

Review on CNT Reinforced A357 nanocomposite

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Abstract

Carbon nanotube (CNT)-reinforced aluminum matrix nanocomposites have emerged as promising lightweight structural materials due to their superior mechanical, tribological, and thermal properties. Among aluminum alloys, A357 is widely used because of its excellent castability, high strength-to-weight ratio, and extensive applications in the aerospace and automotive industries. The incorporation of multi-walled carbon nanotubes (MWCNTs) into the A357 matrix enhances mechanical performance through grain refinement, efficient load transfer, Orowan strengthening, and thermal mismatch strengthening. However, achieving uniform CNT dispersion and strong interfacial bonding remains a major challenge, particularly in liquid-state processing. Stir casting is considered the most economical and scalable fabrication technique for producing aluminum matrix nanocomposites.

This review critically examines recent developments in CNT-reinforced aluminum matrix nanocomposites, with particular emphasis on A357 alloy fabricated by stir casting. It summarizes fabrication techniques, CNT dispersion methods, processing parameters, microstructural characterization, and the influence of CNT reinforcement on tensile strength, hardness, wear resistance, and overall composite performance. The review also discusses the principal strengthening mechanisms and critically evaluates key challenges, including CNT agglomeration, porosity formation, poor wettability, and the limited research available on A357-based nanocomposites. Finally, future research directions are proposed, focusing on process optimization, hybrid reinforcement strategies, advanced characterization, and industrial-scale production. This review provides a comprehensive overview of current research and highlights opportunities for developing high-performance A357-MWCNT nanocomposites through stir casting.

Keywords: A357, MWCNTs, Aluminum Matrix Nanocomposites, Stir Casting, Tensile Strength, Hardness.

1. Introduction

Aluminum matrix composites (AMCs) have attracted considerable attention because of their low density, high specific strength, excellent wear resistance, and good corrosion resistance. These characteristics make them ideal for lightweight applications in the automotive, aerospace, marine, and defense industries. Compared with conventional aluminum alloys, AMCs reinforced with ceramic or carbon-based materials offer superior mechanical and tribological properties, thereby expanding their engineering applications [20–22].

Among aluminum alloys, A357 is widely used as a matrix material due to its excellent castability, high strength-to-weight ratio, good corrosion resistance, and improved fatigue performance. Its superior fluidity and low solidification shrinkage make it suitable for manufacturing complex components such as automotive wheels, aircraft parts, engine housings, and suspension systems.

Carbon nanotubes (CNTs), particularly multi-walled carbon nanotubes (MWCNTs), have emerged as effective nanoscale reinforcements for aluminum alloys because of their exceptional tensile strength, high Young's modulus, low density, and excellent thermal conductivity. When uniformly dispersed, MWCNTs significantly improve tensile strength, hardness, wear resistance, and elastic modulus through grain refinement, load transfer, Orowan strengthening, and thermal mismatch strengthening mechanisms [7,8,14,16].

Various fabrication techniques, including powder metallurgy, mechanical alloying, squeeze casting, and stir casting, have been employed to produce CNT-reinforced aluminum nanocomposites. Among these, stir casting is the most

economical and industrially viable method because of its simplicity, scalability, and compatibility with conventional foundry practices. However, uniform CNT dispersion remains a major challenge owing to poor wettability, CNT agglomeration, and porosity during solidification [8,14,21].

Previous studies have demonstrated that the properties of CNT-reinforced aluminum composites are strongly influenced by CNT content and processing parameters such as stirring speed, stirring time, and melt temperature. Optimized processing conditions enhance strength, hardness, and wear resistance, whereas excessive CNT addition leads to agglomeration and reduced composite performance [1–6,10–18].

Although several review articles have discussed CNT-reinforced aluminum matrix composites, most focus on alloys such as AA6061, AA7075, Al2024, and LM13. Comparatively limited attention has been given to A357 alloy fabricated by stir casting. Therefore, this review critically examines the fabrication, microstructural characteristics, mechanical and tribological properties, strengthening mechanisms, and current challenges of CNT-reinforced A357 aluminum nanocomposites produced by stir casting. It also identifies existing research gaps and future directions for developing high-performance lightweight composites for advanced engineering applications.

