Journal Homepage: - www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

Article DOI: 10.21474/IJAR01/19623
DOI URL: http://dx.doi.org/10.21474/IJAR01/19623

ISSN NO. 2320-5407

RESEARCH ARTICLE

EVALUATION OF PHYSICAL AND MECHANICAL PROPERTIES OF BN REINFORCED AL7079 METAL MATRIX COMPOSITES

Mahesh Kumar V.
Department of Mechanical Engineering, Malnad College of Engineering, Hassan-573202 and Affiliated to Visvesvaraya Technological University, Belagavi, Karnataka, India.

……………………………………………………………………………………………………....

Manuscript Info

……………………….

Manuscript History
Received: 05 August 2024
Final Accepted: 09 September 2024
Published: October 2024

Abstract

………………………………………………………………

Metal matrix composites (MMCs) are regarded as viable alternatives to conventional materials such as metals, plastics, and ceramics in structural applications due to their properties, including lightweight, high specific stiffness, elevated elastic modulus, enhanced specific strength, and excellent wear resistance. Among the many metal composites, aluminum metal matrix composites (MMCs) have emerged as sophisticated engineering materials for several prospective applications in engineering industries due to their superior qualities compared to typical aluminum alloys. Ceramic particles are the most extensively utilized reinforcements in MMCs due to their superior wear resistance, thermal stability, and exceptional bonding with the matrix. This research work has been conducted to develop ceramic particle-reinforced aluminum matrix composites and to evaluate their physical and mechanical properties. Al7079 alloy and Boron Nitride (BN) are selected as the matrix and reinforcement for the study respectively. The stir casting technique was utilized to fabricate the composites.Al7079-BN composites are prepared by varying the percentage of BN reinforcement particles from 0 to 8% by volume, with an increment of 2%. Test specimens were machined from the produced composites for the evaluation of microstructural, physical, mechanical properties according to ASTM standards. The microstructural analysis of the produced samples was conducted using scanning electron microscopy (SEM). The density of the composite was assessed empirically using Archimedes' principle and theoretically through the rule of mixture. Microstructural analysis reveals a homogeneous distribution of BN particles throughout the matrix without any agglomeration, and it also demonstrates excellent bonding. The density of the composites decreased by approximately 4.6% with the incorporation of BN reinforcement up to 8%, attributed to the lower density of BN particles. The mechanical properties such as hardness, tensile strength, Young's modulus, and compressive strength of the composite increases significantly.

……………………………………………………………………………………………………....

Corresponding Author:- Mahesh Kumar V.
Address**:-** Department of Mechanical Engineering, Malnad College of Engineering, Hassan-573202 and Affiliated to Visvesvaraya Technological University, Belagavi, Karnataka, India.

Introduction:-

The 7xxx aluminum alloy possesses high strength, low density and excellent processing capabilities, making it a crucial structural material in the aerospace sector, automobile and marine industry. As these sectors advances, high-strength aluminum alloys must possess exceptional overall qualities. In recent decades, some engineering materials including magnesium alloy, titanium alloy and composite materials, have exhibited significant advancement, presenting challenges to 7xxx aluminum alloy. Consequently, to maintain competitiveness in its primary sector and secure additional prospects in emerging industries, the 7xxx aluminum alloy necessitates continued enhancement of its performance. Micron and nano-scale ceramic particles such as alumina (Al_2O_3), silicon carbide (SiC), titanium oxide (TiO_2), titanium carbide (TiC), aluminium nitride (AlN) and boron carbide (B_4C) are extensively utilized as reinforcements in aluminum matrix composites (AMCs) for many industrial applications. BN particles are among the most commonly utilized reinforcement materials for Al matrix composites, owing to their availability and exceptional qualities, including high mechanical strength and excellent chemical stability at elevated temperatures. The process of liquid casting facilitates the production of composites featuring complex designs. It is preferable to produce lightweight bulk components composed of metal matrix composites that exhibit uniform reinforcing distribution and preserve structural integrity. The use of micro-sized ceramic particles poses difficulties owing to their elevated viscosity, poor wettability in metal matrices, and substantial surface area-to-volume ratio. Attaining a homogeneous distribution of these particles in liquid metals is challenging. To resolve this issue, pretreatment of the particles is essential to improve their bonding capacity with the metal matrix.

