Nano World Journal

https://doi.org/10.17756/nwj.2023-s3-055

Research Article

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Enhancement of Mechanical and Corrosion Properties of AA5128 with Nano Boron Carbide Particulates Using Ultrasonic Cavitation Assisted Stir Casting Technique

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Received: July 28, 2023
Accepted: October 09, 2023
Published: October 11, 2023

Citation: Naranjo E, Palanisamy A, Narayanaswamy J, Palanikumar V, Annamalai B, et al. 2023. Enhancement of Mechanical and Corrosion Properties of AA5128 with Nano Boron Carbide Particulates Using Ultrasonic Cavitation Assisted Stir Casting Technique. *NanoWorld J* 9(S3): S288-S294.

Published by United Scientific Group

Abstract

In this research, ultrasonic cavitation assisted stir casting was used to nano boron carbide particles (nB_4Cp) into the matrix of AA5128 at weight percentages of 0%, 0.6%, 1.2%, 1.8%, 2.4%, and 3.0%. A scanning electron microscope (SEM) was used to analyzethe distribution of the reinforcing particles throughout the material. By adding 1.8% nB_4Cp,the nanoparticles began to aggregate and no longer distributed uniformly was found. An increase in mechanical characteristics was seen after adding 1.8% nB_4Cp, and this increasewas followed by a decrease. With only a 1.8% nB_4Cp addition, AA5128 is able to boost itstensile strength, micro-hardness, elongation percentage, impact strength and corrosion rate by 189.24%, 49.65%, 50.79%, 74.35%, and 40.16% compared to pure AA5128 alloy, respectively. The addition of only 1.8% nB_4Cp has been shown to raise thecoefficient of friction by 15.33%, resulting in a 28% increase in wear resistance. The characteristics tend to degrade when more than 1.8% by adding nB_4Cp, as the nB_4Cp particles begins to cluster, reducing the material's effective surface area.

Keywords

Nanocomposite, Ultrasonic cavitation, Corrosion resistance, Micro-hardness,Tensile strength, Wear

Introduction

By including hard stages of particles, typically carbon or ceramic-based materials, metal matrix composites show potential as a technique to improve the mechanicalbehavior of lightweight metals at room and higher temperatures [1]. Many industries, including electronics, transportation, aerospace, and even biology, stand to benefit economically from the use of nanocomposites. Nanocomposites are multiphase, solid-statematerials with at least one domain or phase that is on the nanometer scale [2]. A material's qualities, including its tensile strength, thermal conductivity, and electrical conductivity, are vastly enhanced when nanoparticles are included into the material. The ultrasonic cavitation method is the most adaptable and suitable way for improved dispersion of reinforcements among the current possibilities for fabricating nanocomposites. Authors [3] developed an nB_4Cp (1% wt.) strengthened AA7150 based nanocomposite using a blend of double stir casting, vortex, and ultrasonic vibration. Grainrefinement and uniform nanoparticle distribution are responsible for this unique method's success in increasing tensile strength by 26.05% and micro-hardness by 10.85%.

Tensile strength, impact strength, and ductility were all improved in nanocomposites with 6% nB_4C reinforcement compared to micron-sized B_4C reinforced particulate composites [4]. This was in addition to a possible 8% improvement in pliability. nB_4C-reinforced aluminum A356 was developed by authors [5] by adding 1% wt. magnesium and 0, 0.10, 0.15, 0.20, 0.25, and 0.30 wt.%. B_4C to an aluminum alloy melt. Researchersfound that 0.25 wt.% nB_4C reinforcement provided the optimum mechanical properties [6]. With this quantity of reinforcing, the tensile strength, impact strength, Brinell hardness, and wear rate are all above average: 175.57 MPa, 0.0287 Joules/mm^3, 56.54 HBN, and 1.75 x 10^5 mm^3/mm, respectively.

Powder metallurgy was used by authors [7] to produce Ti-6Al-4V, a titanium alloy with varying amounts of nB_4Cp. Maximum density of 93.33% was achieved with a compaction pressure of 6.035 MPa. The mechanical qualities of Ti64 alloy are improved by the addition of 5% nB_4Cp composite, as seen by the increased hardness and compressive strength of the material. Researchers [8] studied the mechanical and wear behavior of man-made aluminum-based nanocomposites with and without nB_4C. Theresults showed that the tensile strength and wear resistance may be improved by including 2% nB_4C. Using the compo casting technique, authors [9] found that the yield strength, ultimate tensile strength, and hardness of the material were greatly enhanced while the ductility of the aluminum matrix was not affected.

