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Investigating The Influence of Sic Reinforcement on The Mechanical and Tribological Properties of PA12 Polymer Composites in SLS

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Abstract

The study investigates the mechanical and tribological performance of neat PA12 polymer and SiC-reinforced PA12 polymer composites made via Selective Laser Sintering (SLS). To evaluate just how reinforcement has influence upon overall performance, we incorporated into the PA12 polymer matrix a constant amount of 5 wt.% of Silicon Carbide (SiC). Mechanical testing focused on both tensile and fatigue behavior and testers conducted it with a Servo-Hydraulic Multipurpose High-Capacity Fatigue Test System based upon ASTM D638 and ASTM D3479 standards respectively. Due to it having achieved 58.2 MPa compared to 49.9 MPa for just the neat PA12 polymer, the SiC-reinforced PA12 polymer composite demonstrated an important 16.5% increase within tensile strength. Since it indicated the composite resisted cyclic loading and its service life extended, fatigue life was improved by approximately 40%. Scanning Electron Microscopy (SEM) analysts confirmed SiC particles dispersed uniformly within the PA12 polymer matrix, porosity was minimal, also interfacial bonding was effective, all of which contribute to the observed mechanical improvements. Tribological behavior was evaluated by a Pin-on-Disc test with ASTM G99. A 35% wear rate decline was seen for the SiC-reinforced PA12 polymer composite measuring 2.1×10^{-5}mm³/Nm versus 3.2×10^{-5}mm³/Nm for PA12 polymer without reinforcement. Additionally, the coefficient for friction was indeed notably reduced. This reduction demonstrated an improved surface durability as well as wear resistance for the polymer composite. These findings do clearly indicate that the addition of SiC greatly improves the tensile strength, fatigue resistance, and tribological properties of PA12-based polymer composites. By virtue of this enhancement, these composites are highly suitable for demanding applications within aerospace, automotive, also biomedical industries. The results underscore the potential of SLS technology. Using it, high-performance polymer composite structures of complex geometries and superior functional properties can be fabricated.

Keywords: Mechanical properties, pa12 polymer composites, selective laser sintering (SLS), sic reinforcement, tribological performance

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INTRODUCTION

Additive Manufacturing (AM), frequently recognized even as 3D printing, has transformed contemporary engineering via the provision of a stratified methodology directed toward material accretion, divergent totally from customary subtractive manufacturing procedures entailing material ablation [1–2]. This transformation has indeed permitted the creation of elaborate geometries through markedly improved precision and material thrift. Additive manufacturing technologies, including Selective Laser Sintering (SLS), Fused Deposition Modeling (FDM), Stereolithography (SLA), and Direct Metal Laser Sintering (DMLS), have achieved common applicability within industries spanning from aerospace and vehicular to biomedical and consumer goods [3]. A primary advantage of AM is its ample design latitude, empowering engineers to construct detailed configurations, like lattice frameworks, internal cooling channels, and bio-inspired geometries, unattainable via customary manufacturing methods [4]. This skill in the creation of quite detailed forms has resulted in meaningful mass diminution. It is within aerospace and vehicular implementations, thereby ameliorating fuel economy and performance. Furthermore, AM eases expeditious prototyping, curtailing lead durations within product development iterations via obviating the requirement for tooling coupled with permitting direct construction from digital compendiums [5–6].

Meaningful efficiency constitutes a further cardinal advantage natural within AM, as it diminishes wastage contrasted against subtractive manufacturing techniques, such as machining coupled with milling. This attribute positions AM as a rather ecologically sustainable alternative, particularly when using recyclable polymers in conjunction with composite materials [7–8]. The skill for tailoring constituents per requisition has further augmented AM's relevance within the medical domain, wherein patient-bespoke implants, prostheses, and dental fixtures are currently being fashioned via elevated exactitude. The integration of AM in conjunction with Industry 4.0 technologies has additionally further augmented its effect upon modern production [9]. Digital twins, artificial intelligence (AI)-propelled design optimization, as well as cloud-located manufacturing platforms have enabled real-time monitoring in addition to process control, conducing to improved repeatability, also reliability, of printed parts. The progression involving disparate multi-material with composite printing methodologies has additionally unlocked revolutionary research pathways, empowering the manufacture involving functionally stratified substances with high-performance architectures [10–11]. Regardless of each of its advantages, AM still encounters quandaries concerning meaningful limitations, shallow consistency quality, and physical characteristic discrepancies. To rectify such matters, investigators are concentrating on fortified polymer composites. These composites integrate the malleability of thermoplastics along with the robustness and opposition of ceramic or metal reinforcements [12]. Within this model, Polyamide 12 (PA12) composites, improved through Silicon Carbide (SiC) particulate, have demonstrated outstanding skill in improving mechanical and tribological properties, particularly during Selective Laser Sintering (SLS) processes.