The principal disadvantage of aluminium alloys is their reduced resilience to high temperatures and wear properties. Researchers initiated the enhancement of aluminium alloys to resolve this issue. Utilizing ceramic nanoparticles like boron carbide, silicon carbide, and aluminum oxide. Developing enhanced mechanical strength aluminum matrix composites is crucial for the aerospace and automotive industries to guarantee extended fatigue lifetimes in structural components [1]. Stir casting of an Al6061 matrix using 15-micron B4C particles at 6 to 12 weight percent. The researchers analyzed the mechanical and microstructural properties of aluminum composites. The macrostructural and XRD analyses demonstrated the existence of uniformly dispersed boron carbide particles within the composite. The tensile strength of aluminium matrix composites peaked at 176.37 MPa at 8 wt%, while the Vickers microhardness likewise attained its maximum at 8 wt%, recording 121.31 VHN. The hardness and ultimate tensile strength augmented with the increasing weight percentage of reinforcement [2]. The density of the fabricated AMCs decreased by as much as 9 wt% with the introduction of additional reinforcement, while porosity increased from 3.7% to 11% in the Al/10%SiC/15%RHA composite in comparison to the pure Al alloy. The microstructural examination of the composite revealed a uniform distribution of SiC and RHA particles, with the exception of the 15% RHA composite, which exhibited clustering of RHA particles [3]. This work investigates the synergistic improvement of wear and tribological properties provided by B_4C and TiC, demonstrating that a higher concentration of TiC, namely at 5 wt% TiC and 3 wt% B_4C, boosts performance. TiC and B_4C both improve friction performance. At 4500 rpm, TiC demonstrates a superior ability to improve friction performance relative to B_4C. Furthermore, B_4C markedly affects tribological performance at 6000 rpm, leading to the formation of the B_2O_3 tribofilm [4]. Investigated the impact of B4C on the mechanical and wear properties of Al2618 composites using stir casting. The researchers produced Al2618-B_4C metal matrix composites with B4C concentrations ranging from 2 to 8 weight percent in 2 percent increments. The resulting composites were assessed for hardness, compressive strength, and tensile characteristics. The addition of B_4C particles enhanced the mechanical characteristics and wear resistance of the Al2618 alloy, while it caused a slight reduction in elongation [5]. Investigated the impact of stir casting with SiC and B_4C additions on the mechanical properties of Al6061. The researchers utilized SEM to analyze the composite's microstructure. The results demonstrated that the incorporation of SiC and B_4C reinforcement particles significantly improved the mechanical properties of the Al6061 aluminum alloy [6]. Examined the performance of the aluminum alloy subsequent to reinforcement with titanium and aluminum oxides. The proposed reinforcements were amalgamated in equal proportions (2.5, 5.0, 7.5, and 10 wt%) and produced using the traditional stir casting method. A hybrid composite comprising 5 wt% aluminum oxide and 5 wt% titanium oxide demonstrated enhanced engineering and tensile strength. An increase in the weight fraction of reinforcement leads to a softer surface of the MMC, hence enhancing the material's impact strength and its resistance to maximum force before fracture [7]. Improved Al7075 matrix alloy integrated with ZrB_2 particles via the stir casting technique. A linear correlation between the content of ZrB_2 and its electrical resistivity was noted. The hardness of the composite with 10 wt% ZrB_2 increases by 25.1%, but the hardness of the MMCs with a 15 weight fraction enhances by 29.3% relative to the base material. The ultimate tensile strength increased at 10 wt%; above this threshold, the material demonstrated enhanced stiffness within the elastic range [8]. Examined the tribological and mechanical characteristics of hybrid Al7075-SiC metal matrix composites containing graphite, molybdenum disulfide, and hexagonal boron nitride. The liquid metallurgical stir casting technique was utilized to fabricate hybrid metal matrix composites (MMCs). The composite incorporating Gr exhibited superior hardness, tensile strength, and compressive strength, whereas those with alternative reinforcements were lowered due to porosity in the material. The hBN reinforcement demonstrated enhanced wear properties relative to other reinforcements, due to the establishment of a homogeneous transfer coating by SiC particles, which serve as load-bearing components [9]. Examined the impact of coconut shell ash (CSA) and ZrO_2 on the mechanical properties of AA6082-based composites. Both reinforcements had synergistic benefits; the integration of CSA led to a decrease in the composite's weight without considerably impairing mechanical capabilities, whilst the addition of ZrO_2 markedly enhanced the mechanical qualities [10]. Investigated the influence of including SiC particles and CSA on the properties of the resultant MMCs. In accordance with previous studies, the density decreased due to the incorporation of lightweight, lower-density CSA particles. The hardness and tensile strength of the hybrid composites (Al-10 wt.% SiC-x wt.% CSA) improved with the addition of CSA up to 8 wt.%. The increase in strength was attributed to the obstruction caused by SiC and CSA particles on the movement of dislocations in the hybrid cast composites. In recent decades, researchers worldwide have actively explored the use of nanoparticles as reinforcement due to the exceptional properties of these materials [11]. Analyzed the impacts of reinforcements, manufacturing methods, and property assessments of Al 7075 matrix composites. This review research analyzes the sorts of reinforcing materials utilized, the advantages of reinforcement hybridization, composite manufacturing techniques, essential property assessments, experimental findings, and prospective future uses of Al 7075 composites. Similar to copper, magnesium enhances corrosion resistance, ductility, and weldability [12].

The objective of the project is to develop a lightweight material with a superior strength-to-weight ratio, exhibiting excellent physical and mechanical qualities for sustainable aerospace, automotive, and marine applications. The use of BN enhances the mechanical and compressive strength of the composites. This study seeks to examine the impact of incorporating Boron Nitride (BN) into the Aluminium 7079 alloy (AA7079) matrix as a reinforcement via the stir casting method. The density, Brinell hardness, tensile, and compressive tests are employed to obtain results and facilitate further examination of the manufactured composites.

Material Selection:-

Matrix

The aluminum alloy 7079 has been selected as the matrix material. The Al7079 alloy in its ingot state is depicted in Fig. 1. Zinc is the primary alloying element, added in quantities of 3.8 to 4.8%, and is combined with a lesser percentage of magnesium, 2.9 to 3.7%, resulting in a heat-treatable alloy. The chemical composition of the Al7079 alloy is presented in Table 1. These alloys are advantageous for medium to high-strength applications when copper and chromium are incorporated in minimal proportions. High-strength Al7079 alloy has reduced susceptibility to stress corrosion cracking and is frequently utilized in a slightly lower temper to provide an improved mix of strength, fracture toughness, and corrosion resistance.

Fig. 1:- Al7079 in ingot form.

Table 1:- Composition of Al 7079.

Element	Zn	Mg	Cu	Fe	Si	Mn	Cr	Ti	Al
Contenti(%)	3.8-4.8	2.9 – 3.7	0.40-0.8	0.40 max	0.30 max	0.10 – 0.30	0.10 – 0.25	0.10 max	Remainder

