Materials and Energy Research Center
MERC

Contents lists available at ACERP

Advanced Ceramics Progress

Journal Homepage: www.acerp.ir

Original Research Article

Role of Etching Process of SiC Particles on the Microstructure and Mechanical Properties of Stir Casted Al357−SiC Metal matrix Composite

A. Talezari [a], A. R. Souri [b]*, A. Shanaghi [c]*

[a] MS, Department of Materials Engineering, Faculty of Engineering, Malayer University, Malayer, Hamedan, Iran
[b] Assistant Professor, Department of Materials Engineering, Faculty of Engineering, Malayer University, Malayer, Hamedan, Iran
[c] Associate Professor, Department of Materials Engineering, Faculty of Engineering, Malayer University, Malayer, Hamedan, Iran

ARTICLE INFO

Article History:

Received 15 June 2021
Received in revised form 07 July 2021
Accepted 14 July 2021

Keywords:

Electromagnetic Stir Casting
Etching
Aluminum Matrix Composites
Micron-Sized SiC
Mechanical Properties

ABSTRACT

Owing to their high strength-to-weight ratio, aluminum-ceramic composites, are widely used in various industries. In this study, aluminum matrix composite was fabricated with only 2 wt% micron-sized SiC particles as the reinforcing phase using electromagnetic stir casting. Prior to mixing, the surface of SiC particles were chemically etched by HF, NaOH, and KOH at two heat treatment temperatures of 460 and 510 °C for 30 min. The obtained results indicated better wettability and interaction between the etched SiC particles and Al matrix. In addition, etched SiC particle as a ceramic phase at 460 °C enhanced the mechanical properties of Al as a metal matrix, such as enhancing hardness and E about of 6.6 and 26.6%, respectively, mainly due to the increasing inhibition against movement of dislocation confirmed by the observed brittle behavior of fracture surface.

https://doi.org/10.30501/ACP.2021.289601.1066

1. INTRODUCTION

In the past few decades, numerous studies have investigated the production of low-cost, lightweight metal matrix composites. To this end, aluminum and its low-density alloys were used as matrix materials with several carbon and ceramic particles as the reinforcing materials [1-5]. Among metal matrix composites, Aluminum Metal Matrix Composites (AMMCs) have received significant attention in recent years. They are used in the aerospace (e.g., aircraft parts), automobiles and electronics industries, mainly due to their lightweight, low coefficient of Thermal Expansion (CTE), good machinability and enhanced mechanical properties including 0.2% Yield Stress (YS), Ultimate Tensile Stress (UTS) and stiffness [6-13]. Metal Matrix Composites (MMCs) are the combinations of both metals (ductility and toughness) and ceramic properties (strength and high module). Among famous metal matrix composites, aluminum matrix composites along with reinforcing materials such as Al_2O_3, B_4C, SiC and TiC improved their mechanical properties, and increased the strength-to- weight ratio. Development of SiC reinforced aluminum matrix composites has drawn considerable attention due to their lightweight, toughness, suitable elastic module, high erosion resistance, low thermal

* Corresponding Author Email: arsouri@gmail.com (A. R. Souri), alishanaghi@gmail.com, a.shanaghi@malayeru.ac.ir (A. Shanaghi)
URL: https://www.acerp.ir/article_135650.html

Please cite this article as: Talezari, A., Souri, A. R., Shanaghi, A., "Role of Etching Process of SiC Particles on the Microstructure and Mechanical Properties of Stir Casted Al357−SiC Metal matrix Composite", ***Advanced Ceramics Progress***, Vol. 7, No. 2, (2021), 10-15. https://doi.org/10.30501/ACP.2021.289601.1066

expansion coefficient and variety of fabrication methods [14,15].

