Nano World Journal

https://doi.org/10.17756/nwj.2023-s3-029

Research Article

Open Access

Correlating Tensile Strength of AA5051/SiO_2 Nanocomposite with Monolithic AA5051 Alloy

Athersh Narayan Govind and Gnanasambandam Anbuchezhiyan*

Department of Mechanical Engineering, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamil Nadu, India

***Correspondence to:**

Gnanasambandam Anbuchezhiyan
Department of Mechanical Engineering,
Saveetha School of Engineering,
Saveetha Institute of Medical and Technical Sciences,
Saveetha University,
Chennai, Tamil Nadu, India.
E-mail: anbuchezhiyang.sse@saveetha.com

Received: July 27, 2023
Accepted: September 29, 2023
Published: October 05, 2023

Citation: Govind AN, Anbuchezhiyan G. 2023. Correlating Tensile Strength of AA5051/SiO_2 Nanocomposite with Monolithic AA5051 Alloy. *Nano World J* 9(S3): S148-S151.

Published by United Scientific Group

Abstract

The performance of an AA5051 alloy reinforced with novel silicon dioxide (SiO_2) was synthesized in this work and its tensile strength and percentage of elongation were compared with AA5051 alloy. Recycled AA5051 alloy was used as matrix materials and novel SiO_2 of particle size 60 nm are used as ceramic strengthening particles for synthesizing aluminum alloy nanocomposites using the stir casting method. Two groups of samples were prepared in terms of the control group (Recycled AA5051 Alloy) and experiment group (Recycled AA5051 Alloy + 2 wt.% SiO_2) nanocomposite. The outcomes of the studies were analyzed using t-test, and the significant level of the ultimate tensile strength and percentage of elongation properties of the as-cast recycled AA5051 alloy were compared with nanocomposites that had been synthesized. It was determined that there is a statistically significant difference between the two groups based on the significance value of $p = 0.000$ (2-tailed), which was achieved. This value is lower than the threshold of $p < 0.05$. According to the study's limitations, it was found due to increased surface areas between the immixture it significantly increased the ultimate tensile strength (35.25%) and percentage of elongation (12%) in comparison with cast recycled AA5051 alloy.

Keywords

Metal matrix composites, Recycled AA5051 alloy, Silicon dioxide, Stir casting, Ultimate tensile strength, Percentage of elongation

Introduction

The utilization of nano composites is significant in the automotive sector because of their increased stiffness, Improved wear resistance properties [1]. Nonetheless, the distribution of ceramic debris is an essential aspect in figuring out those properties. The use of micron-scale ceramic reinforcements in matrix alloys shows degradation processes that result in physical property loss. Adding nano-ceramic reinforcing particles to the matrix alloy can solve this problem. Nanoceramic particles have been shown to have improved mechanical properties compared to micron-sized composites [2]. A key drawback in the production of such nanocomposites is the poor wettability and particle agglomeration that occurs between the matrix and the ceramic reinforcing particles [3]. This can be improved by effective process parameters and processing methods. Literature surveys concluded that due to their improved mechanical properties, these nanocomposites are used in aerospace and automotive industries for a variety of applications such as gears, aircraft fins, cylinder liners, disc brakes, and calipers [4].

On Google Scholar, there are about 90 research on aluminum alloys reinforced with new nano-SiO_2 ceramic particulates, and on Science Direct, there are about 102. Using a stir casting process, the impact of SiO_2 reinforced aluminum alloy composites was tested, and their mechanical characteristics were measured in accordance with ASTM standards. It was observed that good interfacial reactions between the mixtures resulted in significantly improved mechanical properties compared to cast alloys [5]. The influence of SiO_2 reinforced aluminum alloy was manufactured utilizing the vacuum assorted stir casting process. It was concluded that only a low percentage of nanoparticles in aluminum alloys leads to uniform distribution of reinforcement in the matrix alloy and improved mechanical properties [6]. Higher material removal rates have been observed compared to micron-sized ceramic reinforcing particles [7]. An examination of the literature revealed that introducing a tiny quantity of nanoceramic reinforcement in the matrix alloy enhanced characteristics, which was considered the most appropriate study for the present analysis [8]. According to the literature review, the utilization of nano-SiO_2 particles in recycled AA5051 alloy has not yet been created, and their physical characteristics have not yet been assessed. In an effort to fill this research void, efforts have been undertaken to both synthesize such composites and investigate their ultimate tensile strength and percentage of elongation for the purpose of developing applications that include weight reduction [9, 10].

