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EXPERIMENTAL INVESTIGATION OF THE TENSILE CHARACTERISTICS OF SHOT PEENING FOR ALUMINUM METAL COMPOSITES

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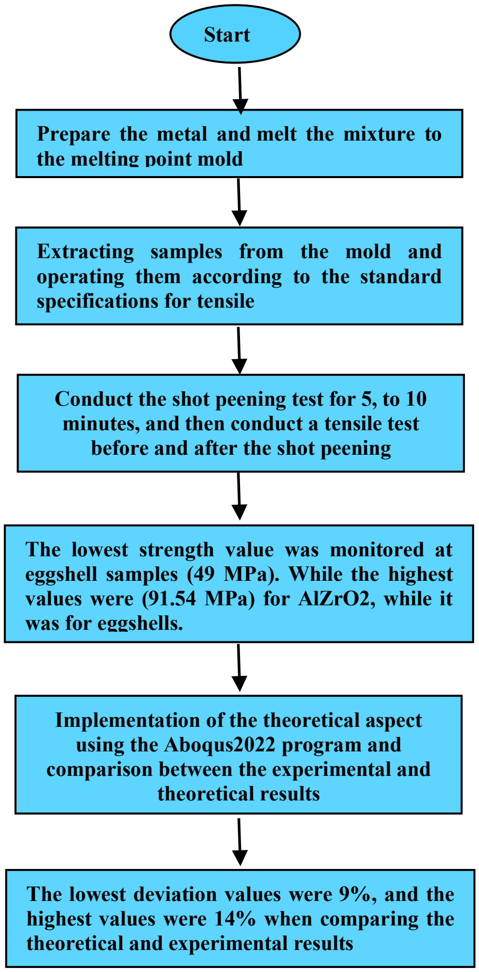
Graphical abstract



Abstract

Aluminum alloys are used in various fields of engineering, aerospace, automobile, and construction industries. However, they have peer wear resistance due to their low hardness compared to metal matrices. Using matrix composites with aluminum as a base material reinforcement with silicon carbide, eggshell, and zirconium oxide improved mechanical strength and usability. The current research investigates the mechanical properties of aluminum reinforced with SiC, ZrO_2, and eggshell particles. Recycled aluminum is manufactured using stir casting with the addition of silicon carbide, eggshell, or zirconium oxide at a rate of 5% each. The samples were divided into four groups to study the mechanical properties before and after shot peening. Using the finite element method, all samples were analyzed by utilizing Abaqus 2022 programming to compare experimental and analytical results. The results detected that the strength value for the $AlZrO_2$ sample was the highest, and the second value of the tensile strength was with the specimen of (Sic). The lowest strength value was monitored in eggshell samples. These values were 91.54 MPa for $AlZrO_2$, while they were 49 MPa for eggshells. The effect of the exposure time of shot peening on samples is direct, and their strength values increase when the holding time increases. All samples benefit from shot peening in terms of improved mechanical qualities. The lowest deviation values were 9%, and the highest values were 14% when comparing the samples that underwent the shot peening test, indicating that the theoretical tensile test results for composite materials are higher than the experimental results.

Keywords: Aluminum, Silica carbide (Sic), Zirconium oxide (ZrO_2), Metal Casting, Shot Peening, Tensile test, Abaqus 2022