There are various composite processing methods, which can be used to make the composite such as die-casting, stirrer casting, semi-solid formation, spray formation and powder metallurgy [10,16,17]. Among these methods, stirrer casting (vortex method) is commercially considered as a low-cost method for making AMMC, owing to its simplicity, flexibility, and application in high volume production. Among all available AMMC production routes, stirrer casting is the most cost-effective one that and allows industries to produce huge components. Generally, in order to obtain AMMC through casting, the following criteria should be taken into consideration: good chemical reaction between reinforcement and matrix alloy, low porosity in the found AMMCs, high wettability between reinforcement and matrix alloy, and uniform distribution of the reinforcement particles. Wettability and reactivity between the metal matrix and ceramic particles determine the quality of the bonding materials [18-25]. Two parameters, namely volume fraction and particle size of the reinforcing particles, can singinficantly affect the performance of reinforcing particles. Upon increasing the volume fraction particles, the strength increases due to more dislocation barriers; however, the ductility decreases, because the deformation is localized on a smaller volume of the plastic matrix, thus leading to its failure to deform [26].

In the stir casting process, the resulting vortex pulls reinforcing particles into the matrix, which the particles may cluster before entering the melt on the surface of the vortex and may be transferred to a relatively stagnant area and appear as a cluster in the casting structure [27]. Sharma et al. [28] used the optimization method to analyze the distribution index of ceramic particles in aluminum and the stirring casting parameters such as stirring speed, furnace temperature and preheating temperature were also examined using surface response method optimization. Suthar et al. [29] mentioned some cases such as porosity, wettability, chemical reactions and particle distribution. These problems were solved by optimizing the stirrer casting parameters. In addition, Sahu et al. [30] used gray relationship analysis to study processing parameters such as friction factors, load and aspect ratio in cold disturbance. Dutta et al. [31] evaluated the parameters of the agitator casting process to achieve effective reinforcing particles. It was observed that stirring time and processing temperature have important effects on mechanical properties (elastic modulus and inhibition) and microstructure of composites, and Kumar et al. [32] analyzed the mechanical behavior of metal matrix composites by changing the composition of the reinforcements.

In this study, the metal matrix composite of Al A357 alloy and micro-sized SiC particles was fabricated using magnetic stir casting. The main novelty of this article is related to improve wettability between the matrix and reinforcement particles, which the SiC powder was etched by NaOH-HF and KOH solutions for better wettability and distribution, thus enhancing uniform microstructure and mechanical properties of Al-SiC composite. To meet all of the mentioned criteria, the reaction between the metal matrix and ceramic phases is critical. In this regard, just 2 wt% SiC powder is used as the reinforcement phase because the machine cannot stir heavier weight well. However, obtaining uniform microstructure, low volume of defects and agglomerated ceramic particles, and high mechanical properties gains significance in fabricating metal matrix composites, evaluated systemically using XRD, SEM, and hardness and tensile tests.

2. MATERIALS AND METHODS

Table 1 presents the chemical composition of Al357, according to magnesium conatnied in this aluminum alloy contributes to the wettability and distribution of reinforcing particles. The SiC powder as a ceramic part with the particle size of 37-100 µm, was used for fabrication of metal matrix composite. To improve the wettability and proper distribution of SiC particles in the Al matrix in this study, chemical etching of SiC powder was conducted using HF, NaOH solution, and KOH powder based on the following instructions [23-25]: first, HF chemical etching was carried out using 10 g SiC powder in 10 mL HF for 2h at 40 °C; then the powder was filtered and placed in an oven at 100 °C for 2h. Second, the obtained powder was added to the stirred NaOH solution and dried at 100 °C for 2h. Third, SiC powder and KOH with the ratio of 70:30% were placed in an electric furnace (Azar furnace) at two different temperatures of 460 and 510 °C for 30 min. Then, the powders were taken out of the furnace, rinsed with distilled water until the pH reached the value of 7, and dried at room temperature (25 °C).