Authors [10] used the stir casting technique to reinforce different quantities of nAl_2O_3p in an AA5128 matrix, demonstrated that abrasive resistance and mechanical strength were significantly increased with the addition of nAl_2O_3p. Powder metallurgy wasused by researchers [11] to create a $TiAl_3$ in-situ reinforcement phase in AA5128, and the material's wear performance was examined after additions of 3%, 6%, and 9% B_4C. As thepercentage of B_4C in a material rises, it becomes harder, denser, and less prone to wear. The addition of 1.8% nB_4Cp significantly boosts impact strength and hardness, but any higher concentration has the opposite effect authors [12]. This is because the ultrasonic cavitation process results in a strengthened microstructure with a uniform distribution of nB_4Cp.

Using nB_4Cp and nAl_2O_3p as reinforcements and the squeeze casting and stir casting methods, respectively, researchers [13] studied mono and hybrid aluminum nanocomposites. The results demonstrate that the tensile strength and hardness of the nanocomposite increases up to a certain nAl_2O_3p level, but then decline as agglomeration sets in. Authors [14], who assessed the synthesis of nanocomposites via mechanical alloying, provided a thorough discussion of the importance of temperature, environment, sintering duration, and the features of the material in the sintering process. Ultimate strength, micro-hardness, and Young's modulus were all found to rise by 246.6 MPa, 945.2MPa, and 97.3 GPa, when AA6061 was reinforced with nB_4Cp to generate aluminum nanocomposites, however ductility was found to decrease by 20.8% [15, 16].

Ultrasonic cavitation assisted stir cast nB_4Cp reinforced AA5128 has not been extensively studied, according to a survey of the relevant literature. Ultrasonic cavitation-stir casting was used to produce an aluminum-based nanocomposite, and its mechanical, corrosion, and wear behavior was studied in line with ASTM standards. The objective of this research was to characterize the final nanocomposite and determine the nB_4Cp reinforcing percentage that would yield the best results. The novelty of this research is in the novel ultrasonic cavitation method used to create cast specimens of the nanocompositeand the determination of their mechanical properties. In addition to mechanical tests, the cast nanocomposite subjected to tests for wear and corrosion in accordance with ASTM specifications. SEM images reveal the distribution of reinforcing phases inside the aluminum matrix and the influence these phases have on the characteristics of nanocomposites. To increase its strength, nB_4Cp is best reinforced with AA5128 at a specific weight fraction.

Materials and Method

Materials

AA5128 has an average level of machinability, reasonable fatigue strength in comparison to various steel materials, and a lesser corrosion resistance than other aluminum alloys [17]. AA5128 is a non-weldable aluminum alloy that ranks among the strongest of the metal's series varieties. Due of its poor fracture toughness in the T6 state, it finds widespread use in applications requiring cryogenic cooling. The chemicalcomposition of AA5128 is listed in table 1. Figure 1 shows SEM micrograph of as-received AA5128 alloy microstructure. The EDX (Energy dispersive X-ray spectroscopy) spectrum provides a visual representation of the elemental composition, confirming the substance to be aluminum-based alloys with numerous trace elements present. The peak location changes of AA5128 depending on the materials used to create it.

Table 1: Chemical composition of AA 5128.

Elements	Wt.%
Si	0.14
Fe	0.26
Cu	0.03
Mn	0.43
Mg	4.18
Zn	0.02
Ti	0.02
Cr	0.06
Al	Bal

Reinforcing material

nB_4Cp are a remarkable ceramic with very high melting point, low density, and great toughness, in addition to being extremely corrosion-resistant and stable in a wide range of chemical conditions. Its uses in thermal management and electronics are only set to grow due to its high thermal conductivity and low electrical conductivity. Figure 2 shows the EDX spectrum and microstructure. Here, B_4C nano powder with a particle size between 45 and 65 nm was used. In the automotive and aerospace industries, the produced light-

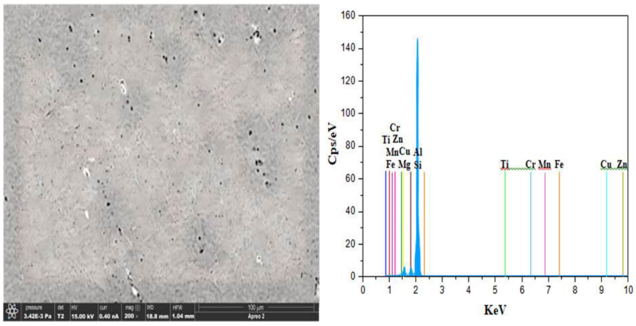

Figure 1: SEM and EDX spectrum of AA5128.