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1.0 INTRODUCTION

P.B Makgabutlane , Manoko studied the importance of using recycled material. Their goal was to develop sustainable and environmentally friendly composite materials by combining plastic waste, fly ash, and agricultural by-products. This approach aims to enhance the mechanical properties of these materials for various applications while minimizing their environmental impact [1]. In such investigation, composite samples have been prepared by Hasan, L. M. *et al.* [2] using recycled aluminum as the matrix, reinforced with eggshells and calcium carbonate (CaCO3) at different weight ratios of 2%, 4%, and 8%. The objective is to evaluate the mechanical properties of the composite. The results showed that Rockwell hardness increased by 37% with eggshells and calcium carbonate in the mixture. Furthermore, the maximum ultimate tensile strength and yield strength were attained after adding 2% of eggshells. To achieve a uniform distribution of reinforcement in aluminum-alloy metal matrix composites (MMCs), various techniques, such as the stir casting method, were effectively utilized. This approach helped to minimize the costs and waste. However, enhancement is a more environmentally friendly process. Silicon carbide (SiC) filler has been used in amounts of weights ranging from 0% to 20%. They were subjected to tensile tests. Models are generated using Computer-Aided Design (CAD) applications. They were employed for finite element analysis. It was found that ductility and elongation reduce when the SiC ratio increases. The elongation rate of the MMCs compared with actual tensile test results. It was obtained that as the content of SiC increased in the MMCs, these materials became brittle this reason reducing the ductility and elongation, then compared with FE analysis considering the lower tensile loads improved (10% and 15%), the best ratio [3] Other researchers investigate Aluminum Metal Matrix Composites (Al MMC) through a series of tests, including impact, hardness, and tensile tests. They utilized the stir casting method to create an aluminum matrix hybrid composite consisting of Al6061 with varying weight percentages of Al_2O_3 and SiC (specifically, X values of 2.5% and 5% for Al_2O_3 and Y values of 5% and 2.5% for SiC). Using tensile test, impact test, hardness measurement, and scanning electron microscopy (SEM) were analyzed to evaluate morphological characteristics. S Ram Kumar *et al.* examined the effects of Al2O3 and SiC reinforcement within the matrix. Ultimately, the authors identified the optimal composition for the AMMC matrix [4]. Stir-casting was utilized to produce Al6063 metal composites. The advanced materials used in many structural and engineering applications have altered due to current developments in metal matrix composites made of titanium oxide (TiO2) and boron carbide (B4C) with aluminum alloy (AA6063). Aluminum is a matrix metal that is lightweight, extremely strong, and easily machined with TiO2 and (B4C) boron carbide, having exceptional hardness and fracture toughness. The current effort focuses on determining the mechanical characteristics of TiO2 and B4C. Particulate-reinforced Al-6063 matrix-based MMC composite. TiO2, B4C, and the AA6063 matrix create the MMCs. Focusing on the mechanical characteristics of Al-6063 metal matrix composites augmented with micro-sized titanium oxide (TiO2) and boron carbide (B4C) particles at varying weight percentages of 1,3, and 5% by the use of a stir casting technique is the current study. A Micro Vicker Hardness Testing Machine is used to test hardness. The materials' compression test yields information about their behavior [5]. Another researcher provides a comprehensive overview of Metal Matrix Composites (MMCs), presenting the experimental evaluation of these materials, including critical tests based on ASTM standards for hardness, tensile strength, compressive strength, fatigue behavior, and tribological performance. The overview covers everything from manufacturing procedures to the systematic evaluation of their properties, making a substantial contribution to the topic [6]. To facilitate the study of finding and selecting the best sandblasting parameters for the surface treatment of alloy parts, explicit dynamic finite element analysis is a compelling alternative that can accurately predict the parameters of the hose cracking process using a suitable material constitutive model and numerical method. The impact of steel bullets of different sizes on a 2618-T61 aluminum alloy plate described by a strain rate-dependent elastic-plastic material model was simulated in this work using ANSYS/LSDYNA software to calculate the impact for different incidence velocities. It investigated how the bullet size and velocity affect the plastic deformation and induced compressive residual stress. The results showed that the plastic deformation of the target increases with the increase of bullet size and velocity. The numerical models were reproduced the patterns of residual stress and plastic deformation in aluminum alloys, which is observed experimentally.The results were in close agreement with the published results [7]. The duration of exposure during the shot-peening process significantly impacts the mechanical properties of the samples. This study examined how shot peening affects the surface roughness and microhardness of the AA7075-T6 alloy. Aluminum alloy samples were subjected to shot peening for 35, 70, 105, and 140 seconds. The results indicated that b surface roughness and microhardness increase to 105 seconds of shot blasting. However, after 140 seconds of shot blasting, there is a slight decrease in surface roughness, accompanied by a marginal improvement in microhardness. The morphology of the samples was analyzed using scanning electron microscopy before and after the shot-peening process [8]. Using a specially designed shot peening (SP) system, aluminum alloy samples (identified as AA1050) were treated with stainless steel shots at pressures of 0.1 MPa and 0.5 MPa, with surface coverage rates of 100% and 1000%. The samples that underwent shot peening exhibited approximately double the hardness compared to those that did not receive treatment. Increasing peening pressure enhanced hardness, while a higher coverage rate did not do so significantly. The shot peening process caused shot embedment and the formation of microcracks. Additionally, surface degradation is indicated by an increase in the average surface roughness of up to 9 µm at coverage rates and peening pressures. The areal coverage of embedded shots varied from 1% to 5% depending on the peening parameters. As both the peening pressure and coverage rate increased, there was a corresponding increase in the number and average size of the embedded shots. The primary deformation mechanisms observed during the shot peening process included crater formation, folding, micro-crack formation, and material removal, as illustrated and explained by the surface and cross-sectional scanning electron microscope (SEM) images. While the integrity of the sample surface significantly declined only at the higher pressure, shot-peened samples generally exhibited improved mechanical properties [9] the introduction of surface nanoparticles caused the reinforcements to inhibit the deformation of the matrix. Compressing the matrix with lead in addition to the reinforcements, nanoparticles formed near the interface between the reinforcements and the matrix. Moreover, as the volume fraction of the reinforcements increased, the average distance between them decreased. Give a significant deformation between the matrix and reinforcements, besides the formation of smaller nanoparticles near the interfaces. Under the same surface processing (SP) conditions, TiC experienced more severe deformation than TiB, leading to a higher density of dislocations around TiC. Additionally, the direction of the shot influenced the shapes and distributions of the reinforcements, affecting the overall results, so the surface deformation, presence of nanoparticles, and high dislocation density in the nanocrystalline layer contributed to SP, enhancing the compressive residual stress (CRS) and hardness of the hammered surface layer [10].

Based on previous studies, the research can be categorized into two sections: the first section focuses on the shot process and the factors that influence it. In contrast, the second section emphasizes the use of additives. The current study explores the potential for recycling materials and incorporating natural additives to enhance their properties during the shot process. The goal is to produce a new environmentally friendly material that helps reduce the accumulation of used materials and agricultural waste in the environment

2.0 MATERIALS AND METHOD

2.1 Materials

Commercially, aluminum plates were purchased from the public market. The chemical species action was investigated by EDS, as shown in Figure 1.