TABLE 1. Chemical composition of Al 357 alloy (wt%)

Al	Si	Fe	Cu	Mn	Mg	Zn	Ti
Bal.	6.5-7.2	0.15	0.05	0.03	0.45-0.6	0.05	0.2

Firstly, the SiC particles were preheated to 80 °C to completely remove the moisture content, and then the SiC reinforcement particles were gradually added to molten alloy. In the casting stage, 2 wt% etched SiC powder and A357 alloy were placed in a fireclay crucible, in an electromagnetic furnace at a temperature of 780 °C, mixer current of 60 mA, and pressure of 8 mtorr (Figure 1). The melting and mixing times were 45 and 30 minutes, respectively, and the casting temperature was 690 °C; then, the molten was poured into the mold to make the sample for analysis.

The phase, structure, chemical composition, and microstructure of the coatings were determined by X-Ray Diffraction (XRD; Philips PW-1800 X-ray diffractometer; Cu Kα λ = 0.154056 nm), Scanning Electron Microscopy (VEGA\\TESCAN-XMU), and Energy-Dispersive X-ray Spectroscopy (EDS). In addition, hardness test was carried out using D1A InstronWol Pert under 62.5 lb in the 20s, and tensile test was done using STM-20, where the samples were fabricated according to ASTM E8.

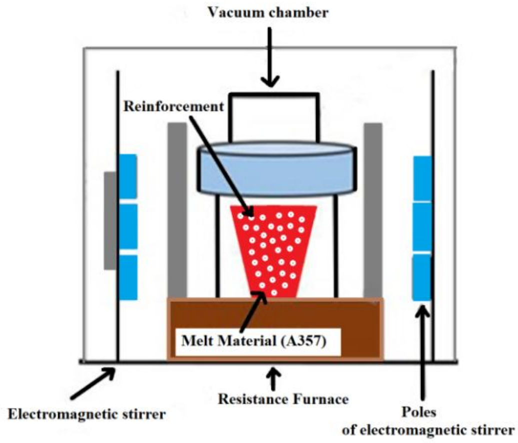


Figure 1. A schematic of the electromagnetic stir casting

3. RESULTS AND DISCUSSION

According to the XRD patterns of green SiC powder, and etched SiC powder to two temperatures of 460 °C and 510 °C in Figure 2, according to the JCPDS card No. 29-1129, all the major peaks belong to SiC with silicon carbide and moissanite structure. Here, the XRD of etched SiC powders indicate some peaks of SiC were disappeared, and changed into SiO_2 with a quartz structure at 66.47° and 76.38°, and confirm the etching process led to change the phase surface properties of SiC powders, for enhancing wettability and interaction between ceramics powder and metal matrix [33,34].

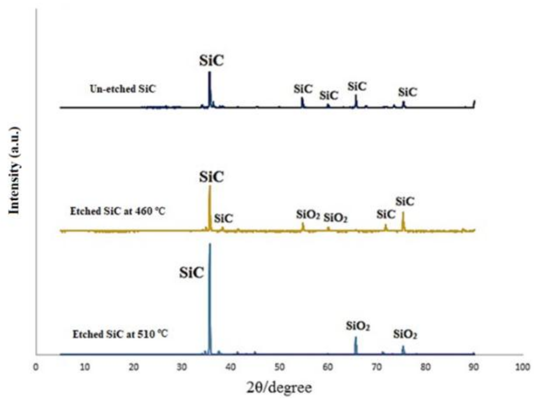


Figure 2. XRD patterns of unetched SiC, etched SiC at 460 and 510 °C

Figure 3 depicts the Back-Scattered Electrons (BSE) images of Al357, Al- un-etched SiC metal matrix composite (AS), and Al-etched SiC metal matrix composite at two different heat treatment temperatures in the etching process. The BSE images indicate that the wettability between the un-etched SiC powder and Al melting is not suitable and the particles still exist on the sample surface (Figure 3c and d). However, the etching of SiC powder causes accumulation of SiC particles in some parts of the Al- etched SiC composite, hence good distribution of SiC particles on the samples, etched at 460 °C rather than 510 °C. These microstructural properties of Al-etched SiC composite are in agreement with the results of obtained by Amirkhanlou et al. [33], Song [16] and El-Sabbagh et al. [17]. Figure 4 presents the secondary electron image of the sample etched at 460 °C to provide a better understanding of the surface of Al-etched SiC composite, demonstaring the proper reaction and relation interface between SiC particle and Al matrix, that includs more than 90% Al with silicon, magnesium and iron, respectively for particle B, which was placed next to the particle A. Part C, which is marked in white, presents the Al-Fe-Si phase.

