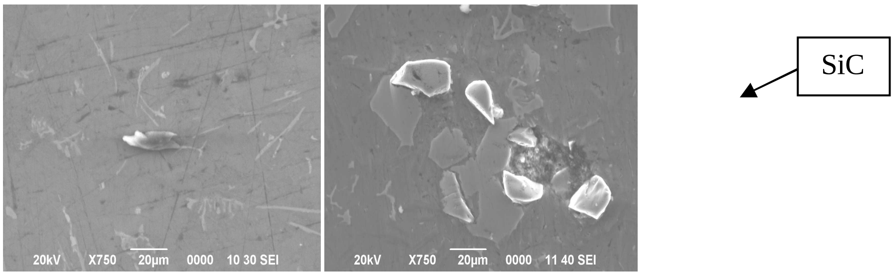
Figure 6: Effect of stirring duration on Brinell hardness and S/N ratios-larger is better

Based on Figure 6, the increasing duration of stirring from 10 to 20 minutes can increase Brinell hardness of Al-SiC composite from 91.12 to 92.53 kg/mm^2, but increasing the time duration above 20 minutes will decrease the hardness. Hardness of Al-SiC composites decreases from 92.53 to 91.28 kg/mm^2 on time duration of 40 minutes. Highest S/N ratio is on time duration of 20 minute with value of 39.27 dB, so the optimum hardness of the composite happened in the time duration of 20 minutes condition. Brinell hardness of Al-SiC composite decrease because when the stirring time duration increases above 20 minutes will increase gas absorbed in the composite melt and form porosity. The longer stirring time duration can increase the absorption of gas in the liquid aluminum matrix and form porosity. However, increasing stirring time duration certainly increases gas absorbability and oxidation of the prepared composites, which can decrease the mechanical properties [24].

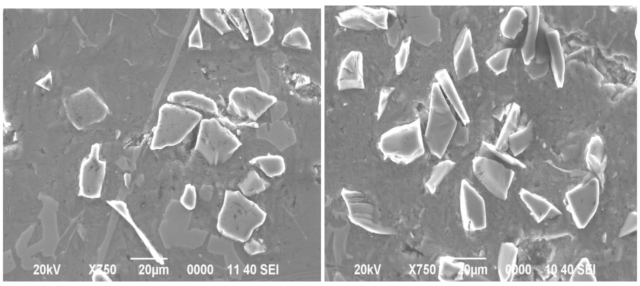
The above results show that the optimum parameters of stir casting process are SiC content of 15 % weight, melting temperatur of 740 ^{o}C, rotation speed of 100 rpm and stirring duration of 20 minutes, with results the Brinell hardness of 102.77 kg/mm^2.

Microstructure Analysis

Microstructure of Al-SiC composite specimen was observed by Scanning Electron Microscope (SEM). Observation results of SiC particles distribution are shown in Figure 7 (a-d) on different content of SiC particles.



(a) 0 % (wt.) SiC (b) 5 % (wt.) SiC



(c) 10 % (wt.) SiC (d) 15 % (wt.) SiC

Figure 7: SEM result of SiC particles distribution on Al-SiC composites on optimum condition

Microstructures of Al-SiC composite show that increasing of SiC content from zero to 15 % (wt.) make SiC particles distribution become more evenly. The increasing of SiC weight fraction will raise number of SiC particles spreading on the composite matrix. Besides that, the existence of SiC particles on the matrix causes the hardness of Al-SiC composite become higher because SiC particles is very hard. The increasing of SiC content in matrix will significantly increase hardness of Al-SiC composite because the SiC particles have high hardness so it can resist the steel ball of hardness testing machine when conducted testing on composite specimen.

Conclusions

The analysis of the effect of parameters on Al-SiC composites hardness using Taguchi method has shown very good results. Increasing parameter of SiC content factors to 15 % (wt.) and melting temperature to 740 ^oC are able to increase the composite hardness made by stir casting process. Increasing rotation speed factor should not be too high from 100 rpm, in this case it would decrease composite hardness. The best duration of stirring is 20 minutes. The optimum process parameters are SiC content of 15 % (wt.), melting temperature of 740 ^oC, rotation speed of 100 rpm and stirring duration of 20 minutes.

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References

[1] Kainer, K. U., 2006, "Metal Matrix Composites", Wiley-VCH Verlag GmbH & Co. KgaA, Weinheim, Chap. 1.

[2] Surappa, M. K., 2003, "Aluminium matrix composites: Challenges and opportunities", Sadhana, 28(1), pp. 319-334.

[3] Chawla, N., and Chawla, K. K., 2006, "Metal Matrix Composites", Springer, USA, Chap. 4.

[4] Hashim, J., 2001, "The Production of Cast Metal Matrix Composite by A Modified Stir Casting Method", Jurnal Teknologi, University Technology Malaysia, 35(A), pp. 9-20.