Materials and Method

The appropriate quantities of Al5051 alloy were employed as matrix materials, while novel nano-SiO_2 particles with particle sizes of 50 nm were used as reinforcement for producing recycled AA5051 alloys nanocomposites. Table 1 displays the recycled AA5051 alloy chemical proportions. Recycled AA5051 alloy nanocomposites were created using a stir casting system with bottom pouring. The necessary alloy material was placed in a resistance heating furnace, and it was heated at 450 ˚C. At 800 ˚C, the alloy was heated and given time to melt. The stirrer was whirled at 500 rpm to make sure the molten metal was completely melted.

Table 1: Chemical constituents (Wt.%) of recycled AA5051 alloys [11].

Cr	Cu	Fe	Mg	Mn	Si	Cr	Zn	Al
0.26	0.11	0.37	2.67	0.19	0.24	0.29	0.21	Bal

It was found that the melting temperature of the aluminum alloy was 786 ˚C, and distinctive nano-SiO_2 ceramic reinforcing particles with a size of 60 nm have been introduced into the molten metal by an external sprue. The agitation speed was enhanced to 500 rpm, and the agitating time was kept at 15 min; this was done to ensure that the matrix alloy included uniform reinforcement distribution. Before pouring the molten slurry into the mold, the temperature was increased to 800 ˚C for the purpose of increasing the viscosity, and the die was warmed to 250 ˚C in an effort to eliminate the porosity that was present in the matrix material. Both of these steps were performed before the molten slurry was poured into the mold. The liquid slurry was poured into the mold and then allowed to cool to room temperature before being removed. Machining synthetic composites in accordance with the requirements set out by ASTM allows for an evaluation of the material's performance characteristics [11, 12].

Statistical analysis

In this study SPSS (Statistical Package for the Social Sciences) v26 software was used to identify the significance between the as cast and synthesized nano composites. An independent samples t-test was used to identify the statistical significance between the groups [13]. To obtain the multiple comparison table and graph, the novel nano-SiO_2 particle reinforced recycled AA5051 alloy composites and percentage of elongation were employed as self-determining variables.

Results and Discussion

In the current study, a unique nano-SiO_2 particle reinforcement was used as reinforcement, and stir casting was used to create aluminum nanocomposites using recycled AA5051 alloys as base materials. The nanocomposite samples of the recycled AA5051 alloy that were produced using the stir casting method are shown in figure 1. They were machined in accordance with ASTM standards. The generated aluminum nanocomposites SPSS bar graph was displayed in figure 2 and figure 3.

Table 2 and table 3 provide a comparison of ultimate tensile strength and percentage elongation of recycled AA5051 alloys with recycled AA5051 alloy with 2% nano-SiO_2. Table 4 illustrates the average ultimate tensile strength and percentage of elongation of as cast recycled AA5051 alloy and 2% SiO_2 reinforced aluminum nanocomposites. Table 5 calculated the average, mean, and standard deviation. Table 6 shows the

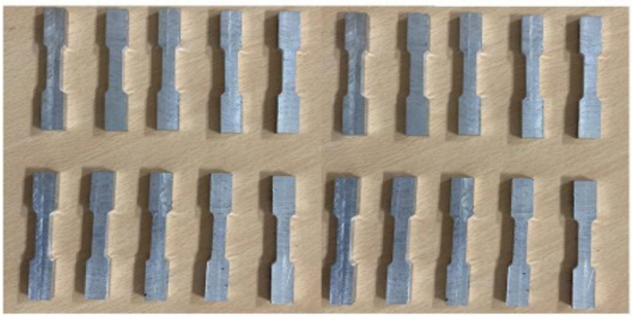

Figure 1: Tensile strength of recycled AA5051/SiO_2 composites.