Reinforcement

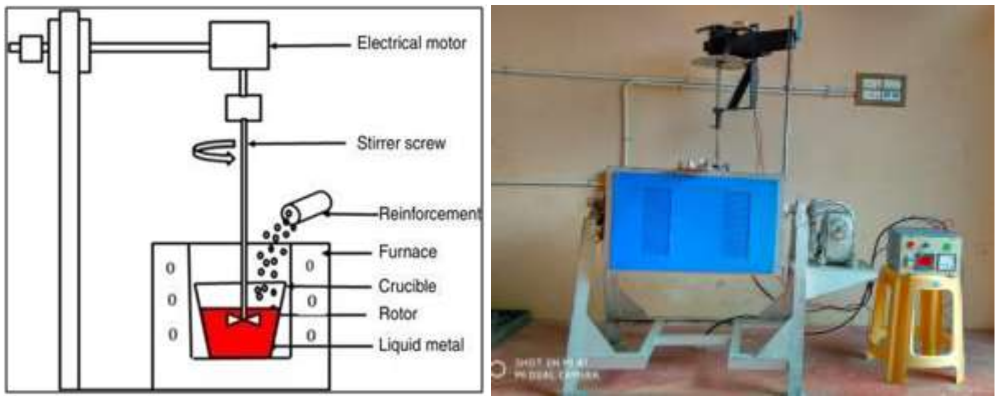
Boron Nitride

Boron nitride (BN) particles of size less than 10 µm shown in fig. 2 (a) are used as reinforcement material. Its SEM image is shown in fig. 2 (b). BN is stable at high temperatures in inert atmospheres and melts at 1300 ˚C, density of BN is 2.1 g/cc. BN is a ceramic compound that consists of boron and nitrogen atoms. It possesses unique characteristics that make it suitable for reinforcement in various composite systems. With addition of BN it improves the mechanical properties, thermal conductivity and electrical resistivity.

Fig.2:- (a) BN powder sample (b) SEM image of BN particles

Fabrication process

The fabrication of specimens with varying percentages of aluminium nitride was conducted via the stir casting technique at ambient temperature, utilizing optimal process conditions. The schematic diagram of stir casting and the actual setup utilized for the current study are illustrated in Fig. 3(a) and (b). This method entails the incorporation of particles into molten aluminium via stirring, followed by the solidification of the material in the mould under standard environmental conditions. The requisite quantity of Al7079 alloy in ingot form was initially melted at 700 – 750 ºC utilizing an electric resistance furnace. The aluminum nitride particles and permanent mold were warmed to 400 ºC to mitigate the chilling impact during solidification. Degassing of the molten metal was accomplished by using commercially available tablets of Hexachloroethane (C_2Cl_6). The primary limitation of the particle reinforced metal matrix composite is wettability, which can be enhanced by using a tiny proportion (<2%) of magnesium chips. Coverall (1%), a drossing flux with a melting temperature of 607 ºC, is incorporated to diminish the surface tension between metals and to create a continuous layer over the molten metal, so safeguarding it against oxidation and the absorption of air hydrogen. The stainless steel stirrer, coated with zirconia and featuring a blade angle of 30º, is employed to create a vortex in the melt. The stirrer height is adjusted to ensure that two-thirds of its length is submerged in the melt. The preheated reinforcement was gradually introduced into the melt, with stirring maintained at 400 rpm for an additional 15 minutes following the complete incorporation of the reinforcement. The temperature was consistently maintained with an accuracy of ±5 ºC via a digital temperature controller.



(a) schematic diagram (b) Actual setup

Fig. 3:- Stir casting process.

Specimen preparation

Specimens of Al7079-BN composites were prepared for microstructural observation, density measurement, hardness testing, tensile testing, and compression testing in accordance with ASTM standards. The dimensions for the tensile test specimen are illustrated in Figure 4.

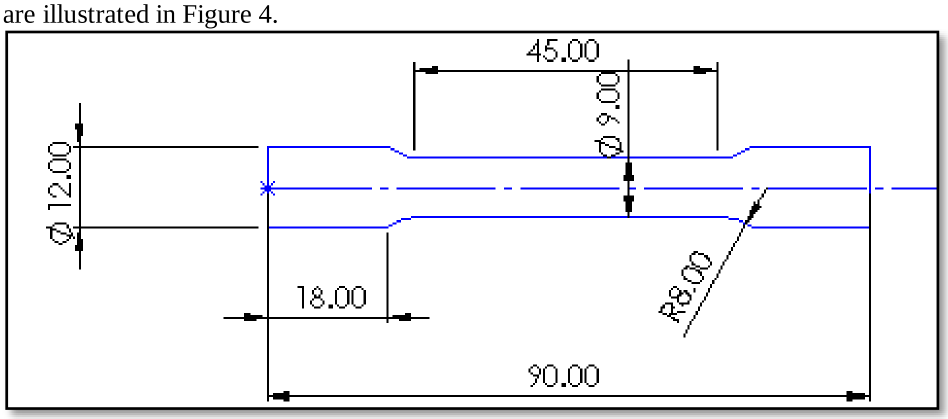


Fig. 4:- Tensile test specimen geometry.

Experimental work

Microstructural study

A metallographic analysis was conducted on the cast aluminum matrix composites utilizing Scanning Electron Microscopy to verify the uniformity of distribution and interfacial adhesion between the matrix and particles.

Density measurement

The effect of BN reinforcement on the density of the developed composites are studied both experimentally by using Archimedes principle and theoretically by using the mass by volume ratio.

The experimental density is determined by using mathematical equation is given below.

$$\rho_{ex} = \frac{m}{m - m_1} \times \rho_w$$

Where

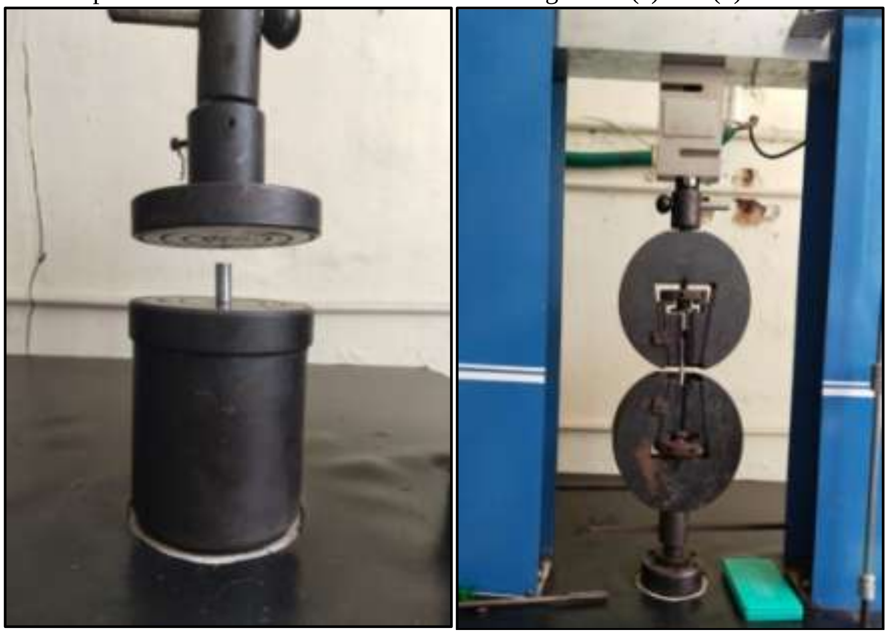
m is the mass of the composite sample in air,