Element	Atomic %	Atomic % Error	Weight %	Weight % Error
O	8.9	0.2	5.5	0.1
Al	91.1	0.3	94.5	0.3

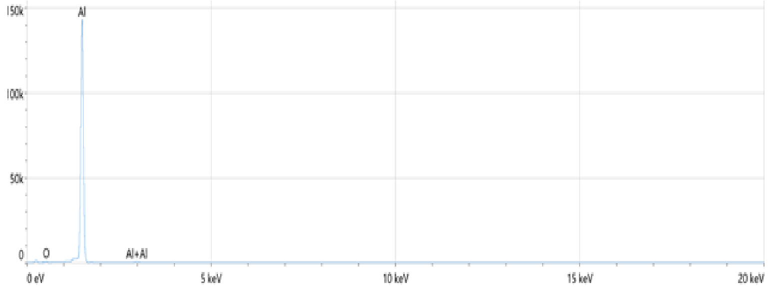

Figure 1 EDS for recycled aluminum

Figure 1 The provided image shows an energy-dispersive X-ray spectroscopy (EDS) study of a sample, which shows the elemental composition in terms of weight and atomic percentages. According to the spectrum's significant peaks for aluminum (Al) and oxygen (O), the substance is mostly made of aluminum with a trace amount of oxygen.

The high-intensity peak at low energy (1.5 keV) confirms the dominance of aluminum in the sample, which is typical of aluminum. Oxygen is represented by the low-intensity peak at about 0.5 keV, which suggests the existence of an oxide layer as opposed to a bulk oxide phase. The absence of notable peaks for other elements in the spectrum confirms the exceptional purity of the sample. This paragraph is fixed with ref. [11,12]

Zirconia is a white crystalline solid that may be made into various hues and used as a substitute for diamonds in jewelry or as ceramic crowns for teeth in medical applications, as shown in Figure 2. It naturally exists as the rare mineral baddeleyite, which has uneven vectors and a monoclinic prismatic crystal structure. It can also occasionally be transparent. Because of its exceptional mechanical qualities, zirconium oxide which is referred to as "ceramic steel," is regarded as one of the most promising restorative materials. It is chemically inert. High mechanical resistance, low thermal conductivity, chemical resistivity, and resistance to expansion at high temperatures [13].

Figure 2 Zirconium oxide

Pure silicon and pure carbon were combined to form silicon carbide, or Sic, a basic semiconductor material, as shown in Figure 3. Although silicon carbide comes in a wide range of forms and purities, it hasn't been widely available for use in semiconductors until recently. High-hardness silicon carbide lump that can withstand oxidation at high temperatures for use as a semiconductor. All of our products are reasonably priced. Silicon carbide 88 lump has stable chemical properties, high thermal conductivity, the ability to remove oxygen and adjust carbon content, and no dust nuisance when feeding the material [14].

Figure 3 Silicon carbide

Eggshells were gathered from the leftover egg waste. After washing with water to get rid of any suspended material and removing the primary materials within the eggs, as demonstrated in Figure 4, eggshells were allowed to dry in the open. It was passed through a sieve after being ground in an electric mill to obtain the right size.. The eggshell is seen in Figure 3(a) following washing and air drying. Eggshells during the filtering stage following the grinding process are depicted in Figure 4(b), together with non-ground components. The first result of the eggshells after they have been cleaned, ground, and filtered is depicted as a precise powder in Figure 4(c). [4]. The particle size of the eggshell is 150 µm.

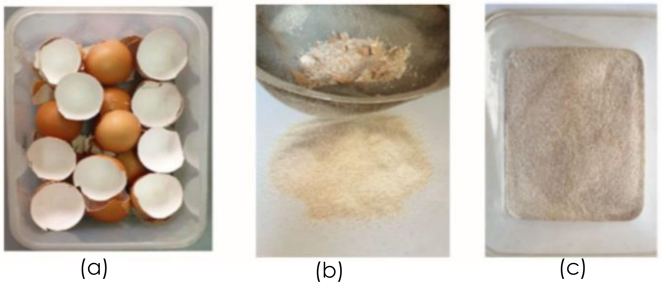
(a) (b) (c)

Figure 4 Eggshells (a) After Cleaning (b) Through filtering (c) Powder

2.2 Methods

Universal testers, which test materials in tension, compression, or bending, are the most widely used testing apparatus. Their main duty is to create the stress-strain curve. Tensile testing of specimens was performed in the mechanical engineering laboratory using the Shimadzu AG-Xplus250 kN universal testing equipment as shown in Figure 5.

Figure 5 Tensile testing.

Machine for Shot Peening, the wheel type employed in this study is the one depicted in Figure 6, with a ball diameter of 2.25 mm and a ball linear velocity of 40 m/min. For nearly all steel (ferrous) parts, the ball hardness ranges from 45 to 50 HRC [15].

Figure 6 Shot Peening Machine

3.0 EXPERIMENTAL PROCEDURE

3.1 Casting

A permanent metal mold is employed to begin the casting process. Use sandpaper to clean the mold by removing dust and rust, as shown in Figure 7.