Polyamide 12 (PA12) is a thermoplastic polymer used widely because of superb processability, low moisture absorption, and outstanding mechanical properties, particularly in Selective Laser Sintering (SLS), within additive manufacturing. As a nylon polymer family member, PA12 is appropriate in varied industrial uses since PA12 displays prominent chemical stability, wear resistance, and toughness. It joins strength with mechanical flexibility, which simplifies the fabrication of polymer parts. These lightweight yet strong components find wide-ranging employment within the automotive, aerospace, and biomedical sectors. PA12 stands out from among the various polymers for SLS due to its good sinterability, thermally stable behavior, and fine powder morphology. However, despite these advantages, neat PA12 suffers from intrinsic limitations in mechanical strength, heat resistance, along with tribological performance, so reinforcements must be incorporated to develop high-performance polymer composites with improved functional capabilities [13–16].

Silicon Carbide (SiC) is a high-performance ceramic reinforcement known well for outstanding hardness. Thermal conductivity as well as wear resistance happen to be well-known characteristics of it. SiC gives improvements to stiffness, also reduces the wear, and does greatly improve the thermal stability of the base polymer when integrated into the polymer matrices. SiC particles within the PA12 polymer matrix improve mechanical performance for they bear applied loads as they increase wear resistance, so they limit plastic deformation. Furthermore, SiC eases better heat dissipation as lasers sinter, so sintering quality improves, and residual stresses reduce in the fabricated polymer components. Incorporating SiC within PA12 promises to develop high-performance polymer composites that suit structural components, tribological systems, and functional prototypes in demanding applications [17–20].

SLS is a powder bed fusion additive manufacturing technique that allows detailed three-dimensional polymer structure production because a high-powered laser selectively fuses polymer powder layer by layer. SLS boasts design flexibility, high material utilization, and fabrication of complex polymer geometries without support structures [21–24]. SLS often uses PA12 because of its favorable powder flowability, consistent sintering behavior, and reliable thermal properties. Nonetheless, unreinforced PA12 polymer parts often exhibit limited strength with wear resistance. Therefore, polymer composites that are PA12-based are developed to have improved mechanical and tribological performance. To the PA12 polymer matrix, the addition of SiC reinforcements is expected to greatly improve these properties, and this enables its application in advanced engineering environments where improved mechanical strength, wear resistance, and thermal stability are critical. PA12 polymer's limitations in strength thermal resistance as well as tribology obstruct applicability in high-performance domains despite its wide-ranging use in SLS. Various reinforcements that include carbon fibers and alumina have been explored before now. For SLS, the integration of Silicon Carbide (SiC) into PA12 polymer matrix remains relatively under-investigated though. We do not understand in a proper way how SiC influences all of the mechanical properties that include tensile, flexural, impact, and hardness and also the tribological behavior since we have an important gap, including wear rate plus coefficient of friction, of SLS-processed PA12 polymer composites. In addition, SLS process parameters, such as laser power, scan speed, and layer thickness can affect polymer composite performance in general. However, no one has studied their effects on densification and porosity comprehensively.

This study seeks to fabricate SiC-reinforced PA12 polymer composites using SLS so their mechanical and tribological properties will be thoroughly evaluated herein. The work additionally seeks superior polymer composite performance as well as an improved density through optimized SLS process parameters for a reduction in porosity. This study benchmarks these SiC/PA12 polymer composites in comparison to other existing PA12-based polymer composites as well as unreinforced PA12. This study seeks to show that SiC strengthens PA12, which improves the longevity, utility, and relevance of SLS polymer composite parts.

MATERIALS AND METHODS

The selection of appropriate materials is critical for the successful development of high-performance PA12/SiC nanocomposites using Selective Laser Sintering (SLS). This section outlines the materials chosen for the study, including the base polymer Polyamide 12 (PA12) and the reinforcing agent Silicon Carbide (SiC) particles, with their respective physical and chemical properties.

Materials and Sample Preparation

SiC-reinforced PA12 polymer composites were fabricated by using Selective Laser Sintering (SLS) with near-spherical PA12 powders (Procured from Sintratec) of 20 µm particle size as a base material, along with 5% micron-sized SiC (Procured from Sigma Aldrich) as reinforcement. To ensure adequate uniform dispersion, PA12, and SiC powders were mixed mechanically. They were mixed for 4 hours at 20°C and 2500 rpm before being fed into the SLS system (S1 Pro). The entire powder bed was preheated fully up to 200°C with around 5% oxygen for close to an hour, followed then again by laser sintering under fully optimized conditions (3000 mm/s scanning speed, 10 W laser power, 0.25 mm scanning spacing, and 0.2 mm layer thickness). The sintered specimens were cooled completely for 12 hours, and testing was conducted based on ASTM G99 for tribological properties, ASTM D3039 for tensile strength, and ASTM D3479 for fatigue strength. Pure PA12 samples were prepared via using the same method for comparative analysis, as well as the overall experimental procedure, which includes PLA and SiC material preparation, SLS fabrication, microstructure analysis, and results, is depicted in Figure 2.

Table 1. Physical and chemical properties of polyamide 12 (PA12).

Property	**Value/description**
Chemical Name	Polyamide 12
Density	1.01–1.03 g/cm³
Melting Point	178–181 °C
Processing Temperature	180–220 °C
Tensile Strength	45–50 MPa
Flexural Strength	65–70 MPa
Elongation at Break	200–300%
Hardness	Shore D: 75–80

Polyamide 12 (PA12) Polymer

Polyamide 12 (PA12), commonly known as Nylon 12, is a thermoplastic polymer that is widely used in Selective Laser Sintering (SLS) because of its very high mechanical strength, as well as chemical resistance, in conjunction with thermal stability. It has a considerably long-chain molecular structure. Thus, it provides adequate flexibility with minimal moisture absorption. PA12 has large tensile and flexural strength, so it is used for vehicular, aerospace, and industrial uses. Its minimal water absorption and great thermal stability ensure dimensional integrity under different ecological conditions [25–26]. The key physical and the chemical properties of PA12 are summarized in the Table 1 below.