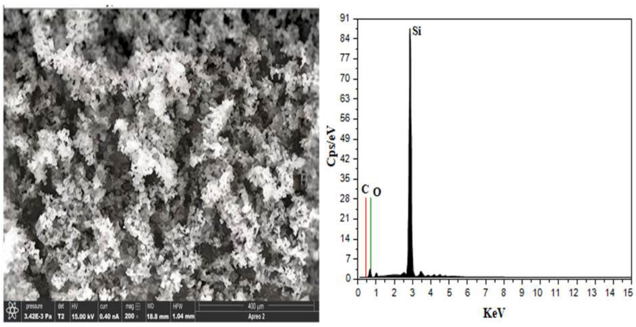

Figure 2: SEM and EDX spectroscopy of nano B_4C particles.

weight composite canreplace steel and other expensive materials. Aerospace, military, bicycle components, electronics, and sports equipment are just some of the industries that might benefit from aluminum-based nanocomposites.

Mechanical characterization

The performance of many alloys and metals is critically determined by factors like as grain size, grain structure, secondary phase distributions, and twins [18]. Microscope examination of as-polished samples reveals several defects, including stringers and inclusions present in materials. These flaws serve as potential failure hotspots, thus it's important to assess their size and distribution in order to establish a correlation between engineering reliability and material properties [19].

Tensile test is typically used to determine the stress-strain relationship [20]. The material response to impact stress can be revealed by conducting an impact test. The breaking energy of the test sample has been determined. The test needs to be carried out in accordance with the requirements of ASTM E23. It standardizes a material's mechanical strength to ensure that proper safeguards are activated during its actual application [21]. The ASTM E384 standard defines micro-Vickers hardness as the hardness measured withindentation weights of less than 1 Kg. However, the size of the indenter is more closely associated with the amount of force used [22]. Micro-hardness tests typically use loadings between 100 and 500 g, while loadings as low as 1 g may be used in special circumstances.

Corrosion is the deterioration of materials by surface chemical reactions due to the presence of a hostile environment. While direct current sources are typically used to measure corrosion resistance, alternating current sources are used in the electrochemical impedance spectroscopy technique. The test was conducted with a NaCl solution containing 3.5% by weight. The electrochemical impedance spectroscopy method collects impedance information by frequency at a fixed voltage in accordance with ASTM standard G106 [23]. A tribological meter can be used to measure the rate of wear [24, 25].

Experimental process

Ultrasonic cavitation method was used to incorporate B_4C nanoparticles into an aluminum matrix during the solidification process seen in figure 3. Liquid-state processingof metal matric nanocomposites makes it challenging to achieve a homogenous distribution of nanoparticles inthe metal matrix, even at low reinforcement volume fractions [26, 27]. This is due to thefact that nanoparticles tend to clump together and float or settle in the molten metal in theabsence of a repulsive force.

Dispersing nanoparticles in metal melts using ultrasonic cavitation was first used in 2004. Cavitation nuclei have been proposed as a mechanism for the dissemination of nanoparticles; these would be pockets of air or vapor within the clusters themselves. Usingacoustic streaming and transient cavitation, fine particle clusters can be broken up and dispersed more evenly throughout the molten matrix, leading to greatly improved wet among the molten metal and elements [28]. This is because the micro hotspots in the molten metal are heated and the particle surface was cleaned.

The first step in making the nanocomposite involves melting 995 g of AA5128 in a graphite crucible at 750 °C and then adding 5 g of micro B_4C powders (0.6 wt.%). The percentages of nB_4Cp added to AA5128 are also similar: 1.2% for 990 g of AA5128 with10 g of nB_4Cp, 1.8% for 985 g of AA5128 with 15 g of nB_4Cp, 2.2% for 980 g of AA5128 with 20 g of nB_4Cp, and 3.0% for 975 g of AA5128 with 25 g of nB_4Cp. When nanoparticles are mixed into the matrix, the material's viscosity increases dramatically, yet the high casting