Figure 7 Cleaning and heating the mold

Set up the workshop's gas furnace, turned it on, and added metal pieces to melt them completely. The aluminum bits began to slowly melt and transform into a molten liquid once the furnace's temperature exceeded 660 degrees Celsius, removing the impurities from the aluminum until it was free of all visible contaminants. To prevent casting faults caused by the temperature difference between the mold and the molten aluminum, the mold was heated to a temperature close to the aluminum's melting point and set in a suitable location to receive the metal, as shown in Figure 8.

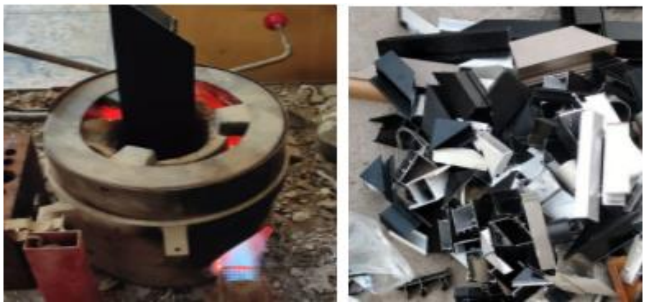

Figure 8 Gas furnaces, and recycling materials

Prepare the filler additives after measuring the weight of the added percentage using a sensitive scale balance, then wrap it completely with aluminum foil. Mixed it with molten aluminum while stirring continuously using an electric mixer as shown in Figure 9.

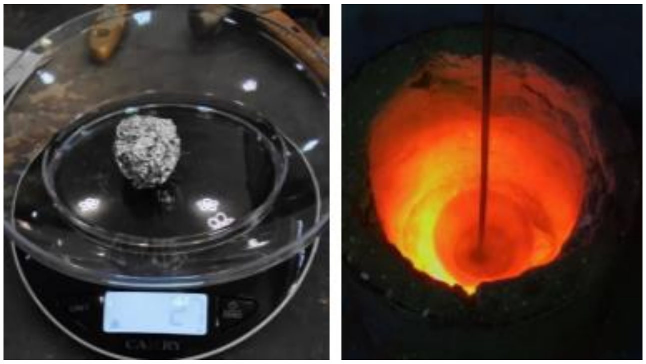

Figure 9 Balance and electrical mixture

Water poured slowly and steadily into the mold. This gradual introduction of water helps reduce the risk of internal cracking due to sudden temperature changes associated with rapid cooling. After the molten solidification, open the mold. Samples are carefully drawn out and extruded to avoid damage. The next step involves cleaning the samples by subsequent machining operations. This equipment facilitates the removal of residual material, ensuring that the samples are intact and ready for further processing or testing as shown in Figure 10.

Figure 10 Casting Process

Lastly, the samples were extruded from the mold and prepared for machining as displayed in Figure 11.

Figure 11 Extracted the samples

3.2 Machining

Samples were taken on the lathe to smooth the surface, remove excess measurements, and shape them according to the required specifications for the tensile test as shown in Figure 12.

Figure 12 Sample on lathe machine

3.3 Tensile Test

This work formed a set of samples by combining eggshell materials with pure aluminum and adding weight percentages of silicon carbide and zirconium oxide. Figure 13 depicts a set of samples created by first melting aluminum, adding each component separately, and then mixing it with pure aluminum once more.

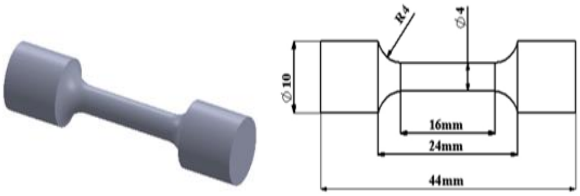

Figure 13 The samples before machining

The samples were carefully machined to meet the specifications outlined in ASTM E-8 standards, which provide guidelines for tensile testing of metallic materials. Following the machining process, the samples were evaluated using a sophisticated computerized Universal Testing Machine (UTM), specifically the TUE-C-600 model. This state-of-the-art equipment was designed to deliver precise measurements and reliable testing results, ensuring the integrity of the data collected.

As illustrated in Figure 14, the specimens underwent meticulous smoothing and cutting processes to achieve uniform dimensions and surface finishes, which are critical for accurate testing. This figure also compares sets of samples before and after undergoing shot peening, a surface treatment technique aimed at improving the material's mechanical properties by inducing compressive residual stresses.

To further enhance the mechanical performance of these samples, they were subjected to a controlled bombardment with a metal ball for varying durations of five and ten minutes. The shot peening process not only increases the fatigue life of the materials but also contributes to overall strength and durability, making it an essential step in preparing them for subsequent testing and analysis.

Figure 14 The samples after machining

In the above Figure 14, samples prior to shot peening are represented by the first column of the group for each sample, samples exposed to shot peening within five minutes are represented by the second column of samples, and samples exposed to shot peening within ten minutes are represented by the last column of samples. Figure 15 shows the dimensions of specimens of the tensile test.

Figure 15 Dimensions of specimen.

