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Research Article

Microstructure and Mechanical Characteristics of Stir-Casted AA6351 Alloy and Reinforced with Nanosilicon Carbide Particles

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The main aim of this research is to analyze the mechanical performances of the influence of silicon carbide (SiC) particles with AA6351 aluminum alloy. The aluminum metal matrix composites were prepared with liquefying stir casting to produce the metal matrix composites (MMCs). The following weight fractions are AA6351-0% SiC, AA6351-2.5% SiC, AA6351-5% SiC, and AA6351-7.5% SiC utilized to compose the MMCs. The mechanical performances like hardness, flexural, impact, compressive, and tensile studies were investigated on the processed MMCs. The scanning electron microscope (SEM) was employed to examine the strengthened particle of SiC. During the SEM examinations, uniformly dispersed SiC-strengthened particles were analyzed. The entire MMCs specimens achieve greater mechanical characteristics; the specimen fabricated with a maximum volume fraction of 7.5 wt% of SiC accumulates higher strength than the other volume fractions samples. The SiC plays a very tedious role in improving mechanical attributes. The fabricated MMCs were highly utilized in the applications of automotive and aerospace usages. This application is fully employed with lesser weight and maximum strength conditions to fulfill the mechanical performances. The stir-casting process was a highly efficient technique to compose better MMCs to achieve greater strength.

1. Introduction

Commonly matrix-based composites like metal matrix composites (MMCs), ceramic-categorized matrix composites, polymer, and hybrid composites are classified as per the reinforcement phases (strengthened particles) and matrix [1]. The matrix composites are fabricated through the varied condition of mixed materials and are highly capable of gaining mechanical performances compared to the base material. Generally, one or more assorted metals are developed to produce the MMCs along the properly strengthened reinforcements and the parent material [2]. In recent decades, automotive and its related manufacturing sectors have been highly utilized to withstand the heavy load weight on the body, keeping less weight, and maximum strength combinations are majorly required. So this condition is possibly satisfied with aluminum matrix composites (AMCs) [3]. Specifically, superior characteristics are mainly accomplished with extraordinary combinations, namely lesser weight and greater strength to execute outstanding performances like less in density, resistance to wear, and exceptional strength in the AMCs [4]. Last recent periods, production development people mainly contemplated producing efficient mechanical-related components with the capability of resistance to corrosion and wear materials. The prominent ductility state and more excellent mechanical properties are highly attained in aluminum matrix composites and accommodate the mechanical deformation conditions [5]. In the same way, automotive spare materials, namely pistons, drum sections, brake lining parts, and cylinder blocks, are accomplished with maximum life span and incomparable alternates for automotive productions [6]. The aluminum alloys are reputed when this alloy is mingled with proper arrangements of strengthened materials. Because the formability structure, resistance to wear, resistance to corrosion, and improved clear-cut strength are mainly adapted in automotive and aerospace applications [7]. In this research, AA6351 is considered the parent material. Normally this alloy contains greater age-hardening characters with the generation of transistors Mg–Si intermetallic multiparts and a small quantity of silicon and magnesium. Another specific reason to select AA6351 due to less expensive materials compared to 7xxx and 2xxxx series of alloy [8]. Other significant relations are about the microstructure examination with their impacts on mechanical behaviors, which is a better understanding to obtain superior properties. Therefore, AA6351 is the best-suited material for this study, and this base alloy is an essential choice for blending the reinforcements to get desired applications on AMCs [9]. The mechanical attributes of processed AMCs are mainly based on base metal and suitable reinforcements. It is revealed that the intrinsic properties among the base and strengthened particles and its volume ratio to improve their AMCs performances [10]. This study used nanosilicon carbide (nSiC) as strengthened particles for AA6351 alloy. The intricate surface layers are diminished with advanced incorporation nSiC blended on the AA6351. Similarly, the robust interfacial bonding is accumulated with nSiC-strengthened reinforcements and AA6351 alloys. In special cases, inhomogeneous scattering is occurred on the processed MMCs by the contemptible wetting during the other processes like powder metallurgy, squeeze casting, and solid-state process. To overcome these issues, stir-casting liquefied process is as suitable technique [11].