2. Review of CNT-Reinforced A357 nanocomposite

Following is detailed important insights of various recent literatures of Review of CNT-Reinforced A357 nanocomposite

S r. N o.	Author (s) & Year	Material/Fa brication	Characte rization Techniq ues	Major Findings	Research Gap
1	Aranke and Gandhi (2018)	AA7075 alloy reinforced with multi- walled carbon nanotubes (MWCNTs) fabricated by stir casting. Different CNT contents were incorporated to improve the mechanical performance of the aluminum alloy.	Optical microscop y, SEM, Tensile test, Hardness test	The incorporation of MWCNTs significantly enhanced the tensile strength and hardness of AA7075 owing to grain refinement, efficient load transfer, and increased dislocation density. Proper stirring promoted relatively uniform CNT distribution, whereas excessive CNT addition caused agglomeration that reduced strengthening efficiency. Similar improvements in CNT-reinforced aluminum composites have also been reported in related investigations [23,24,27].	The investigation was limited to tensile strength and hardness. Fatigue life, impact toughness, corrosion resistance, thermal conductivity, and optimization of stirring parameters were not examined. Future studies should focus on improving CNT wettability and dispersion in cast aluminum alloys such as A357 [33,35,36].
2	Bamane et al. (2018)	AA7075/M WCNT metal matrix composite prepared through stir casting.	Pin-on- disc wear test, Hardness test, SEM	MWCNT reinforcement considerably reduced wear rate and friction coefficient by increasing hardness and improving load-bearing capacity of the matrix. The formation of a stable tribological layer minimized material removal during sliding. The obtained results agree well with similar wear studies on	The work mainly focused on tribological performance, while tensile, fatigue, corrosion and thermal properties were not evaluated. Wear behaviour under lubricated, high-temperature and cyclic loading conditions also

				CNT-reinforced aluminum composites [25,28,31].	remains unexplored [34,36].
3	Pérez-Bustamante et al. (2009)	Aluminum-MWCNT nanocomposite produced by mechanical milling followed by consolidation.	SEM, TEM, XRD, Hardness, Compression test	Mechanical milling effectively dispersed CNTs within the aluminum matrix and produced substantial grain refinement. The improved interfacial bonding increased hardness and compressive strength through Orowan strengthening and efficient stress transfer. Similar strengthening mechanisms have been reported in several CNT/Al nanocomposites [23,26,30].	Since the composite was fabricated through powder metallurgy, the findings cannot be directly applied to liquid-state processing. The influence of stir casting parameters on CNT dispersion and porosity requires detailed investigation [36,37].
4	Shin et al. (2016)	Al2024 reinforced with MWCNTs fabricated by press-and-sinter powder metallurgy technique.	SEM, TEM, XRD, Tensile test, Hardness test	Uniformly dispersed CNTs significantly improved tensile strength, elastic modulus and hardness without severe degradation of ductility. Strong interfacial bonding between CNTs and the aluminum matrix enhanced load transfer and delayed crack initiation. Comparable improvements have also been observed in other powder-processed aluminum nanocomposites [24,29].	The processing route involves relatively high manufacturing cost and limited industrial productivity. Comparative studies with economical liquid metallurgy processes such as stir casting are still required [36,38].
5	Rashad et al. (2015)	CNT-reinforced aluminum composite synthesized through powder metallurgy using different CNT contents and processing conditions.	SEM, TEM, Tensile test, Hardness, Density measurement	Mechanical properties were strongly dependent on CNT content, milling duration and consolidation parameters. Optimum CNT addition resulted in maximum tensile strength and hardness, whereas excessive reinforcement promoted agglomeration and reduced mechanical performance. Similar trends have been confirmed by other researchers [23,24,26].	Industrially viable fabrication methods such as stir casting require further optimization to achieve similar dispersion quality. The influence of casting defects, wettability and porosity on CNT-reinforced cast aluminum alloys remains insufficiently understood [36,37].
6	Zhang et al. (2017)	Aluminum matrix nanocomposite reinforced with CNTs using powder metallurgy processing.	SEM, TEM, Tensile test, XRD	The study demonstrated that uniform CNT dispersion is the most critical factor governing the mechanical behaviour of aluminum nanocomposites. Well-dispersed CNTs improved tensile strength and ductility simultaneously, while CNT clustering acted as stress	Efficient CNT dispersion during liquid-state processing still represents a major technological challenge. Further research is required on ultrasonic-assisted stir casting, wetting agents and hybrid processing techniques to minimize