4.0 RESULTS AND DISCUSSIONS

4.1 Experimental Tensile Test

In this work, four samples of aluminum beams are mixed with a percentage weight of powder consisting of silicon carbide, eggshell, and zirconium oxide, and then the tensile test is performed on them. The test uses an untied test that loads 25 KN at the Mechanical Engineering department's laboratory. Several samples of both aluminum without and composite materials were used in the test. The number of samples and the chemical makeup of each sample are explained in Table 1.

Table 1 Percentage weight for composite for 4 specimens for each sample

No. of sample	Al (g)	Egg shells (g)	ZrO_2(g)	Sic(g)
1	400	0	0	0
2	380	20	0	0
3	380	0	20	0
4	380	0	0	20

As demonstrated by the results, the mechanical properties of aluminum are considerably improved by the inclusion of ceramic reinforcements, especially ZrO_2 and SiC. Since it exhibits the maximum strength, the Al-ZrO_2 composite can be used in wear-resistant and structural applications. A less efficient but sustainable reinforcing option is offered by the Al-Eggshell composite. Depending on the particular engineering application, the choice of reinforcement must balance cost, environmental impact, and mechanical qualities.

Figure 16 shows the stress-strain curve for four different models of aluminum metal added to 5% of different materials (zirconia oxide, silicon carbide, eggshell powder) to clarify the effect of this percentage on the behavior of the base metal (aluminum) without shot peening. It is noted from Figure 16 that adding eggshell powder to pure aluminum leads to a decrease in the mechanical behavior of the composite material by 0.85% compared to the mechanical behavior of the base metal (aluminum). It can also be noticed that adding zirconium oxide) and (silicon carbide) improves the mechanical properties compared to the mechanical properties of the base material [17,18,19]. In addition, adding silicon carbide improves mechanical properties by 1.1%, while zirconium oxide increases by 1.3%. This means that the rate of improvement in mechanical properties by adding zirconium is better than adding silicon carbide after comparing it to the mechanical properties of the base metal. It can be also noted that the value of the highest stress that can be obtained from this curve for the base metal is (70.416MPa), while the peak value of the highest stress that can be obtained from adding nibs and zinc from eggshell powder is (59.85 MPa), while the value of the stress increases to (77. 45MPa) from the addition of silicon carbide and (91.54 MPa) from the addition of zirconium oxide

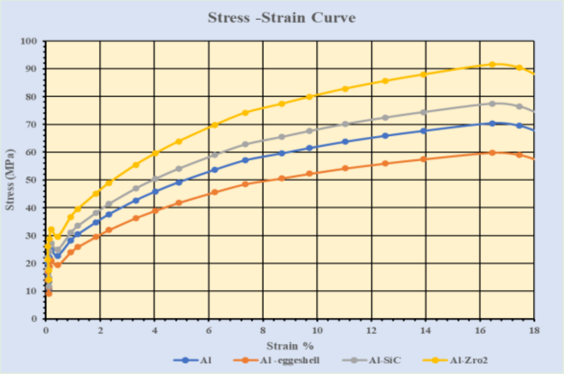

Figure 16 Stress-Strain curve without shot peening

The mechanical properties of pure aluminum metal are shown in Figure 17 following exposure to varying shot peening times (5 and 10 minutes).

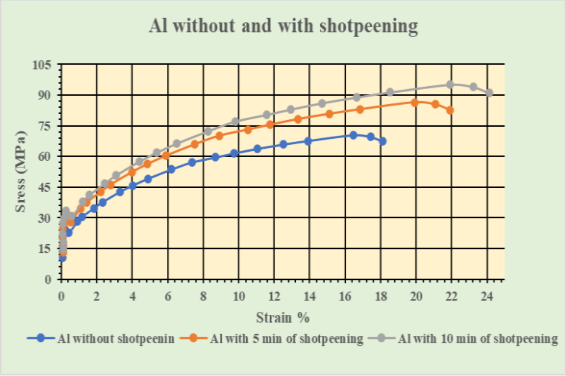

Figure 17 Stress-Strain for base metal (Aluminum) with and without shot peening

The findings show that longer exposure times result in a rise in mechanical qualities [20]. In particular, a 1.228% improvement is seen after 5 minutes of shot peening, with the maximum stress and strain reaching 86.74 MPa and 21.894%, respectively. The improvement rose to 1.332% as the exposure duration increased to 10 minutes. Tensile stress and strain both continue to increase throughout this time, peaking at 95.061 MPa and 24.112%, respectively. Shot peening results in microstructural alterations that improve strain hardening and stress by decreasing grain size, increasing dislocation density, and introducing compressive residual stresses

In Figures 18 through 20, the aluminum base metal has a fixed proportion of 5%, and different materials of silicon carbide (SiC), zirconium oxide (ZrO_2), and eggshell powder are applied before and after shot peening two different times (5 and 10 minutes). According to the results, extending the exposure duration to 10 minutes considerably improves the mechanical properties of all samples. In Figure 20, Peak stress rises significantly in the aluminum-zirconium oxide composite, which shows the most noticeable improvement. Because zirconium oxide has a high hardness and excellent load-bearing capacity, it improves strength. As a result, the Al-ZrO_2 composite is the strongest material tested.