Sekar et al. [12] fabricated the stir-casted MMCs on AA6082 with strengthened zirconium oxide particles and silicon carbide. The hardness strength was improved at 1 wt% of SiC and ZrO_2 compared to the base material. SiC as major reason to enhance the mechanical strength with uniform dispersion of reinforcements. Rajmohan et al. [13] optimized the machining parameters of processed MMCs by drilling. The MMCs were prepared with Al356 and SiC combinations by stir-casting process. During the machining, surface roughness and wear of the tool was enhanced surface finishes with proper mixing of base metal Al356 and SiC due to carbide particles. Daniel et al. [14] investigated the MMCs and developed the optimized milling parameters on processed MMCs of Al5059 and SiC combinations. The influence of SiC plays a significant aspect in improving the machining characteristics by increasing the SiC content. Christy et al. [15] focused the stir-casted process on the alumina and aluminum oxide. Most of the samples occurred with porosities on the MMCs. Mainly, models with 5.95 wt% of Al_2O_3 attained lesser porosity when compared to another set of pieces. Kannan et al. [16] studied the optimized turning process parameters on the processed MMCs. These MMCs were prepared by the combinations of Al7075 and SiC with 10 wt% by stir-casting technique. The optimal parameters are attained at the MMCs, which were processed at 3% SiC, while the surface finish appeared to be the best. Kumar et al. [17] investigated the MMCs prepared from their combinations of aluminum and SiC-strengthened particles. The machining characteristics like surface roughness and material removal rate are attained in 9 wt% SiC with the presence of aluminum.

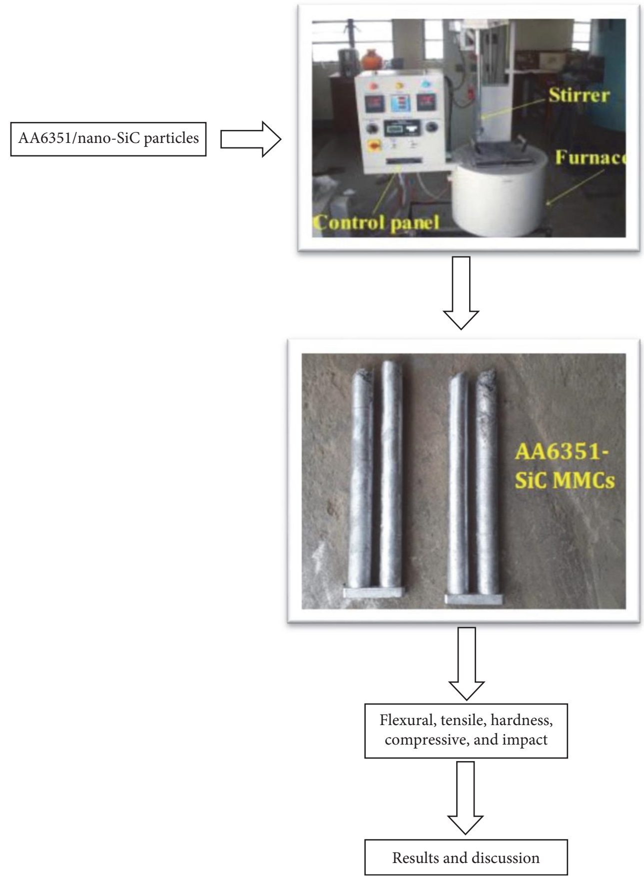


Figure 1: Experimental layout with graphical representation.

From the detailed survey of the literature, there is some lacking investigations have been accomplished on AA6351 and SiC arrangements. This paper considered AA6351 and nSiC composites with different fractions of weight, namely, 0%–7.5%, by increasing of 2.5 wt%. The following mechanical performances hardness, flexural, impact, compressive, and tensile studies were made on the processed MMCs.