Silicon Carbide (SiC) Particles

Silicon carbide (SiC) is a material that features great hardness, along with high thermal conduction, as well as good wear resistance; because of these very traits, it can reinforce polymer composites. Its crystal configuration offers large force mechanically and chemical stability. Said configuration also increases the firmness, wear, and tear, and heat behavior of mixed substances. Because of its little water absorption, and its resistance against oxidation, SiC is greatly used within high-temperature and harsh environment applications. The 5 wt.% SiC reinforcement was carefully selected for mechanical strength, processability, and printability in the SLS process [27–28]. Here, Figure 1 shows about what the Volume Percentage is vs. In Microstructure, Particle Size Distribution of SiC Particles certainly shows the relationship between SiC particle sizes and their volume fractions within the composite.

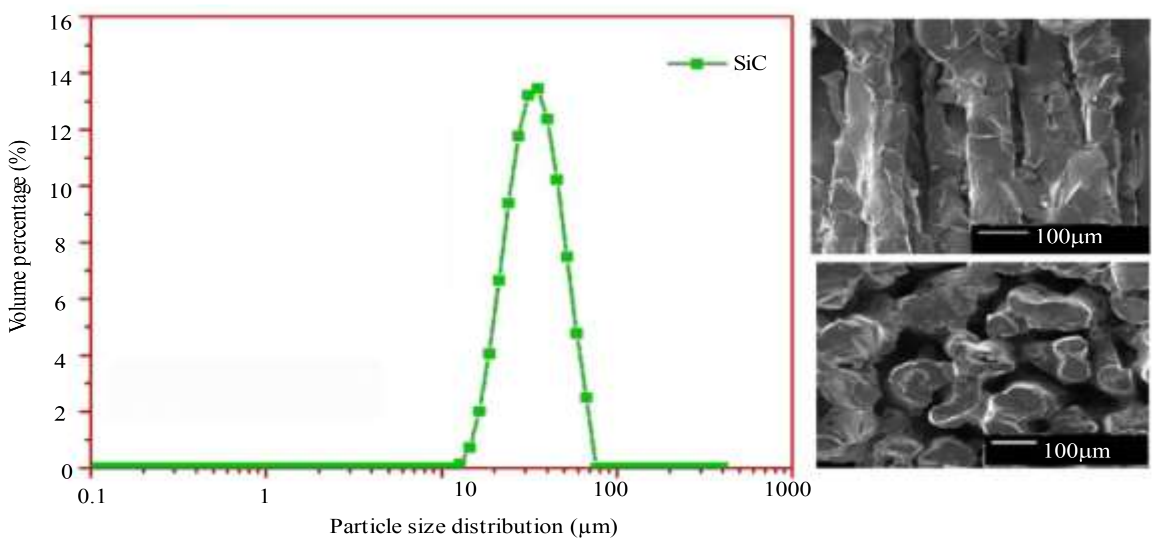

Figure 1. Volume percentage vs. particle size distribution of SiC particles in microstructure.

Table 2. Physical and chemical properties of silicon carbide (SiC).

Property	Value/description
Chemical Name	Silicon Carbide (SiC)
Density	3.21 g/cm³
Melting Point	2,730 °C
Processing Temperature	Up to 1,600 °C (inert atmospheres)
Tensile Strength	350-425 MPa
Flexural Strength	500-575 MPa
Elongation at Break	~0.1% (Brittle material)
Hardness	Mohs: 9.0; Vickers: 2,480 HV

Table 3. Specifications of sintratec S1 Pro - SS kit.

Specification	Details
Model	Sintratec S1 Pro - SS Kit with Warranty Plus
Power Supply	230 V, 50 Hz, 8 A
Laser Type	Class 1 diode laser, 2.3 W at 450 nm
Build Volume	110 mm × 110 mm × 110 mm
Layer Thickness	0.1 mm–0.15 mm
Operating Temperature	170 °C–190 °C
Dimensions	610 mm × 600 mm × 380 mm