Table 2 summarizes the mechanical properties of the samples, determined by tensile tests. The obtianed results indicated that some defects such as pores and holes could be eliminated through Ultimate Tensile Strength (UTS). The ultimate strength of thesamples etched for 30 min at 460 °C was higher than that of other samples, which heat treated at 510 °C. However, all the strength values were lower than those of the Al- unetched SiC composite. Such a low strength value would cause defects such as cavities and pores on the surface of the samples; this finding is in agreemnet with the results obtained by Lioyd et al. [15] and Balaji et al. [34]. Actually, understanding of the mam sources of the porosity could be helpful in avoiding or decreasing porosity and defect of casting. In general porosity arises from three causes, firstly, gas entrapment during stirring, secondly, hydrogen evolution, and finally, shrinkage during solidification. However, the better interface reaction between the Al matrix and etched SiC at 460 °C, could cause more shrinkage during solidification and hydrogen evolution [35], which need more detailed research about this phenomenon. In addition, the hardness of Al- unetched SiC composite is 56.8 BHN, which is similar to Al 357. However, the etching process can enhance the hardness of Al- etched SiC composite, which can be related to much wettability and the interaction between SiC particle and Al matrix. This result indicates a 12% increase in hardness by adding the SiC particles from 0 to 5%. Of note the maximum E belongs to Al- etched SiC composite heat-treated at 460 °C. Totally, the obtanied results confirmed that the etching SiC particle at 460 °C exhibits better mechanical properties than other samples.

TABLE 2. Mechanical properties such as Ultimate Tensile Strength, Brinell Hardness and Young's Modulus values of Al 357, Al- unetched SiC composite (AS), and heat treated Al-etched SiC composite at 460 °C and 510 °C

Mechanical test	Al 357	AS	460 °C	510 °C
Ultimate Tensile Strength (MPa)	181.4	201.37	191.35	181.06
Brinell Hardness (BHN)	56.8	56.8	60.54	61.1
Young's modules (MPa)	14.907	12.570	15.912	13.064

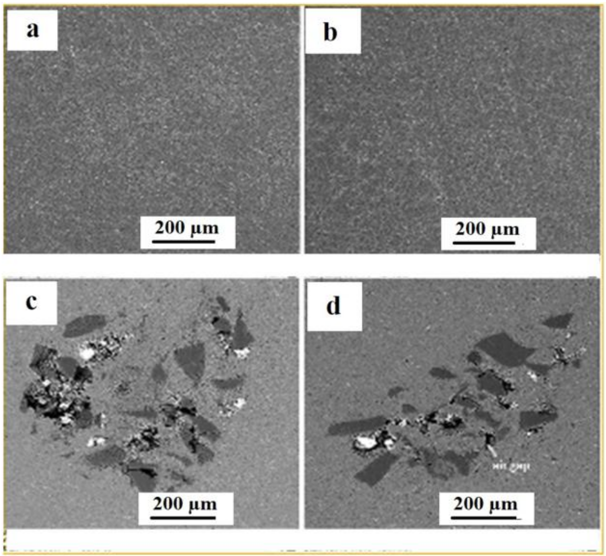
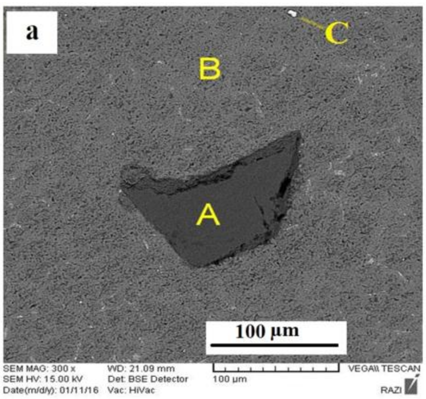