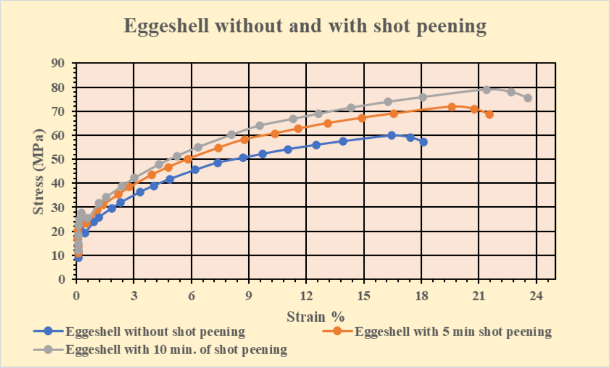

Figure 18 Stress-Strain Eggshell with and without shot peening

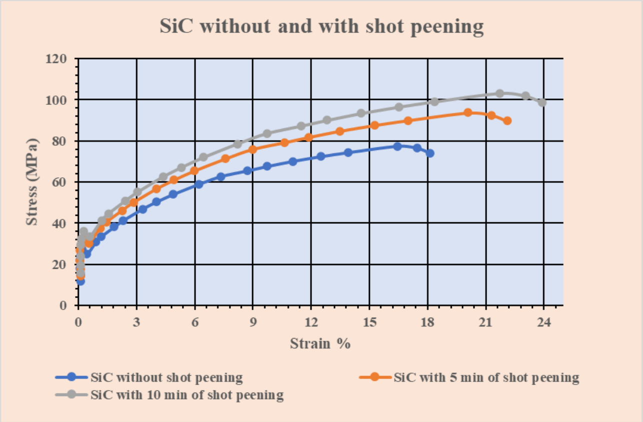

Figure 19 Stress-Strain SiC with and without shot peening

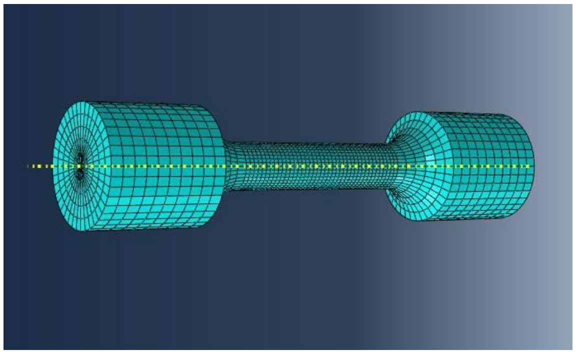

Figure 20 Stress-Strain ZrO_2 with and without shot peening

The stress distribution for each sample, both before and after the shot peening, is displayed in Figure 21. We observe that the sample is subjected to 10 minutes in the shot peening device and that the maximum values of stress occur when the composite material is made entirely of aluminum with 5% zirconium oxide added. Sample No. 4 exhibits a stress of 119.003 MPa, while sample No. 2 exhibits a minimum stress of 59.85 MPa in the absence of shot peening.

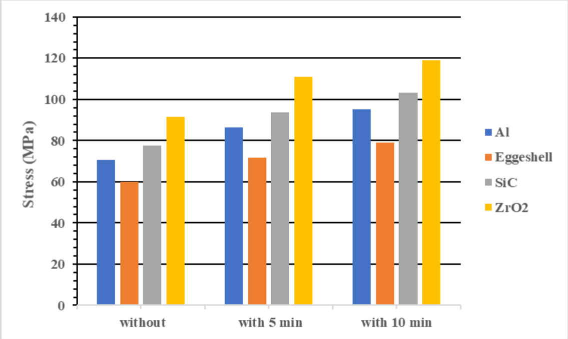

Figure 21 Distributed Stress for different composite materials with and without shot peening

4.1 Theoretical Tensile Test

Abaqus/CAE 2022 is the computer program [21] used to do the finite element analysis of the tensile test of composite samples. The results have been obtained. The stress-strain curve for the SiC sample clearly shows that the samples adhere to Hooke's Law, which states that stress and strain are directly proportionate. The sample experiences necking after the linear zone in the graph, and eventually, it breaks.

Sample No. 3, displayed in Table No. 2, is the tensile sample used in the theoretical analysis. It was put to the test by shot peening for ten seconds. The three-dimensional sample was created using the program using the dimensions displayed in Figure 15 and the standard dimensions specified by the ASTM E-8 standard. In the elasticity zone, the elastic modulus values were input while accounting for the plastic deformation that occurs in the plasticity zone and the outcomes of the practical tensile test.

The tensile test sample was processed and examined using the finite element method. Figure 22 illustrates the Structured - Hexahedral element type C3D8R was selected, and 16400 elements were employed in the mesh.