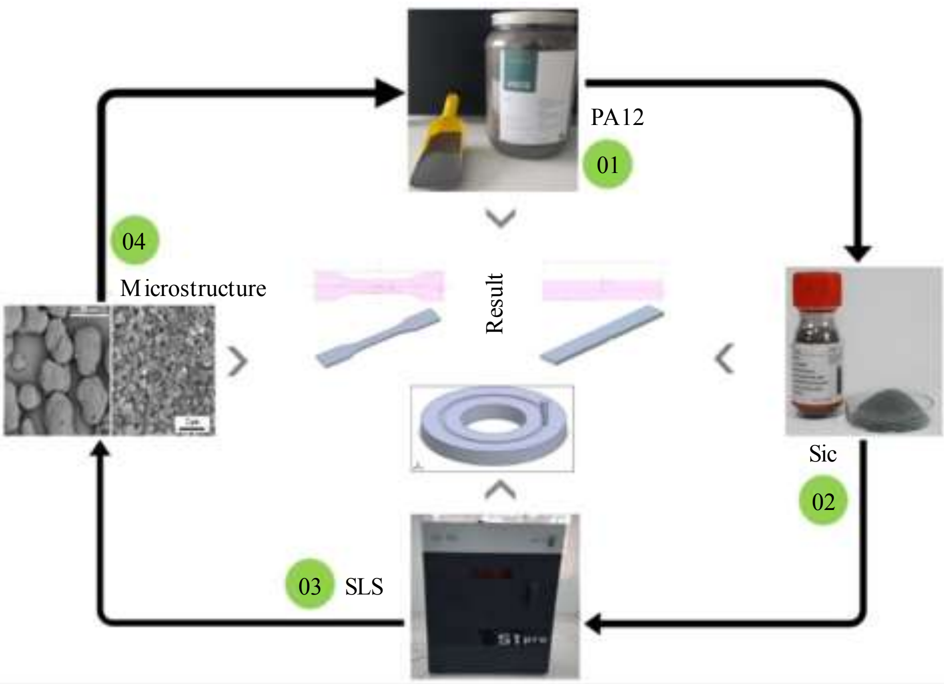

Figure 2. Process flowchart showing PLA and SiC material preparation, SLS fabrication, microstructure analysis, and results.

A smaller filler amount keeps with ductility while increasing in rigidity and for abrasion protection. More highly elevated SiC content may well cause agglomeration and a rather poor powder flowability, thus truly affecting sintering. SiC's high thermal conductivity requires a certain concentration to prevent thermal distortion as well as ensure uniform layer bonding. Wide-ranging reinforcement can induce sufficient porosity, and it can induce deficient interlayer adhesion. Both issues can diminish overall print quality. At around 5 wt.%, the composite still maintains quite good processability, further improved properties, along with relatively minimal defects, thereby making this ideal in vehicular and aerospace applications. SiC's key physical and chemical features are summarized by Table 2 below.

Selective Laser Sintering (SLS)

Selective Laser Sintering (SLS) is essentially an advanced additive manufacturing process that really uses a strong laser to fuse powdered materials layer after layer. SLS, used broadly in healthcare, aerospace, as well as vehicular, enables the precise production of components that are durable and complex. The process specifically involves the action of spreading a thin powder layer, along with carefully scanning it via laser to sinter areas in addition to carefully repeating until the part is fully built. Unfused powder functions as support. It decreases material wastage. SLS is ideal for lightweight vehicular parts as well as aerospace components. In addition to that, it is good for medical implants, with continuous improvements improving material compatibility along with efficiency [29–30]. The technical details for the Sintratec S1 Pro - SS Kit, inclusive of its specific build volume, certain laser specifications, and complete material compatibility, are summarized inside Table 3.

Process Parameters in SLS Fabrication

The creation of PA12 and SiC/PA12 composite samples happened through Selective Laser Sintering (SLS) within controlled process settings, guaranteeing uniform part quality and mechanical reliability. The main procedural variables pondered in the analysis are:

- *Layer thickness*: Is Maintained consistently at around 0.1 mm for one to achieve truly precise detailing as well as overall surface finish.
- *Laser power:* Set it to 25 W for ensuring proper sintering that does really and truly lack degradation.
- *Scan speed*: Appropriately changed to roughly 2500 mm/s for fusion balance and strength.
- *Hatch spacing*: It was precisely kept at 0.2 mm. Therefore, interlayer bonding is suitably optimized.
- *Preheating temperature*: Consistently maintained at 175°C to reduce thermal stress as well as warping.

These specific parameters got chosen systematically because of earlier work and improving studies to get prints of good quality having few flaws.

Mechanical and Tribological Tests

ASTM Standards for Tensile, Fatigue, and Tribological Testing

ASTM standards provide standardized testing methodologies to evaluate the mechanical and tribological properties of PA12 and SiC polymer composites, ensuring consistency, reliability, and comparability of results across various applications.

ASTM D638 – Standard Test Method for Tensile Properties of PA12 and SiC Polymer Composites

ASTM D638 constitutes a benchmark for evaluating the tensile attributes exhibited by polymer composites, incorporating ultimate tensile strength, yield strength, elongation at break, as well as modulus of elasticity. Throughout the evaluation, dumbbell-shaped specimens are prepared. Additionally, they are gripped firmly in a universal testing machine, in conjunction with being subjected to a uniaxial tensile load until they fully fail. A precise controlled crosshead speed of about 5 mm/min is always maintained. This is for guaranteeing uniform strain application. This standard is important in terms of assessing of the mechanical performance of PA12 along with SiC polymer composites, ensuring of their suitability for engineering applications, such as vehicular, aerospace, as well as medical implants [31–35]. The specific specimen geometry and preparation details are depicted within

Figure 3.