m_1 is the mass off the same composite sample in distilled water.

ρ_w is the density of the distilled water.

Mechanical properties

The mechanical parameters, including ultimate tensile strength, modulus of elasticity, ductility, and ultimate compressive strength of the produced samples, were assessed at room temperature using a servo-controlled computerized universal testing machine. Hardness values were determined utilizing a Brinell hardness tester. The configuration for the compression and tensile tests is illustrated in figures 5 (a) and (b).



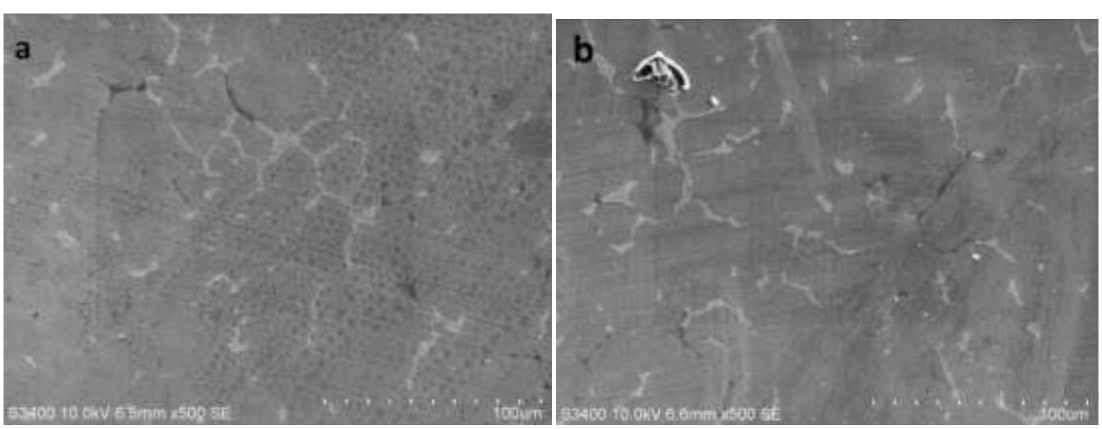
(a) Compression (b) Tensile

Fig. 5:- Mechanical Test setup.

Results and Discussions:-

Microstructural analysis

The microstructure and distribution of BN reinforcement particles in the developed composites were analysed using SEM. Fig. 6 (a) to (e) shows the SEM images of fabricated composites. It reveals the presence of BN particles in aluminium metal matrix and it is observed that the reinforcement particles are adequately dispersed in the matrix. The composites display a substantial interface between the matrix and alloy. During the solidification of the composites, the dendrites of aluminum solidify first, whereas BN particles are excluded by the solid-liquid interface, leading to the segregation of BN particles in the inter-dendritic zone. The produced composites are noted to be devoid of casting flaws, including porosity, slag inclusions, and shrinkage, which may arise from inadequate bonding between the matrix and reinforcement during casting and solidification [12]. The average distance between the reinforcement particles diminishes as the reinforcement content increases. The uniform distribution of particles in the fabricated composites can be ascribed to the parameters chosen for their production. The microstructure of the composites demonstrates that the stirring method was sufficient to attain a uniform structure. The distribution of reinforcement particles is contingent upon the density differential between the molten alloy and the particles [13].