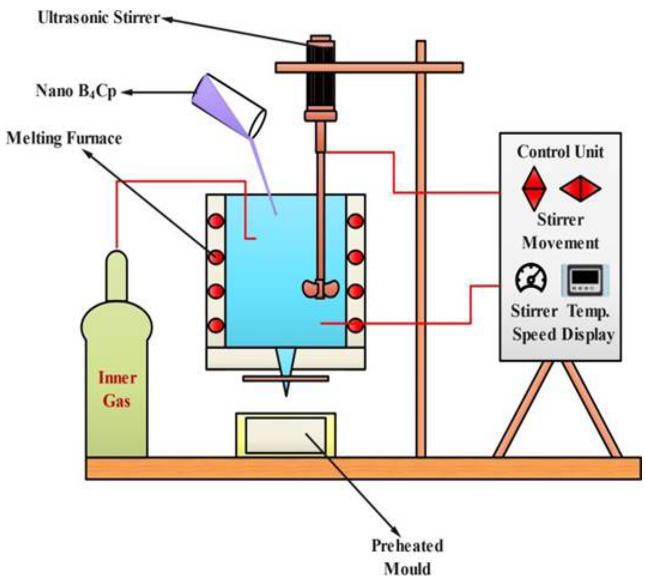

Figure 3: Setup for stir casting using ultrasonic cavitation.

temperature (750 °C) keeps the molten charge fluid andable to move freely within the mold cavity. Warming an everlasting steel die to 600 °C allowed the charge to be cast into the desired shape. The horn is spun at 40 rpm at a frequency of 20 kH for duration of 30 min; inert gas was not used in the casting process. In a stir casting configuration, the stirrer speed was adjusted to 500 rpm, and thematerial was stirred for 10 min.

Results and Discussion

Ultrasonic cavitation was used in the present study to reinforce different nB_4Cp weight fractions in an AA5128 matrix for consistent nanoparticle distribution. The percentages of weight that were taken into account were 0%, 0.6, 1.2%, 1.8%, 2.4%, and 3.0%. SEM images of cast nanocomposite specimens were used to examine the dispersal of strengthening phases in the Al composites. The characterization studies then used the ASTM standards.

The number of nanoparticles in a micrograph tends to rise with increasing nB_4Cp content. It was easy to make out the grains and grain boundaries. By fusing the nB_4Cp particles on the grain boundaries, the migration of dislocations and boost the nanocomposites' overall quality was limited. Mechanical strength, corrosion resistance, and wear characteristics of cast alloy and aluminum nanocomposite specimens were evaluated using ASTM standards. The obtained results for various nB_4Cp weight fractions in conjunction with a cast AA5128 alloy are shown in table 2.

The micro-Vickers hardness test was used to measure the nanocomposites' mechanical strength. Micro-Vickers hardness increases up to 1.8% wt. of nB_4Cp, as seen in SEM images, due to the increased surface area of nanoparticles, but then decreases when a cluster of particles forms farther on. Nanoparticles acted as a barrier for dislocations in the matrix, leading to an increase in hardness values.

During an impact test, the amount of energy absorbed by the material is a good indicator of how well it will hold up to a sudden application of force [28]. Figure 4 showsthe results of impact tests performed on several nanocomposites and as-cast alloy, demonstrating that the addition of nB_4Cp significantly improves the nanocomposites' energy-absorbing ability. Nanocomposites with 1.8% wt. nB_4Cp were shown to absorb energy at a higher rate than those with lower concentrations of the material. The energy absorption of nB_4Cp reinforced samples is greater compared to that of a cast specimen.

Figure 5 displays the tensile strength of many manufactured nanocomposites. Authors discovered that the tensile strength of as-cast AA518 was improved by the addition of nB_4Cp owing to the appropriate bonding of reinforcing particles. The Orowan strengthening process is responsible for this improved deformation resistance. The nanoparticles' even distribution increase tensile strength. The increased tensile strength canbe attributed to the stronger interfacial bonding made possible by the nanoparticles'increased surface area.

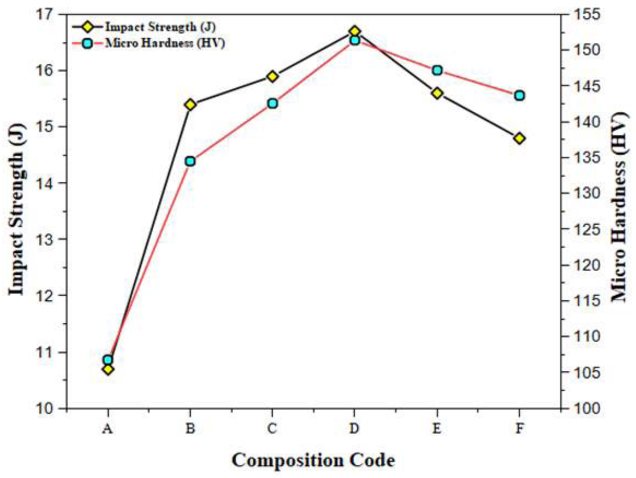

Figure 4: Comparison of **(a)** Impact strength and **(b)** Micro-Vickers hardness of various nanocomposites.