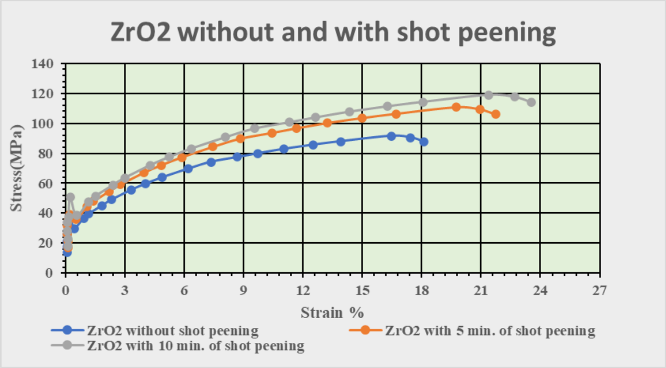

Figure 22 The meshing of the tensile element

The distribution of fractures and stresses in the sample is displayed in Figure 23. Figure 24 shows the theoretical and experimental stress-strain curve. The figure indicates that, as a result of different test implementation conditions, the theoretical stress and strain values are higher than the actual test findings. It is noted that there is a 14.28% percentage difference between the two outcomes

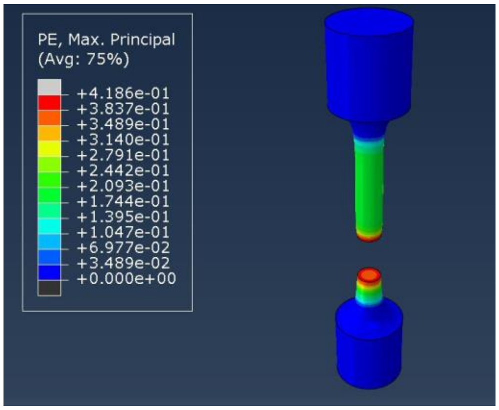

Figure 23 Stress distributed for tensile test

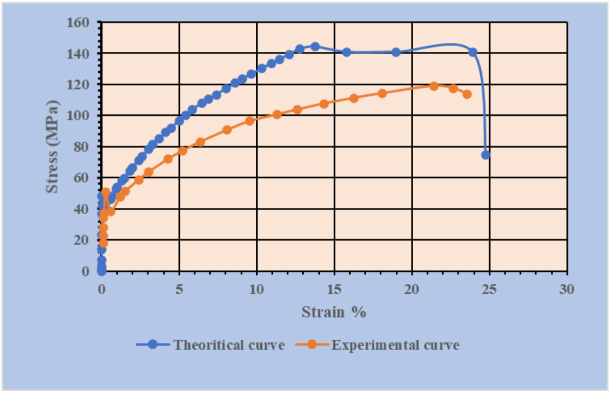

Figure 24 Theoretical and Experimental stress-strain curve for SIC

Table 2. Shows the theoretical and experimental maximum stress when the specimens were subjected to the test of shot peening for 10 minutes. This table shows that the maximum deviation between the theoretical and experimental results is 14.28%. The value of deviation ranges between 9.3% and 14.28%.

Table 2 Theoretical and Experimental for Maximum Stress after Shot Penning (10 minutes)

No. of Samples	Maximum Stress (MPa)		Percentage %
	Theoretical	Experimental	
AL-PURE	105.6241	95.06171	10%
AL-EGGSHELL	89.27326	79.00684	11.5%
AL-ZRO_2	144.225	119.0032	14.3%
AL-SIC	117.2427	103.1736	12%

5.0 CONCLUSION

Aluminum alloys are used in various fields of engineering, aerospace, automobile, and construction industries. However, they have peer wear resistance due to their low hardness compared to metal matrices. Using matrix composites with aluminum as a base material reinforcement with silicon carbide, eggshell, and zirconium oxide improved mechanical strength and usability. The current research investigates the mechanical properties of aluminum reinforced with SiC, ZrO_2, and eggshell particles. Recycled aluminum is manufactured using stir casting with the addition of silicon carbide, eggshell, or zirconium oxide at a rate of 5% each. The samples were divided into four groups to study the mechanical properties before and after shot peening. Using the finite element method, all samples were analyzed by utilizing Abaqus 2022 programming to compare experimental and analytical results. The results detected that the strength value for the $AlZrO_2$ sample was the highest, and the second value of the tensile strength was with the specimen of (Sic). The lowest strength value was monitored in eggshell samples. These values were 91.54 MPa for $AlZrO_2$, while they were 49 MPa for eggshells. The effect of the exposure time of shot peening on samples is direct, and their strength values increase when the holding time increases. All samples benefit from shot peening in terms of improved mechanical qualities. The lowest deviation values were 9%, and the highest values were 14% when comparing the samples that underwent the shot peening test, indicating that the theoretical tensile test results for composite materials are higher than the experimental results.

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Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

References

[1] Makgabutlane, P. B., Maubane-Nkadimeng, M. S., Coville, N. J., & Mhlanga, S. D. 2022. Plastic-fly Ash Waste Composites Reinforced with Carbon Nanotubes for Sustainable Building and Construction Applications: A Review. *Case Studies in Construction Materials.* 4: 100405. https://doi.org/10.1016/j.cscm.2022.100405.

[2] Hasan, L. M., & Ali, A. M. 2023. Assessment of Eggshell and $CaCO_3$ Reinforced Recycled Aluminium Green Metal Matrix. *Journal of Achievements in Materials and Manufacturing Engineering*. https://journalamme.org/article/537662/en.

[3] Thotappa, C., & Koppalada, A. 2020. Study and Analysis of Tensile Strength of Aluminum Alloy LM-12 Reinforcement with SiC and Comparison of Displacement with Finite Element Analysis. *International Journal of Advances in Engineering and Management.* 2(7): 177–186. https://doi.org/10.35629/5252-0207177186.