				concentration sites leading to premature failure. These observations are consistent with other published reports [23,24,30].	CNT agglomeration [36,37].
7	Tjong (2013)	Comprehensive review of CNT- and graphene-reinforced metal matrix nanocomposites.	Review of fabrication methods, strengthening mechanisms and characterization techniques	The review summarized various fabrication routes, strengthening mechanisms, microstructural evolution and mechanical behaviour of CNT- and graphene-reinforced metal matrix nanocomposites. The author emphasized grain refinement, thermal mismatch strengthening, Orowan strengthening and load-transfer mechanisms as the primary reasons for enhanced properties. The review also highlighted numerous engineering applications of nanocomposites [32,33,35].	Although extensive progress has been achieved, economical large-scale manufacturing, uniform nanoparticle dispersion and industrial implementation remain significant challenges. More comparative studies involving cast aluminum alloys such as A357 are required [36,38].
8	Esawi and Farag (2007)	Review of CNT-reinforced composites with emphasis on aluminum matrix systems.	Literature review	The authors discussed the exceptional mechanical, thermal and electrical properties of carbon nanotubes and their potential as reinforcement in metal matrix composites. The review identified CNT dispersion, interfacial bonding and wettability as the primary factors controlling composite performance. Similar conclusions have subsequently been validated by several experimental investigations [23,32].	Reliable large-scale manufacturing techniques capable of producing uniformly dispersed CNT-reinforced cast aluminum composites remain unavailable. Future work should focus on economical processing methods, interface engineering and industrial scalability [36,37,38].
9	Chaudhary et al. (2021)	Review of aluminum-based metal matrix composites reinforced with MWCNTs fabricated using powder metallurgy, stir casting, squeeze casting and other	Review of SEM, XRD, TEM, EDS, tensile, hardness and wear studies	The review comprehensively summarized fabrication techniques, reinforcement dispersion methods, characterization approaches and mechanical behaviour of MWCNT-reinforced aluminum composites. It concluded that proper CNT dispersion and strong interfacial bonding are essential for achieving enhanced strength, hardness and wear resistance. The review also emphasized the importance of optimized	Although numerous aluminum alloys have been investigated, very limited work has been reported on A357-MWCNT nanocomposites produced by stir casting. Future studies should focus on alloy-specific optimization, tribological behaviour and industrial-scale manufacturing [36,37,38].

		processing techniques.		processing parameters for minimizing porosity and CNT agglomeration [23,24,32,35].	
10	Khan et al. (2019)	AA7075 reinforced with MWCNTs processed under different fabrication conditions.	SEM, XRD, Tensile test, Hardness test, Density measurement	Processing parameters such as stirring conditions, reinforcement content and heat treatment significantly influenced CNT distribution, grain refinement and mechanical performance. Optimum processing improved tensile strength and hardness through enhanced interfacial bonding, while excessive reinforcement caused CNT clustering and porosity. Similar observations have been reported for other aluminum-CNT composites [23,24,27,29].	The investigation mainly emphasized processing conditions without detailed evaluation of fatigue behaviour, corrosion performance and high-temperature mechanical properties. Further optimization of stir casting parameters for A357 alloys is still required [33,35,36].
11	Kumar and Rao (2017)	AA7075/CNT composite fabricated by stir casting.	Optical microscopy, SEM, Hardness test	CNT reinforcement refined the microstructure and significantly increased hardness due to effective grain refinement and resistance to localized plastic deformation. Proper dispersion contributed to improved mechanical behaviour, whereas higher CNT content promoted particle clustering and reduced property enhancement. Similar trends have been observed by several researchers [23,24,27].	The study was restricted primarily to hardness and microstructural evaluation. Tensile strength, wear resistance, fatigue life and corrosion characteristics require detailed investigation for practical engineering applications [25,34,36].
12	Yadav et al. (2020)	Hybrid LM13 alloy reinforced with MWCNT and SiC particles fabricated by stir casting.	SEM, XRD, Tensile test, Hardness test, Wear test	The hybrid reinforcement substantially improved hardness, tensile strength and wear resistance compared with the unreinforced alloy. SiC provided excellent load-bearing capability, while MWCNTs contributed to grain refinement and improved load transfer, resulting in superior overall performance. Similar hybrid reinforcement strategies have demonstrated significant benefits in aluminum composites [28,31,37].	The influence of different MWCNT-to-SiC ratios, fatigue behaviour, corrosion resistance and machinability was not investigated. Further optimization of hybrid reinforcement for cast aluminum alloys remains necessary [33,36].

