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Enhancement of Tensile properties of AA 5052 aluminum alloy by reinforcement of ZnO nanoparticles

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Abstract: Present study was carried out to understand the effect of zinc oxide (ZnO) nanoparticles (NPs) on mechanical properties of AA 5052 aluminum alloy. The incorporated nanoparticles were prepared by conventional sol–gel technique while aluminum alloy composites were synthesized employing mold casting method. The synthesized ZnO NPs reflects have average crystallite sizes of around 60 nm. AA5052 with increasing concentrations of ZnO NPs from 1 – 4% with steps of 1% in between was synthesized. Tensile properties of these alloy samples of various reinforcement concentrations were evaluated by Ultimate Tensile Strength (UTS), Yield Strength and Percentage Elongation studies. The results revealed that an addition of ZnO nanoparticle to alloy have considerably enhanced the tensile strength and the hardness. The maximum tensile strength and hardness of this alloy was 207.6 MPa, which occurred at 4 wt% of ZnO NPs.

Introduction

Airplanes are increasingly using aluminum composites because of their better tensile and yield strength and corrosion resistance, which makes them ideal for use in aircraft structures. High-speed flight conditions need the use of composite materials that can withstand high temperatures [1,2]. As a result, they've widened the scope of their composites research to encompass uses in aircraft operating at higher Mach numbers and temperatures ranging from 200–250° C [3]. Furthermore, for aerospace industries such as wing structures, airframes and heat exposure of Al composites to maximum temperatures are critical [4]. High strength alloys are stable and resistant to corrosion features of aluminum alloys are particularly impressive [5]. High-temperature applications have seen an increase in the characteristics of Al castings synthesized by chemical stir casting [6]. It is essential to improve the mechanical properties aluminum by incorporating NPs or mixing other metals. The examination of addition of NPs on the microstructure and the mechanical properties of this alloy is what mainly focused on in this study. Among NPs, zinc oxide (ZnO) is considered a semiconductor material, self-activated crystal and multi-functional because of low dielectric constant, high catalytic activity, more economical and wide band gap around 3.37 eV with high exciting binding energy [7–9]. Therefore, this is used in field of nanotechnology and material science to improve workability of various components in nanometer scale by various techniques. In addition, it is used in solid-state gas sensor, solar cell, electronic nanodevices, UV lasing diode, nanowire, nanoresonators and piezoelectric transducers [10–13]. Raghukiran et al. [14] studied the effect of the scandium addition on the mechanical and wear behavior of Al–x%Si–0.8Sc alloys. The results show the Al–x%Si–0.8Sc alloys give higher tensile strength and flow stress, and an improvement in the wear behavior at low concentration ratio of silicon for ternary alloys. In addition, the effect of scandium on hardening and composition of the Al–Ca eutectic alloys were investigated by Blow et al. [15]. It was found the scandium addition to this alloy does not leave an influence on the strengthening. Hengcheng et al. [16] investigated the effect of an addition of strontium on grain structure of Al–13 wt% Si alloy. It was observed that the eutectic grain structure was refined with an addition in Sr and the faster cooling rate leads to the increasing in eutectic nucleation rate. El-Mahallawi et al. [17] used three types of nanoparticles such as (Al_2O_3), titanium dioxide (TiO_2) and zirconia (ZrO_2) to improve the properties of A356 aluminum alloys. There is an enhancement in the mechanical properties with an addition of NPs of Al_2O_3, TiO_2 and ZrO_2. With these available results an attempt is made here to find out the influence of ZnO NPs on AA5052 alloy.

Experimental procedure

Zinc oxide nanocrystalline synthesis

ZnO nanoparticles were synthesized by employing sol–gel technique. Zinc acetate dehydrate [Zn(CH3COO)2·H2O], isopropanol and diethanolamine [HN(CH2-CH2OH)2, DEA] were used as raw materials for the synthesis of ZnO NPs. The reagents, provided in analytical grade, were utilized without further purification. First, solution which consists of 6.585 g of Zn(CH3COO)2·H2O and 75 mL of isopropanol was stirred at 60 °C for 1 h. Then DEA with molar ratio three times that of Zn(CH3COO)2·H2O was added gradually to the obtained solution and kept on the magnetic stirrer for another hour at the same temperature. The solution becomes clear and homogeneous gel after 2 min from adding DEA. With a view to achieve the final ZnO nanocrystalline powder, the obtained gel was refluxed for 1 h at 140 °C and then the result was calcined at 600 °C for 6 h. The crystal structure of the synthesized ZnO powder was examined by means of X-ray diffraction (XRD) microstructure of the synthesized ZnO NP powder was investigated by high-resolution transmission electron microscope for confirmation of ZnO formation.