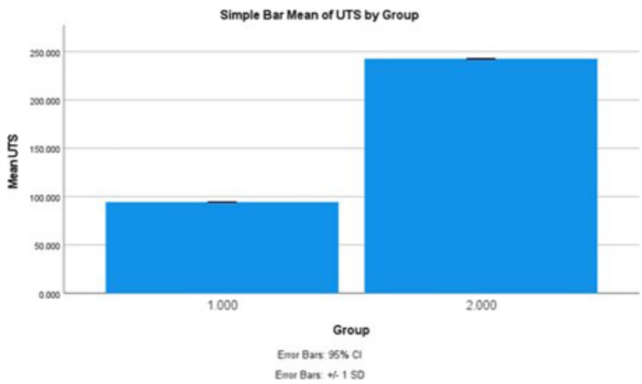

Figure 2: Ultimate tensile strength of recycled AA5051 alloys and 2 wt.% of SiO_2/AA5051 nanocomposites.

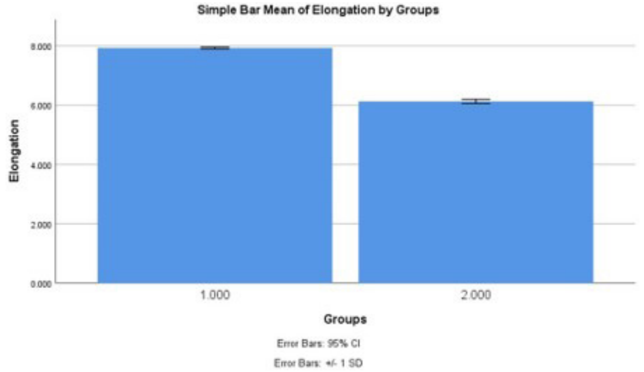

Figure 3: Percentage of elongation of recycled AA5051 alloys and 2 wt.% of SiO_2/AA5051 nanocomposites.

Table 2: Comparison of ultimate tensile strength of recycled AA5051 alloys with recycled AA5051 Alloy with 2 wt.% of nano-SiO_2.

Exp. No.	AA5051 alloy (MPa)	Recycled AA5051 alloy + 2 wt.% of nano-SiO_2 (MPa)
1	92.33	243.87
2	93.38	244.13
3	93.35	241.82
4	93.41	244.85
5	93.82	242.81
6	93.37	243.79
7	93.28	241.84
8	93.42	243.52
9	92.97	242.92
10	93.39	242.98
11	92.68	243.63
12	92.81	242.76
13	92.44	243.18
14	93.52	243.61
15	93.40	243.78
16	93.33	243.17
17	93.51	241.38
18	93.68	243.72
19	93.81	241.79
20	93.14	243.91

Table 3: Comparison of percentage of elongation of recycled AA5051 alloys with recycled AA5051 alloy with 2 wt.% of nano-SiO_2.

Exp. No.	Elongation % of recycled AA5051 alloy	Elongation % of recycled AA5051 alloy + 2 wt.% of nano-SiO_2
1	7.92	5.92
2	7.85	5.91
3	7.82	6.01
4	7.87	5.15
5	7.89	6.11
6	7.64	5.12
7	7.77	5.15
8	7.82	5.14
9	7.93	5.17
10	7.92	5.15
11	7.94	5.98
12	7.96	5.92
13	7.91	5.13
14	7.92	5.19
15	7.93	6.17
16	7.91	6.15
17	7.91	6.18
18	7.90	6.17
19	7.91	6.18
20	7.94	6.16

Table 4: Average ultimate tensile strength and percentage elongation of as cast recycled AA5051 alloy and 2 wt.% of SiO_2 reinforced aluminum nanocomposites.

Combinations	Tensile strength (MPa)	Elongation %
Recycled AA5051 alloy	93.43	6.9305
Recycled AA5051 alloy + 2 wt.% of nano-SiO_2	241.65	5.1285

significant values for the independent sample test for ultimate tensile strength, which are p = 0.001.