2. Material Details and Processing Procedure and Testing Standards of Processed MMCs

AA6351 and nSiC are the materials to consider the stir-casting process in this investigation. The following chemical elements of AA6351 are 1 wt% of Si, 0.6 wt% of Fe, 0.75 wt% of Mg, 0.5 wt% of Mn, 0.2 wt% of Ti, 0.1 wt% of C, 0.1 wt% of Zn, Bal of Al, and nSiC particle size is 10 nm, and it was purchased from the CBE metal mart, Kovai, respectively. The matrix and strengthened particle volumes are evenly measured per the indicated fractions by weight balancing. Initially, the AA6351 is poured into the crucible heating system with a maintained temperature at 750°C. Then nSiC was preheated at 430°C. The indicated weight fractions of strengthened particles were added to the molten stage of AA6351 to compose the four sets of MMCs specimens. The processed MMCs specimens are AA6351-0% nSiC, AA6351-2.5% nSiC, AA6351-5% nSiC, and AA6351-7.5% nSiC. During the process, samples

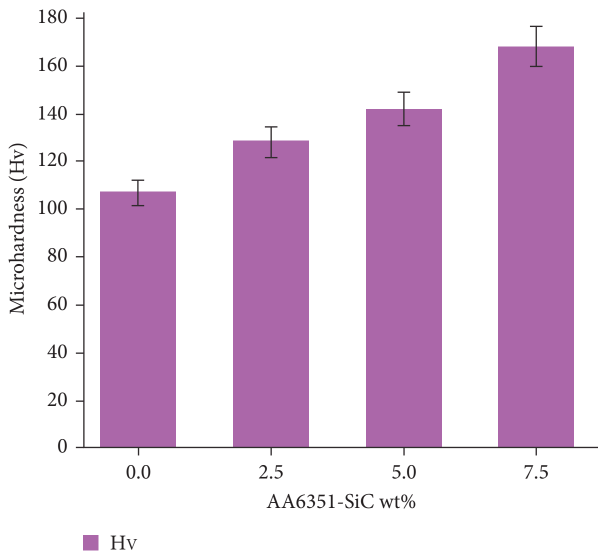


FIGURE 2: Hardness analysis on processed MMCs (AA6351-SiC wt%).

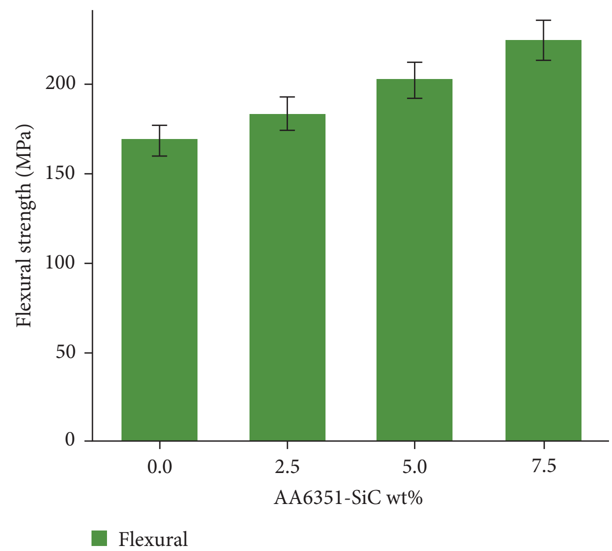


FIGURE 3: Flexural properties on processed MMCs (AA6351-SiC wt%).

were prepared at a maintained stirring speed and time of 650 rpm and 7 min, respectively. Figure 1 shows the experimental layout with a graphical representation.

The scanning electron microscope (SEM) examination was used to analyze the dispersion of strengthened particles on the processed MMCs. The round-shaped die was utilized to compose the desired shapes of MMCs specimens, mainly derived from the molten state of composites. The following mechanical tests with their ASTM standards are hardness (E384-08), flexural (C1161), impact (E23), compressive (E9), and tensile studies (E8-08), respectively [18].