Preparation of nanocomposite

AA 5052 alloy was utilized as a base material in this study. Zinc oxide nanopowders were used as reinforcement phase at different weight concentration from 1 to 4% with in-between steps of 1%. The chemical composition analysis of the base material is summarized in Table 1 of our earlier study [1]. Permanent mold casting technique (PM) was used to produce the hypereutectic Al–16 Si %. The more details about the casting procedure and the cooling conditions were presented in the previous work. The desired amount alloy and synthesized ZnO NPs were in total mass 1 kg. The needed mass of alloy was placed into the copper crucible of the electrical furnace after cutting it into small pieces and primates to melt inside the furnace up to 710 °C. Then ZnO nanoparticles with different weight percent was added to AA5052 alloy in the liquid or semisolid state at 750 °C. Molten mixture of alloy and NPs were poured into the copper crucible and

stirred manually for 5 min after the addition of the ZnO NPs. Finally, the melt was poured manually to the metal mold. AA5052 alloy specimens before and after adition of ZnO NPs were cut according to ASTM standard for further measurements. Studies on Tensile Properties
ASTM E8-95 requirements as in Figure 1 were followed in the preparation of the composites, which had tensile properties with a gauge width of 12.5 mm and gauge span of 62.5 mm. Fine devices (Miraj, Maharashtra, India) manufactured TFUN-600 UTM was used to characterize the specimens and the tensile testing results were listed using the strain rate of 1.5 percent per minute (0.00025/s).

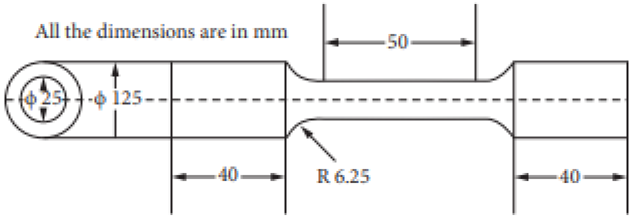

Figure 1: Schematic representation of the sample considered for tensile test.

Results and Discussions

Ultimate Tensile Strength (UTS). According studies associated with reinforcement effects on AA 5052 shows that UTS of composites rises with the rise in weightage percent of fillers. Results obtained for these aluminum samples shows similar variation in support to earlier reports. With the addition of ZnO NPs, the mechanical properties such as tensile strength, yield strength have shown a significant improvement linearly with the increase in filler concentration. They concluded that highperformance hybrid aluminum composites were needed. Controlled dispersion of ZnO NPs in Al solid solution makes it easier to form strong bonds between matrix and reinforcements, which this current study is focused on. Due to stronger bonding and interstitial strengthening, thermal treatment is necessary in order to improve the composites' tensile characteristics. A similar study in [18] found that the mechanical characteristics of aluminum-fly ash compounds can be enhanced by thermal treatment. Using different weight percentages of fly ash and heat treatments on composite specimens, they were able to improve the mechanical characteristics by altering the crystalline structure, which was then followed by different weight percentages and particle sizes of fly ash. The figure showing values of tensile strength and yield strength is shown in Fig 2.

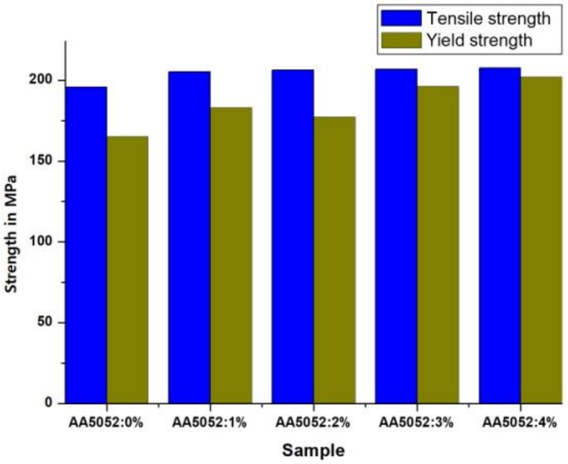

Figure 2. Bar graph representing Tensile and yield strength of the alloy samples.

Yield Strength. The results of yield strength obtained for the sample represented in the Figures 3, show a supportive variation which is in accordance with the literature. The spline plot of variation of tensile strength and yield strength is represented together to identify the comparative variation of these data across the samples with various reinforcement percentage. From the graph it is evident that, the addition of filler increases the YS of the composites, indicating that the filler ZnO is effective in enhancing the strength of the alloy effectively. Even though the improvement of tensile strength/ yield strength is not linear with the increase in filler concentration, the overall effect is proven to be constructive.