Figure 3. BSE image of, a) Al 357 b) Al-un-etched SiC composite, and heat treated Al- etched SiC composite at c) 460 °C, and d) 510 °C



b

Element (Wt%)	series	A	B	C
Aluminum	K		94.80	71.32
Silicon	K	76.95	4.81	7.35
Carbon	K	23.05		
Iron	K		0.33	21.33
Magnesium	K		0.06	

Figure 4. SEM image and EDX results of heat treated Al- etched SiC composite at 460 °C

In order to better study the mechanical behavior of Al-SiC composite, the fracture surface of samples after tensile test were observed through the SEM image (Figure 5). Obviously, the Al- etched SiC composite, heat-treated at 460 °C, exhibits brittle behavior compared to other samples, mainly due to more distribution of etched SiC particles in the Al matrix. In fact, SiC as a ceramic phase enhances the mechanical properties of Al as a metal matrix due to increased inhibition against the movement of dislocation. This finding is consistent with the results of such researches as Dong et al. [26], Cioffi et al. [36] and Li et al. [37].

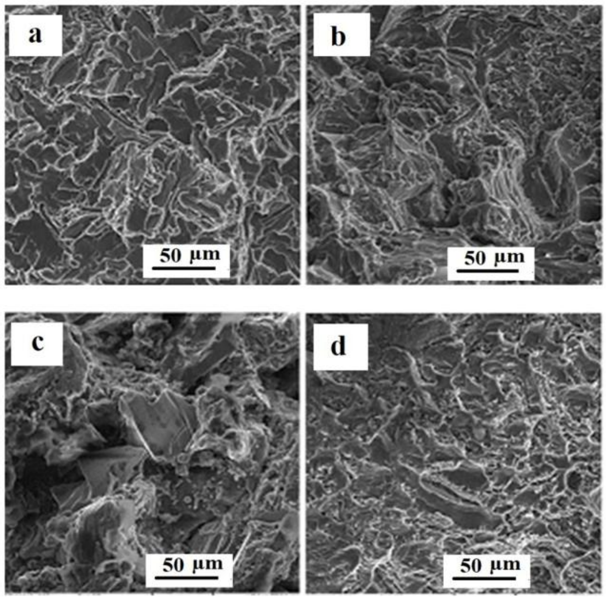


Figure 5. SEM images from the fracture surfaces of, a) Al 357 b) Al-unetched SiC composite, and heat treated Al-etched SiC composite at c) 460 °C, and d) 510 °C

4. CONCLUSION

In this study, micron-sized SiC particles were incorporated into a melt of pure aluminum using etching particles in HF, NaOH Solution and KOH powder to improve the wettability and interaction between SiC and Al matrices and fabricate aluminum matrix composite due to changes in the phase surface properties of SiC powders to SiO_2 phase, as well as good distribution of SiC particles at heat treatment temperature of 460 °C. According to the finding, the ultimate strength of samples etched for 30 min at 460 °C is higher compared to other samples, heat treated at 510 °C, and etched SiC particle as a ceramic phase at 460 °C enhanced the mechanical properties of Al as a metal matrix (enhancing hardness and E about 6.6 and 26.6%, respectively), due to increased inhibition against movement of dislocation. The fracture surface of the Al- etched SiC composite is heat treated at 460 °C, exhibits brittle behavior rather than other samples, that can be related to more distribution etched SiC particles in the Al matrix.

ACKNOWLEDGEMENTS

This work was financially supported by Malayer University Research Grant No. 1397.

