Materials Research. 2025; 28: e20250488
DOI: https://doi.org/10.1590/1980-5373-MR-2025-0488

CC BY

An Investigation of Microstructural and Mechanical Behaviour of AA7050/Si_3N_4 Composites Fabricated Via Powder Metallurgy

KL. Hari Krishna[a]*

[a]*Sri Sivasubramaniya Nadar College of Engineering, Department of Mechanical Engineering, Kalavakkam, Chennai, India.*

Received: June 04, 2025; Revised: July 30, 2025; Accepted: September 06, 2025

This experimental study investigates the microstructural characteristics, density, and mechanical properties of AA 7050 composites incorporating 5 and 15 wt.% Si_3N_4. These composites were fabricated using a powder metallurgy (P/M) process. The fabrication involved the mechanical milling of AA 7050 and Si_3N_4 composite powders, followed by a systematic blending, pressing, and sintering procedure. The sintered samples have been characterised using an optical microscope. The fabricated samples are subject to density analysis, Hardness, compressive strength, impact and tensile strength have been experimentally investigated. The optical microscope reveals a uniform distribution of Si_3N_4 particles and the increase in hardness of AS15 is 43.06% compared to the basic material A0. A 50.08% enhancement in the compressive strength of the AS15 composite compared to the basic material (A0). The AS15 composite exhibits a maximum tensile strength of 230.65 MPa compared to all fabricated alloys and composites. Conversely, the AS15 composite shows a decreased effect strength of up to 9.25J compared to all fabricated composites, attributed to the increased weight percentage of Si_3N_4, which contributes to crack formation at the particle-matrix interface.

Keywords: *AA7050, Powder metallurgy, Optical microscope, Mechanical behaviour, Fracture analysis.*

1. Introduction

In the automotive, aerospace, defence, and electronics sectors, aluminium matrix composites (AMCs) are used as high-performance materials that provide an improved substitute for traditional materials[1]. The industry is focused on developing higher-performance alloys; however, another important strategy for improving the performance of airframe structures involves optimising material utilisation[2]. The strength and damage tolerance are carefully balanced in the alloy composition and heat treatment design of aluminium alloys of the 7000 series for aeronautical applications[3]. Among the various 7XXX series alloys, AA7050 aluminium alloy has been designed to achieve an optimal balance of strength and fracture toughness among other alloys. This alloy is extensively used in interior frameworks, including wing and fuselage connections[4].

The addition of ceramic particles such as TiC, B_4C SiC, AlN and Al_2O_3 contributes to the improvement of the mechanical properties of AMMCS. In the fabrication of composite materials, reinforcement particles like metal nitrides (Si_3N_4) ceramic particles, known for their high mechanical strength and excellent wear resistance, can also serve as reinforcement materials in the manufacturing of AMCs[5,6]. Due to its strong chemical resistance, low coefficient of thermal expansion, oxidation resistance, and thermal stability, silicon nitride (Si_3N_4) ceramics have been investigated for use as engine and metallurgical components[7].

*e-mail: harikrishnakl@ssn.edu.in
Associate Editor: Aloisio Klein.
Editor-in-Chief: Luiz Antonio Pessan.

A number of cutting-edge processes, such as casting, powder metallurgy, spray atomisation, co-deposition, and pressure infiltration, are used for the manufacture of the aluminium composite material. The above techniques enable the manufacturing of materials with improved characteristics that are suitable for a range of applications[8]. A uniform distribution of reinforced particles throughout the matrix is a particularly beneficial feature of the powder metallurgy process. This consistency significantly enhances the material's mechanical and structural characteristics while additionally efficiently controlling the microstructure[9].

Canakci and Varol[10] examined the microstructural and mechanical properties of AA7075/Al–SiC composites fabricated through hot pressing powder metallurgy. Their findings showed that the hardness of the composites decreased by adding aluminium powder content, likely due to higher porosity. This increase in aluminium content negatively impacted the densification ability of the chip–powder mixtures, resulting in enhanced porosity in the composites. Estrada-Guel et al.[11] investigated the impact of milling duration on AA7075/graphite composites. The results indicated a significant increase of 40% in maximum tensile strength and 20% in hardness compared to the as-mixed and extruded control samples. Flores-Campos et al.[12] evaluated the mechanical and microstructural properties of AA7075/silver nanoparticles manufactured via powder metallurgy. Microhardness increases with an increase in Ag-C NP content. Microhardness in the nanocomposite improves with prolonged milling duration.

Ghasalia et al.[13] investigated the mechanical properties as well as the microstructure of Al/ZrB2/Co composites. Their results demonstrated that cobalt additives significantly reduced crack formation and porosity in the microstructure. Additionally, aluminium and ZrB_2 were identified as the only crystalline phases present at higher sintering temperatures. Venkatesan and Xavior[14] examined AA7050/Graphene composites produced by stir and squeeze casting techniques. They found that the presence of graphene significantly affects the yield strength of stir-cast composites, while the melting temperature is the key factor influencing yield strength in squeeze-cast specimens.