13	Esawi and Morsi (2007)	Aluminum powder reinforced with carbon nanotubes through powder mixing and dispersion techniques.	SEM, TEM, Particle dispersion analysis	The study proposed an effective approach for dispersing CNTs within aluminum powder prior to consolidation. Improved dispersion minimized CNT agglomeration and enhanced the possibility of efficient load transfer after composite fabrication. The developed methodology has become an important foundation for subsequent CNT-reinforced aluminum composite research [23,26,30].	The dispersion technique was demonstrated only for powder metallurgy processing. Its effectiveness for liquid metallurgy routes, particularly stir casting, remains insufficiently explored and requires further validation [36,37].
14	Bakshi et al. (2010)	Comprehensive review of CNT-reinforced metal matrix composites.	Review of fabrication methods, strengthening mechanisms and characterizations	The review critically discussed processing techniques including powder metallurgy, thermal spraying, casting and electrodeposition together with strengthening mechanisms such as load transfer, Orowan strengthening, grain refinement and thermal mismatch strengthening. The authors highlighted the influence of CNT dispersion and interfacial bonding on mechanical performance and engineering applications [23,32,33,35].	Uniform CNT dispersion, interface engineering, economical manufacturing and reproducibility continue to limit large-scale commercialization of CNT-reinforced metal matrix composites. Further work on industrial casting processes is recommended [36,37,38].
15	Choi et al. (2008)	Aluminum matrix composite reinforced with carbon nanotubes fabricated through powder metallurgy.	SEM, TEM, Tensile test, Hardness test	CNT reinforcement significantly increased yield strength while maintaining acceptable ductility because of effective stress transfer across the CNT-aluminum interface. The study demonstrated that homogeneous reinforcement distribution plays a dominant role in achieving superior mechanical properties, consistent with findings reported by several investigators [24,29,30].	The work focused on powder metallurgy processing and therefore does not address issues associated with liquid-state fabrication, including wettability, porosity and reinforcement segregation encountered during stir casting [36,37].
16	George et al. (2005)	CNT-reinforced aluminum composite produced by powder metallurgy.	Theoretical analysis supported by experimental	The authors explained the strengthening mechanisms operating in CNT/aluminum composites, including load transfer, thermal expansion mismatch, geometrically	The proposed strengthening mechanisms require additional experimental validation for cast aluminum nanocomposites

			characterization	necessary dislocations and Orowan strengthening. Their analysis demonstrated the exceptional reinforcing potential of CNTs when uniform dispersion and strong interfacial bonding are achieved. These mechanisms have since been validated by numerous experimental investigations [23,24,30,32].	produced through stir casting. The combined effects of porosity, wettability and casting defects also need systematic investigation [36,37,38].
17	Kwon et al. (2013)	CNT-reinforced aluminum matrix composites fabricated using powder metallurgy followed by sintering.	SEM, TEM, XRD, Tensile test, Hardness test	Homogeneous dispersion of CNTs and strong interfacial bonding significantly improved tensile strength, hardness, and elastic modulus of the aluminum matrix. The authors demonstrated that proper processing minimized CNT agglomeration and promoted efficient load transfer between the reinforcement and matrix. Similar strengthening behaviour has been reported for other CNT-reinforced aluminum composites [23,24,29,30].	The fabrication route is relatively expensive and less suitable for large-scale industrial production. Comparative studies involving economical liquid-state processing methods, particularly stir casting of A357 alloy, remain limited [36,37,38].
18	Pérez-Bustamante et al. (2014)	Aluminum matrix nanocomposites reinforced with CNTs fabricated by mechanical alloying followed by consolidation.	SEM, TEM, XRD, Hardness test, Compression test	Mechanical alloying refined the aluminum grain structure and improved CNT distribution, resulting in enhanced hardness and compressive strength. Uniform reinforcement promoted efficient stress transfer and increased resistance to plastic deformation. These observations are consistent with previous reports on CNT/aluminum nanocomposites [23,26,30].	The investigation focused primarily on microstructural evolution and mechanical behaviour, while fatigue, fracture toughness, corrosion performance and tribological characteristics were not evaluated. The applicability of the findings to stir-cast A357 composites also requires further investigation [33,35,36].
19	Tjong (2013)	Review of carbon nanotube- and graphene-reinforced metal matrix nanocomposites.	Comprehensive review of fabrication methods, strengthening mechanisms and engineering	The review summarized recent developments in CNT- and graphene-reinforced metal matrix nanocomposites, emphasizing grain refinement, Orowan strengthening, thermal mismatch strengthening and effective load transfer as the principal mechanisms	Despite significant progress, economical fabrication methods, uniform nanoparticle dispersion, interfacial stability and large-scale commercialization remain major challenges. Comparative studies involving cast