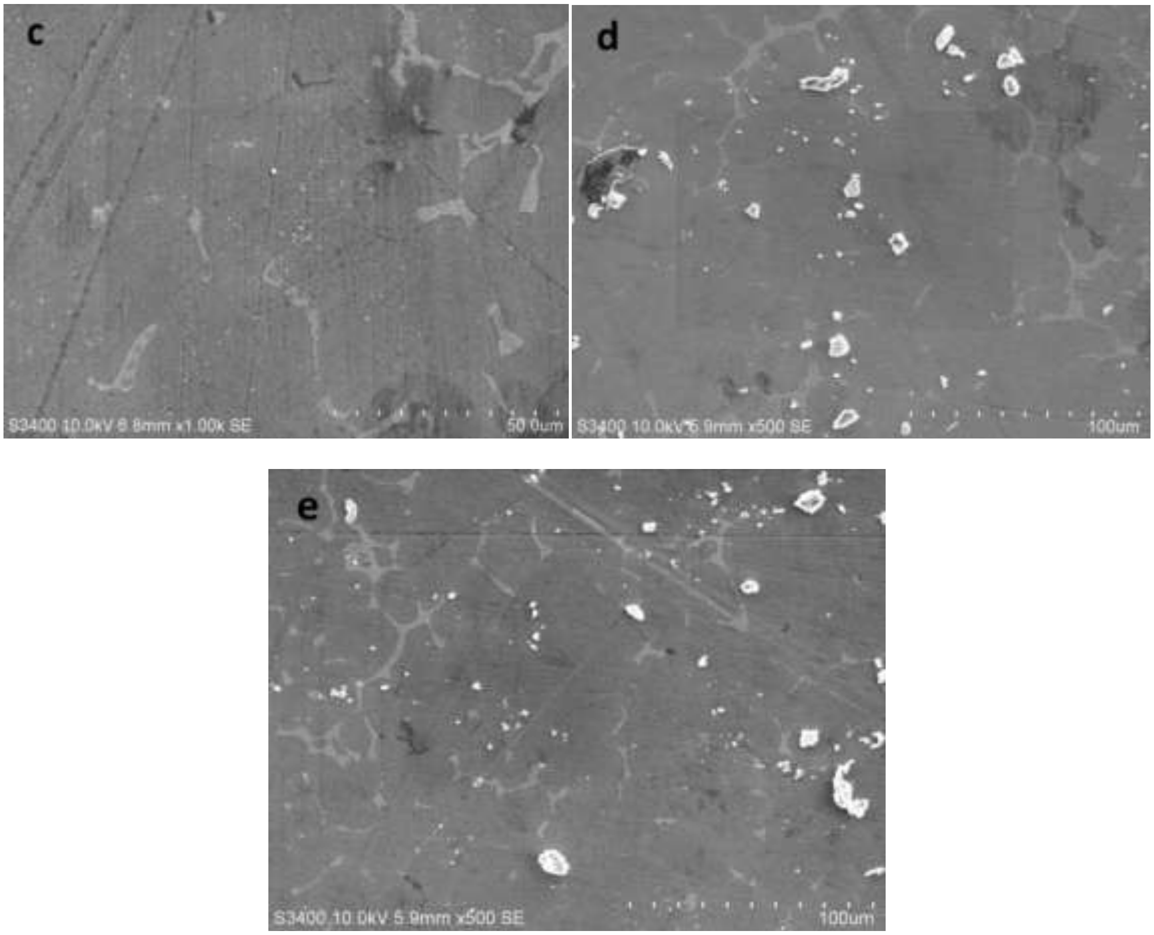


Fig 6:- SEM images of (a) Al7079 (b) Al7079+2%BN (c) Al7079+4%BN (d) Al7079+6%BN (e) Al7079+8%BN

Density

The variation of density values with respect to increasing reinforcement percentage is illustrated in fig. 7. From the results it is observed that experimental density of Al7079 alloy was 2.56×10^{-3} g/mm^3 and density of Al7079 -8% BN composite is found to be 2.68×10^{-3}g/mm^3 and theoretical density of Al7079 alloy is 2.61×10^{-3} g/mm^3 and density of Al7079 -8% BN composite is found to be 2.71×10^{-3} g/mm^3. Theoretical and actual densities of the samples fall by 4.6% and 3.8%, respectively, with the addition of about 8% BN particles. The reduction in density is ascribed to the diminished density of reinforcing particles [15,16]. The reduction in density is ascribed to the incorporation of marginally lower density BN particles (2.11 g/cm^3) into the higher density Al7079 alloy (2.72 g/cm^3).

Hardness

It is observed that hardness for unreinforced Al7079 alloy is 76.9 BHN and for Al7079 -8% BN composite is 95.72 BHN. From the results it is observed hardness of the composite increased by 24.4% for the addition of BN reinforcement about8%. The variation of Brinell hardness with percent of reinforcement is shown in Fig. 8.

The augmentation in hardness of the samples can be attributed to particle strengthening and the ability to withstand stress due to the elevated content of the relatively harder reinforcement inside the matrix [17]. The incorporation of BN particles into the continuous matrix enhances its surface area and diminishes the grain size of the aluminum matrix. The presence of BN particles provides substantial resistance to plastic deformation, resulting in an improvement in the hardness of the resultant composites [18,19].

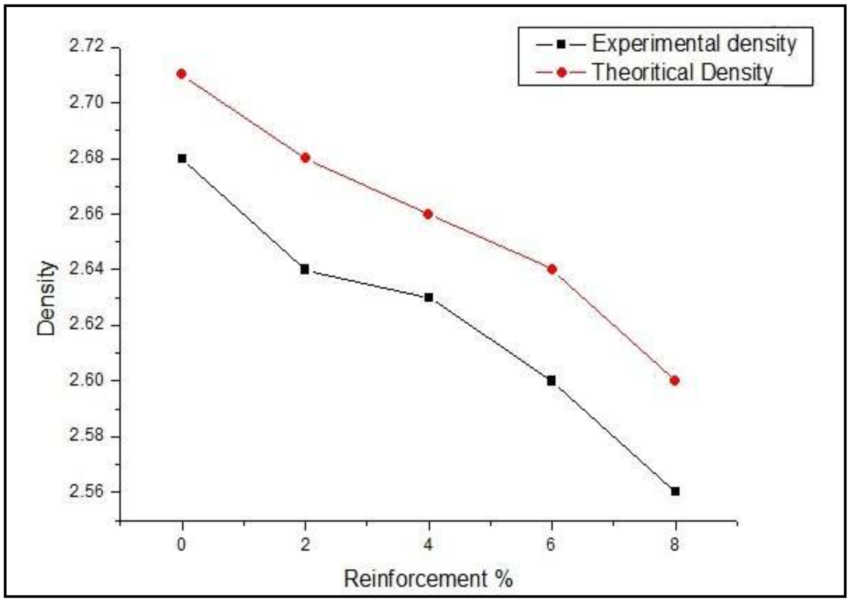


Fig. 7:- Variation of density with various % of reinforcement.