Venkatesh and Deoghare[15] carried out an investigation on AA7050/Kaolin composites manufactured via powder metallurgy. The results demonstrated a reduction in the density of the composite material with an increase in the amount of reinforcement. The decrease in density can be attributed to the integration of lighter Kaolin reinforcements. Zhu et al.[16] reported that the presence of dispersed TiB_2 particles significantly enhances the effects of particle-stimulated nucleation (PSN) during recrystallization while concurrently inhibiting grain growth. The initial formation of fine grains is advantageous for dynamic recrystallization (DRX) and superplastic deformation processes.

Bhaskar et al.[17] investigated the impact of Si_3N_4 on AA2024 hybrid composites manufactured through powder metallurgy. The mechanical properties significantly enhance with reinforcement. The alloy composite containing 6 wt.% Si_3N_4 particles exhibit optimal mechanical properties, such as ultimate tensile strength[17]. Arik[18] described the manufacturing of Al–α-Si_3N_4 metal matrix composites (MMCs) via powder metallurgy. A more homogeneous dispersion of α-Si_3N_4 particles was achieved in the Al matrix by the mechanical alloying process based on the conventional mixing method[18]. Shashi Prakash Dwivedi said that the mechanical and microstructural behaviour of the Al-Al_2O_3-Si_3N_4 hybrid composite was examined, manufactured by powder metallurgy procedures. The hardness, compressive strength, and tensile strength of aluminium were enhanced after the incorporation of 5 wt.% Al_2O_3 and 5 wt.% Si_3N_4[19]

According to the literature, there has been no systematic study on examines the mechanical and microstructural behaviours of AA7050/Si_3N_4 composites. The primary objective of this investigation was to fabricate aluminium matrix composites utilizing powder metallurgy techniques. The microstructures of the produced composites were analyzed using optical microscopy (OM), and mechanical properties were evaluated through hardness testing, tensile strength, compressive and impact analysis as per the ASTM standard. The fracture analysis on tensile and impact samples is analysed through Scanning Electron Microscope [SEM].

2. Experimental Procedure

2.1. Fabrication process

The base material utilized in the present experimental investigation consists of powder derived from AA7050, which was subjected to sieving to obtain a fraction with an average particle size of 30 µm. Commercially available silicon nitride (Si_3N_4) particles, with an average size of 20 µm, were incorporated as reinforcing materials in their as-received state. All elemental powders underwent a drying process at 110 °C for one hour in an oven. The Scanning Electron Micrographs of the as-received aluminium and Silicon Nitride (Si_3N_4) particles are presented in Figures 1a and 1b.

Base matrix and three distinct compositions were prepared with varying weight percentages of Si_3N_4 (5-15 wt%) to conduct this study. To achieve uniform dispersion throughout the matrix, the weight fraction of Si_3N_4 reinforcement was sustained at around 5–15 wt.% concentration. Upon additional increases in Si_3N_4 density, a decrease may occur, maybe owing to agglomeration. A mixture of AA7050 and Si_3N_4 powders was subjected to milling in a planetary ball mill to produce an aluminium composite. The resultant milled powders were amalgamated in a uniaxial die at room temperature, by maintaining a constant pressure of 700 MPa, which results in the formation of green compacts. Prior to each experimental run, the die walls were manually lubricated with zinc stearate.

The green compacts were subsequently sintered at a carefully regulated temperature of 530°C for a duration of 60 minutes. Following the sintering process, the composites underwent solution treatment at 540°C in a muffle furnace for 120 minutes and were then subjected to water quenching. The composites were allowed to naturally age for a period of 72 hours. The fabricated alloy and composites are presented in Figure 2. The fabricated samples are designated as A0, AS5, AS10, AS15 as per the varying Si_3N_4 of (0, 5, 10 and 15 wt.%), respectively.

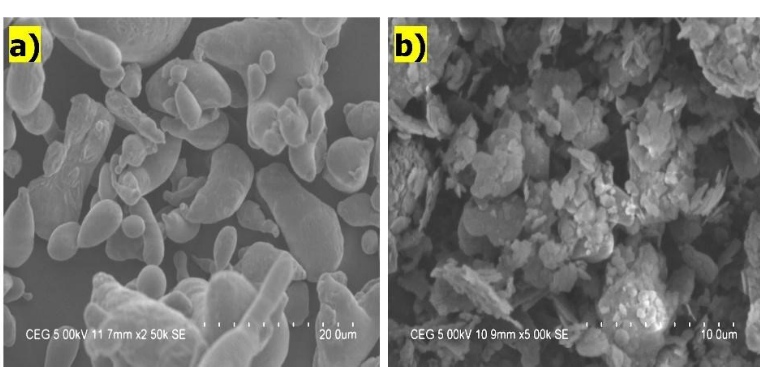

Figure 1. Morphology of as-received (a) AA7050, (b) Si_3N_4 powder.

