Materials Sciences and Applications, 2023, 14, 1-19
https://www.scirp.org/journal/msa
ISSN Online: 2153-1188
ISSN Print: 2153-117X

Development and Characterization of Aluminium-Based Metal Matrix Composites

M. A. Gafur[1], Al Fahad Ahmed[2], Raisul Abrar[2], Surya Sabrin Soshi[3]

[1]Pilot Plant & Process Development Centre, Bangladesh Council of Scientific & Industrial Research (BCSIR), Dhaka, Bangladesh
[2]Department of Naval Architecture and Marine Engineering, Military Institute of Science and Technology, Dhaka, Bangladesh
[3]Department of MPE, AUST, Dhaka, Bangladesh
Email: d_r_magafur@yahoo.com, shadahmed162@gmail.com, raisulabrar@gmail.com, rayarin007@gmail.com

How to cite this paper: Gafur, M.A., Ahmed, A.F., Abrar, R. and Soshi, S.S. (2023) Development and Characterization of Aluminium-Based Metal Matrix Composites. *Materials Sciences and Applications*, **14**, 1-19.
https://doi.org/10.4236/msa.2023.141001

Received: October 2, 2022
Accepted: January 26, 2023
Published: January 29, 2023

Abstract

Aluminum based metal matrix composites were fabricated using stir casting where silicon carbide and alumina were the reinforcements. Different types of properties (physical-density, mechanical-tensile, hardness, chemical-corrosion etc.) were measured and compared with base metals/alloys. The properties were significantly varied. The highest density was obtained for pure aluminium with 5% Al_2O_3 whereas the lowest was obtained for AA-4032 alloy. The highest hardness was obtained for AA-4032 with 5% Al_2O_3 whereas the lowest was obtained for pure Al with 5% Al_2O_3. The highest strength was obtained for AA-6061 with 5% coarse SiC whereas the lowest was obtained for pure Al. The highest impact strength was obtained for AA-4032 with 5% Al_2O_3 whereas the lowest was obtained for AA-6061. The corrosion resistance of all composites was lower than that of the base materials.

Keywords

Al, AA-6061, AA-4032, SiC, Al_2O_3, Stir-Casting, Metal Matrix Composite, MMC, Nanocomposites

1. Introduction

A new material known as a composite is created by mixing two or more different suggested materials, such as metal, ceramic, or plastic, to provide qualities that are superior to those of the parent materials alone. Composites are now regarded as one of the most important tribes of engineered materials in the modern era. Due to their exceptional specific strength, stiffness, and high thermal and electrical conductivities, these composites have also drawn attention. In addition to its usage for structural purposes, composites are also used in electrical, thermal, tribological, and environmental applications. Because of their superior machining, joining, and processability, Al-based metal matrices are referred to as adaptable materials that may be employed for a wide range of engineering applications. Al alloys are better material for engineering applications due to their inexpensive cost, enhanced strength-to-weight ratio, high elastic modulus and other ecologically favorable features. The reinforcement consists of the discontinuous members silicon carbide (SiC) and aluminium oxide (Al_2O_3) used to strengthen the aluminum metal, while the continuous phase (aluminum or aluminum alloy) in molten form during casting is known as the matrix, which becomes solid after solidification. In this study, SiC and Al_2O_3 was used because of their diverse properties and availability. SiC is a commonly used and economical choice for reinforcement. SiC is hard, brittle but it can enhance ductility, density and hardness. SiC reinforced MMC is very cost effective and easy to cast. Like SiC, Al_2O_3 was chosen because of its versatile properties. Al_2O_3 is a hard ceramic particle that has high thermal conductivity and can supplement the mechanical and tribological properties. Alumina can also be helpful for weathering as metal aluminium can be reactive with the atmospheric oxygen. Depending on the need and application, many researchers created a variety of composite materials employing various matrices, reinforcement sizes, shapes, and volumes, as well as acceptable processing methods. According to Balasivanandha Prabu *et al.*, by adjusting the stirring speed and duration, it was possible to improve the performance of the aluminum-Si-based composite by adding 10% silicon carbide [1]. Various effects on microstructure and other properties change with varying stirring speed and time. According to B. Roebuck *et al.*'s research, silicon carbide (SiCp)-reinforced aluminum metal matrix composites (MMC) outperform comparable non-reinforced matrix alloy systems in terms of yield strength, thermal expansion coefficient, elastic modulus, and wear resistance by up to 20% [2]. When the stirring speed and duration are changed, different impacts on the microstructure and other properties also change. According to Amit Raturi *et al.*, yield strength constantly increases with an increase in Al_2O_3 particle concentration up to 1 weight percent, but when more particles are added—1.5 weight percent, yield strength decreases [3]. The ultimate tensile strength and yield strength of the composite increased by 37% and 81%, respectively, relative to the alloy matrix at the optimal concentration of nano-Al_2O_3 particulates (1 wt%). A359/Al_2O_3 composite was created by Abhishek Kumar *et al.* using the electromagnetic stir casting method [4]. The author noticed that compared to pure alloy, the hardness values increased to 72.8 HRC (46HRC). In addition, compared to pure alloy (103.7 N/mm^2), the composite's tensile strength increased to 148.7 N/mm^2. The size of the Al_2O_3 particle affects wear behavior. Wear resistance also increases as particle size increases. According to the literature, there has been comparatively less research on the electrical and thermal properties of SiC and Al_2O_3 reinforced Al-MMC, but much more on the microstructure and mechanical properties (hardness, tensile qualities, friction). Therefore, using silica and alumina as reinforcement, we experimentally examined the composite's electrical, thermal, and mechanical properties. Another fabrication technique, such as squeeze casting, powder casting, spray casting, etc., can be used to carry out the same experiment, and the results can then be compared to those of the stir casting technique. By using different reinforcement grains of the same particle, as in this experiment, the research can be furthered. A number of properties like thermal expansion coefficient, corrosion resistance etc. of the SiC/Al_2O_3 reinforced Al/Al alloys MMC are not well studied. This study focused on the different properties of SiC/Al_2O_3 reinforced Al/Al alloys MMC.

2. Experimental Procedure

2.1. Materials

All the raw materials (Pure Al, AA-6061, AA-4032, SiC) were collected from local market (chemical composition shown in **Tables 1(a)-(c)**). **Table 2** shows the size distribution of the course and fine SiC particles. **Table 3** shows composition of 7 samples of MMC.

Table 1. (a) The chemical composition of pure Aluminium; (b) The chemical composition of AA-6061; (c) The chemical composition of AA-4032.

(a)

% Fe	Si	Al
0.13	0.55	99.22

(b)

% Ti	% Mn	% Cu	% Fe	% Zn	Mg	Si	Al
0.02	0.02	0.35	0.6	0.7	0.75	0.85	96.71

(c)

% Cr	% Zn	% Ti	% Cu	% Mn	% Mg	% Fe	% Si	Al
0.02	0.02	0.02	0.05	0.06	0.23	0.28	13.25	86.07

Table 2. The Size of course and fine SiC.

Course		Fine	
Size	Amount (%)	Size	Amount (%)
2 - 1 mm	96.530	-	-
1 - 0.50 mm	3.190	1 - 0.50 mm	0.182%
0.5 - 0.25 mm	0.189	0.50 - 0.25 mm	99.259%
0.25 - 0.125 mm	0.043	0.25 - 0.125 mm	0.559%
0.125 - 0.063 mm	0.043	0.125 - 0.63 mm	-

Table 3. Different types of sample.

Sample 1	AA-6061 + 5% Coarse SiC	Sample 5	Pure Al
Sample 2	AA-6061 + 5% Finer SiC	Sample 6	AA-6061
Sample 3	Pure Al + 5% Al_2O_3	Sample 7	AA-4032
Sample 4		AA-4032 + 5% Al_2O_3	

2.2. Fabrication

A crucible furnace (VBF-1200×, MTI corporation, USA) to melt the metal/alloys used as matrix of the MMC. 40 min requires to raise the temperature 750˚C and then it was kept at 750˚C for 30 min. A local made stir casting set was used for making MMC (as shown in Figure 1). A motor was utilized to regulate the stirrer's rotation. In order to control the motor's rpm, we connected a dimmer to it. The controlled voltage range for the dimmer was from 0 to 250 Volts. The motor's RPM range was 250. A steel frame that served as a hanger for the motor was placed in the center of the furnace.

2.3. Testing

Density is measured with the help of Archimedes' principle using electronic balance (AS 220/C/2, RADWAG, Polland).

To determine the hardness of the material a micro-hardness tester (HMV-2T, Shimadzu Corporation, Japan) was used in this work. Samples with a 10 × 5 × 5 mm dimension were used for the hardness test. The specimens were polished using different grades of emery (400 to 1800). The samples were tested after being polished. The indentation was place for 10 seconds with 500 g of load. Five indentions were measured and the average was ultimately chosen.

The materials were cut into precise measurements for tensile testing after creating the appropriate samples. A computer operated UTM (H10KS, Hounsfield, UK) was used for tensile properties measurement. 5 samples were used for each set of sample. The arms moved at a 2 mm/second speed.

The impact test of the manufactured materials was measured using impact tester (QPI-IC-21J, Qualitest, USA). The experiment's specimens were 40 × 10 × 10 mm in size with V-shaped notch at the center with 2 mm depth and 45˚ notch angle. 3 samples were used for each set of sample test.

3. Result and Discussion

3.1. Physical Properties

Physical properties are those properties that can be measured without changing the composition of the material. In our present work, we only measure density as the physical properties of the material.

3.1.1. Density Measurement

Results of calculated density are illustrated in Figure 2.