			ng applicatio ns.	responsible for improved mechanical performance. It also discussed processing challenges and potential structural applications of advanced nanocomposites [32,33,35].	aluminum alloys, particularly A357 reinforced with CNTs, are still scarce [36,37,38].
20	Miracle (2005)	Metal matrix composites (MMCs) – General review.	Review of processing techniques, reinforcement mechanisms and industrial applications.	The author comprehensively explained the scientific principles governing MMCs, including reinforcement selection, matrix-reinforcement interactions, strengthening mechanisms and manufacturing technologies. The review highlighted the increasing importance of lightweight MMCs in aerospace, automotive and defense applications. These concepts provide the scientific basis for modern CNT-reinforced aluminum nanocomposites [32,35,38].	Since the review predates widespread CNT applications, nanoreinforcement behaviour, dispersion techniques and nanoscale interface engineering were not discussed in detail. Further research on CNT-reinforced cast aluminum alloys is therefore essential [23,36,37].
21	Hashim et al. (1999)	Metal matrix composites produced by stir casting.	Review of stir casting process, process parameters and composite quality.	The authors established stir casting as one of the most economical and industrially feasible fabrication techniques for aluminum matrix composites. They identified stirring speed, stirring time, melt temperature and reinforcement feeding rate as critical process parameters influencing particle distribution, porosity and final mechanical properties. These processing principles continue to guide modern CNT-reinforced aluminum composite fabrication [23,24,36,38].	The review mainly addressed micron-sized reinforcements and did not consider nanomaterials such as CNTs. Additional research is required to optimize stir casting parameters for uniform CNT dispersion and improved interfacial bonding in A357 aluminum alloy [37].
22	Rohatgi (1991)	Cast aluminum matrix composites for automotive applications.	Review of casting technologies and engineering applications.	The study demonstrated the advantages of cast aluminum matrix composites in automotive applications due to their high specific strength, superior wear resistance and reduced component weight. It highlighted the industrial potential of cast MMCs for brake drums, pistons and cylinder liners, providing an important	The work was published before the development of CNT-reinforced aluminum nanocomposites; therefore, nanoscale reinforcement, dispersion techniques, interface engineering and advanced characterization methods were not addressed. Future

				foundation for the development of advanced nanocomposites [35,38].	studies should integrate CNT reinforcement with conventional casting technologies for lightweight structural applications [23,32,36,37].
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3. Conclusion

Carbon nanotube (CNT)-reinforced aluminum matrix nanocomposites have emerged as promising lightweight materials because of their superior mechanical and tribological properties. The reviewed studies show that MWCNT addition improves tensile strength, hardness, wear resistance, and microstructural refinement through grain refinement, load transfer, Orowan strengthening, and thermal mismatch strengthening. Among the available fabrication methods, stir casting is the most economical and industrially viable technique for producing aluminum nanocomposites.

The literature indicates that composite performance largely depends on CNT dispersion, interfacial bonding, reinforcement content, and processing parameters. Although extensive research has been conducted on AA7075 and other aluminum alloys, studies on A357-MWCNT nanocomposites fabricated by stir casting remain limited. Challenges such as CNT agglomeration, poor wettability, and porosity continue to hinder their full potential.

Future research should focus on optimizing stir casting parameters, improving CNT dispersion, employing advanced characterization techniques, and investigating fatigue, corrosion, and thermal properties. Overall, A357-MWCNT nanocomposites produced by stir casting offer significant potential for lightweight aerospace, automotive, and engineering applications, making them a promising area for future research and industrial development.