2.2. Optical microstructure

Metallographic samples were made by hand polishing silicon carbide papers with grit sizes of 240, 600, 800, and 1000. Further refinement was carried out using one micrometer diamond paste combined with refined water to attain a mirror-like finish. The developed samples were subsequently exposed to a Keller etching solution that included 1.5 ml of hydrochloric acid, 1 ml of hydrofluoric acid along with 2.5 ml of nitric acid diluted in 95 ml of refined water. The etch-polish-etch method was employed to ensure an enhanced microstructure. The fabricated sample is subjected to X-ray diffraction (XRD) in order to confirm the phase analysis and chemical composition.

2.3. Physical and mechanical characterization

The density of the specimens was determined utilizing a high-precision digital electronic balance with an accuracy of 0.0001 g, in accordance with Archimedes' principle. A microhardness test was conducted on the polished samples as per ASTM standard E384-99[20] applying a load of 100 g with a dwell time of 15 seconds. The indentation was carried out in four different locations, and the average value is reported. The compression test was performed to assess the mechanical properties of the samples in accordance with the ASTM E9-89[21] standard, using computerised testing equipment at a feed rate of 1 mm per minute. Tensile strength of alloys and composites is carried out as per ASTM E8[22], using a universal testing machine (UTM), with a cross-head speed of 1.0 mm/min. Charpy Impact test conducted as per ASTM A370[23], all the tests were carried out three times, and the average value is reported. The fracture analysis on tensile and impact strength is analysed using SEM.

3. Results and Discussion

3.1. Microstructural characterization

Figure. 3a illustrates the microstructure of a sintered pure AA7050 matrix. This figure indicates a robust chemical bonding among the aluminium (Al) particles, which coalesce to form a solid structure, as depicted in Figure 3a. Figure 3b-d displays the microstructure of the sintered aluminium incorporated with Si_3N_4 particles.

Figure 2. Fabricated samples.

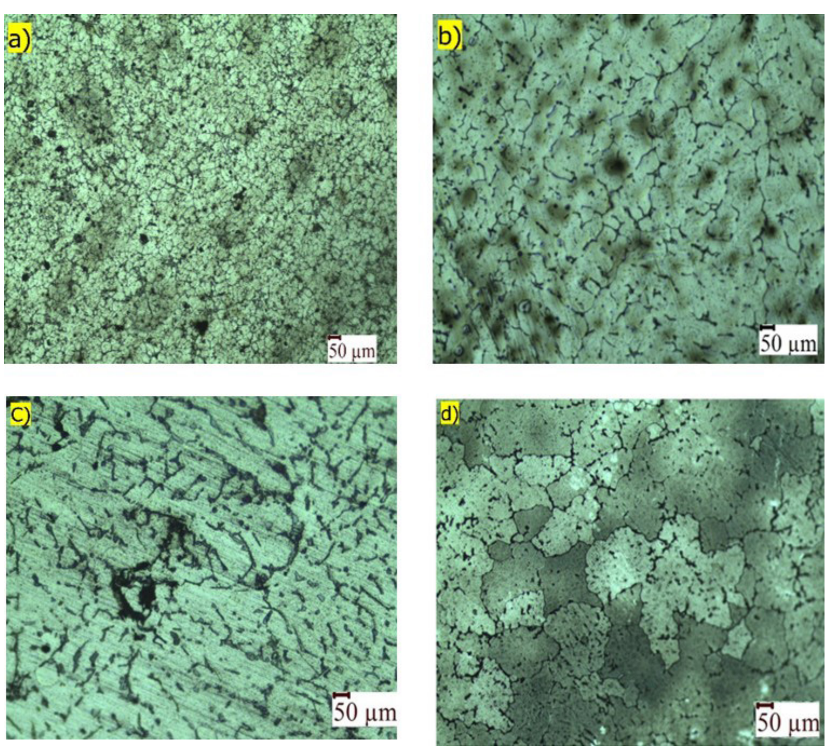

Figure 3. Optical micrograph of fabricated alloy and composites (a) A0 (b) AS5 (C) AS10 (d) AS15.