3. Results and Discussions

3.1. Hardnessstudies on Processed MMCs Specimens. Figure 2 displays the hardness results of AA6351 and nSiC MMCs. The grain refinement was successfully accompanied by the proper dispersion of mixed pores in the maximum volume fraction of AA6351-7.5 wt% of nSiC. It is revealed that the maximum SiC incorporated well in the aluminum alloy improves the hardness due to the presence of carbide elements [19]. Also, the SiC creates the strengthened materials for hardening purposes when accomplished with AA6351. The MMCs specimens were increased gradually by developing the volume fraction of SiC. Therefore, Figure 2 indicates that the more significant fraction of AA6351-7.5 wt% of nSiC increases the hardness strength (168 Hv). It is implicit that the insertion of nSiC-strengthened nanoparticles with AA6351 generates enhanced hardness strength based on the Orowan mechanism [20]. The lesser hardness strength (107 Hv) was attained at AA6351-0 wt% of nSiC.

3.2. Flexuralstudies on Processed MMCs Specimens. Figure 3 exhibits the bar charts of flexural properties on fabricated MMCs on AA6351-SiC wt%. The greater flexural properties (224 MPa) are attained by the more excellent weight ratio of AA6351 and 7.5 wt% of SiC, compared to other various sets

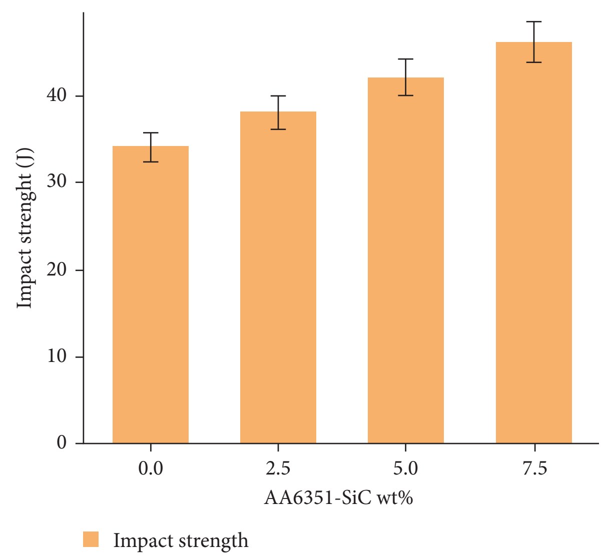


FIGURE 4: Impact properties on processed MMCs (AA6351-SiC wt%).

of weighted samples. It is implicit that the expanding weight ratio of SiC establishes the flexural potency in the composed MMCs. It is revealed that the secondary phase strengthened particle SiC was migrated the load from the AA6351 alloy [21]. At the same time, interfacial bonding was well created in the improved flexural specimens [22].

3.3. Impact Properties on Fabricated MMCs Specimens. The impact properties of fabricated MMCs of AA6351 and wt% of SiC are presented in Figure 4. The impact properties were successfully performed on the processed MMCs with potential and robustness performances. Due to the bear-up with a lack of caution was accumulated below the vibration of MMCs, which was close to the rupture below the rapid stress [23]. The proper interfacial bonding improved the impact

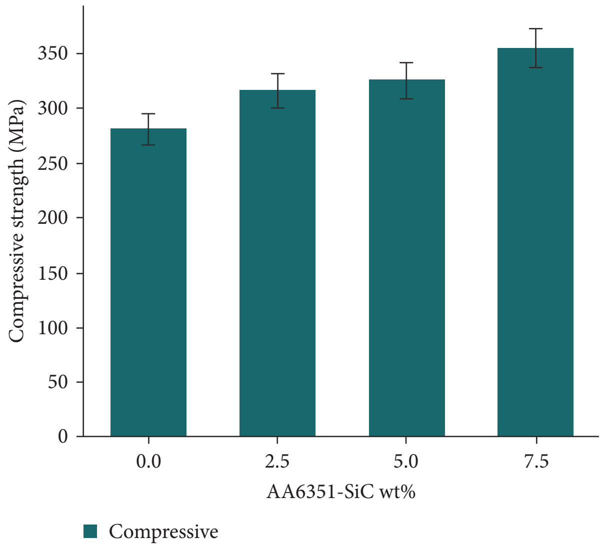


FIGURE 5: Compressive properties on processed MMCs (AA6351-SiC wt%).