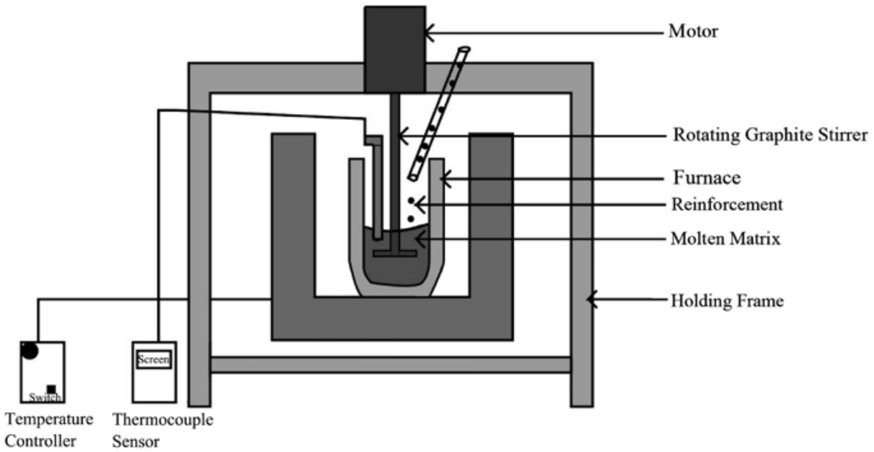


Figure 1. Stir casting setup.

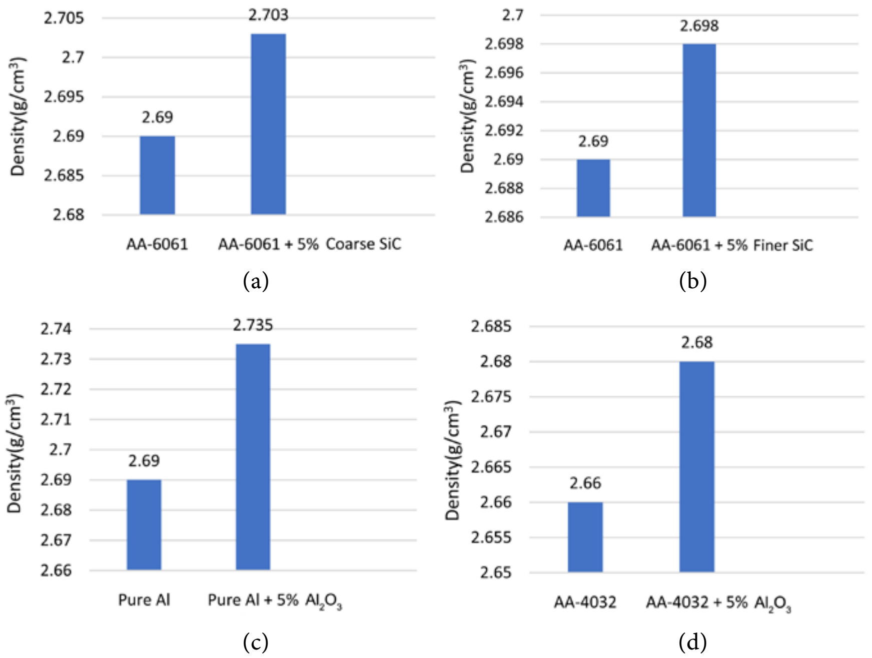


Figure 2. (a) Effect of 5% course SiC addition with AA 6061 alloy on density; (b) Effect of 5% fine SiC addition with AA 6061 alloy on density; (c) Effect of 5% Al_2O_3 addition with Pure Al on Density; (d) Effect of 5% Al_2O_3 addition with AA 4032 alloy on density.

Figure 2(a) shows the effect of course SiC addition on the density of AA-6061 it shows that the density increases with the addition of SiC. It is because of denser particle (3.21 gm/cc) addition with lighter materials AA-6061 (2.70 gm/cc). According to mixer rule, the density of the MMC is 2.7255 which is very similar to obtained density of the MMC (2.703 gm/cc). The slight variation might be associated with voids. Figures 3(b)-(d) show the effect particulate additions (5% fine SIC, 5% Al_2O_3, and 5% Al_2O_3) on different matrix (AA-6061, pure Al and AA-4032). Both the reinforcements are denser than the pure Al/Al alloy. From the above bar charts, the density of the matrix is raised when a greater density reinforcement is used with a lower density matrix material. According to

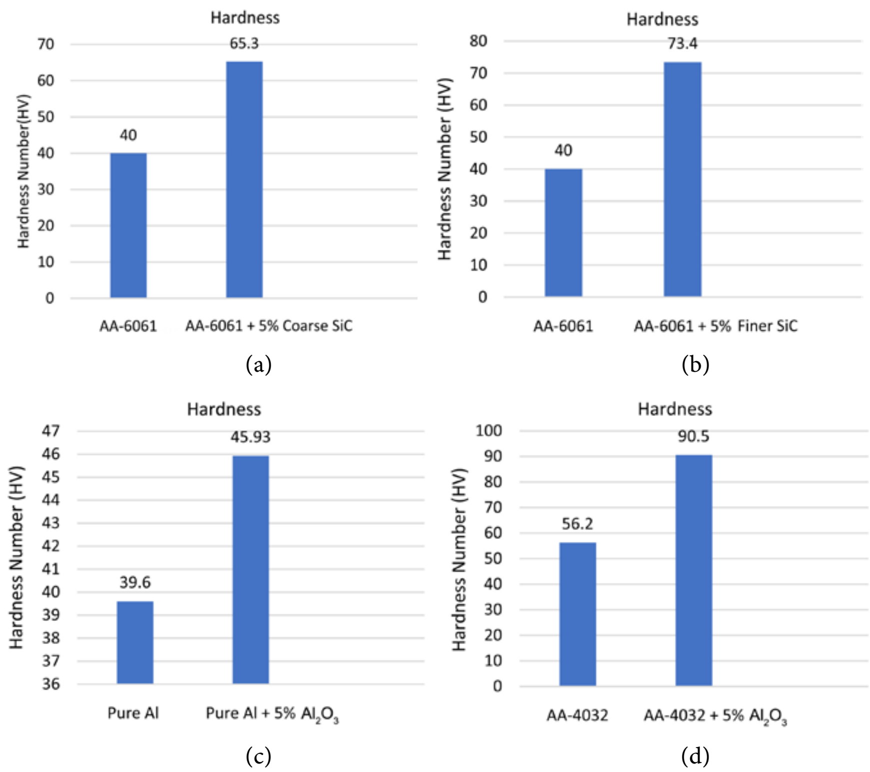


Figure 3. (a) Effect of 5% coarse SiC addition with AA-6061 alloy on Hardness; (b) Effect of 5% fine SiC addition with AA-6061 alloy on Hardness; (c) Effect of 5% Al_2O_3 addition with Pure Al on Hardness; (d) Effect of 5% Al_2O_3 addition with AA-4032 alloy on Hardness.

Ozben T, Kilickap Erol *et al.* the average density of aluminium alloy is 2.6 and after adding reinforcement, the density increases [5]. The density of SiC and alumina are 3.21 and 3.95 gm/cc.

Very similar results were obtained by Balasubramanya *et al.* (2019).

3.2. Mechanical Properties

Different mechanical properties of the composites are discussed below:

3.2.1. Hardness Test

Figure 3(a) and **Figure 3(b)** show the effect SiC addition on AA-6061. It shows that with 5% course SiC addition enhances the hardness at 63.25%. For 5% fine SiC enhances the hardness 83.5% (**Figure 1(b)**). Finer particle increases hardness more because of more surface area to resist the slip. **Figure 4(c)** and **Figure 4(d)** show effect of 5% Alumina addition on pure Al and AA-4.32 alloy. The increase in hardness is 15.98%, and 61.03%, respectively. The base materials behave differently. AA-4032 yield more hardness than that of pure aluminium.

The material's resistance to plastic deformation was boosted via particle reinforcement, which also increased the material's hardness. From the results above, it can be inferred that adding reinforcement to the matrix material resulted in the manufactured material's hardness being higher than the base material. The

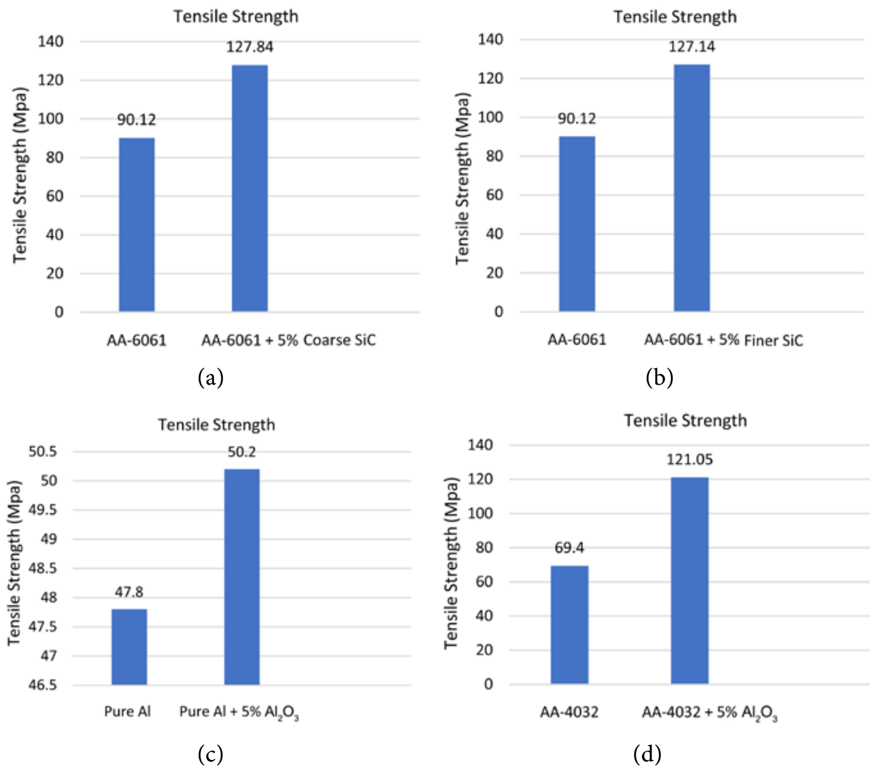


Figure 4. (a) Effect of 5% Coarse SiC Addition with AA 6061 alloy on Tensile Strength; (b) Effect of 5% fine SiC Addition with AA 6061 alloy on Tensile Strength; (c) Effect of 5% Al_2O_3 Addition with Pure Al on Tensile Strength; (d) Effect of 5% Al_2O_3 Addition with AA 4032 alloy on Tensile Strength.

test findings demonstrate that the composite's hardness increases when hard particles are present inside the matrix. Balasubramanya HS obtained HV20.5 to 30 with the increase of SiC upto 20% SiC in pure Al.