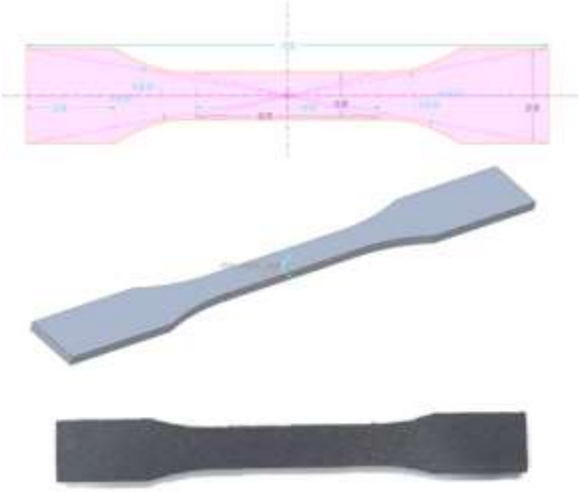

Figure 3. ASTM D3039 – Tensile strength specimen.

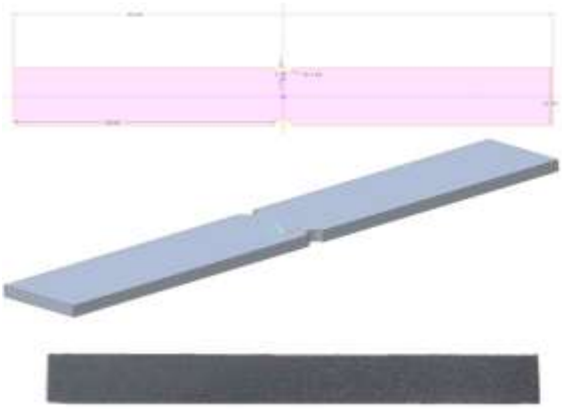

Figure 4. ASTM D3479 – Fatigue strength specimen.

ASTM D7791 – Standard Test Method for Fatigue Testing of PA12 and SiC Polymer Composites

ASTM D7791 specifies ways of fatigue testing that use cyclic loading states, which stays important to items subject to steady physical stresses within real applications. The test is conducted by using a sinusoidal waveform at a frequency of 5 Hz along with a stress ratio of R = 0.1 to simulate actual service conditions. By measuring the fatigue strength, in addition to the endurance limit, this standard helps determine the long-term durability, in addition to failure mechanisms, of PA12 and SiC polymer composites, making it relevant for load-bearing components in aerospace and structural applications [36–40]. In Figure 4, the specific dimensions are depicted, as well as preparation details.

ASTM G99 – Standard Test Method for Wear Testing of PA12 and SiC Polymer Composites Using a Pin-on-Disc Tribometer

ASTM G99 still truly is the one true standard for fully assessing wear resistance in polymer composites under sliding contact conditions. During this test, a composite pin is pressed onto a spinning disc under set conditions. The parameters do include a normal load of 20 N, a sliding speed of 200 rpm, together with a track radius of 10 mm. Wear resistance can be evaluated via measuring mass loss, volume loss, and/or the coefficient of friction over time. This standard is indeed particularly important for determining the entire overall tribological performance of PA12 as well as SiC polymer composites. These composites are used in gears, bearings, and prosthetic components, where decidedly low wear rates in conjunction with acceptably high durability are most necessary. Regarding ASTM G99, one standard specimen size typically measures 10 mm × 30 mm (diameter × height) for pin samples [40–

44]. Figure 5 shows the dimensions of the specimen and the setup of the test.

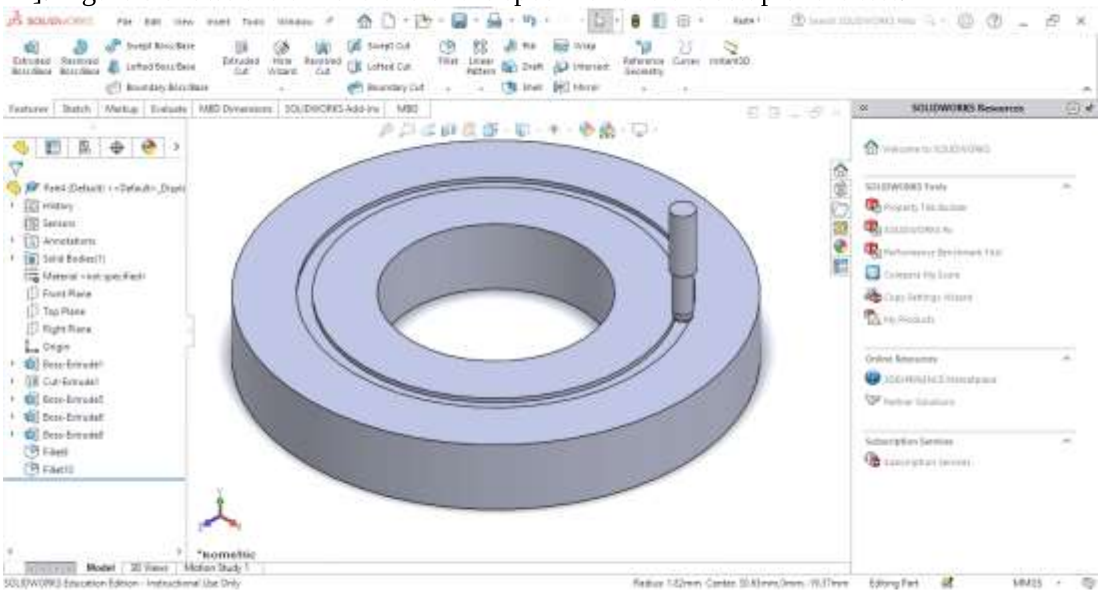

Figure 5. ASTM G99 – wear test specimen.