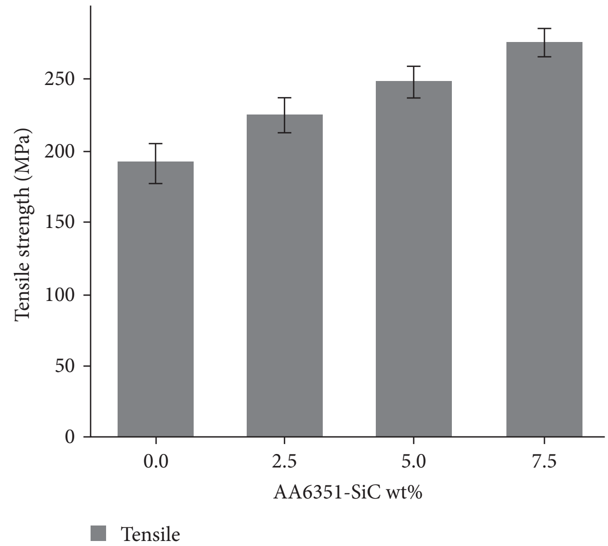


FIGURE 6: Tensile strength on processed MMCs (AA6351-SiC wt%).

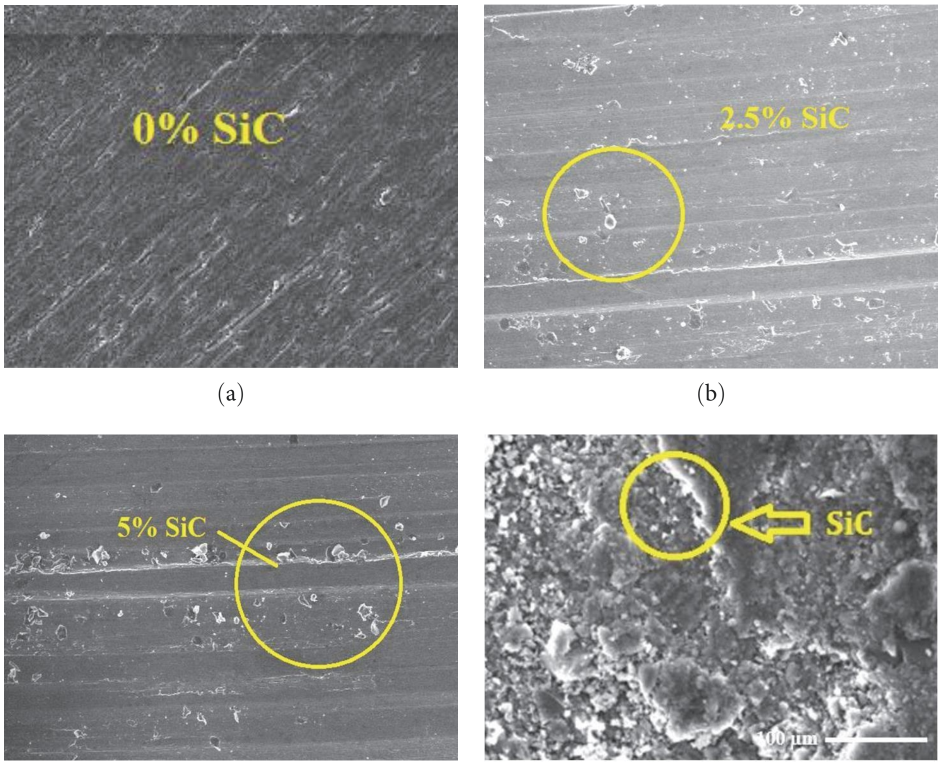
properties created in the MMCs. The increment of SiC-strengthened nanoparticles enhances their impact strength (46 J) and is exhibited in Figure 4.