REFERENCES

1. Surappa, M. K., “Aluminum matrix composites: challenges and opportunities”, ***Sadhana***, Vol. 28, No. 1-2, (2003), 319-334. https://doi.org/10.1007/BF02717141
2. Kumar, G. S. P., Koppad, P. G., Keshavamurthy, R., Alipour, M., “Microstructure and mechanical behavior of in situ fabricated AA6061-TiC metal matrix composites”, ***Archives of Civil and Mechanical Engineering***, Vol. 17, No. 3, (2017), 535-544. https://doi.org/10.1016/j.acme.2016.12.006
3. Murthy, K. S., Girish, D. P., Keshavamurthy, R., Varol, T., Koppad, P. G., “Mechanical and thermal properties of AA7075/TiO_2/Fly ash hybrid composites obtained by hot forging”, ***Progress in Natural Science: Materials International***, Vol. 27, No. 4, (2017), 474-481. https://doi.org/10.1016/j.pnsc.2017.08.005
4. Ram, H. A., Koppad, P. G., Kashyap, K. T., “Influence of multiwalled carbon nanotubes on the aging behavior of AA 6061 alloy matrix nanocomposites”, ***Transactions of the Indian Institute of Metals***, Vol. 67, No. 3, (2014), 325-329. https://doi.org/10.1007/s12666-013-0350-y
5. Ebrahimi, M., Zarei-Hanzaki, A., Abedi, H. R., Azimi, M., Mirjavadi, S. S., “Correlating the microstructure to mechanical properties and wear behavior of an accumulative back extruded Al-Mg2Si in-situ composite”, ***Tribology International***, Vol. 115, (2017), 199-211. https://doi.org/10.1016/j.triboint.2017.05.034
6. Roshan, M. R., Mousavian, T. R., Ebrahimkhani, H., Mosleh, A., “Fabrication of Al-based composites reinforced with Al_2O_3–TiB_2 ceramic composite particulates using vortex-casting method”, ***Journal of Mining and Metallurgy, Section B: Metallurgy***, Vol. 49, No. 3, (2013), 299-305. https://doi.org/10.2298/JMMB120701032R
7. Valibeygloo, N., Khosroshahi, R. A., Mousavian, R. T., “Microstructural and mechanical properties of Al-4.5 wt% Cu reinforced with alumina nanoparticles by stir casting method”, ***International Journal of Minerals, Metallurgy, and Materials***, Vol. 20, No. 10, (2013), 978-985. https://doi.org/10.1007/s12613-013-0824-2
8. Mohammadpour, M., Khosroshahi, R. A., Mousavian, R. T., Brabazon, D., “Effect of interfacial-active elements addition on the incorporation of micron-sized SiC particles in molten pure aluminum”, ***Ceramics International***, Vol. 40, No. 6, (2014), 8323-8332. https://doi.org/10.1016/j.ceramint.2014.01.038
9. Mohammadpour, M., Khosroshahi, R. A., Mousavian, R. T., Brabazon, D., “A novel method for incorporation of micron-sized SiC particles into molten pure aluminum utilizing a Co coating”, ***Metallurgical and Materials Transactions B***, Vol. 46, No. 1, (2015), 12-19. https://doi.org/10.1007/s11663-014-0186-9
10. 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 Materials Processing Technology***, Vol. 166, No. 3, (2005), 430-439. https://doi.org/10.1016/j.jmatprotec.2004.09.043
11. Naher, S., Brabazon, D., Looney, L., “Computational and experimental analysis of particulate distribution during Al–SiC MMC fabrication”, ***Composites Part A: Applied Science and Manufacturing***, Vo. 38, No. 3, (2007), 719-729. https://doi.org/10.1016/j.compositesa.2006.09.009
12. Mousavian, R. T., Damadi, S. R., Khosroshahi, R. A., Brabazon, D., Mohammadpour, M., “A comparison study of applying metallic coating on SiC particles for manufacturing of cast aluminum matrix composites”, ***The International Journal of Advanced Manufacturing Technology***, Vol. 81, No. 1, (2015), 433-444. https://doi.org/10.1007/s00170-015-7246-4