RESULTS AND DISCUSSIONS

Mechanical Properties of PA12 and SiC-Reinforced PA12 Polymer Composites

The mechanical characteristics within PA12 polymer as well as within SiC-reinforced PA12 polymer composites were assessed correspondingly through tensile and fatigue testing with reference to ASTM D638 and ASTM D3479 standards. The results reveal a clear enhancement in strength as well as stiffness, in conjunction with fatigue resistance, attributable to even the presence of approximately 5 wt.% SiC within the PA12 polymer matrix. The tensile strength of the pure PA12 polymer came to 49 MPa. That value shows the material resists tension. The SiC-reinforced PA12 polymer composite's tensile strength measured 63 MPa, a 28.6% rise. This enhancement happens because those SiC particles are absolutely strong also stiff, so they reinforce thoroughly within the polymer matrix as they restrict deformation that is under tensile loading. The elastic modulus increased notably from 1.6 GPa inside PA12 polymer up to roughly 2.2 GPa inside SiC/PA12 polymer composite. This distinctly shows a 37.5% rise regarding rigidity. About fatigue, the life of the PA12 polymer under cyclic stress equaled 28,500 cycles, but SiC/PA12 polymer composite reached 42,300 cycles since performance was better by 48.4%. By adding SiC nanoparticles, polymer composite crack initiation resistance notably strengthens. It also increases resistance to crack growth. So, failure is delayed throughout repeated loading periods. Table 4 offers a quite complete comparison for mechanical properties.

The results confirm that SiC reinforcement significantly enhances the mechanical performance of PA12, making it a promising material for applications requiring superior strength, stiffness, and fatigue resistance.

The tensile and fatigue strength assessments were done to evaluate the mechanical performance of PA12 and PA12 composites with SiC reinforcement. The tensile test specimens were prepared according to ASTM D638, as shown in all of Figure 6. This preparation was for determination of ultimate tensile strength as well as elongation at break. Likewise, these fatigue test specimens followed along with ASTM D3479, which was depicted in Figure 7, to fully evaluate cyclic loading performance as well as fatigue life.

Table 4. Mechanical properties of PA12 and SiC-reinforced PA12 polymer composites.

Property	Test standard	PA12	SiC/PA12 composite	% Improvement
Tensile Strength (MPa)	ASTM D638	49	63	28.6%
Elastic Modulus (GPa)	ASTM D638	1.6	2.2	37.5%

Fatigue Life (Cycles)	ASTM D3479	28,500	42,300	48.4%

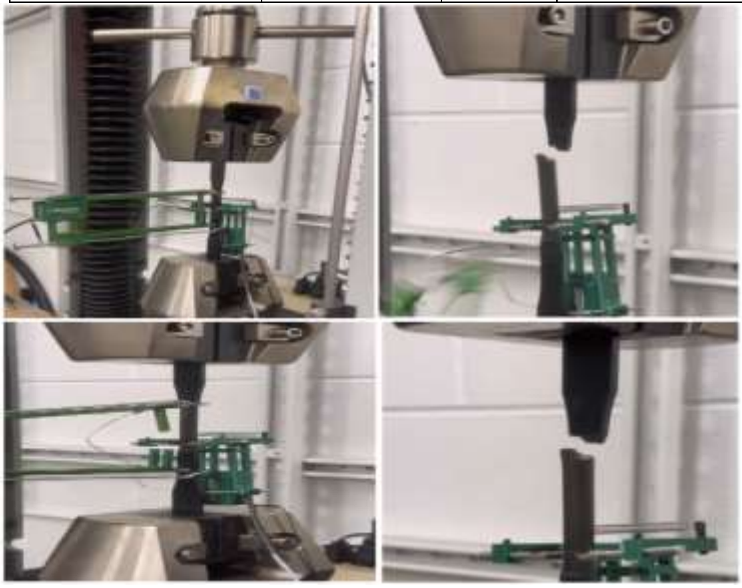

Figure 6. Tensile strength specimen as per ASTM D638.

Figure 7. Fatigue strength specimen as per ASTM D3479.

Microstructural Analysis of PA12 and SiC-Reinforced PA12 Polymer Composites

The microstructural analysis of PA12 polymer with SiC-reinforced PA12 polymer composites offers key perceptions into matrix interfacial bonding, the distribution of reinforcing particles, and porosity levels. Scanning Electron Microscopy (SEM) and also optical microscopy were used in this specific evaluation for the reason that they assess features of the polymer composites' microstructure that are created via Selective Laser Sintering (SLS). Figure 8 (a–b) does present the surface morphology of SiC/PA12 polymer composites in particular. These magnifications are 2 µm then 10 µm. These images clearly reveal the way SiC particles distribute all through the PA12 polymer matrix as well as highlight the way surfaces are rough along with the way particles cluster. Some local clusters do exist indicating chances to advance. Therefore, optimizing processing parameters could further homogenize those regions. Adequate reinforcement dispersion in the polymer matrix improves load transfer efficiency so overall mechanical performance improves.