[4] Kumar, S. R., Ramakrishnan, S., Risvak, M., Thauffeek, S., & Yuvaraj, T. 2021. Experimental Analysis and Characterization of Mechanical, Physical Properties of Aluminium (Al6061) Metal Matrix Composite Reinforced with SiC and Al_2O_3 using Stir Casting. *IOP Conference Series: Materials Science and Engineering,* 1145(1): 012109. https://doi.org/10.1088/1757-899X/1145/1/012109.

[5] Pattar, J. 2023. Study of the Mechanical Properties of Composite Materials AA6063 Reinforced with B_4C & TiO_2 for Engineering Applications. *Journal of Propulsion Technology.* 44(3).

[6] Namdev, N., Vishwanathaiah, M. K., Nagaral, M., Kumar, S. M., & Lakshmipathy, C. G. 2024. A Review on Processing and Properties of Aluminum-based Metal Matrix Composites. *Brazilian Journal of Development, 10*(5), 1–23.

[7] Ullah, H., Ullah, B., Rauf, A., & Muhammad. R. 2019. Dynamic Finite Element Analysis of Shot Peening Process of 2618-T61 Aluminium Alloy. *Scientia Iranica B.* 26(3): 1378.

[8] Venumurali, J., Reddy, G. B., & Subramanyam, J. 2019. Effect of Shot Peening Exposure Time on Surface Properties of AA7075 Aluminium Alloy. *International Journal of Innovative Research in Advanced Engineering.* 6(6).

[9] Avcu, Y. Y., Gönül, B., Yetik, O., Sönmez, F., Cengiz, A., Guney, M., & Avcu, E. 2021. Modification of Surface and Subsurface Properties of AA1050 Alloy by Shot Peening. *Materials.* 14(21): 6575. https://doi.org/10.3390/ma14216575

[10] Wen, Y., Wu, Y., Hua, L., Xie, L., Wang, L., Zhang, L. C., & Lu, W. 2021. Effects of Shot Peening on Microstructure Evolution and Mechanical Properties of Surface Nanocrystal Layer on Titanium Matrix Composite. *Materials & Design.* 206: 109730.

[11] Smith, J. A., & Doe, R. B. 2023. Advances in X-ray Spectroscopy Techniques. *Applied Spectroscopy.* 77(2): 128–145. https://doi.org/10.1002/appl.202300128).

[12] Smith, R. J., & Lee, T. K. 2024. Energy-dispersive X-ray Spectroscopy in a Low-energy Electron Microscope. *Journal of Electron Microscopy*. 73(1): 25–40. https://pubmed.ncbi.nlm.nih.gov/38330595/.

[13] Alsharari, S. S., Alenez, M. A., Al Tami, M. S., & Soliman, M. 2023. Recent Advances in the Biosynthesis of Zirconium Oxide Nanoparticles and Their Biological Applications. *Baghdad Science Journal.* 20(1): 41–57.

[14] Daniel, E., & Obiukwu, O. (2021). Mechanical and Physical Properties of Silicon Carbide, Aluminum Oxide, And Epoxy Hybrid Composite: An Overview. *Global Scientific Journal.* 9(11).

[15] Al-rubaiey, S. I. J., & Kamil, J. Y. 2019. Effect of Shot Peening Time on Fatigue and Corrosion Fatigue Life for A27 Cast Carbon Steel. *University of Thi-Qar Journal for Engineering Sciences*. 10(1). http://www.doi.org/10.31663/tqujes.10.1.353.

[16] Rebba, B., & Ramanaiah, N. 2014. Evaluation of Mechanical Properties of Aluminium Alloy (Al-2024) Reinforced with Molybdenum Disulphide (MoS_2) Metal Matrix Composite. *Procedia Materials Science*. 6: 1161–1169. https://doi.org/10.1016/j.mspro.2014.07.194.

[17] Mr. M. Tamilarasan, Dr. P. S. Sampath. 2020. A Study on Effect of SiC on Mechanical Properties of Aluminium 8011 Metal Matrix. *International Research Journal of Engineering and Technology*. 07(04): 18–21.

[18] Muharrem Pul. 2021. Effect of ZrO2 Quantity on Mechanical Properties of ZrO2- Reinforced Aluminum Composites Produced by the Vacuum Infiltration Technique. *Revista de Metalurgia*. 57(2): e195. https://doi.org/10.3989/revmetalm.195,pp. (1-11).

[19] Sumarji, Albajili, N. F., Darsin, M., Sakura, R. R., & Sanata, A. 2022. Effect of Variation of SiC and Mg Mass Fraction on Mechanical Properties of Al-SiC Composite using stir Casting Method. *Journal of Mechanical Engineering Science and Technology*. 6(1): 23–33.

[20] Naef, A. A., Al-Khazraji, I., Amoori, E. T., & Al-Taie, H. 2015. The Effect of Shot Peening on the Notch Sensitivity Factor and Neuber Characteristic Length For 7075-T6 Aluminum Alloy. *Journal of Engineering and Development*. 19: 4.

[21] Zaini, M., Ait El Fqih, M., Idiri, M., Bouab, W., & Chafiq, J. 2022. Experiment and Simulation Study of the Effect of Fillers on Mechanical Properties of Sustainable Composite. *Journal of Mechanical Engineering*. 72(2): 239–246.