As a result of the experimental observation, it was deduced that the synthesized aluminum alloy nanocomposites performed much better than the as-cast recycled AA5051 alloy when compared in terms of ultimate tensile strength and percentage of elongation [14]. It's because the nano-SiO_2 ceramic strengthening particles are scattered uniformly throughout the matrix alloy, therefore expanding the intermixture's surface area [15]. It was found that reducing the composite's porosity below the maximum level and improving grain texture have a big effect on the composite's final tensile strength [16]. It was inferred that nano ceramic particulates (SiO_2) in recycled AA5051 alloy slightly improve grain refinement because they create intergranular structures and strengthen grain boundaries, which increases the ductility of developed nanocomposites and significantly raises the percentage of elongation, as reported in the similar findings [17].

The study's limitations were that it was noted that the ultimate tensile strength and percentage of elongation were significantly increased by adding a minimum weight percentage of nano ceramic particles into the aluminum matrix alloy. According to a research review, the agglomeration of micro ceramic strengthening particles caused by an increase in weight percentage in the matrix alloy decreased the physical properties of synthesized aluminum alloys composite. This can be

Table 5: Tensile strength (Mean value, standard deviation, and standard error) of Al-Mg-Cr alloy nanocomposite.

	N	Mean	Std. deviation	Std. error	95% CI of the difference		Minimum	Maximum
					Lower	Upper		
Recycled AA5051 alloy	20	94.32	0.014951	0.0334	-148.48	148.17	93.92	94.44
Recycled AA5051 alloy + 2 wt.% of nano-SiO_2	20	242.7	0.031458	0.0703	148.484	148.17	241.9	243.1
Total	40	168.5	0.02320	0.0518	0.002	148.17	167.91	168.77

Table 6: Independent sample test for ultimate tensile strength represents the significance values p = 0.001.

		Levene's test for equality of variances		T-test for equality of means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	95% CI of the difference	
									Lower	Upper
Ultimate tensile strength	Equal variance assumed	31.66	0.001	-118.498	38	0.000	-174.361	1.4714	-177.34	-171.382645
	Equal variance not assumed			-118.498	22	0.00	-174.3614	1.471430	-177.413143	-171.309657

avoided by an effective processing method in the matrix alloy and different processing methods can be considered with lower cost, which is thought to be the investigation's future focus.

Conclusion

The stir casting method was used to create unique nano-SiO_2 reinforced recycled AA5051 alloys within the confines of the current study. The ultimate strength and percentage of elongation of synthesized composites were then analyzed and compared to monolithic recycled AA5051 alloys. It was shown that, as compared to cast aluminum alloy, the ultimate tensile strength and percentage of elongation of novel nano-SiO_2 reinforced recycled AA5051 alloy composites significantly enhanced to 59.45% and 28%, respectively.

Acknowledgements

None.

Conflict of Interest

None.