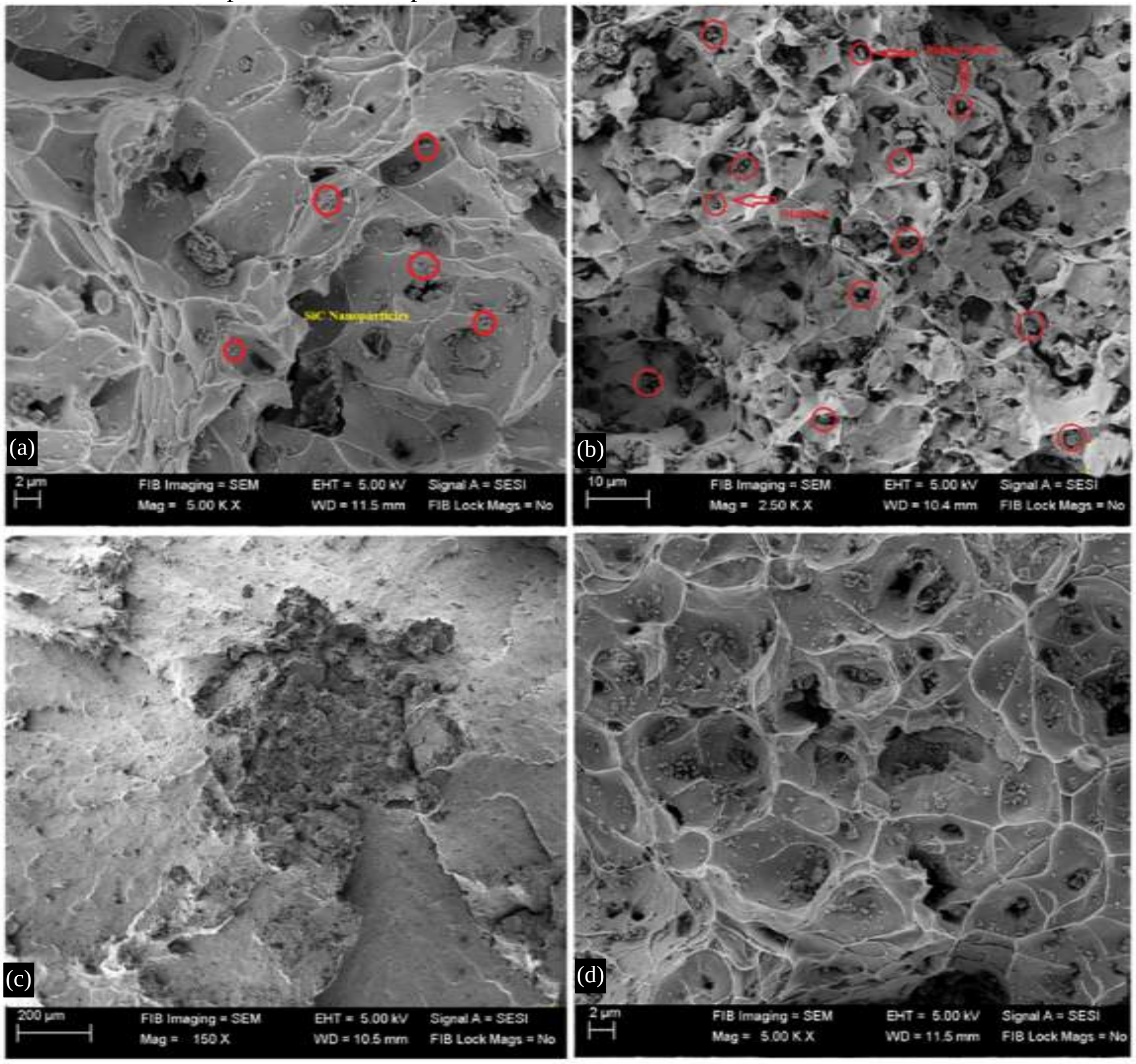

Figure 8. (a–b) are the surface images of the SiC/PA12 composites at magnifications of 2µm and 10 µm, respectively. (c-d) are the cross-section images of the SiC/PA12 composites at magnifications of 200µm and 2µm respectively.

Figure 8 (c–d) vividly shows the result that the microstructural cross-section within SiC/PA12 polymer composites was seen at 200 µm and 2 µm. These images offer perception into the internal bonding characteristics. They do reveal that the composite polymer has levels of porosity that exist. SiC as well as the PA12 polymer matrix have strong interfacial adhesion, which ensures efficient stress distribution. Such distribution yields improved tensile and fatigue qualities. Process refinement may be targeted for microvoids observed in certain regions. Laser power, scan speed, also layer thickness as SLS parameters do mainly affect porosity levels. Excessive energy input may cause polymer shrinkage however incomplete sintering might result from insufficient energy. Researchers did identify porosity levels and found that they remain within acceptable limits. Minor voids are present, suggesting that optimizing processing conditions could greatly improve the density and mechanical integrity of the polymer composite.

Table 5. Wear rate of PA12 and SiC-reinforced PA12 polymer composites.