[5] Bhushan, R. K., and Kumar. S., 2011, "Influence of SiC Particles Distribution and Their Weight Percentage on 7075 Al Alloy", Journal of Materials Engineering and Performance, 20, pp. 317-323.

[6] Naher, S., Brabazon, D., and Looney, L., 2007, "Computational and Experimental Analysis of Particulate Distribution during Al-SiC MMC Fabrication", Composites, 38A, pp. 719-729.

[7] Ravi, K. R., Pillai, R. M., Pai, B. B., and Chakraborty, M., 2007, "Influence of Interfacial Reaction on The Fluidity of A356 Al-SiC_p Composites: A Theoretical Approach", Metallurgical and Materials Transaction, ProQuest Science Journals, 38A(10), pp. 2531-2539.

[8] Aqida, S. N., Ghazali, M. I., and Hashim, J., 2004, "Effects of Porosity on Mechanical Properties of Metal Matrix Composite: An Overview", Journal Technology, University Technology Malaysia, 40A, pp. 17-32.

[9] Jit, N., Tyagi, A. K., Singh, N., and Singh, A., 2011, "Comparison of Porosity and Density for $(A384.1)_{1-x}$ $[(Reinforcement)_p]_x$ MMC System Using Adaptive Neuro-Fuzzy Inference System", Advances in Applied Science Research, 2(4), pp. 240-250.

[10] ASTM International, 2003, “Annual Book of ASTM Standards”, Section 3: Metals Test Methods and Analytical Procedures, Volume 03.01, Designation: E10-01.
[11] Belavendram, N., 1995, “Quality by Design: Taguchi Techniques for Industrial Experimentation”, Prentice Hall, London.
[12] Kayal, S., Behera, R., Nandi, T., and Sutradhar, G., 2011, “Solidification Behavior of Stir-Cast Al Alloy Metal Matrix Composites”, International Journal of Applied Engineering Research, Dindigul, 2(2), pp. 350-358.
[13] Behera, R., Das, S., Chatterjee, D., and Sutradhar, G., 2011, “Forgeability and Machinability of Stir Cast Aluminum Alloy Metal Matrix Composites”, Journal of Minerals & Characterization & Engineering, 10(10), pp. 923-939.
[14] Tofigh, A. A., and Shabani, M. O., 2013, “Applying Various Training Algorithms in Data Analysis of Nano Composites”, Acta Metallurgica Slovaca, 19(2), pp. 94-104.
[15] Vanarotti, M., Kori, S. A., Sridhar, B. R., and Padasalgi, S. B., 2012, “Synthesis and Characterization of Aluminum Alloy A356 and Silicon Carbide Metal Matrix Composite”, International Conference on Industrial Technology and Management (ICITM), IACSIT Press. Singapore, 49 (3), pp. 11-15.
[16] Mathur, S., and Barnawal, A., 2013, “Effect of Process Parameter of Stir Casting on Metal Matrix Composites”, International Journal of Science and Research (IJSR), vol. 2(12), pp. 395-398.
[17] Laurent, V., Chatain, D., and Eustathopoulos, N., 1987, “Wettability of SiC by Aluminum and Al- Si Alloys”, Journal of Materials Science, 22, pp. 244-250.
[18] Hashim, J., Looney, L., and Hashmi, M. S. J., 2001, “The Wettability of SiC Particles by Molten Aluminium Alloy”, Journal of Materials Processing Technology, vol. 119, pp. 324-328.
[19] Jayashree, P. K., Gowri, S. M. C., Kini, A., Sharma, S. S. and Shetty, R., 2013, “Review on Effect of Silicon Carbide (SiC) on Stir Cast Aluminium Metal Matrix Composites”, International Journal of Current Engineering and Technology, vol. 3(3), pp. 1061-1071.
[20] Muttharasan, M., Muralidharan, M., Sozhamannan, G. G., and Prabu, S. B., 2014, “Effect of Processing Temperature and Holding Time on Al/SiC Composites: An Experimental Study”, International Journal of Advanced Mechanical Engineering, vol. 4(1), pp. 69-76.
[21] Shasha, Y., Peng, Z., Yunhul, D., Jun, Z., and Xiaopeng, L., 2012, “Influence of Stirring Speed on SiC Particles Distribution in A356 Liquid”, China Foundry, vol. 9(2), pp. 154-158.
[22] Prabu, S. B., Karunamoorthy, L., Kathiresan, S., and Mohan, B., 2006, “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.

[23] Hamedan, A. D., and Shahmiri, M., 2012, "Production of A356-1 wt% SiC Nanocomposite by the Modified Stir Casting Method", Materials Science & Engineering A, vol. 556, pp. 921-926.

[24] Zhang, H., Geng, L., Guan, L., and Huang, L., 2010, "Effect of SiC Particle Pretreatment and Stirring Parameters on the Microstructure and Mechanical Properties of SiC_P/Al-6,8 Mg Composites Fabricated by Semi-solid Stirring Technique", Materials Science & Engineering A, vol. 528, pp. 513-518.