3.2.2. Tensile Test

Figure 4(a) and **Figure 4(b)** show the effect SiC addition on UTS of AA-6061. It shows that with 5% course SiC addition enhances the UTS at 41.85%. For 5% fine SiC enhances the hardness 41.07% (**Figure 4(b)**). **Figure 4(c)** and **Figure 4(d)** show effect of 5% Alumina addition on pure Al and AA-4.32 alloy. The increase in hardness is 5.02%, and 72.42%, respectively. The base materials behave differently. AA-4032 yield more strength than that of pure aluminium.

From literature evaluations, numerous instances of a similar outcome were seen. According to Mohamed *et al.* MMC made of AA-6061 and 5% SiC has an approximate 70 MPa tensile strength and a 55% elongation [6]. Chiga *et al.* found that AA-6061 with 5% SiC had an elongation of 17.5% and a tensile strength of 52.08 MPa [7].

Figure 5 shows that the elongation of Al and Al alloys with the addition 5% particulate materials. It shows that the % of elongation increases for all except for AA-4032. From **Figure 5(c)**, the pure Al + 5% Al_2O_3 sample shows more ductile than any other alloys (**Figures 5(a)-(c)**). According to the third sample's

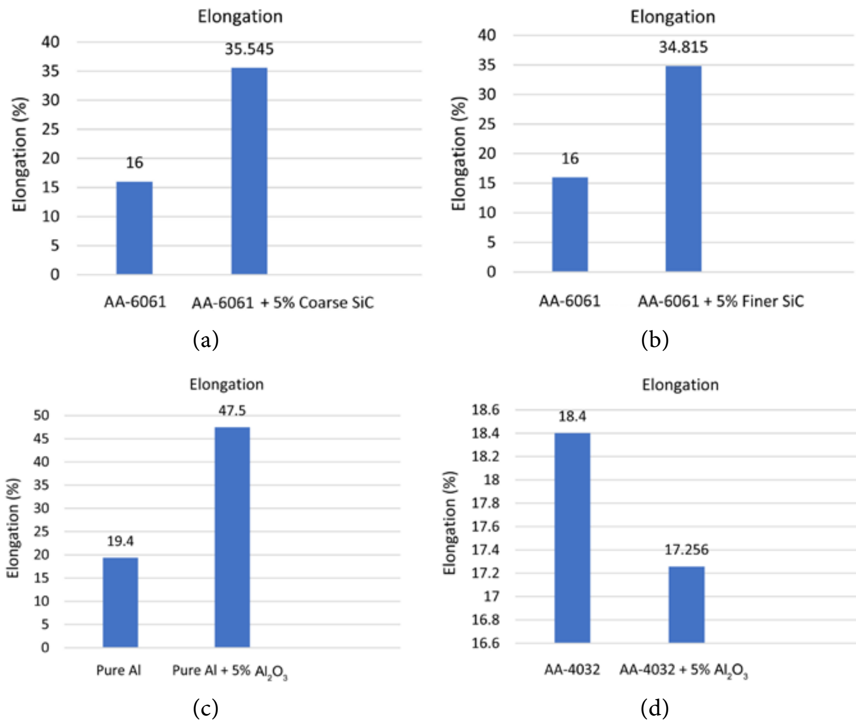


Figure 5. (a) Effect of 5% Coarse SiC Addition with AA-6061 alloy on Elongation; (b) Effect of 5% fine SiC addition with AA-6061 alloy on Elongation; (c) Effect of 5% Al_2O_3 Addition with Pure Al on Elongation; (d) Effect of 5% Al_2O_3 Addition with AA-4032 alloy on Elongation.

elongation %, it has ductile properties as found in Figure 5(c). The AA-4032 + 5% Al_2O_3 composite, on the other hand, has very little elongation and is hence a brittle material.

Based on extensive literature reviews, instances of similar outcomes were seen. According to Mohamed *et al.*, MMC of AA-6061 and 5% SiC had an elongation of 55% [6]. Additionally, Chiga *et al.* found that AA-6061 with 5% SiC had an elongation of 17.5% [7].

3.2.3. Impact Test

Results of Izod impact test measurements are illustrated in below.

Figure 6 shows the impact energy of Al and Al alloys with the addition 5% particulate materials From the preceding figure, it can be inferred that the AA-4032 + 5% Al_2O_3 sample fractures at a maximum energy of 24.08 J. The all-fabricated composites' impact energy is raised in this instance. Figure 6(a) and Figure 6(b) show that sample 1 and 2 have the most increased impact energy than its base materials.

Ozden *et al.* noticed the attributes of AA-6063 reinforced with approximately 5% SiC (511 m^2) heat treated at 515˚C and liquid cooled for 2 hours had an impact strength of 13.08 J. This was used as a comparison. Compared to the publication, these results were more favorable [8].

Electrical Properties:

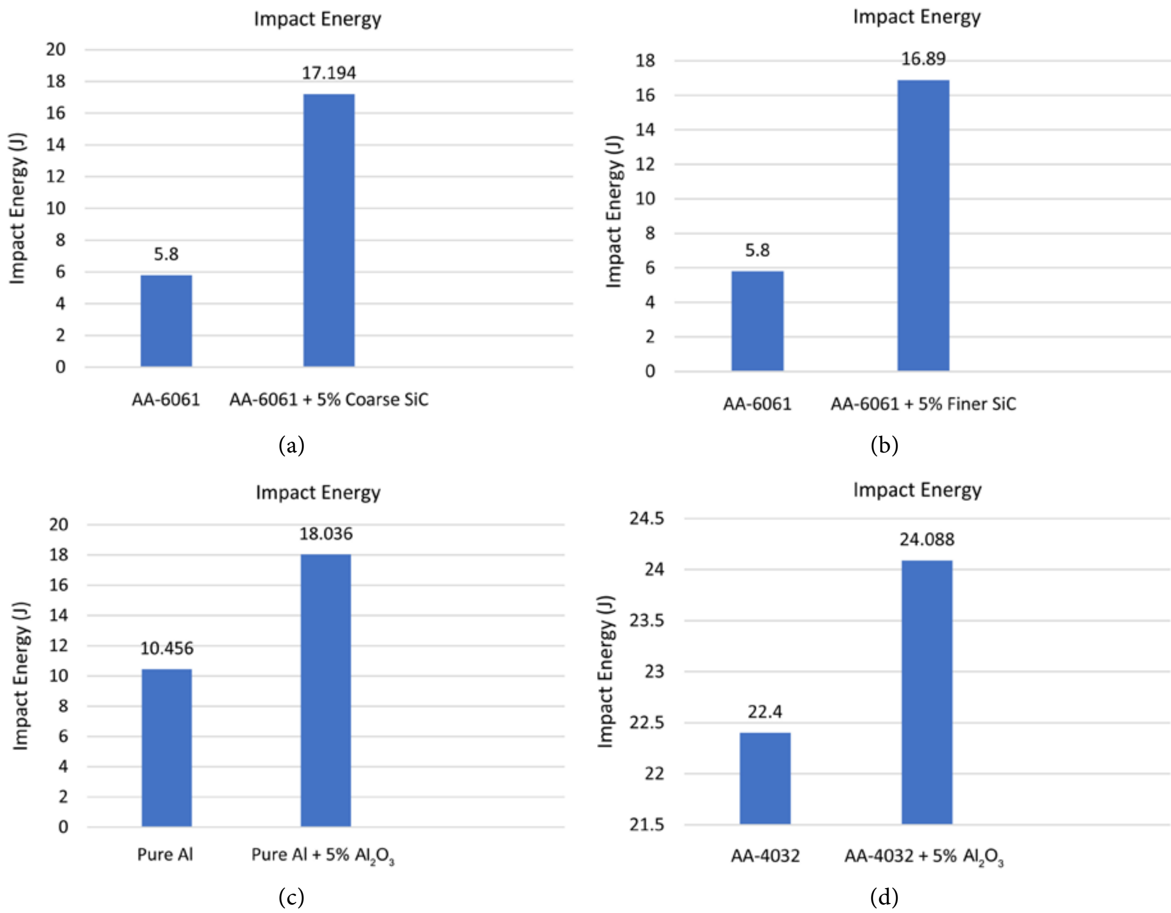


Figure 6. (a) Effect of 5% Coarse SiC Addition with AA-6061 alloy on Impact Energy; (b) Effect of 5% fine SiC addition with AA-6061 alloy on Elongation; (c) Effect of 5% Al_2O_3 Addition with Pure Al on Elongation; (d) Effect of 5% Al_2O_3 Addition with AA-4032 alloy on Tensile Strength.