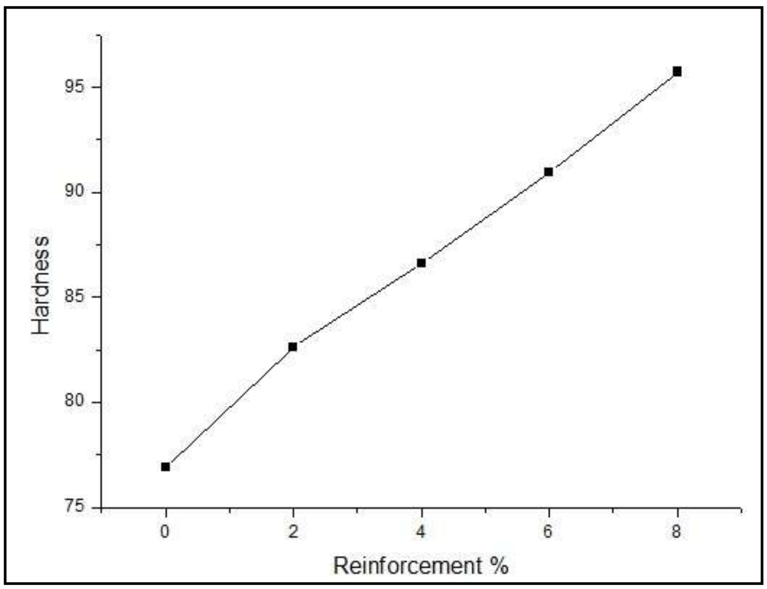


Fig. 8:- Variation of hardness value with various % of reinforcement.

Tensile strength

The impact of reinforcing particles on the ultimate tensile strength (UTS) and Young's modulus of Al7079 composites is illustrated in Figures 9 and 10, respectively. The ultimate tensile strength (UTS) and Young's modulus of the Al7079-BN composite are measured at 139.71 MPa and 26.8 GPa, respectively, when the reinforcing content is elevated to 8%. Reinforcement particles are regarded as highly successful in enhancing the strength properties of composites, resulting in a 40.2% increase in ultimate tensile strength and a 19.1% rise in Young's modulus with the inclusion of 8% reinforcement particles. The augmentation in UTS and Young's modulus may be attributed to the distribution of BN particles within the matrix. BN particles impart their strength to the matrix alloy by a strengthening mechanism, resulting in the transfer of load from the matrix to the reinforcing particles, hence enhancing the composite's resistance to induced tensile stress [20]. As the reinforcement content increases, a greater load is transferred from the matrix to the reinforcement, hence enhancing tensile strength. Furthermore, the presence of hard ceramics such as BN restricts plastic deformation due to the dispersion of hard particles within the matrix, hence enhancing the tensile strength of the composite [21,22].

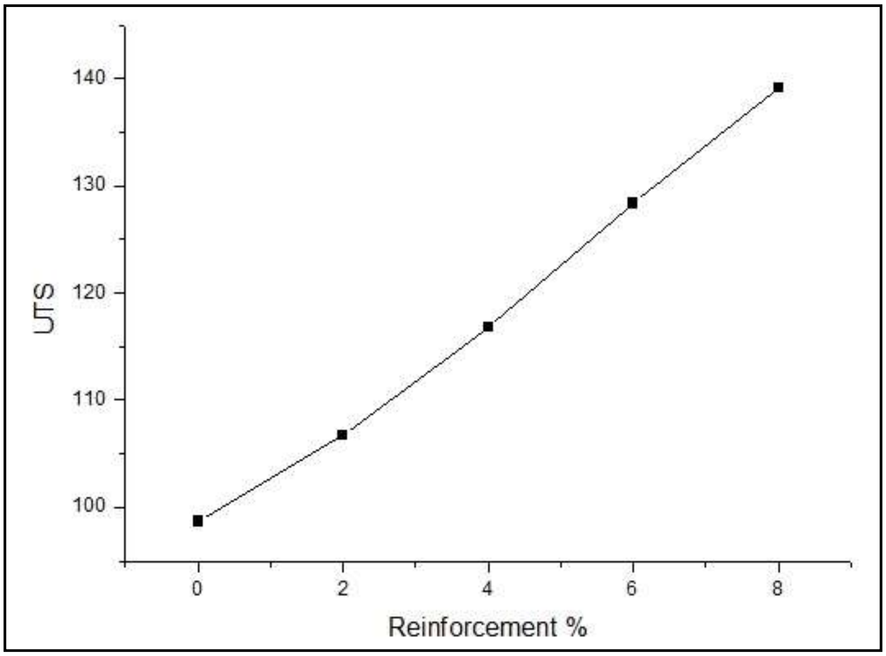


Fig. 9:- Variation of Ultimate tensile strength value with various % of reinforcement.

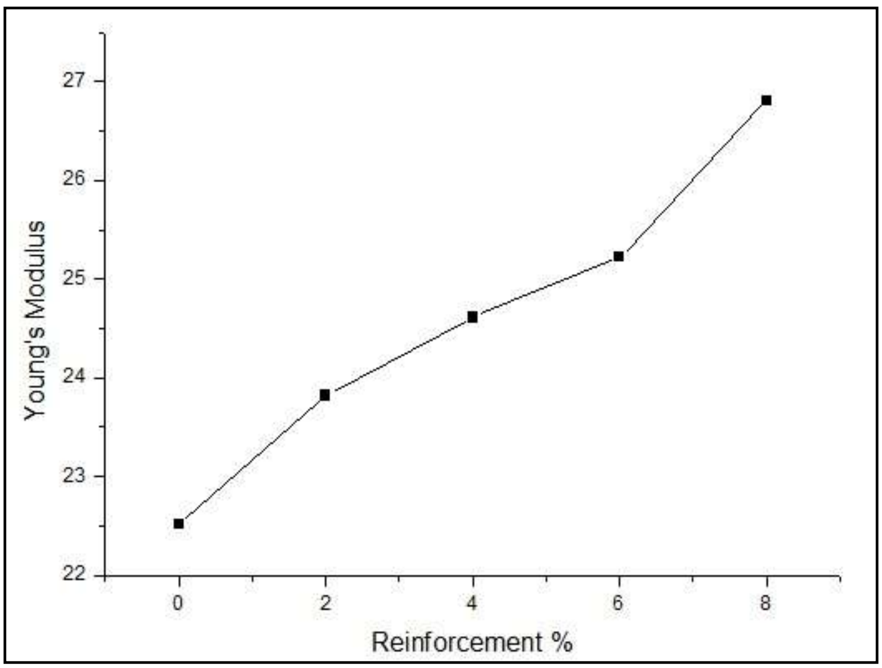


Fig. 10:- Variation of Young's Modulus value with various % of reinforcement.