The micrographs demonstrate that the particles are uniformly distributed throughout the matrix phase, with no cracks detectable in the alloy and composites. Furthermore, the amalgamation of aluminium powder and reinforcement particles during the sintering process has resulted in effective chemical bonding between the components[24]. Figure 4 shows XRD analysis of AS15 composites, it confirms that Si_3N_4 particles are present in the aluminium matrix. The m20axima of silicon and nitrogen are clearly observable in the XRD pattern. The peak of Al in the constructed AMCs appears to be a little shifted towards lower 2 theta angles in comparison to that of AA7050.

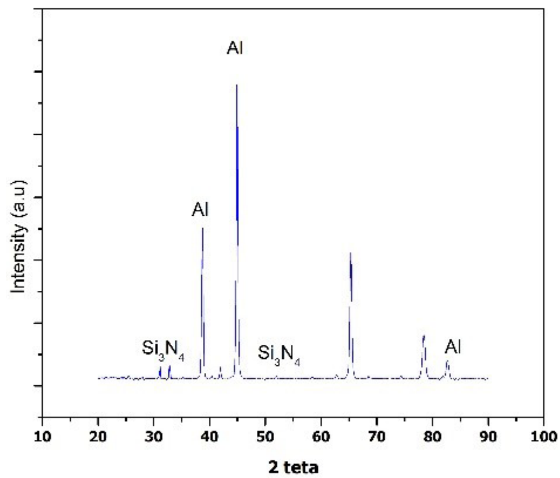

Figure 4. XRD analysis of AS15 composite.

3.2. Sintered density of alloy and composites

Figure 5 shows the density of alloys and composites. It reveals a significant correlation has been seen between the density of composites and the amount of silicon nitride (Si_3N_4) present. An increase in Si_3N_4 reinforcement is associated with an increase in the density of the composites. This phenomenon is due to enhanced atomic diffusion at higher sintering temperatures, which enhances the sinterability of the composites[25].

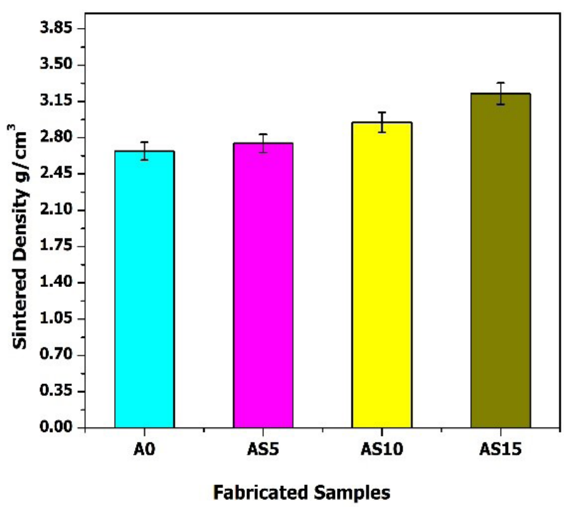

Figure 5. Sintered density of alloy and composites.

3.3. Micro Vickers hardness

Figure 6 presents the Vickers hardness values for AA7050 and the AA7050/Si_3N_4 composites. The incorporation of reinforcing particles, specifically Al– Si_3N_4, into the matrix material significantly enhances hardness. Notably, the composite exhibiting the highest hardness contains 15 wt% Si_3N_4. This improvement in hardness is attributed to the uniformly distributed and considerably stronger reinforcements present within the composite structure[26].

The incorporation of hard particles significantly enhances the base matrix's resistance to deformation when subjected to applied loads. At sintering temperatures, diffusion facilitates the effective bonding between the matrix and the Si3N4 reinforcement. Si3N4 exhibits a substantial specific surface area, which contributes to its effectiveness[27]. AS15 composite shows 30.65% when 15 weight percent of 20 µm Si_3N_4 particles is integrated into the alloy, an impressive 43% increase in hardness is observed. This enhancement is attributable to the greater surface area of the finely dispersed particles within the matrix, which ultimately leads to improved performance and durability.

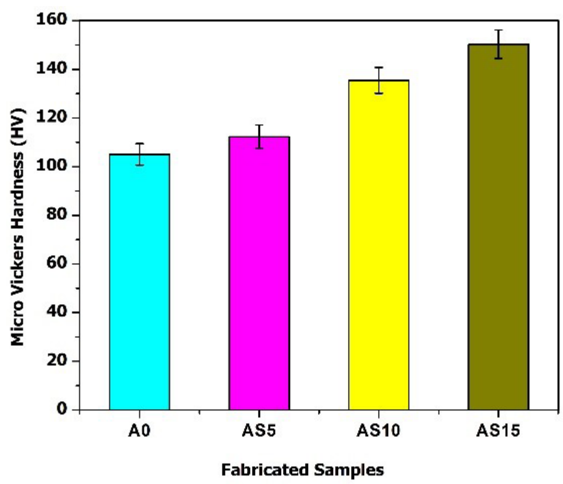

Figure 6. Micro Vickers hardness of alloys and composites.