Electrical Conductivity (% IACS):

Figure 7 shows the effect of particulate addition on the electrical conductivity of MMC. It depicts that electrical conductivity increases with addition of particles. Cui X *et al.* concluded in their study that Al-0.5Mg-0.35Si and Al-0.5Fe-0.2Si can reach electric conductivity of 52.4% and 51.8% IACS [9]. Zhukov I *et al.* iterated in their paper that aluminum alloy with reinforced Al_2O_3 can reach electric conductivity of 36.03% ± 1.38% IACS [10]. Tokutomi J *et al.* stated in their paper that pure al has electric conductivity of 63.2% IACS [11]. From the few papers stated above, it is evident that the results of this study are similar.

Thermal Properties:

Thermal Expansion Co-efficient (TEC):

Figures 8(a)-(d) show the effect on particulate materials addition on TEC of Al/Alloy MMC. It shows TEC increases with the increase of particulate additions. But the increases in TEC are 9.69, 10.37, 1.52 and 17.87 × 10^{-6}/˚C for the alloys. Hashihuchi D. *et al.* published in their study that Al-6061, Al-2124A (17% SiC), Al-6061B (40% SiC) has a TEC of 23.17 × 10^{-6}/˚C and 13.4 × 10^{-6}/˚C respectively [12]. Huber T *et al.* have expressed in their study that A359 alloy with

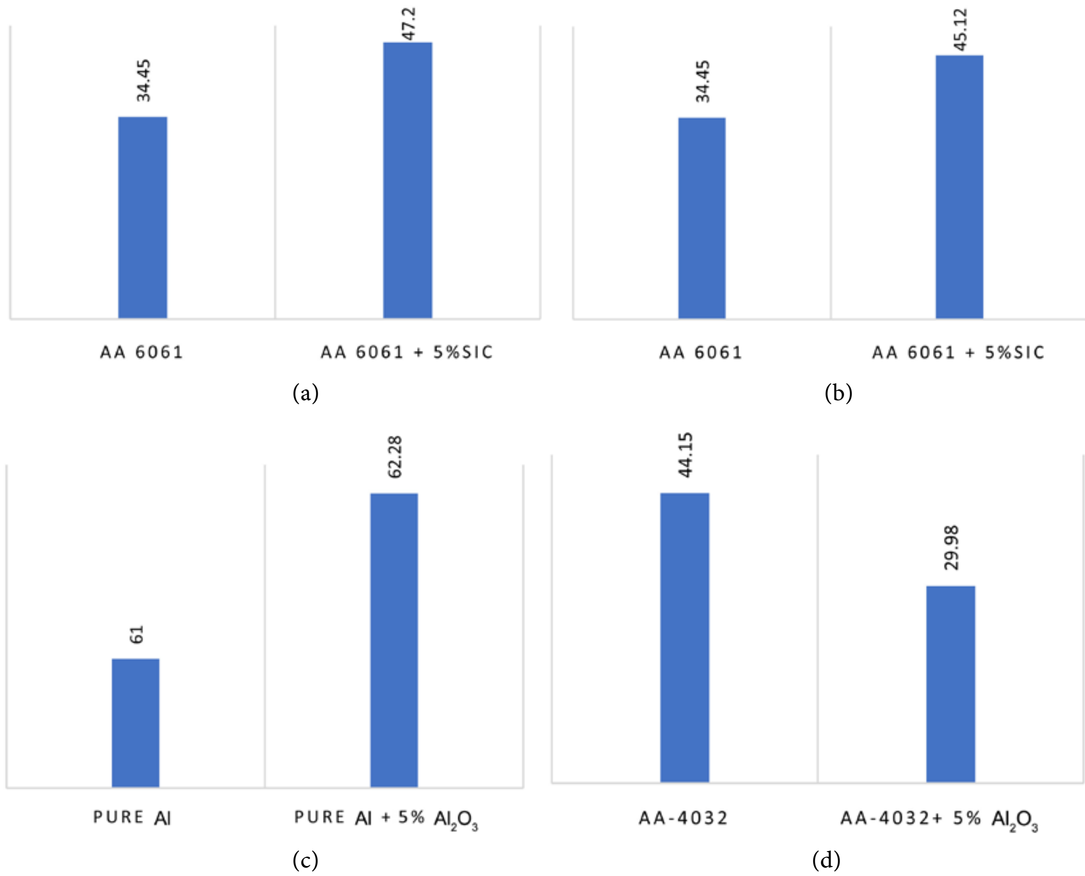


Figure 7. (a) Effect of 5% Coarse SiC Addition with AA-6061 alloy on Electrical Conductivity (% IACS); (b) Effect of 5% fine SiC addition with AA-6061 alloy on Conductivity (% IACS); (c) Effect of 5% Al_2O_3 Addition with Pure Al on Conductivity (% IACS); (d) Effect of 5% Al_2O_3 Addition with AA-4032 alloy on Conductivity (% IACS).

10% SiC reinforcement can reach co-efficient of thermal expansion of approximately $25 \times 10^{-6}/˚C$ [13]. The aforementioned papers confirm the results of this study.

TGDTA

Figure 9 shows the DTA of pure Al, AA 6061, and AA-4032. These are obtained at 20˚/min heating rate. The following Table 4 shows different thermal data of the three materials, it shows that with the increase of alloying element particularly Si, the melting point peak temperature decreases, but heat of fusion increase. The melting point of Aluminium is slightly less than that of pure Aluminium, because it is commercially pure containing 0.55% Si and 0.13% Fe. The melting points/solidus temperatures are 658.7˚C, 642.6˚C and 582.0˚C.

For AA6061, containing 0.85% Si, from phase diagram (Al-Si) it is found that at room temperature it is a single-phase solid solution having 1.65% Si maximum solubility at 577˚C eutectic temperature. But Al-0.85% Si alloy crosses two lines (solidus and liquidus), consequently two temperatures 642.6˚C and 672.3˚C are obtained as solidus and liquidus temperatures. There is existed one 2nd phase melted at 686.3˚C.