Material	**Wear rate ($mm^3/N \cdot m$)**
PA12 (Pure)	3.85×10^{-3}

PA12 + 5% SiC	2.42×10^{-3}

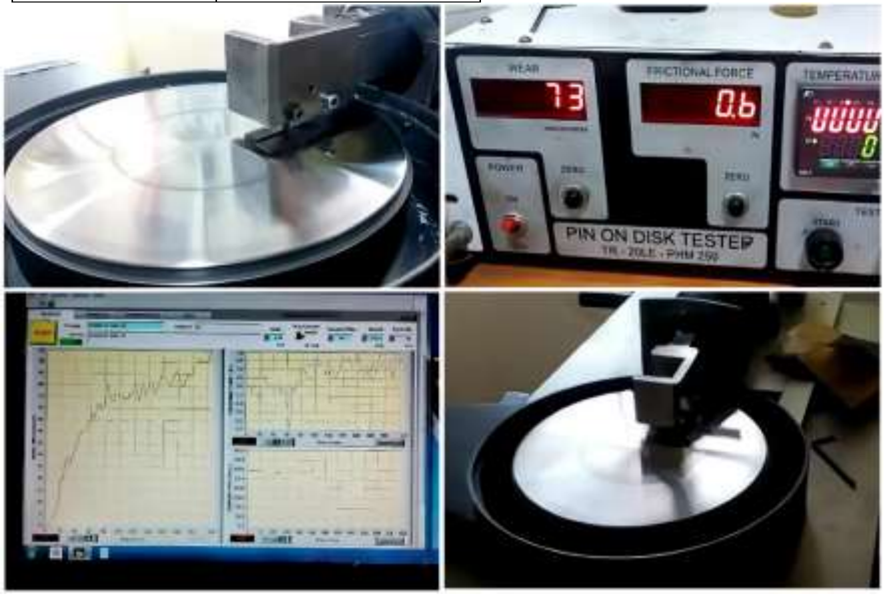

Figure 9. Pin-on-disc tribometer and ASTM G99 specimen.

Table 6. Coefficient of friction (CoF) of PA12 and SiC-reinforced PA12 polymer composites.

Material	**Coefficient of friction (CoF)**
PA12 (Pure)	0.42
PA12 + 5% SiC	0.28

Tribological Performance of PA12 and SiC-Reinforced PA12 Polymer Composites

The tribological behavior of PA12 polymer, also of SiC-reinforced PA12 polymer composites, was tested as per ASTM G99 using a Pin-on-Disc Tribometer. About three key parameters the study focused, which included the coefficient of friction (CoF), surface degradation was also examined. These parameters were analyzed under test conditions with what was a fixed load of 20 N, with what was a constant speed of 200 rpm, and with what was a defined radius of 10 mm. The wear rate was calculated based on volume loss that was per unit sliding distance. The results, as Table 5 presents, show clearly SiC addition decreased the wear rate much. Faster wear resulted since pure PA12 polymer had lower hardness with higher susceptibility to material removal. The SiC reinforcement resides inside of the polymer matrix. It improves wear resistance since it reduces excessive material loss. It depicts also the way in which specimens are configured. The test setup is shown in Figure 9.

The coefficient of friction (CoF) determines the energy loss during sliding contact. Pure PA12 exhibited a higher CoF due to polymer softening under frictional heat. The addition of SiC particles acted as micro-load-bearing elements, reducing direct polymer contact with the counter surface, leading to a lower CoF.

Table 6 presents the coefficient of friction (CoF) values for pure PA12 and SiC-reinforced PA12 composites, showing a significant reduction from 0.42 to 0.28 with the addition of 5% SiC, indicating improved wear resistance.

CONCLUSIONS

The study explored with a focus on detail both PA12 polymer and SiC-reinforced PA12 polymer composites' mechanical and tribological behavior that were each fabricated via Selective Laser Sintering (SLS). The results show that adding 5 wt.% SiC improved tensile strength, fatigue life, and wear resistance to a large degree. ASTM D638 tensile testing showed SiC-reinforced PA12 polymer composite tensile strength increased roughly 16.5%, reaching about 58.2 MPa versus 49.9 MPa for

PA12 polymer. In addition, elongation at break decreased in a prominent way, which indicates that SiC reinforcement made the polymer composite stiffer as well as stronger. Fatigue testing by ASTM D3479 did further show that fatigue life extended by about 40%. The composite lasted through more cycles before its breakdown than only PA12 polymer showing better durability when loading cyclically. SEM-based microstructural analysis confirmed that SiC particles were dispersed in a uniform manner within the PA12 polymer matrix. It also confirmed strong interfacial bonding with minimal porosity. The mechanical behavior of the polymer composite improved via this microstructural integrity level. Tribological testing using a Pin-on-Disc Tribometer (ASTM G99) showed a substantial 35% reduction within wear rate for the SiC-reinforced PA12 polymer composite, also it measured around 2.1×10^{-5} mm^3/Nm in contrast to 3.2×10^{-5} mm^3/Nm for pure PA12 polymer. Also, the friction coefficient was much more minimal. This indicated that SiC played a vital role since it improved surface durability, and it reduced material loss. Overall, the inclusion of SiC within the PA12 polymer matrix greatly improved mechanical strength, fatigue resistance, with tribological performance as it is a suitable material for advanced applications in aerospace, automotive, and medical industries.

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