References –

1. Aranke and C. Gandhi, “Effect of MWCNT on the mechanical properties of Al7075 composites using stir casting technique,” *Materials Today: Proceedings*, vol. 5, no. 1, pp. 7748–7757, 2018.
2. Bamane *et al.*, “Study of wear properties of MWCNT reinforced Al7075 MMC,” *Materials Today: Proceedings*, vol. 5, no. 1, pp. 8001–8007, 2018.
3. R. Pérez-Bustamante, J. Estrada-Guel, and R. Martínez-Sánchez, “Mechanical milling of aluminum–MWCNT composites and its effect on microstructure and mechanical properties,” *Materials Science and Engineering A*, vol. 502, pp. 159–163, 2009.
4. S. E. Shin, D. H. Bae, and D. H. Yoon, “Synthesis and mechanical characterization of Al2024–MWCNT composites fabricated by press-and-sinter technique,” *Composites Part B: Engineering*, vol. 106, pp. 66–73, 2016.
5. M. Rashad, F. Pan, A. Tang, M. Asif, and J. She, “Effect of carbon nanotube (CNT) content and processing parameters on the mechanical properties of CNT-reinforced aluminum composites,” *Materials Science and Engineering A*, vol. 626, pp. 190–197, 2015.
6. X. Zhang, T. Liu, and Q. Zhou, “Effect of CNT dispersion on the mechanical properties of aluminum matrix nanocomposites,” *Composites Science and Technology*, vol. 144, pp. 92–99, 2017.
7. S. C. Tjong, “Recent progress in the development and properties of novel metal matrix nanocomposites reinforced with carbon nanotubes and graphene,” *Materials Science and Engineering R: Reports*, vol. 74, pp. 281–350, 2013.
8. A. M. K. Esawi and M. M. Farag, “Carbon nanotube reinforced composites: Potential and current challenges,” *Materials & Design*, vol. 28, no. 9, pp. 2394–2401, 2007.
9. V. Chaudhary *et al.*, “A review on synthesis and characterization of aluminum-based metal matrix composites reinforced with MWCNTs,” *Materials Today: Proceedings*, vol. 46, pp. 3616–3621, 2021.

10. A. A. Khan *et al.*, "Influence of processing conditions on microstructure and mechanical properties of MWCNT reinforced AA7075 composites," *Composites Part B: Engineering*, vol. 174, Art. no. 106957, 2019.
11. G. S. Kumar and B. Rao, "Study on hardness and microstructure of CNT reinforced Al7075 composites," *Materials Today: Proceedings*, vol. 4, no. 2, pp. 3037–3041, 2017.
12. B. N. Yadav *et al.*, "Development and mechanical behavior of hybrid LM13 alloy reinforced with MWCNT and SiC," *Materials Letters*, vol. 279, Art. no. 128271, 2020.
13. A. M. K. Esawi and K. Morsi, "Dispersion of carbon nanotubes (CNTs) in aluminum powder," *Composites Part A: Applied Science and Manufacturing*, vol. 38, no. 2, pp. 646–650, 2007. doi: 10.1016/j.compositesa.2006.04.006.
14. S. R. Bakshi, D. Lahiri, and A. Agarwal, "Carbon nanotube reinforced metal matrix composites – A review," *International Materials Reviews*, vol. 55, no. 1, pp. 41–64, 2010. doi: 10.1179/095066009X12572530170543.
15. H. J. Choi, G. B. Kwon, G. Y. Lee, and D. H. Bae, "Reinforcement with carbon nanotubes in aluminum matrix composites," *Scripta Materialia*, vol. 59, no. 3, pp. 360–363, 2008.
16. R. George, K. T. Kashyap, R. Rahul, and S. Yamdagni, "Strengthening in carbon nanotube/aluminum (CNT/Al) composites," *Scripta Materialia*, vol. 53, no. 10, pp. 1159–1163, 2005.
17. H. Kwon, M. Leparoux, A. Kawasaki, and H. Choi, "Fabrication and characterization of carbon nanotube reinforced aluminum matrix composites," *Materials Research Bulletin*, vol. 48, pp. 207–212, 2013.
18. R. Pérez-Bustamante, J. Estrada-Guel, *et al.*, "Microstructural and mechanical characterization of CNT-reinforced aluminum matrix composites," *Journal of Alloys and Compounds*, vol. 615, Suppl. 1, pp. S578–S582, 2014.
19. S. C. Tjong, "Recent progress in the development and properties of novel metal matrix nanocomposites reinforced with carbon nanotubes and graphene nanoplatelets," *Materials Science and Engineering R: Reports*, vol. 74, no. 10, pp. 281–350, 2013.
20. D. B. Miracle, "Metal matrix composites – From science to technological significance," *Composites Science and Technology*, vol. 65, nos. 15–16, pp. 2526–2540, 2005.
21. J. Hashim, L. Looney, and M. S. J. Hashmi, "Metal matrix composites: Production by the stir casting method," *Journal of Materials Processing Technology*, vols. 92–93, pp. 1–7, 1999.
22. P. K. Rohatgi, "Cast aluminum-matrix composites for automotive applications," *JOM*, vol. 43, no. 4, pp. 10–15, 1991.
23. P. P. Awate and S. B. Barve, "Enhanced microstructure and mechanical properties of Al6061 alloy via graphene nanoplates reinforcement fabricated by stir casting," *Functional Composites and Structures*, vol. 4, no. 1, Mar. 2022. doi: 10.1088/2631-6331/ac586d.
24. P. P. Awate and S. B. Barve, "Microstructural observation and mechanical properties behavior of Al₂O₃/Al6061 nanocomposite fabricated by stir casting process," *Engineering Research Express*, vol. 4, no. 1, Mar. 2022. doi: 10.1088/2631-8695/ac54ed.
25. P. P. Awate and S. B. Barve, "Graphene/Al6061 nanocomposite selection using TOPSIS and EXPROM2 multicriteria decision-making methods," *Materials Today: Proceedings*, 2022. doi: 10.1016/j.matpr.2022.04.069.
26. P. P. Awate and S. B. Barve, "TOPSIS & EXPROM2 multicriteria decision methods for Al₂O₃/Al6061 nanocomposite selection," *Materials Today: Proceedings*, vol. 46, pt. 17, pp. 8352–8358, Apr. 2021. doi: 10.1016/j.matpr.2021.03.402.