3.4. Compressive strength of fabricated alloy and composites

The compressive strength of the composite is subjected to experimental investigation. The compressive strength of the aluminium matrix is maximised with a reinforcement content of 15%. Figure 7 presents the experimental results, indicating that an increase in Si3N4 content correlates with an enhancement in the compressive strength of Al-MMC. Si3N4 particles and Al-based solid solutions effectively inhibit fracture growth under load. Consequently, increased stress would induce additional plastic deformation[28,29] consequently, an increase in Si3N4 composition results in enhanced compressive strength.

3.5. Tensile strength and fracture analysis

The strength of composites has been shown to increase when the weight percentage of Si3N4 particles increases, as shown in Figure 8. The improved level of tensile strength attributed to Si3N4 particles enhances the matrix's strength with higher resistance to tensile stresses. The homogenous distribution of particles within the matrix material sustains the applied tensile load[30]. The percentage of elongation decreases with an increase in the wt.% of reinforcement particles.

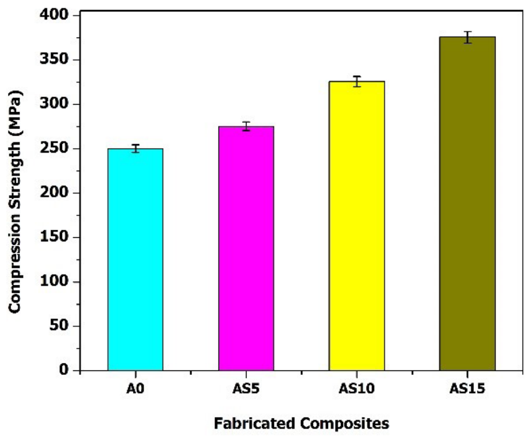

Figure 7. Compressive strength of alloy and composites.

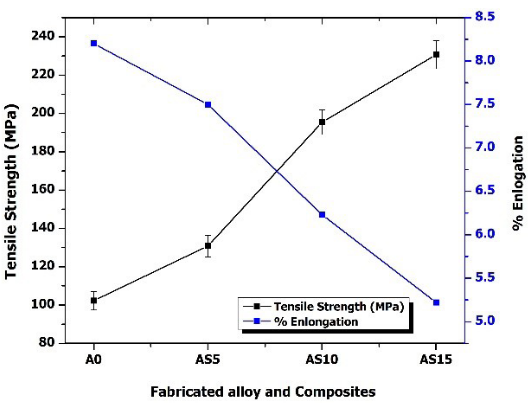

Figure 8. Tensile strength and % elongation of alloy and composites.

The fracture surface's SEM micrograph on A0 shows significant plastic flow before failure. This indicates a ductile fracture mode, seen by the dimple structure in Figure 9a. Due to substantial plastic deformation before failure, several of the ridges that were near the dimple structure were revealed. The composite materials exhibit both ductile and brittle fracture characteristics as represented in Figure 9b. Interface fractures and glossy cleavage surfaces were indicative of the brittle fracture that transpired in the composite after the incorporation of hard particles.

3.6. Impact strength and fracture analysis

The impact energy of the specimen results from the energy received by the material prior to fracture, as shown in Figure 10. The increased effect of aluminium is ascribed to its superior ductility, which facilitates more plastic deformation before fracture in regions of elevated stress concentration. The inclusion of ceramic reinforcements (Si_3N_4) increases the brittleness of the composite, resulting in a diminished energy absorption capacity of the samples as the proportion of reinforcements increases.

The existence of dimples and voids on the fractured surface of the aluminium alloy is indicative of ductile behaviour, as seen in Figure 11a. In all composites, the formation of dimples is diminished owing to the presence of hard particles that alter the failure mechanism from ductile to brittle mode. Figure 11b illustrates that the proliferation of Si_3N_4 particles leads to the formation of fractures at the interface between the particles and the matrix, hence diminishing the energy absorption capacity of the manufactured composites.