13. Boostani, A. F., Tahamtan, S., Jiang, Z. Y., Wei, D., Yazdani, S., Khosroshahi, R. A., Mousavian, R. T., Xu, J., Zhang, X., Gong, D., “Enhanced tensile properties of aluminum matrix composites reinforced with graphene encapsulated SiC nanoparticles”, ***Composites Part A: Applied Science and Manufacturing***, Vol. 68, (2015), 155-163. https://doi.org/10.1016/j.compositesa.2014.10.010
14. Ray, S., “Synthesis of cast metal matrix particulate composites”, ***Journal of Materials Science***, Vol. 28, No. 20, (1993), 5397−5413. https://doi.org/10.1007/BF00367809
15. Lloyd, D. J., “Particle reinforced aluminium and magnesium matrix composites”, ***International Materials Reviews***, Vol. 39, No. 1, (1994), 1−23. https://doi.org/10.1179/imr.1994.39.1.1
16. Song, M., “Effects of volume fraction of SiC particles on mechanical properties of SiC/Al composites”, ***Transactions of Nonferrous Metals Society of China***, Vol. 19, No. 6, (2009), 1400-1404. https://doi.org/10.1016/S1003-6326(09)60040-6
17. El-Sabbagh, A. M., Soliman, M., Taha, M. A., Palkowski, H., “Effect of rolling and heat treatment on tensile behaviour of wrought Al-SiCp composites prepared by stir-casting”, ***Journal of Materials Processing Technology***, Vol. 213, No. 10, (2013), 1669-1681. https://doi.org/10.1016/j.jmatprotec.2013.04.013
18. Seo, Y. H., Kang, C. G., “Effects of hot extrusion through a curved die on the mechanical properties of SiCp/Al composites fabricated by melt-stirring”, ***Composites Science and Technology***, Vol. 59, No. 5, (1999), 643-654. https://doi.org/10.1016/S0266-3538(98)00123-7
19. Xu, Y., Chung, D. D. L., “Low-volume-fraction particulate preforms for making metal-matrix composites by liquid metal infiltration”, ***Journal of Materials Science***, Vol. 33, No. 19, (1998), 4707-4709. https://doi.org/10.1023/a:1004480819365
20. Naher, S., Brabazon, D., Looney, L., “Simulation of the stir casting process”, ***Journal of Materials Processing Technology***, Vol. 143-144, (2003), 567-571. https://doi.org/10.1016/S0924-0136(03)00368-6
21. Seo, Y. H., Kang, C. G., “The effect of applied pressure on particle-dispersion characteristics and mechanical properties in melt-stirring squeeze-cast SiCp/Al composites”, ***Journal of Materials Processing Technology***, Vol. 55, No. 3-4, (1995), 370-379. https://doi.org/10.1016/0924-0136(95)02033-0
22. Skibo, M., Morris, P. L., Lloyd, D. J., “Structure and properties of liquid metal processed SiC reinforced aluminium”, In ***Cast Reinforced Metal Composites: Proceedings of the International Symposium on Advances in Cast Reinforced Metal Composites Held in Conjunction with the 1988 World Materials Congress,*** Fishman, S. G. and Dhingra, A. K. (eds.), Chicago, Illinois, 24-30 September 1988, USA: ASM International, (1988), 257-261. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.997.7513&rep=rep1&type=pdf#page=253
23. Arima, K., Hara, H., Murata, J., Ishida, T., Okamoto, R., Yagi, K., Sano, Y., Mimura, H., Yamauchi, K., “Atomic-scale flattening of SiC surfaces by electroless chemical etching in HF solution with Pt catalyst”, ***Applied Physics Letters***, Vol. 90, No. 20, (2007), 202106. https://doi.org/10.1063/1.2739084
24. Weyher, J. L., “Characterization of wide-band-gap semiconductors (GaN, SiC) by defect-selective etching and complementary methods”, ***Superlattices and Microstructures***, Vol. 40, No. 4-6, (2006), 279-288. https://doi.org/10.1016/j.spmi.2006.06.011