References

1. Reddy MCS, Rajesh G, Anbuchezhiyan G, Anichai J, Chinka SSB, et al. 2023. Synthesis and characterization of silicon dioxide reinforced AZ91D magnesium composites. *Mater Today Proc* 1-6. https://doi.org/10.1016/j.matpr.2023.05.626
2. Şenel MC, Üstün M. 2023. Effect of silicon dioxide-graphene content on the microstructure, sliding wear behavior, and compressive strength of aluminum hybrid composites. *J Mater Eng Perform* 32(3): 1248-1260. https://doi.org/10.1007/s11665-022-07194-5
3. 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 Mater Sci Eng* 2023: 5442809. https://doi.org/10.1155/2023/5442809
4. Saini S, Gupta A, Mehta AJ, Pramanik S. 2023. Effect of graphite and rice husk-derived SiO_2 on mechanical and thermal properties of re-sintered aluminium-based metal matrix hybid nanocomposites. *J Therm Anal Calorim* 148(6): 2335-2344. https://doi.org/10.1007/s10973-022-11897-1
5. Liu H, Yang L, Liu X, Cao JP, Zhang J, et al. 2023. Silicon dioxide nanoparticle decorated graphene with excellent dispersibility in natural rubber composites via physical mixing for application in green tires. *Compos Part B Eng* 258: 110700. https://doi.org/10.1016/j.compositesb.2023.110700
6. Ahmed HU, Mohammed AA, Mohammed AS. 2023. Effectiveness of silicon dioxide nanoparticles (Nano SiO_2) on the internal structures, electrical conductivity, and elevated temperature behaviors of geopolymer concrete composites. *J Inorg Organomet Polym Mater* 1-21. https://doi.org/10.1007/s10904-023-02672-2
7. Zhang C, Wu W, Hu H, Rui Z, Ye J, et al. 2023. Preparation of SiO_2/Si_3N_4ws/PU reinforced coating and its reinforcement mechanism for SLS-molded TPU materials. *J Appl Polym Sci* 140(35): e54355. https://doi.org/10.1002/app.54355
8. Anbuchezhiyan G, Mubarak NM, Karri RR, Khalid M. 2022. A synergistic effect on enriching the Mg–Al–Zn alloy-based hybrid composite properties. *Sci Rep* 12(1): 20053. https://doi.org/10.1038/s41598-022-24427-8
9. Tharanikumar L, Mohan B, Anbuchezhiyan G. 2022. Enhancing the microstructure and mechanical properties of Si_3N_4–BN strengthened Al–Zn–Mg alloy hybrid nano composites using vacuum assisted stir casting method. *J Mater Res Technol* 20: 3646-3655. https://doi.org/10.1016/j.jmrt.2022.08.093
10. Ravichandran S, Jegathaprathaban R, Radhakrishnan J, Usha R, Vijayan V, et al. 2022. An investigation of electrospun *Clerodendrum phlomidis* leaves extract infused polycaprolactone nanofiber for *in vitro* biological application. *Bioinorg Chem Appl* 2022: 2335443. https://doi.org/10.1155/2022/2335443
11. Parthiban SR, Loganathan M, Venkatesh R, Vijayan V. 2021. Effect of the use of biodiesel on the materials of the engine components. *J Sci Ind Res* 80(7): 606-611. https://doi.org/10.56042/jsir.v80i7.49772
12. Kumar VV, Raja K, Chandrasekar VS, Ramkumar T. 2019. Thrust force evaluation and microstructure characterization of hybrid composites (Al7075/B_4C/BN) processed by conventional casting technique. *J Braz Soc Mech Sci Eng* 41: 1-14. https://doi.org/10.1007/s40430-019-1728-5
13. Raja K, Chandrasekar VS, Kumar VV, Ramkumar T, Ganeshan P. 2020. Microstructure characterization and performance evaluation on AA7075 metal matrix composites using RSM technique. *Arab J Sci Eng* 45: 9481-9495. https://doi.org/10.1007/s13369-020-04752-8
14. Selvam R, Vignesh M, Pugazhenthi R, Anbuchezhiyan G, Gupta MS. 2023. Effect of process parameter on wire cut EDM using RSM method. *Int J Interact Des Manuf* 1-12. https://doi.org/10.1007/s12008-023-01391-9
15. Sager A, Esen I, Ahlatçi H, Turen Y. 2023. Characterization and corrosion behavior of composites reinforced with ZK60, AlN, and SiC particles. *Eng Sci Technol* 41: 101389. https://doi.org/10.1016/j.jestch.2023.101389
16. Mahesha CR, Sree Jayan MM, Kulkarni S, Sharma A, Al-Ammar EA, et al. 2022. Tribological behavior of AA7075 reinforced with Ag and ZrO_2 composites. *Adv Mater Sci Eng* 2022: 7105770. https://doi.org/10.1155/2022/7105770
17. Rajesh G, Thiyagaraj J, Narayana KJ, Anbuchezhiyan G, Saravanan R, et al. 2023. Microstructure and mechanical properties of AZ91D/Si_3N_4 composites using squeeze casting method. *Mater Today Proc* 1-6. https://doi.org/10.1016/j.matpr.2023.04.470