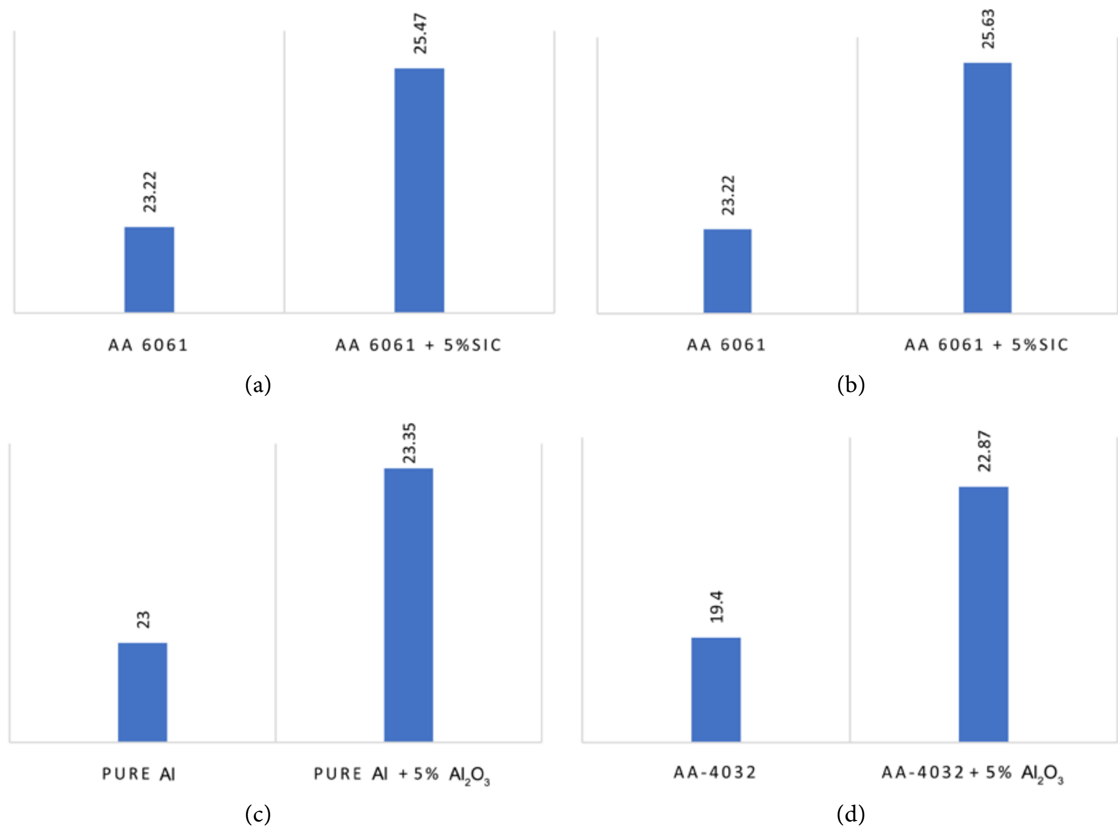


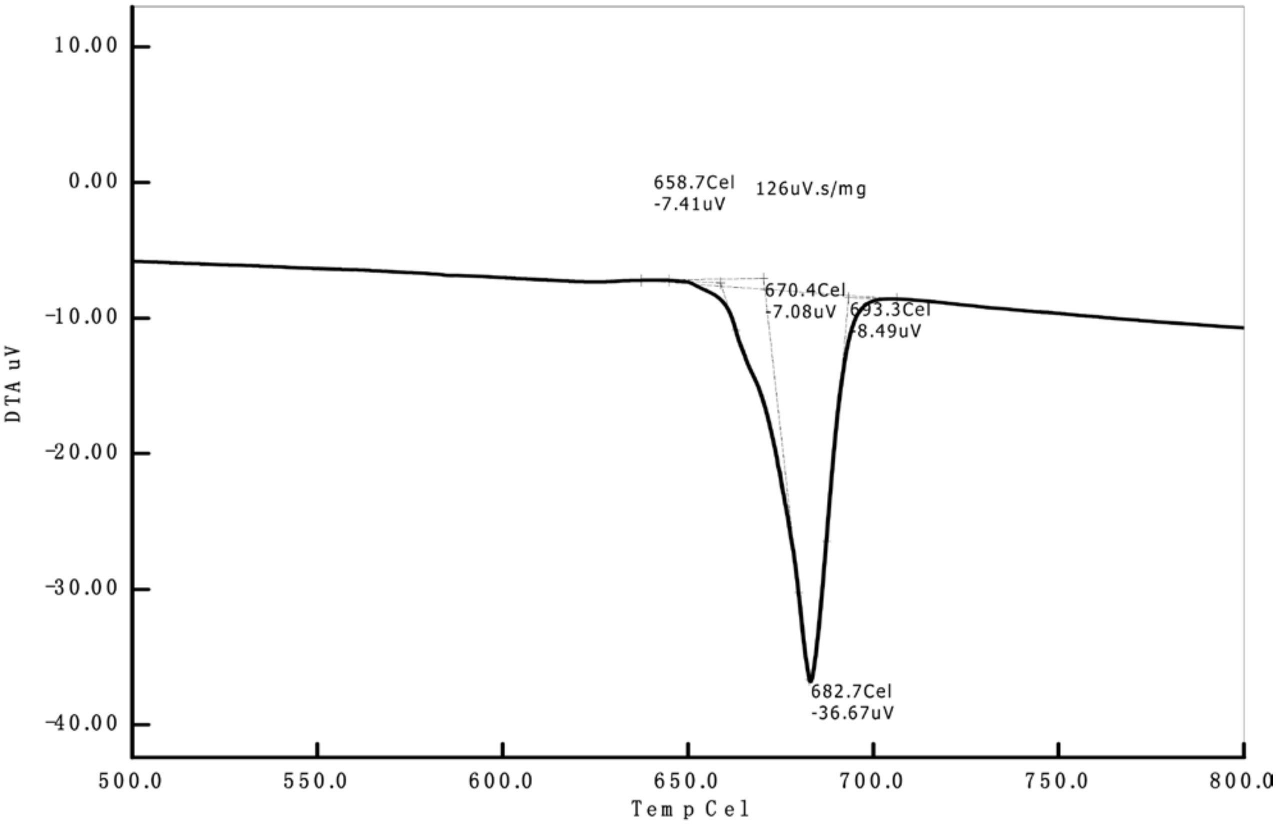
Figure 8. (a) Effect of 5% coarse SiC on TEC (/˚C, ×10[6]) of AA-6061; (b) Effect of 5% fine SiC on TEC (/˚C, ×10[6]) of AA-6061; (c) Effect of 5% Al_2O_3 on TEC (/˚C, ×10[6]) of Pure Al; (d) Effect of 5% Al_2O_3 on TEC (/˚C, ×10[6]) of AA-4032.

Table 4. Thermal data of three base metal/alloys from differential thermal analysis.

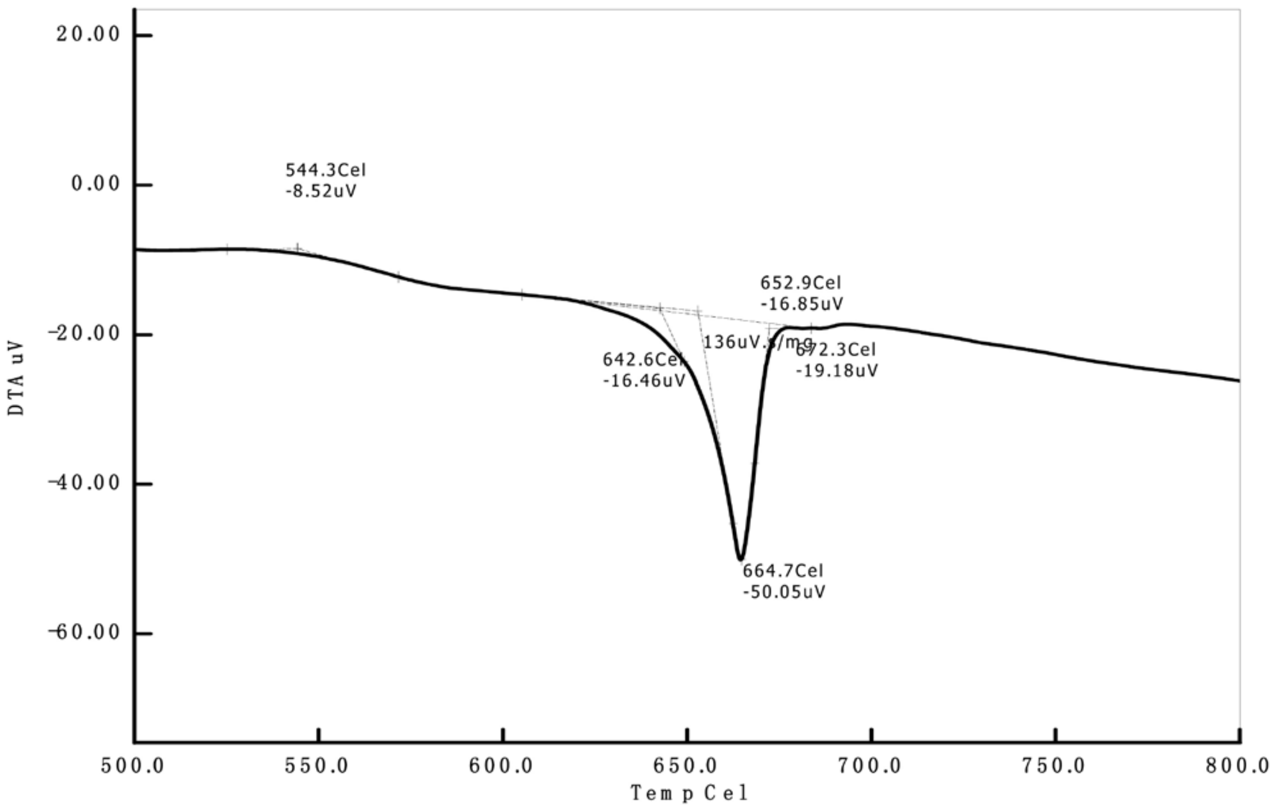
	Melting Point	Peak temperature	Heat of fusion	Presence of 2nd Phase
Commercially Pure	658.7	682.7	126	-
AA 6061	642.6	664.7	136	One after at 686.3
AA 4032	582.0	591.8	175	One after, at 647.0

For AA4032, containing 13.6% Si, it is a near eutectic alloy. The melting point is 582.0˚C which very near to equilibrium eutectic temperature 577˚C. It is slightly higher because higher heating rate. There is existence of another phase melt at 647.0˚C.

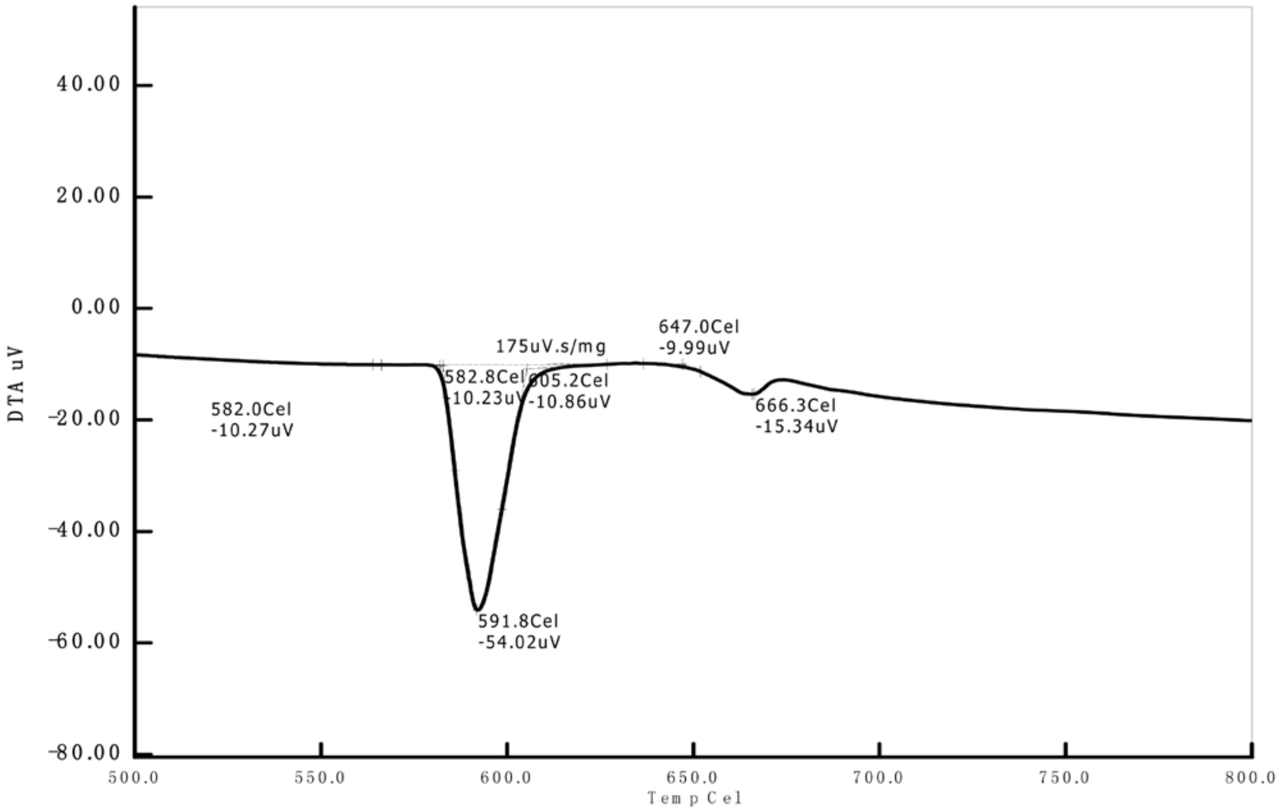
Figure 10(a) shows the comparative DTA curve of commercially pure Al, AA 6061 and AA4032. The most right on is for commercially pure Al and most left on is for AA-4032. AA6061 is in between the two curves. **Figure 10(b)** shows the comparative DTA curve of AA6061, AA 6061 with 5% course SiC and AA 6061 with 5% fine SiC. It reveals that SiC addition increase the thermal stability. The peak temperatures are 664.1˚C, 669.0˚C and 667.6˚C. **Figure 10(c)** show the comparative DTA curve of pure Al and pure Al with 5% Al_2O_3. It reveals that Al_2O_3 addition increase the thermal stability. The peak temperatures are 677.4˚C