3.4. Compressive Strength on Processed MMCs Samples. Figure 5 displays the compressive strength contributions on processed MMCs of AA6351 and various fractions of SiC. It is concluded that the compressive properties were superior, with a maximum weight fraction of 7.5 wt% of nSiC, and its maximum compressive value is 355 MPa. This processed specimen was entirely protected with even scattering of SiC on the base material during the process [24]. During the performance test, the load was relocated from parent metal to the uniform dispersed strengthened regions to produce the refinement structure in the grain boundary areas. These results were mainly supported by Orowan strengthening mechanism [25]. The lesser value was composed in the without strengthened composite specimens. The specimens having 2.5 and 5 wt% in SiC was better results when compared to naked AA6351. The distributed SiC-strengthened particles are very minimized during the stir casting while strength was slightly maximum and far minimum than the highest volume fraction of SiC. The presence of carbide particles in the MMCs created more compressive strength during the test, and it was a major reason to enhance the compressive in entire reinforced composites.

3.5. Tensile Properties Studied on Various SiC Weight Fractions on MMCs. The tensile properties of stir cast AA6351 and SiC wt% fractions are presented in Figure 6. From Figure 6, AA6351 and its nano-based SiC-strengthened particles attained greater tensile strength with a uniform dispersion of reinforcements. AA6351 and nSiC gathered intermetallic bonding potency through solid phases protected by their strengthened materials [26]. Meanwhile, migrated load was satisfactory in developing the MMCs attributes. Normally, the SiC is a significant factor in enhancing the intermetallic potency of strengthened MMCs than the other strengthened ceramic particles. The MMCs processed at 7.5 wt% in SiC with AA6351 accommodates the greater tensile strength (276 MPa) than other MMCs specimens AA6351-0 wt% of SiC (192 MPa), AA6351-2.5 wt% of SiC (225 MPa) and AA6351-5 wt% of SiC (248 MPa), respectively [27]. The increment of SiC on the AA6351 at particular weight fraction results in superior tensile properties. The Ororwan strengthening mechanism significantly improves their strength in the processed MMCs. This same specimen also gets better-reinforced dispersion in the maximum weight fraction samples. The grain refinement achieves better tensile strength in the MMCs.

4. Microstructure on the Processed Specimen with a Maximum Fraction of AA6351/SiC

Figure 7 exhibits the micrographs on processed MMCs with 7.5 wt% of SiC/AA6351 combinations. During the process, some minor porosity and small cracks were accumulated in the MMCs. But in this case, SiC significantly removes these minor issues during the stir casting. Figure 7 shows that the sample was accomplished with evenly dispersed SiC-strengthened particles, and mechanical characteristics also improved simultaneously [28]. Identifying the SiC particles in the micrographs is necessary for revealing the evidence. Thermal stability was maintained in the interface of MMCs when analyzing the mechanical properties. The interfacial betterment occurred in this specimen due to SiC by in situ reactions, and well bonded was created in the examined micrograph [29]. Figure 7(a)–7(d) indicates that SiC particles with different weight fractions of nSiC and which were spread more in the processed MMCs by the various-volume fraction. The micrograph analysis clearly shows the intermetallic particles in the processed specimen. The SEM image was analyzed with 100 μm to identify the particles.



(a) (b) (c) (d)

Figure 7: (a) SEM analysis on AA6351-SiC 0 wt%; (b) SEM analysis on AA6351-SiC 2.5 wt%; (c) SEM analysis on AA6351-SiC 5 wt%; (d) SEM analysis on AA6351-SiC 7.5 wt%.

5. Conclusion

(i) The stir-casting liquefying technique was effectively employed with AA6351 and SiC arrangements.

(ii) The mechanical performance, like hardness, flexural, impact, compressive, and tensile studies, was successfully conducted on the processed MMCs.

(iii) These properties were enhanced by increasing the weight fraction SiC on the base alloy AA6351.

(iv) The specimen was fabricated with a high volume fraction of SiC 7.5 wt%, and AA6351 combinations procured maximum strength when compared to other processed MMCs.

(v) The SEM analysis was studied effectively on the same high-fraction specimen. The presence of SiC particles was dispersed uniformly during SEM analysis, and identified strengthened particles were seen in the processed MMCs.

(vi) The future implications of processed MMCs investigations are gray, and TOPSIS approaches will be implemented to identify the optimal parameters.

Data Availability

The data used to support the findings of this study are included in the article. Should further data or information be required, these are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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