Compressive strength

The fluctuation in ultimate compressive strength for Al 7079-BN composites is illustrated in Fig. 11. The graph indicates that the final compressive strength rises with an increase in the volume fraction of reinforcement. The compressive strength of the Al7079 alloy was 353 MPa, while the compressive strength of the Al7079 -8% BN composite was determined to be 480 MPa. The compressive strength of the composites increases by 36% with the incorporation of 8% reinforcement in the matrix alloy. The enhancement in compressive strength is ascribed to the presence of reinforcement particles with superior compressive strength compared to the monolithic alloy. It can be observed that, in contrast to tensile strength, compressive strength has increased linearly due to the interface between the uniformly distributed reinforcement and the matrix alloy [23]. The incorporation of tougher BN particles within the matrix serves as obstacles that hinder the mobility of dislocations and plastic flow in the matrix alloy. The presence of reinforcing particles in the composites minimizes crack propagation for fracture by restricting material flow [24,25].

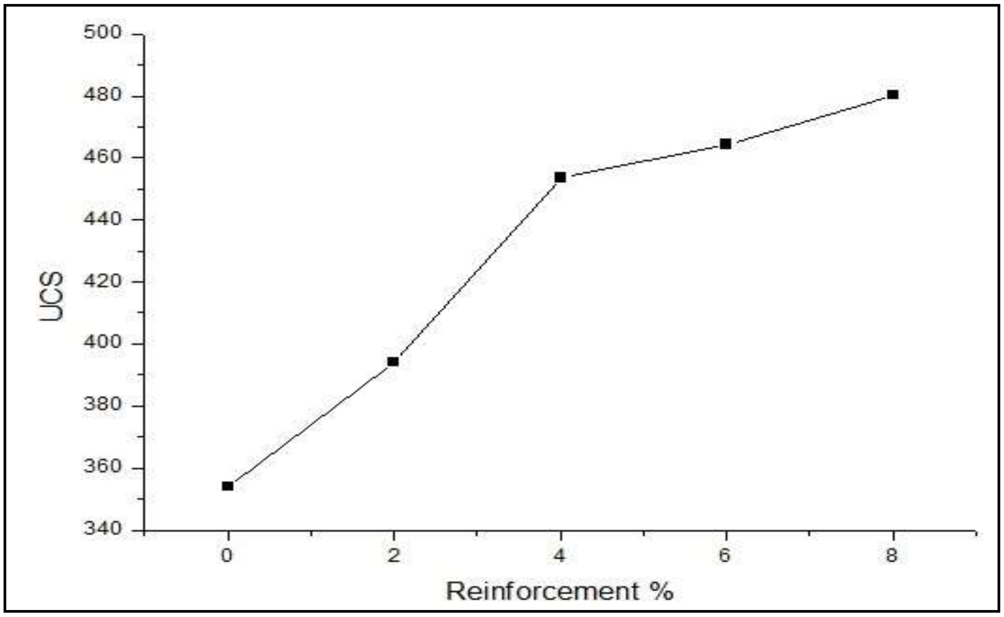


Fig. 11:- Variation of Ultimate compressive strength value with various % of reinforcement.

Conclusion:-

Al7079-BN composites were effectively produced via the stir casting method. The microstructural analysis of composites reveals a uniform distribution of reinforcement particles within the matrix, devoid of agglomeration, and exhibits robust bonding attributed to the incorporation of K_2TiF_6 and the preheating of reinforcement particles, which enhances their wettability. The density of the composites increased by approximately 4.6% with an increase in BN particle reinforcement content up to 8%.The hardness of the composite increased by 24.4% with the incorporation of 8% BN particles.The addition of reinforcement particles by 8% resulted in a 40% increase in UTS and a 19% increase in Young's modulus. The addition of 8% reinforcement in the matrix alloy results in a 36% increase in the compressive strength of the composites. The incorporation of BN particles within the matrix serves as obstacles that inhibit the movement of dislocations and the plastic flow in the matrix alloy.

References:-

[1] Vasanthakumar P, Sekar K. Koduru Venkatesh Recent developments in powder metallurgy-based aluminium alloy composite for aerospace applications. Mater Today Proc 2019;18:5400–9. https://doi.org/10.1016/j.matpr.2019.07.568

[2] U B, Gopal Krishna. Effect of percentage reinforcement of B4C on the tensile property of aluminium matrix composites. International Journal of Mechanical Engineering and Robotics Research 2012;1:290–5.

[3] Naim Shaikh Mohd Bilal, Arif Sajjad, Aziz Tariq. Microstructural, mechanical and tribological behaviour of powder metallurgy processed SiC and RHA reinforced Al-based composites. Surface Interfac 2019;–15:166–79. https://doi.org/10.1016/j.surfin.2019.03.002.

[4] Wu J, Li Z, Luo Y, Gao Z, Li Y, Zhao Y, Liao Y, Wu C, Jin M. Influence of synergistic strengthening effect of B_4C and TiC on tribological behaviour of copper-based powder metallurgy. Ceram Int 2022. https://doi.org/10.1016/j. ceramint.2022.09.282.

[5] Veeresha G, Manjunatha B, Bharath V, et al. Synthesis, microstructural characterization, mechanical, fractographic and wear behavior of micro B_4C particles reinforced Al2618 alloy aerospace composites. Frattura ed Integrità Strutturale. 2022;16(62):385–407. https://doi: 10.3221/IGF- ESIS.62.27

[6] Uvaraja VC, Natarajan N. Comparison on Al6061 and Al7075 alloy with sic and B_4C reinforcement hybrid metal matrix composites. Journal of Minerals and Materials Characterization and Engineering. 2012 Feb;11:757-68.