10.00
0.00
-10.00
-20.00
-30.00
-40.00
DTA uV
658.7Cel
-7.41uV
126uV.s/mg
670.4Cel
-7.08uV
693.3Cel
-8.49uV
682.7Cel
-36.67uV
500.0
550.0
600.0
650.0
700.0
750.0
800.0
Temp Cel

(a)


20.00
0.00
-20.00
-40.00
-60.00
DTA uV
544.3Cel
-8.52uV
652.9Cel
-16.85uV
136uV.s/mg
642.6Cel
-16.46uV
672.3Cel
-19.18uV
664.7Cel
-50.05uV
500.0
550.0
600.0
650.0
700.0
750.0
800.0
Temp Cel

(b)



(c)

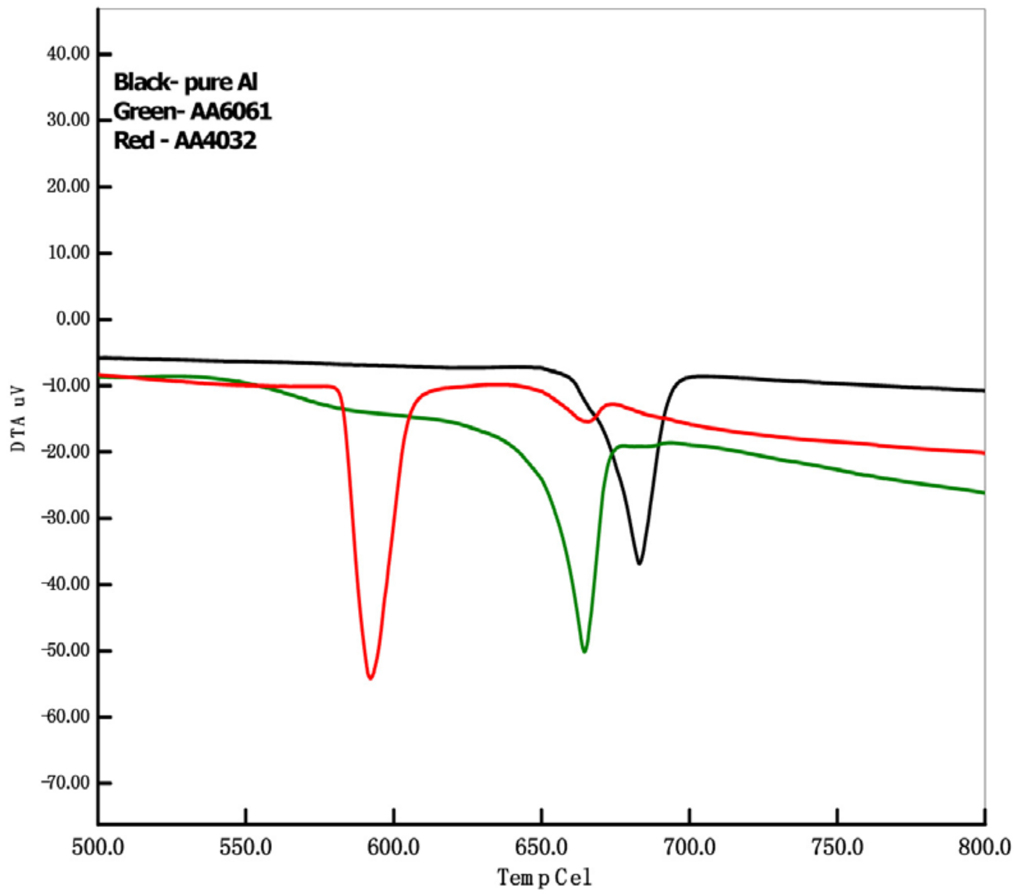
Figure 9. (a) Pure Aluminium; (b) AA6061; (c) AA4032.

and 682.7˚C. **Figure 10(d)** shows the comparative DTA curve of AA4032 nd AA 4032 with 5% Al_2O_3. It reveals that Al_2O_3 addition increase the thermal stability. The peak temperatures are 591.9 and 598.6˚C.

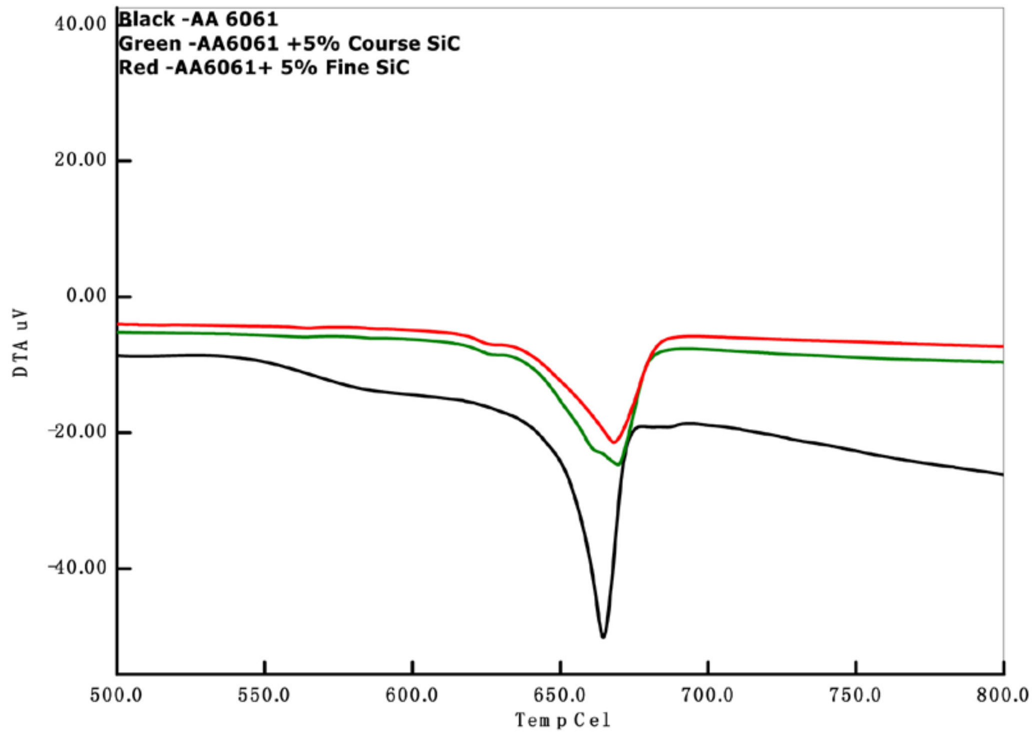
3.3. Chemical Properties

3.3.1. Corrosion Test

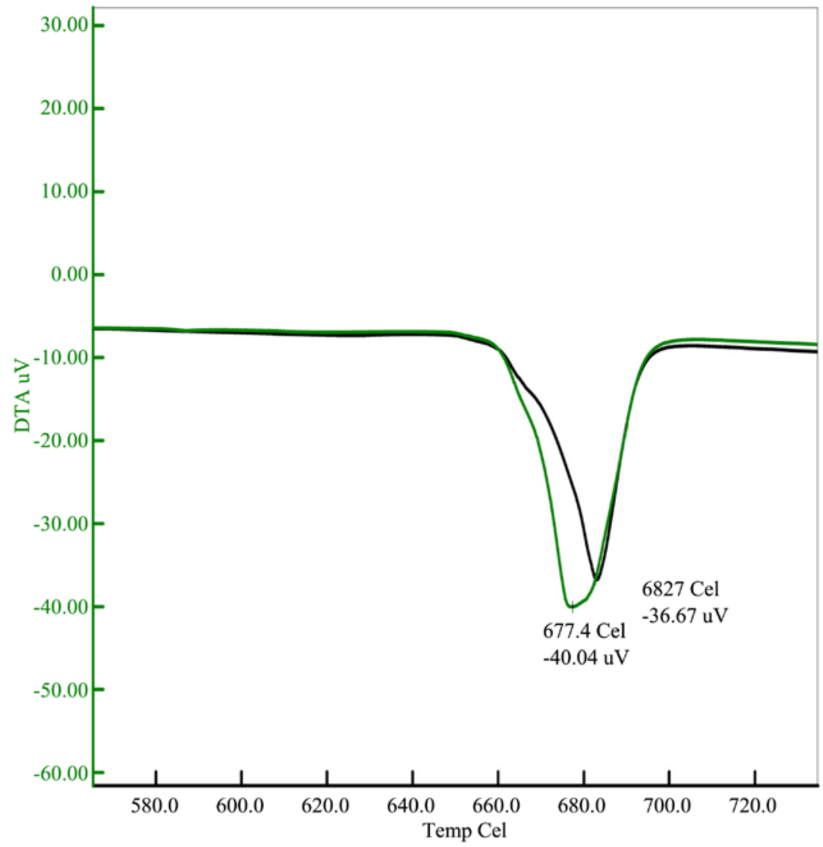
4% NaCl solution was used for creating environmental conditions. Gamry Reference 3000 Potentiostat/Galvanostat/ZRA machine have been used to perform the corrosion test. Through this test, we investigate I_{corr} and corrosion rate. **Figure 11** and **Figure 12** show the findings for the corrosion test that all of the samples I_{corr} values and corrosion rates have risen with the incorporation of reinforcement compared to the base metal and alloy. This is because the alloy matrix's reinforcement content condenses the cathodic zones to a small number of impurities, porosities, and reinforcements. The favored sites for dissolving and pitting are also thought to be the residual stresses in the matrix that result from the disparity in thermal and mechanical characteristics between the matrix and reinforcement [14]. Additionally, the areas where pits first form are more likely to experience galvanic corrosion at the junction of hard ceramic particles and soft matrix alloy [15]. **Figure 11** and **Figure 12** depict that Icorr and corrosion rate have been increased more for the reinforced particles with finer size,