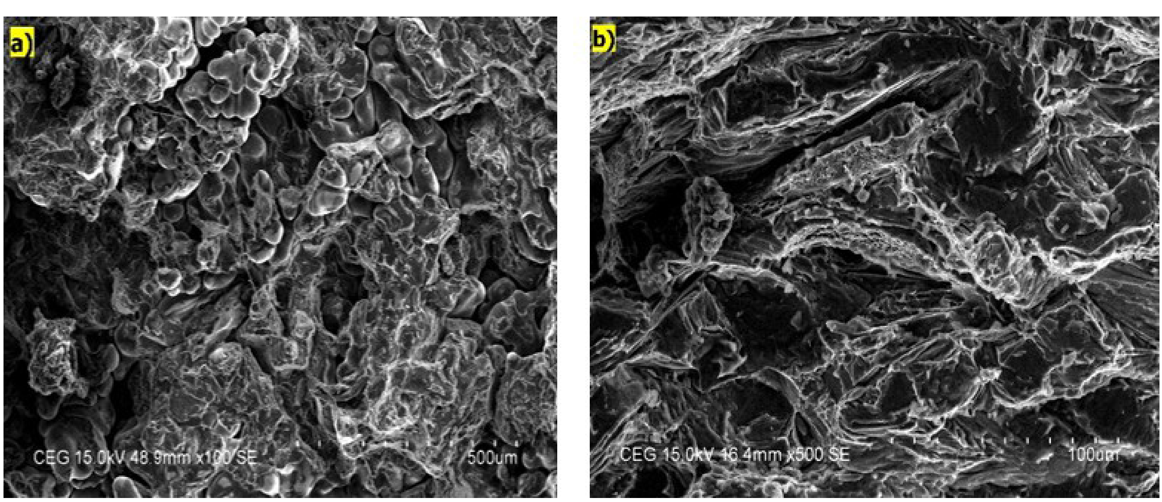

Figure 9. SEM analysis of fractured surface (a) A0, (b) AS10.

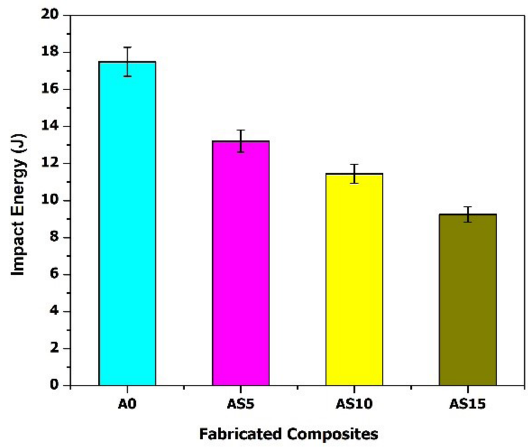

Figure 10. Impact strength of alloy and composites.

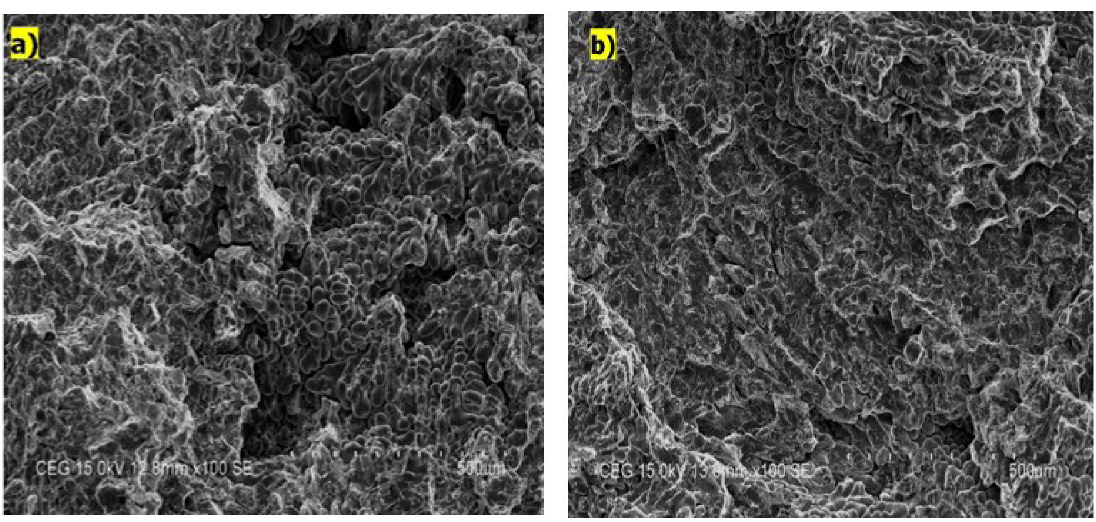

Figure 11. SEM micrograph of fractured surface (a) A0, (b) AS10.

4. Conclusions

The AA7050/ Si_3N_4 composite material was successfully prepared at 5, 10, and 15 wt.% using the powder metallurgy technique. The particle distribution on the matrix material was analysed using an optical microscope. Density, mechanical strength were evaluated, and the results are summarised below.

1. The optical micrograph shows a consistent distribution of Si_3N_4 particles within the matrix, with no defects observed and XRD analysis confirms the presence of Si_3N_4 particles in the matrix material.

2. The density of the composite material increased with the addition of reinforcement, which was attributed to the presence of Si_3N_4 reinforcements.

3. The composite's hardness increases from 105 VHN to 150.32VHN as the Si_3N_4 reinforcement increases from 0% to 15%. The impact of a strong bonding between the base material and the reinforcement is significant.