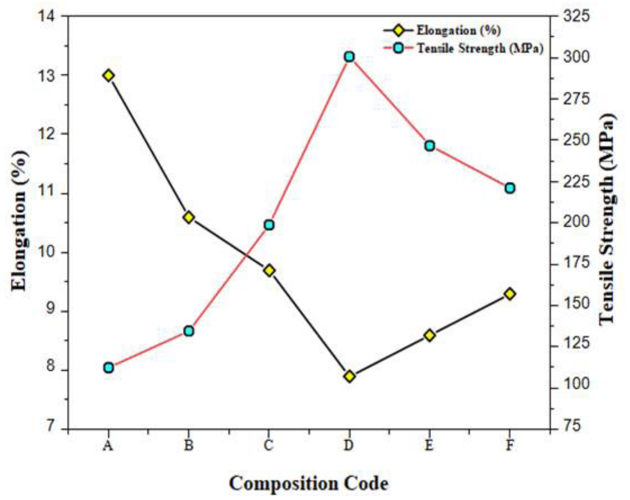

Figure 5: Evaluation of **(a)** Elongation and **(b)** Tensile properties of various composites.

Table 2: Mechanical characteristics of manufactured nanocomposites.

Composition code	Composition	Elongation	Tensile strength	Impact strength	Micro hardness	CoF	Wear	Corrosion
Units	-	%	MPa	J	HV	-	Microns	mm/year
A	AA5128	13	112.47	10.7	106.8	0.395	0.376	0.901
B	AA5128 + 0.6%nB_4Cp	10.6	134.59	15.4	134.5	0.381	0.336	0.735
C	AA5128 + 1.2%nB_4Cp	9.7	198.76	15.9	142.6	0.368	0.321	0.672
D	AA5128 + 1.8%nB_4Cp	7.9	300.64	16.7	151.4	0.356	0.312	0.593
E	AA5128 + 2.4%nB_4Cp	8.6	246.81	15.6	147.2	0.355	0.317	0.531
F	AA5128 + 3.0%nB_4Cp	9.3	221.09	14.8	143.7	0.352	0.323	0.492

After 1.8% wt. reinforcement of nB_4Cp in AA5128, however, tensile strength of the material's often decreases due to the nanoparticles agglomerating to form micron-scale particles. The results of a tensile test on nanocomposites are shown in figure 5 as a percentageof elongation. A greater percentage of elongation may be seen in the as-cast specimen, indicating more ductility. However, as more nB_4Cp is added, the composite loses ductility owing to increased interfacial bonding between the ceramic particles, and the tensile strength increases up until about 1.8% nB_4Cp content. When more nB_4Cp is added to AA5128, the percentage of elongation drops below that of solutions with lower concentrations of nB_4Cp because the nanoparticles stick together and form micron-sized particles. Two and a half percentage of nB_4Cp elongation was more than that of as-cast AA5128 alloy.

Figure 6 depicts the corrosion behavior of cast metal and cast nanocomposites. Corrosion testing was conducted in a room temperature, 3.5% NaCl solution for 10 h.The corrosion test employs a sweeping potential of 300 mV/min, with a starting potential of -300 mV and a final potential of 300 mV. Since ceramic nanoparticles are inert and unaffected by the corrosive medium, it was shown that the corrosion resistance displays arising trend with nanoparticles inclusion. Corrosion in nanocomposites was lower than in as-cast AA518. The corrosion potential is demonstrated to be lowest for the AA5128 alloy in figure 7, whereas the addition of nB_4Cp particles enhances corrosion resistance and, consequently, raises the corrosion potential.

The wear performance of both the fabricated and as-cast specimens was put to the test for 10 min using POD equipment developed by Ducom at 300 rpm of sliding speed, 20 N of applied force, and 2 m/s of sliding velocity. The dimensions of the test specimen were 20 mm in length and 8 mm in diameter. Data from the equipment's data acquisition system was measured in microns to determine the wear value. The wear test outcomes aredepicted in figure 8. The wear resistance to abrasion is improved up to 1.8 % nB_4Cp in the aluminum matrix, but drops off beyond that due to the decreasing hardness and strength of the generated nanocomposites.