Black- pure Al
Green- AA6061
Red - AA4032
40.00
30.00
20.00
10.00
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
-60.00
-70.00
DTA uV
500.0
550.0
600.0
650.0
700.0
750.0
800.0
Temp Cel

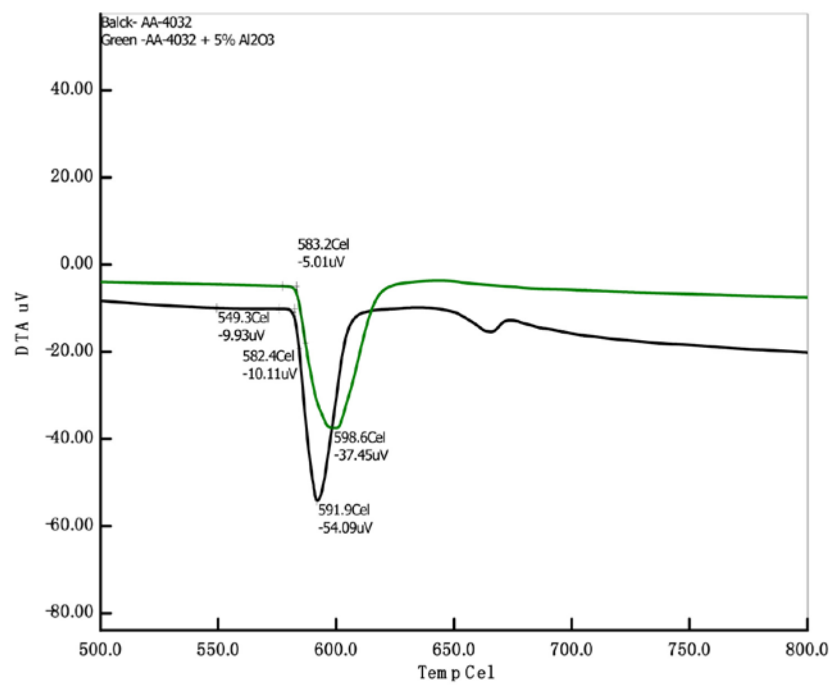
(a)


Black -AA 6061
Green -AA6061 +5% Course SiC
Red -AA6061+ 5% Fine SiC
40.00
20.00
0.00
-20.00
-40.00
DTA uV
500.0
550.0
600.0
650.0
700.0
750.0
800.0
Temp Cel

(b)



(c)



(d)

Figure 10. (a) DTA of Pure Al, AA6063, and AA4032; (b) Effect of 5% SiC Addition with AA6061 on DTA signal; (c) Effect of 5% fine Al_2O_3 Addition with Pure Al on DTA signal; (d) Effect of 5% Al_2O_3 Addition with AA4032 on DTA signal.

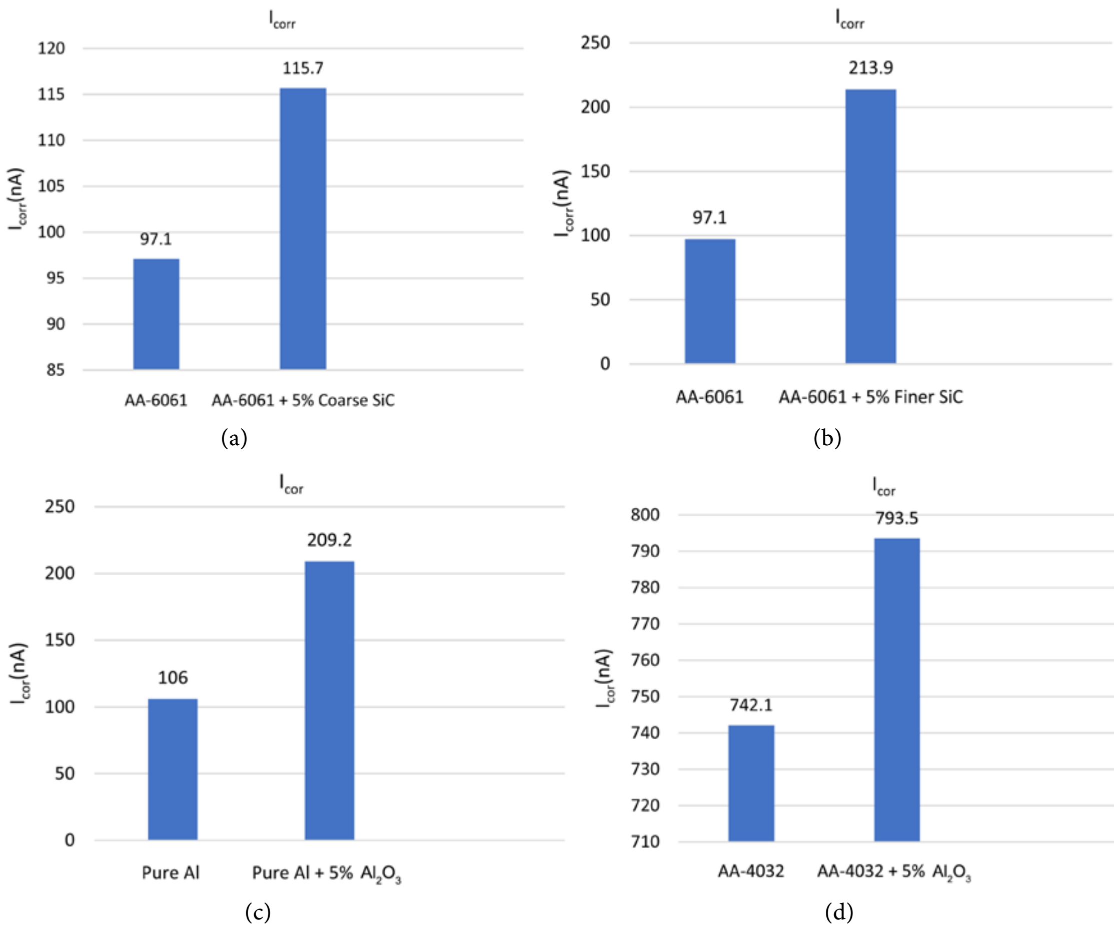


Figure 11. (a) Effect of 5% Coarse SiC Addition with AA-6061 alloy on I_{cor}; (b) Effect of 5% fine SiC addition with AA-6061 alloy on I_{cor}; (c) Effect of 5% Al_2O_3 Addition with Pure Al on I_{cor}; (d) Effect of 5% Al_2O_3 Addition with AA-4032 alloy on I_{cor}.

indicating more susceptibility to pitting corrosion. These findings concur with those of other studies [16]. This is because composite materials have a high surface area content of reinforcements, which speeds up the growth of pits into the metal.

3.3.2. Microstructure

The microstructure of the samples was under an optical microscope. SiC particles with a deep golden color and wedge shapes were seen in and around the interdendrite regions, leading to an increased aspect ratio. It is obvious that the coarser SiC particle distribution is less even than that of the finer SiC particle. There's some dendritic growth seen on the AA-6061 + 5% coarse SiC. A little cracking can be seen on the AA-6061 + 5% finer SiC sample. The matrix of the composite with alumina particles showed even dispersion without any discontinuities. The grain disparity between the pure aluminium and aluminium alloy is clearly seen in **Figure 3** and **Figure 4**. The discontinuity and issues in the samples can be seen because of the inconsistency in stirring, low wettability, presence of air trapped on the furnace etc. (**Figure 13**).