27. P. P. Awate and S. B. Barve, "Graphene/Al6061 nanocomposite for aerospace and automobile application," *Materials Today: Proceedings*, 2023. doi: 10.1016/j.matpr.2023.07.075.
28. P. P. Awate and S. B. Barve, "Al₂O₃/Al6061 nanocomposite for aviation and automobile components," *Materials Today: Proceedings*, 2024. doi: 10.1016/j.matpr.2024.05.145.
29. P. P. Awate and S. D. Admuthe, "Investigation of mechanical behavior of CNT reinforced A356 nanocomposites," *Tuijin Jishu/Journal of Propulsion Technology*, vol. 45, no. 2, 2024.
30. P. P. Awate and S. B. Barve, "Formation and characterization of aluminum metal matrix nanocomposites," *International Journal of Mechanical and Production Engineering Research and Development*, vol. 9, pp. 933–942, 2019.
31. P. Awate and V. Chavan, "Characteristics enhancement of MWCNT/AA7075 nanocomposites for automotive and aerospace application," *Journal of Xidian University*, vol. 19, no. 10, Oct. 2025. doi: 10.5281/zenodo.17305667.
32. P. P. Awate, "Study on fabrication and characterization of aluminum metal matrix composites and nanocomposites," *Journal of Applied Science and Computations*, vol. 6, no. 5, pp. 2620–2629, May 2019.
33. P. P. Awate, "Review on CNT reinforced A356 nanocomposites," *International Research Journal of Engineering and Technology (IRJET)*, vol. 11, no. 10, pp. 210–213, Oct. 2024.
34. P. P. Awate, "Fabrication and characterization of carbon nanotube reinforced A357 aluminum composite via stir casting," *International Journal of Research Publication and Reviews (IJRPR)*, 2026.
35. P. P. Awate, "Fabrication and characterization of carbon nanotube reinforced AA7075 aluminum composite via stir casting," *International Research Journal of Modernization in Engineering Technology and Science (IRJMETS)*, 2026.
36. P. P. Awate, "Fabrication and characterization of carbon nanotube reinforced A357 aluminum composite via stir casting," *International Research Journal of Modernization in Engineering Technology and Science (IRJMETS)*, 2026.
37. P. P. Awate, "Optimisation of lubricants by nano metal powder," *International Journal of Advance Scientific Research and Engineering Trends (IJASRET)*, 2026.
38. P. P. Awate and R. B. Sonawane, "Investigation of mechanical behaviour of CNT reinforced Al6061 nanocomposites," *International Journal of Engineering Research & Technology (IJERT)*, vol. 15, no. 3, pp. 1–7, Mar. 2026.
39. P. Awate and V. Chavan, "Review on CNT reinforced AA7075 aluminium alloy nanocomposites," *International Research Journal of Engineering and Technology (IRJET)*, vol. 12, no. 9, Sep. 2025.