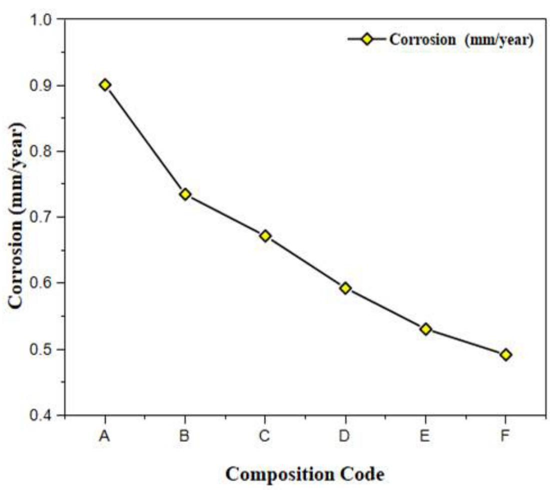

Figure 6: Resistances to corrosion for as cast and nanocomposites.

As a ratio of frictional force to normal force, the CoF is a dimensionless quantity thatcharacterizes the level of friction between two surfaces. Sliding occurs with less effort when the CoF is low compared to when it's high. Figure 8 shows the enhanced strength and surface area supplied by the nano-ceramic particles; the addition of nanocomposites often results in a lower CoF value.

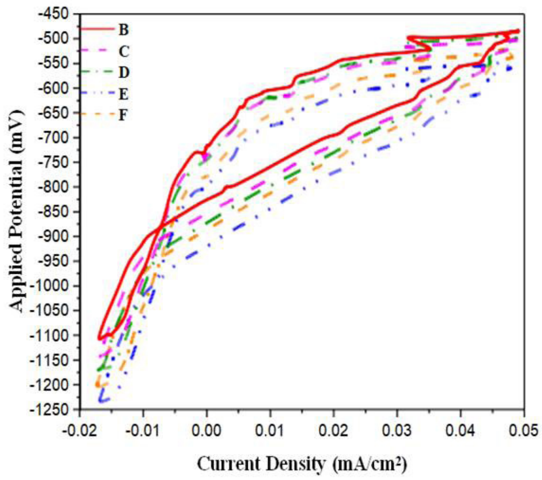

Figure 7: Corrosion current density versus potential graph.

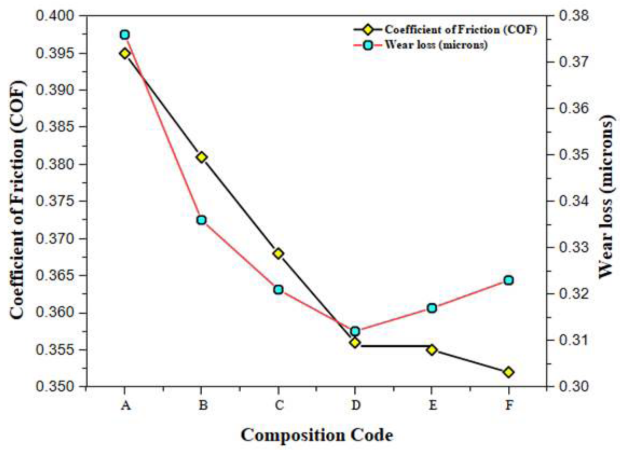

Figure 8: Comparison of coefficient of friction (CoF) and wear loss of as cast and nanocomposites.

Conclusions

Characterization of cast nanocomposites generated by ultrasonic cavitation-prepared AA5128 matrices with varying nB_4Cp reinforcement weight proportions yielded the following conclusions.

- It was found that nanoparticles were distributed homogeneously in the aluminum matrix, and that agglomeration and distinct grain boundaries appeared with increasing reinforcement percentage.
- Good bonding of micro ceramic particles up to 1.8 wt.% was the driving force behind the improved

strength, which is known as the Orowan strengthening mechanism. Due to nanoparticle aggregation, tensile strength tends to decrease with increased addition of nB_4Cp. A greater percentage of elongation may be seen in the as-cast specimen, indicating more ductility. However, after nB_4Cp is incorporated, the composite loses some of its ductility as a result of increased interfacial adhesion between the ceramic particles.