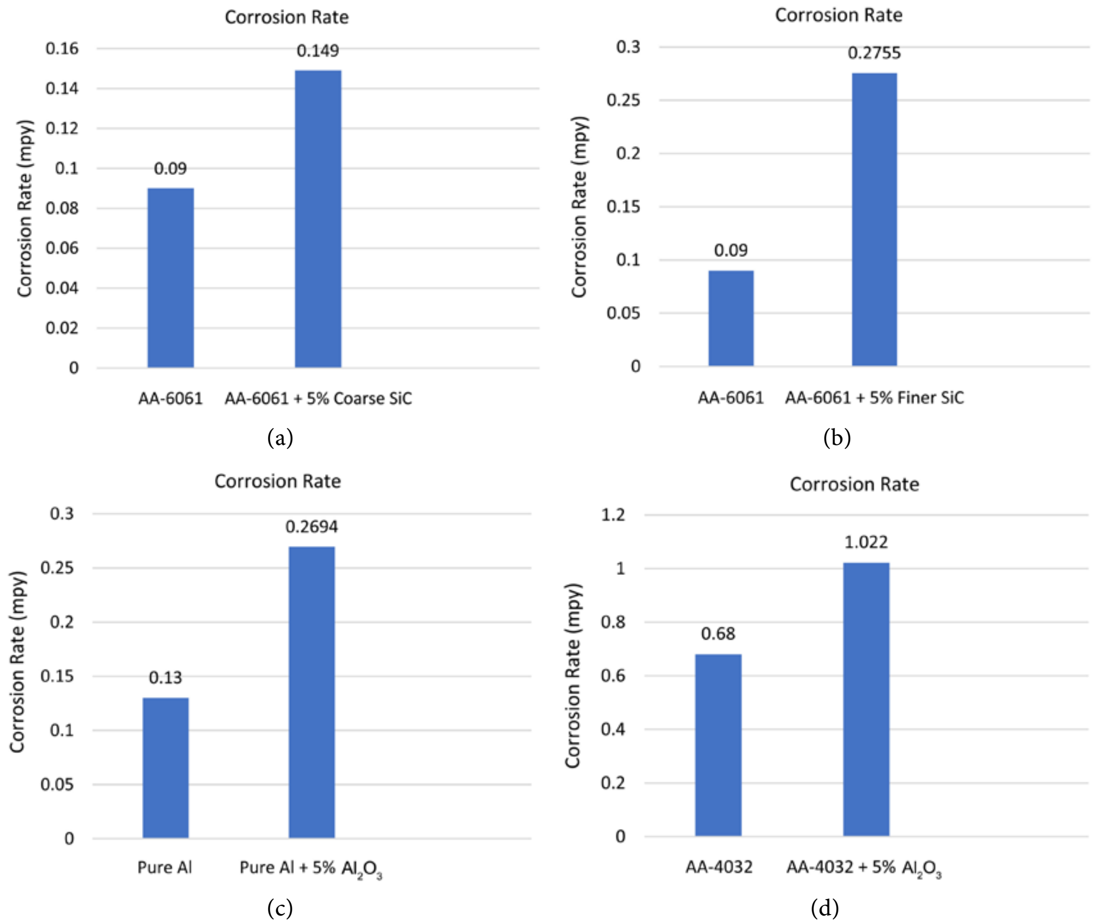


Figure 12. (a) Effect of 5% Coarse SiC Addition with AA-6061 alloy on Corrosion rate; (b) Effect of 5% fine SiC addition with AA-6061 alloy on Corrosion rate; (c) Effect of 5% Al_2O_3 Addition with Pure Al on Corrosion rate; (d) Effect of 5% Al_2O_3 Addition with AA-4032 alloy on Corrosion rate.

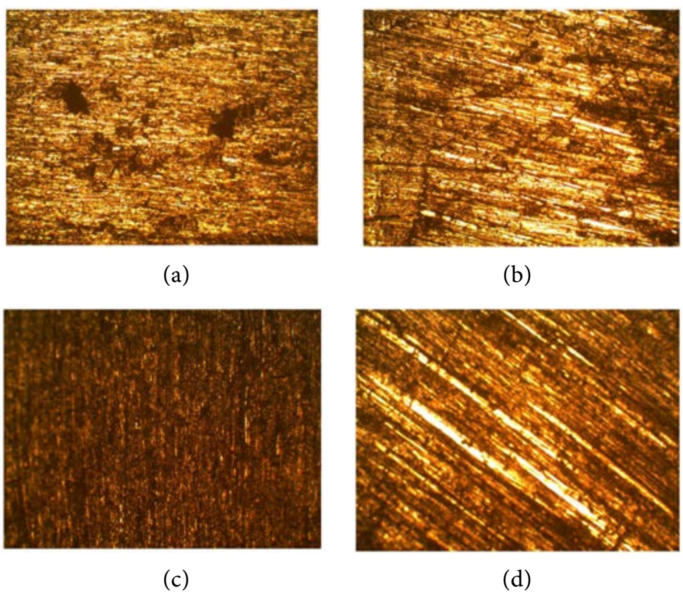


Figure 13. (a) AA-6061 + 5% Coarse SiC; (b) AA-6061 + 5% Finer SiC; (c) Pure Al + 5% Al_2O_3; (d) AA-4032 + 5% Al_2O_3.

4. Conclusions

The following conclusions can be taken from the development and experimental analysis:

- The stir casting method has been successfully used to fabricate the metal matrix composite with an aluminum basis.
- A few variables can influence the manufacture of the MMC to produce better outcomes. The parameters include the casting process, the stirrer design, the size of the stirrer, the rpm and time of the stirring, the temperature of the preheating process, the uniform distribution of the particles, etc. In this example, changing parameters may result in various outcomes.
- Every sample created in this experiment displayed improved qualities, except for the third sample (pure aluminum + 5% Al_2O_3). The third sample, Pure Aluminium + 5% Al_2O_3, had a poor outcome in the hardness test since the sample's hardness reduced. The aforementioned variables may be able to explain why the third sample's hardness was reduced.
- During the corrosion test, it is found that the samples' corrosion rate and Icorr were higher than those of the basic matrix materials. The materials will erode more quickly than the underlying materials as the corrosion rate and Icorr rise. This experiment's bad outcome is that the samples' corrosion rate and Icorr have increased.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] 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*, **171**, 268-273. https://doi.org/10.1016/j.jmatprotec.2005.06.071

[2] Roebuck, B. (1987) Fractography of a SiC Particulate Reinforced Aluminium Metal Matrix Composite. *Journal of Materials Science Letters*, **6**, 1138-1140. https://doi.org/10.1007/BF01729162

[3] Raturi, A., Dhanola, A., Mer, Dr.K.K.S. and Kothiyal, P. (2015) Analysis of Mechanical and Micro Structural Behaviour of Al Based Metal Matrix Composite Reinforced with Ball Milled Nano Particles: A Review. *International Journal of Mechanical Engineering and Technology* (*IJMET*), **6**, 1-19. http://www.jifactor.com/

[4] Kumar, A., Lal, S. and Kumar, S. (2013) Fabrication and Characterization of A359/Al_2O_3 Metal Matrix Composite Using Electromagnetic Stir Casting Method. *Journal of Materials Research and Technology*, **2**, 250-254. https://doi.org/10.1016/j.jmrt.2013.03.015

[5] Ozben, T., Kilickap, E. and Çakır, O. (2008) Investigation of Mechanical and Machinability Properties of SiC Particle Reinforced Al-MMC. *Journal of Materials Processing Technology*, **198**, 220-225. https://doi.org/10.1016/j.jmatprotec.2007.06.082

[6] Mohamed, S.S., Abdallah, S.A. and Alazem, H.K.H. (2018) An Investigation on the Mechanical and Physical Properties of AL6061/SiCp/Gr Metal Matrix Composites. *International Journal of Engineering and Applied Sciences*, **5**, 1-5. www.ijeas.org

[7] Chigal, G. and Saini, G. (2012) Mechanical Testing of Al6061/Silicon Carbide Metal Matrix Composites. *International Journal of Research in Engineering and Applied Sciences*, **2**, 220-238. http://www.euroasiapub.org

[8] Ozden, S., Ekici, R. and Nair, F. (2007) Investigation of Impact Behaviour of Aluminium Based SiC Particle Reinforced Metal-Matrix Composites. *Composites Part A*: *Applied Science and Manufacturing*, **38**, 484-494. https://doi.org/10.1016/j.compositesa.2006.02.026

[9] Cui, X., Wu, Y., Zhang, G., Liu, Y. and Liu, X. (2017) Study on the Improvement of Electrical Conductivity and Mechanical Properties of Low Alloying Electrical Aluminum Alloys. *Composites Part B*: *Engineering*, **110**, 381-387. https://doi.org/10.1016/j.compositesb.2016.11.042

[10] Zhukov, I., *et al.* (2019) The Impact of Particle Reinforcement with Al_2O_3, TiB_2, and TiC and Severe Plastic Deformation Treatment on the Combination of Strength and Electrical Conductivity of Pure Aluminum. *Metals* (*Basel*), **9**, Article 65. https://doi.org/10.3390/met9010065

[11] Tokutomi, J., Uemura, T., Sugiyama, S., Shiomi, J. and Yanagimoto, J. (2015) Hot Extrusion to Manufacture the Metal Matrix Composite of Carbon Nanotube and Aluminum with Excellent Electrical Conductivities and Mechanical Properties. *CIRP Annals*, **64**, 257-260. https://doi.org/10.1016/j.cirp.2015.04.083

[12] Hashiguchi, D., Tricker, D., Tarrant, A., Campbell, J. and Pokross, C. (2017) Discontinuously Reinforced Aluminum MMC Extrusions. *Metal Powder Report*, **72**, 252-258. https://doi.org/10.1016/j.mprp.2016.01.074

[13] Huber, T., Degischer, H.P., Lefranc, G. and Schmitt, T. (2006) Thermal Expansion Studies on Aluminium-Matrix Composites with Different Reinforcement Architecture of SiC Particles. *Composites Science and Technology*, **66**, 2206-2217. https://doi.org/10.1016/j.compscitech.2005.12.012

[14] Nunes, R.C.R. and Ramanathan, L.V. (1995) Corrosion Behaviour of Alumina-Aluminium and Silicon Carbide-Aluminium Metal-Matrix Composites. *Corrosion*, **51**, 610-617. https://doi.org/10.5006/1.3293621

[15] Dabrzanski, L.A., Wladarczyk, A. and Adamiak, M. (2005) Structure Properties and Corrosion Resistance of PM Composite Material Based on ENAW-2124 Aluminum Alloys Reinforced with Al_2O_3 Ceramic Particles. *Journal of Materials Proccessing Technonolgy*, **162/163**, 27-31. https://doi.org/10.1016/j.jmatprotec.2005.02.006

[16] Ehsani, R. and Reihani, S.M.S. (2004) Aging Behavior and Tensile Properties of Squeeze Cast Al 6061/SiC Metal Matrix Composites. *Scientia Iranica*, **11**, 392-397.