25. Van Dorp, D. H., Weyher, J. L., Kelly, J. J., "Anodic etching of SiC in alkaline solutions", ***Journal of Micromechanics and Microengineering***, Vol. 17, No. 4, (2007), S50. https://doi.org/10.1088/0960-1317/17/4/S04
26. Dong. P. Y., Zhao, H. D., Chen, F. F., Li, J. W., "Microstructures and properties of A356–10% SiC particle composite castings at different solidification pressures", ***Transactions of Nonferrous Metals Society of China***, Vol. 23, No. 8, (2013), 2222-2238. https://doi.org/10.1016/S1003-6326(13)62721-1
27. Kumar, M. S., Begum, S. R., Pruncu, C. I., Asl, M. S., "Role of homogeneous distribution of SiC reinforcement on the characteristics of stir casted Al–SiC composites", ***Journal of Alloys and Compounds***, Vol. 869, (2021), 159250. https://doi.org/10.1016/j.jallcom.2021.159250
28. Sharma, A., Rastogi, V., Agrawal, A. K., "Multi-parametric optimisation by quantitative assessment of distribution index and area fraction of composite", ***Practical Metallography***, Vol. 57, No. 9, (2020), 588–613. https://doi.org/10.3139/147.110636
29. Zhang, W. Y., Du, Y. H., Zhang, P., "Vortex-free stir casting of Al-1.5 wt% Si–SiC composite", Journal of Alloys and Compounds, Vol. 787, (2019), 206–215. https://doi.org/10.1016/j.jallcom.2019.02.099
30. Sahu, M. K., Valarmathi, A., Baskaran, S., Anandakrishnan, V., Pandey, R. K., "Multi- objective optimization of upsetting parameters of Al–TiC metal matrix composites: A grey Taguchi approach", ***Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture***, Vol. 228, No. 11, (2014), 1501–1507. https://doi.org/10.1177/0954405413519434
31. Dutta, S., Narala, S. K. R., "Experimental investigation to study the effects of processing parameters on developed novel AM (Al–Mn) series alloy", ***Materials and Manufacturing Processes***, Vol. 35, No. 16, (2020), 1842-1851. https://doi.org/10.1080/10426914.2020.1813889
32. Kumar, A., Kumar, P., Singh, R. C., "The effect of alumina on mechanical behavior of Al 6064 alloy", In ***IOP Conference Series: Materials Science and Engineering***, Vol. 802, No. 1, (2020), 012004. https://doi.org/10.1088/1757-899X/802/1/012004
33. Amirkhanlou, S., Niroumand, B., "Effects of reinforcement distribution on low and high temperature tensile properties of Al356/SiCp cast composites produced by a novel reinforcement dispersion technique", ***Materials Science and Engineering: A***, Vol. 528, No. 24, (2011), 7186-7195. https://doi.org/10.1016/j.msea.2011.06.013
34. Balaji, V., Sateesh, N., Hussain, M. M., "Manufacture of aluminium metal matrix Composite (Al7075-SiC) by Stir Casting Technique", ***Materials Today: Proceedings***, Vol. 2, No. 4-5, (2015), 3403-3408. https://doi.org/10.1016/j.matpr.2015.07.315
35. Orlowicz, W., Tupaj, M., Mróz, M., Betlej, J., Ploszaj, F., "Effect of refining process on porosity and mechanical properties of high pressure Al-Si alloy die casting", ***Iranian Journal of Materials Science and Engineering***, Vol. 9, No.1, (2012), 1-10. http://ijmse.iust.ac.ir/article-1-409-en.html
36. Cioffi, F., Ibáñez, J., Fernández, R., González-Doncel, G., "The effect of lateral off-set on the tensile strength and fracture of dissimilar friction stir welds, 2024Al alloy and 17% SiC/2124Al composite", ***Materials & Design (1980-2015)***, Vol. 65, (2015), 438-446. https://doi.org/10.1016/j.matdes.2014.09.042
37. Li, X. P., Liu, C. Y., Ma, M. Z., Liu, R. P., "Microstructures and mechanical properties of AA6061–SiC composites prepared through spark plasma sintering and hot rolling", ***Materials Science and Engineering: A***, Vol. 650, (2016), 139-144. https://doi.org/10.1016/j.msea.2015.10.015