4. The investigation into the compressive strength of the developed material reveals that, consistent with the principles of hardness, the compressive strength increases with a higher concentration of Si_3N_4. This enhancement in strength can be attributed to the presence of hard particles, which play a significant role in enhancing the material's overall performance.

5. The tensile strength of AS15 composite exhibits a maximum tensile strength of 230.65 MPa compared to all fabricated alloys and composites due to effective sintering of the composite and presence of Si_3N_4 particles.

6. The impact strength of composites decreases with an increase in wt.% of reinforcement due to diminished energy absorption capacity of the samples as the proportion of reinforcements increases.

5. References

1. Liu YQ, Wei SH, Fan JZ, Ma ZL, Zuo T. Mechanical properties of a low-thermal-expansion aluminum/silicon composite produced by powder metallurgy. J Mater Sci Technol. 2014;30(4):417-22. http://doi.org/10.1016/j.jmst.2013.11.003.
2. Oksüz KE, Bagirov H, Şimşir M, Karpuzoğlu C, Ozboluk A, Demirhan YZ, et al. Investigation of mechanical properties and microstructure of AA2024 and AA7075. Appl Mech Mater. 2013;390:547-51. http://doi.org/10.4028/www.scientific.net/AMM.390.547.
3. Dumont D, Deschamps A, Brechet Y. On the relationship between microstructure, strength and toughness in AA7050 aluminum alloy. Mater Sci Eng A. 2003;356(1-2):326-36. http://doi.org/10.1016/S0921-5093(03)00145-X.
4. Cavalcante TRF, Pereira GS, Koga GY, Bolfarini C, Bose WW Fo, Avila JA. Fatigue crack propagation of aeronautic AA7050-T7451 and AA2050-T84 aluminum alloys in air and saline environments. Int J Fatigue. 2022;154:106519. http://doi.org/10.1016/j.ijfatigue.2021.106519.
5. Ravindran P, Manisekar K, Narayanasamy R, Narayanasamy P. Tribological behaviour of powder metallurgy-processed aluminium hybrid composites with the addition of graphite solid lubricant. Ceram Int. 2013;39(2):1169-82. http://doi.org/10.1016/j.ceramint.2012.07.041.
6. Sharma P, Sharma S, Khanduja D. Production and some properties of Si3N4 reinforced aluminium alloy composites. J Asian Ceram Soc. 2015;3(3):352-9. http://doi.org/10.1016/j.jascer.2015.07.002.
7. Santos C, Ribeiro S, Strecker K, Rodrigues D Jr, Silva CRM. Highly dense Si_3N_4 crucibles used for Al casting: an investigation of the aluminum–ceramic interface at high temperatures. J Mater Process Technol. 2007;184(1-3):108-14. http://doi.org/10.1016/j.jmatprotec.2006.11.012.
8. Lian Y, Yang Z, Yang J, Mao C. Processing and mechanical properties of 2024 aluminum matrix composites containing Tungsten and Tantalum prepared by PM. Rare Met. 2006;25(6):136-40. http://doi.org/10.1016/S1001-0521(08)60068-6.
9. Rajkumar PR, Kailasanathan C, Senthilkumar A, Selvakumar N, Rajan AJ. Study on formability and strain hardening index: influence of particle size of boron carbide (B_4C) in magnesium matrix composites fabricated by powder metallurgy technique. Mater Res Express. 2020;7(1):016597. http://doi.org/10.1088/2053-1591/ab6c0b.
10. Canakci A, Varol T. Microstructure and properties of AA7075/Al–SiC composites fabricated using powder metallurgy and hot pressing. Powder Technol. 2014;268:72-9. http://doi.org/10.1016/j.powtec.2014.08.016.
11. Estrada-Guel I, Carreño-Gallardo C, Mendoza-Ruiz DC, Miki-Yoshida M, Rocha-Rangel E, Martínez-Sánchez R. Graphite nanoparticle dispersion in 7075 aluminum alloy by means of mechanical alloying. J Alloys Compd. 2009;483(1-2):173-7. http://doi.org/10.1016/j.jallcom.2008.07.190.
12. Flores-Campos R, Mendoza-Ruiz DC, Amézaga-Madrid P, Estrada-Guel I, Miki-Yoshida M, Herrera-Ramírez JM, et al. Microstructural and mechanical characterization in 7075 aluminum alloy reinforced by silver nanoparticles dispersion. J Alloys Compd. 2010;495(2):394-8. http://doi.org/10.1016/j.jallcom.2009.10.209.
13. Ghasali E, Yazdani-Rad R, Rahbari A, Ebadzadeh T. Microwave sintering of aluminum- ZrB_2 composite: focusing on microstructure and mechanical properties. Mater Res. 2016;19(4):765-9. http://doi.org/10.1590/1980-5373-MR-2015-0799.