- Due to the larger surface area of nanoparticles, the micro-Vickers hardness value tendsto rise with nB_4Cp addition, up to a weight fraction of 1.8%. Because the nanoparticles were located in the grain boundaries, they were able to prevent the matrix dislocationsfrom moving in and out, hence increasing the hardness values.
- Adding nB_4Cp to the nanocomposites significantly boosts their ability to absorb energy.Adding more nB_4Cp to a nanocomposite causes it to lose strength and, thus, reduces theenergy-absorbing properties of the nanocomposites.
- Adding nB_4Cp to an aluminum matrix increases wear resistance up to 1.8%, but the benefits diminish after that owing to the reduced hardness and tensile properties of the resulting nanocomposites. The CoF value decreases when nanocomposites are included because to the enhanced tensile properties and increased surface of nano-ceramic particles.
- Since ceramic particles are inert and unaffected by the corrosive medium, they tend to increase resistance to corrosion. The corrosion rate of nanocomposites was drastically lower than that of as-cast AA5128.

Acknowledgements

None.

Conflict of Interest

None.

References

1. Sambathkumar M, Gukendran R, Mohanraj T, Karupannasamy DK, Natarajan N, et al. 2023. A systematic review on the mechanical, tribological, and corrosion properties of Al 7075 metal matrix composites fabricated through stir casting process. *Adv Maters Sci Eng* 2023: 5442809. https://doi.org/10.1155/2023/5442809
2. Sutharsan SM, Senthilkumar P, Koodalingam B, Nattarselvi U, Kumar KM, et al. 2021. Analysis of mechanical behavior of Al 6061 metal matrix with boron carbide and graphite. *Mater Today Proc*. https://doi.org/10.1016/j.matpr.2021.03.354
3. Singh R, Rai RN. 2018. Characterization of B_4C-composite-reinforced aluminum alloy composites. *AIP Conf Proc* 1943(1): 020073. https://doi.org/10.1063/1.5029649
4. Varun KM, Goud RR. 2019. Investigation of mechanical properties of Al 7075/SiC/MoS_2 hybrid composite. *Mater Today Proc* 19: 787-791. https://doi.org/10.1016/j.matpr.2019.08.131
5. Gurunagendra GR, Raju BR, Pujar V, Amith DG, Siddesha HS. 2021. Mechanical, wear and corrosion properties of micro particulates reinforced ZA-27 hybrid MMC by stir casting: a review. *Mater Today Proc* 46: 7602-7607. https://doi.org/10.1016/j.matpr.2021.01.892
6. Balaji R, Jeyan JVML, Basithrahman A, Rani TE, Abirami S. 2021. Comparative Analysis on Mechanical Properties of Al 6061 and Al 7075 Cross Matrix Composites. In Prakash C, Krolczyk G, Singh S, Pramanik A (eds) Advances in Metrology and Measurement of Engineering Surfaces. Lecture Notes in Mechanical Engineering. Springer, Singapore, pp 25-33).
7. Chakravarthy MP, Rao DS. 2022. Evaluation of mechanical properties of aluminium alloy (AA 6082) reinforced with rice husk ash (RHA) and boron carbide (B_4C) hybrid metal matrix composites using stir casting method. *Mater Today Proc* 66: 580-586. https://doi.org/10.1016/j.matpr.2022.06.293
8. Srivallirani K, Rao MV. 2021. Fabrication and mechanical characterization of Al 7050/TiO_2/BN hybrid metal matrix composites. *Mater Today Proc* 39: 1750-1753. https://doi.org/10.1016/j.matpr.2020.06.386
9. Kara M, Coskun T, Gunoz A. 2022. Influence of B_4C on enhancing mechanical properties of AA2014 aluminum matrix composites. *Proc Inst Mech Eng Part C J Mech Eng Sci* 236(5): 2536-2545. https://doi.org/10.1177/09544062211058599
10. Ramadoss N, Pazhanivel K, Anbuchezhiyan G. 2020. Synthesis of B4C and BN reinforced Al7075 hybrid composites using stir casting method. *J Mater Res Technol* 9(3): 6297-6304. https://doi.org/10.1016/j.jmrt.2020.03.043
11. Boobalan V, Sathish T. 2022. A comprehensive study on boron carbide reinforcement in aluminum-and its alloy composites. *Mater Today Proc* 69: 1238-1241. https://doi.org/10.1016/j.matpr.2022.08.319
12. Ranjith R, Giridharan PK, Devaraj J, Bharath V. 2017. Influence of titanium-coated (B_4C_p + SiC_p) particles on sulphide stress corrosion and wear behaviour of AA7050 hybrid composites (for MLG link). *J Aust Ceram Soc* 53: 1017-1025. https://doi.org/10.1007/s41779-017-0119-6
13. Chakrapani P, Suryakumari TSA. 2021. Mechanical properties of aluminium metal matrix composites-a review. *Mater Today Proc* 45: 5960-5964. https://doi.org/10.1016/j.matpr.2020.09.247
14. Mahanta S, Chandrasekaran M, Samanta S. 2020. New emerging Al7075 based hybrid nanocomposite for automotive applications: a sustainability approach. *Key Eng Mater* 856: 29-35. https://doi.org/10.4028/www.scientific.net/KEM.856.29
15. Aherwar A, Pruncu CI, Mia M. 2022. Optimal design based on fabricated SiC/B_4C/porcelain filled aluminium alloy matrix composite using hybrid AHP/CRITIC-COPRAS approach. *Silicon* 14(2): 603-615. https://doi.org/10.1007/s12633-020-00916-1
16. Sathish T, Mohanavel V, Velmurugan P, Alfarraj S, Al Obaid S, et al. 2022. Evaluation of MWCNT particles-reinforced magnesium composite for mechanical and catalytic applications. *Bioinorg Chem Appl* 2022: 7773185. https://doi.org/10.1155/2022/7773185
17. Sambathkumar M, Gukendran R, Vijayanand M. 2022. Investigation of corrosion behaviour of Al 7075/B_4C/Al_2O_3 hybrid metal matrix composite. *Mater Today Proc* 50: 1606-1610. https://doi.org/10.1016/j.matpr.2021.09.123
18. Bose S, Mondal D, Chattaraj A, Rakshit R, Nandi T. 2020. A proximate analysis in aluminum hybrid metal matrix composites using additive ratio assessment approach with the experimental results altering different proportions of the reinforcements. *Mater Today Proc* 24: 538-547. https://doi.org/10.1016/j.matpr.2020.04.307
19. Veeraiah G, Kumar MS, Varma VV, Sudhakar I. 2018. Synthesis of nano particles reinforced composites using A356 aluminium alloy as matrix for brake shoes using stir casting route. *IOP Conf Ser Mater Sci Eng* 455(1): 012077. https://doi.org/10.1088/1757-899X/455/1/012077
20. Poornachandiran N, Pugazhenthi R, Ananth SV, Krishnan TG, Vairavel M. 2020. Investigation of mechanical properties of Al6061 with reinforcement of SiC/B_4C metal matrix composites. *AIP Conf Proc* 2283(1): 020113. https://doi.org/10.1063/5.0025004
21. Prema CE, Suresh S, Ramanan G, Sivaraj M. 2020. Characterization, corrosion and failure strength analysis of Al7075 influenced with B_4C