[7] Ahamad N, Mohammad A, Sadasivuni KK, et al. Structural and mechanical characterization of stir cast Al–

Al_2O_3–TiO_2 hybrid metal matrix composites. J Compos Mater. 2020;54 (21):2985–2997. https://doi.org/10.1177/0021998320906207
[8] Vithal DN, Krishna BB, Krishna GM. Microstructure, mechanical properties and fracture mechanisms of ZrB_2 ceramic reinforced A7075 composites fabricated by stir casting. Materials Today Communications. 2020 Dec 1;25.
[9] Devaganesh S, Dinesh Kumar PK, Venkatesh N, et al. Study on the mechanical and tribological performances of hybrid SiC-Al7075 metal matrix composites. J Mater Res Technol. 2020;9:3759–3766. https://doi.org/10.1016/j.jmrt.2020.02.002
[10] Ravi Kumar K, Pridhar T, Balaji VSS. Mechanical properties and characterization of zirconium oxide (ZrO_2) and coconut shell ash(csa) reinforced aluminium (Al 6082) matrix hybrid composite. J Alloys Compd. 2018;765:171–179. https://doi.org/10.1016/j.jallcom.2018.06.177
[11] Satheesh M, Pugazhvadivu M. Investigation on physical and mechanical properties of Al6061-Silicon Carbide (SiC)/coconut shell ash (CSA) hybrid composites. Phys B Condens Matter. 2019;572:70–75. https://doi.org/10.1016/j.physb.2019.07.058
[12] Kesharwani R, Jha KK, Imam M, Sarkar C, Barsoum I. Comparison of microstructural, texture and mechanical properties of SiC and Zn particle reinforced FSW 6061-T6 aluminium alloy. Journal of Materials Research and Technology. 2023 Sep 1;26:3301-21. https://doi.org/10.1016/j.jmrt.2023.08.161
[13] Yao H, Xu X, Luo Y, Han T, Zhou Q. Microstructure and properties of a HIP manufactured SiCp reinforced high alloyed Al–Zn–Mg–Cu–Zr–Ti aluminum matrix composite. Journal of Materials Research and Technology. 2024 May 1;30:4856-67. https://doi.org/10.1016/j.jmrt.2024.04.190
[14] Wang Y, Monetta T. Systematic study of preparation technology, microstructure characteristics and mechanical behaviors for SiC particle-reinforced metal matrix composites. Journal of Materials Research and Technology. 2023 Jul 19. https://doi.org/10.1016/j.jmrt.2023.07.145
[15] Bharathiraja P, Xavior A. Effect of B_4C and graphene on the microstructural and mechanical properties of Al6061 matrix composites. Journal of Materials Research and Technology. 2024 Jul 1;31:496-505. https://doi.org/10.1016/j.jmrt.2024.06.098
[16] Liu J, Khan U, Coleman J, Fernandez B, Rodriguez P, Naher S, Brabazon B. Graphene oxide and graphene Nanosheet reinforced aluminium matrix composites: powder synthesis and prepared composite characteristics. Mater Des 2016;94: 87–94. https://doi.org/10.1016/j.matdes.2016.01.031
[17] Barakat WS, Habba MI, Ibrahim A, Fathy A, Elkady OA. The effect of Cu coated Al_2O_3 particle content and densification methods on the microstructure and mechanical properties of Al matrix composites. Journal of Materials Research and Technology. 2023 May 1;24:6908-22. https://doi.org/10.1016/j.jmrt.2023.05.010
[18] Mohamed A, Mohammed MM, Ibrahim AF, El-Kady OA. Effect of nano Al_2O_3 coated Ag reinforced Cu matrix nanocomposites on mechanical and tribological behavior synthesis by P/M technique. Journal of Composite Materials. 2020 Dec;54(30):4921-8. https://doi.org/10.1177/0021998320934860
[19] Sadoun AM, Mohammed MM, Elsayed EM, Meselhy AF, El-Kady OA. Effect of nano Al_2O_3 coated Ag addition on the corrosion resistance and electrochemical behavior of Cu-Al_2O_3 nanocomposites. Journal of Materials Research and Technology. 2020 May 1;9(3):4485-93. https://doi.org/10.1016/j.jmrt.2020.02.076
[20] Dwivedi SP, Sharma S, Li C, Zhang Y, Kumar A, Singh R, Eldin SM, Abbas M. Effect of nano-TiO_2 particles addition on dissimilar AA2024 and AA2014 based composite developed by friction stir process technique. Journal of Materials Research and Technology. 2023 Sep 1;26:1872-81. https://doi.org/10.1016/j.jmrt.2023.07.234
[21] Prakash Dwivedi Shashi, Pachauri Praveen, Maurya Manish, Saxena Ambuj, Butola Ravi, Sahu Rohit, et al. Alumina catalyst waste utilization for aluminum based composites using the friction stir process. Mater Test 2022;64(4):533e40. https://doi.org/10.1515/mt-2021-2074
[22] Yang X, Yang L, Zhu D, Wang H, Chen T, Chu C, Jiang Z. Effect of graphene sheet diameter on the microstructure and properties of copper-plated graphene-reinforced 6061-aluminum matrix composites. Journal of Materials Research and Technology. 2024 Jan 1;28:3286-96. https://doi.org/10.1016/j.jmrt.2023.12.259
[23] Kumar A, Rana RS, Purohit R. Microstructure evolution, mechanical properties, and fractography of AA7068/Si_3N_4 nano composite fabricated thorough ultrasonic-assisted stir casting advanced with bottom pouring technique. Materials Research Express. 2022 Jan 27;9(1):015009 https://doi.org/10.1088/2053-1591/ac4b78
[24] Rajak SK, Aherwar A, Pruncu CI. Mechanical and tribological properties of composite made of marble dust-reinforced C93200 copper alloy. Materials Research Express. 2020 Jan 6;7(1):016543. https://doi.org/10.1088/2053-1591/ab6534
[25] Jayalakshmi S, Sahu S, Sankaranarayanan S, Gupta S, Gupta M. Development of novel Mg–Ni60Nb40 amorphous particle reinforced composites with enhanced hardness and compressive response. Materials & Design. 2014 Jan 1;53:849-55. https://doi.org/10.1016/j.matdes.2013.07.022.