14. Venkatesan S, Xavior MA. Characterization on aluminum alloy 7050 metal matrix composite reinforced with graphene nanoparticles. Procedia Manuf. 2019;30:120-7. http://doi.org/10.1016/j.promfg.2019.02.018.
15. Venkatesh VSS, Deoghare AB. Fabrication and mechanical behaviour of Al-Kaoline metal matrix composite fabricated through powder metallurgy technique. Mater Today. 2021;38:3291-6. http://doi.org/10.1016/j.matpr.2020.10.021.
16. Zhu H, Liu J, Wu Y, Zhang Q, Shi Q, Chen Z, et al. Hot deformation behavior and workability of in-situ TiB_2/7050Al composites fabricated by powder metallurgy. Materials. 2020;13(23):5319. http://doi.org/10.3390/ma13235319.
17. Bhaskar S, Kumar M, Patnaik A. Effect of Si_3N_4 ceramic particulates on mechanical, thermal, thermo-mechanical and sliding wear performance of AA2024 alloy composites. Silicon. 2022;14(1):239-62. http://doi.org/10.1007/s12633-020-00810-w.
18. Arik H. Effect of mechanical alloying process on mechanical properties of α-Si_3N_4 reinforced aluminum-based composite materials. Mater Des. 2008;29(9):1856-61. http://doi.org/10.1016/j.matdes.2008.03.010.
19. Dwivedi SP. Effect of microwave sintering on the microstructure and mechanical properties of Al-Al_2O_3-Si_3N_4 hybrid composite fabricated by powder metallurgy techniques. Proc Inst Mech Eng, C J Mech Eng Sci. 2023;237(21):5052-65. http://doi.org/10.1177/09544062231159826.
20. ASTM: American Society for Testing and Materials. ASTM E384-99: standard test method for microindentation hardness of materials. West Conshohocken: ASTM; 1999.
21. ASTM: American Society for Testing and Materials. ASTM E9-89a: standard test methods of compression testing of metallic materials at room temperature. West Conshohocken: ASTM; 1995.
22. ASTM: American Society for Testing and Materials. ASTM E8-89a: standard test methods of tension testing of metallic materials. West Conshohocken: ASTM; 1995.
23. ASTM: American Society for Testing and Materials. ASTM A370-22: standard test methods and definitions for mechanical testing of steel products. West Conshohocken: ASTM; 2022.
24. Ravindran P, Manisekar K, Kumar SV, Rathika P. Investigation of microstructure and mechanical properties of aluminum hybrid nano-composites with the additions of solid lubricant. Mater Des. 2013;51:448-56. http://doi.org/10.1016/j.matdes.2013.04.015.
25. Rashad M, Pan F, Tang A, Asif M, Hussain S, Gou J, et al. Improved strength and ductility of magnesium with addition of aluminum and graphene nanoplatelets (Al+ GNPs) using semi powder metallurgy method. J Ind Eng Chem. 2015;23:243-50. http://doi.org/10.1016/j.jiec.2014.08.024.
26. Rashad M, Pan F, Asif M, Hussain S, Saleem M. Improving properties of Mg with Al–Cu additions. Mater Charact. 2014;95:140-7. http://doi.org/10.1016/j.matchar.2014.06.020.
27. Sevik H, Kurnaz SC. Properties of alumina particulate reinforced aluminum alloy produced by pressure die casting. Mater Des. 2006;27(8):676-83. http://doi.org/10.1016/j.matdes.2005.01.006.
28. Sankhla AM, Patel KM, Makhesana MA, Giasin K, Pimenov DY, Wojciechowski S, et al. Effect of mixing method and particle size on hardness and compressive strength of aluminium based metal matrix composite prepared through powder metallurgy route. J Mater Res Technol. 2022;18:282-92. http://doi.org/10.1016/j.jmrt.2022.02.094.
29. Kumar AJP, Rajesh M, Loganathan P, Dhanashekar M, Ayyanar S, Nadanakumar V, et al. Effect of TiB_2 on dry sliding wear behaviour of aluminium-based metal matrix composites fabricated via powder metallurgy. In: Lazar P, Palani IA, Kumar M, editors. High-performance sustainable materials and structures. Cham: Springer; 2024. p. 145-56. http://doi.org/10.1007/978-3-031-72527-2_12.
30. Venkatesh VSS, Deoghare AB. Microstructural characterization and mechanical behaviour of SiC and kaoline reinforced aluminium metal matrix composites fabricated through powder metallurgy technique. Silicon. 2022;14(7):3723-37. http://doi.org/10.1007/s12633-021-01154-9.

Data Availability

The supporting data is available with the corresponding author, Dr. K.L. Hari Krishna.