and Nano-Al_2O_3 composite using online acoustic emission. *Mater Res Express* 7(1): 016524. https://doi.org/10.1088/2053-1591/ab6257

22. Mirzadeh H. 2023. Surface metal-matrix composites based on AZ91 magnesium alloy via friction stir processing: a review. *Int J Miner Metall Mater* 30(7): 1278-1296. https://doi.org/10.1007/s12613-022-2589-y
23. Narayana KL, Benal MM, Shivanand HK. 2021. Effect of graphite on aluminium matrix composites fabricated by stir casting route–a review. *Mater Today Proc* 45: 327-331. https://doi.org/10.1016/j.matpr.2020.11.051
24. Haider K, Alam MA, Redhewal A, Saxena V. 2015. Investigation of mechanical properties of aluminium based metal matrix composites reinforced with SiC & Al_2O_3. *Int J Eng Res Appl* 5(9): 63-69.
25. Umanath K, Nithyanandhan T, Ajayan A, Devika D, Prasath MG, et al. 2022. Machinability study of Aluminium 6082 reinforced with boron carbide and titanium by stir casting method using Abrasive water jet machining process. *Eng Res Express* 4(1): 015011. https://doi.org/10.1088/2631-8695/ac4ab3
26. Kashyap S, Tripathi H, Kumar N. 2022. Mechanical properties of marble dust reinforced aluminum matrix structural composites fabricated by stir casting process. *Mater Phys Mech* 48(2): 282-288.
27. Duraipandian M. 2021. Effects of Fe_2O_3 and B_4C addition on the mechanical properties and corrosion resistance of Al-Mg-Si Alloy in 3.5% brine solution. *Met Mater Int* 27: 1506-1518. https://doi.org/10.1007/s12540-019-00548-0
28. Paulraj D, Jeyakumar PD, Rajamurugan G, Krishnasamy P. 2021. Influence of nano TiO_2/micro (SiC/B_4C) reinforcement on the mechanical, wear and corrosion behaviour of A356 metal matrix composite. *Arch Metall Mater* 66(3), 871-880. https://doi.org/10.24425/amm.2021.136392