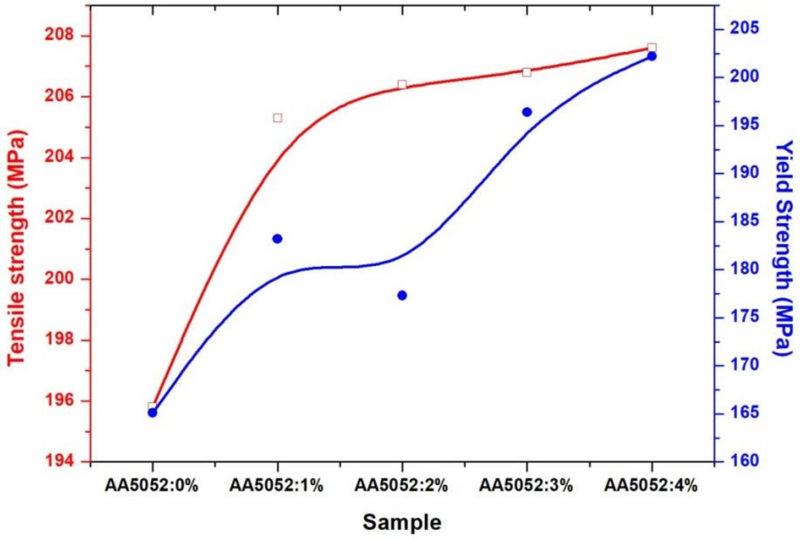

Figure 3. Variation of Tensile and yield strength across alloy samples.

Percentage Elongation. A composite's ductility can be assessed by measuring the percent of elongation, which gives an idea of how long the material can stretch in the plastic zone before snapping. Figure 4 shows the percentage of elongation that the alloy samples undergo before rapture. Since, the parent alloy specimen (AA 5052) lack stiffness and are unable to absorb applied loads before failure, the %El of these samples is greater than that of the composites. Tough, the %El reduces with the addition of reinforcements, particularly ZnO, results show that it increases the strength and hardness of a material, causing embrittlement in the composites.

These results are also in accordance with the earlier studies [19,20] which found that elongation reduces with increasing strength. Higher tensile and Young's modulus results in higher level of strength, which in turn leads to a higher stiffness of the material, which reduces the amount of strength connected to elongation. Further, addition of NPs may not show a very linear variation of physical parameters with the addition of fillers, but the holistic property of the alloy have been enhanced with the increase in NPs concentration. This non-linear variation can be attributed to many physico-mechanical accepts that influence on the structure of the material as addressed in literature [21-25].

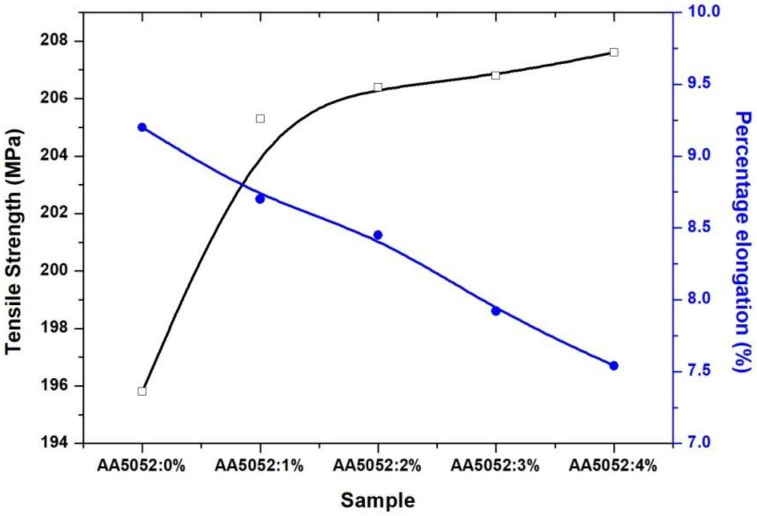

Figure 4. Variation of Tensile and percentage elongation for alloy samples across concentrations of ZnO.

Conclusions

The results show that addition of metal NPs, ZnO to aluminum alloy, increases the strength of the parent metal significantly. Along with this, the earlier studies have reported that the addition of ZnO to aluminum decreases the corrosion rate of the metal considerably making it more corrosion resistant [26]. Thus the new nanocomposite AA5052 alloy proposed here in this study proves to be strong and more stable compared to its pure counterpart.

References:

1. K. Mallikarjuna, M. K. Harikeerthan, B. S. Shubhalakshmi, K. S. Vinay Kumar, Ravindra Pratap Singh, Maddali Srikanth, Y. Krishna Srinivasa Subba Rao, Suresh Kumar and Aggegnenu Shara Shata, "Effect of Reinforcement on Tensile Characteristics in AA 5052 with ZrC and Fly Ash-Based Composites" Advances in Materials Science and Engineering Volume 2022, Article ID 7070304
2. V. Mohanavel, K. Rajan, and M. Ravichandran, "Synthesis, characterization and properties of stir cast AA6351-aluminium nitride (AlN) composites," Journal of Materials Research, vol. 31, no. 24, pp. 3824–3831, 2016.

3. M. Toozandehjani, N. Kamarudin, Z. Dashtizadeh, E. Yee Lim, A. Gomes, and C. Gomes, "Conventional and advanced composites in aerospace industry: technologies revisited," American Journal of Aerospace Engineering, vol. 5, no. 1, pp. 9–15, 2018
4. R. Ramesh, I. Dinaharan, E. T. Akinlabi, and N. Murugan, "Microstructure and mechanical characterization of frictionstir-welded dual-phase brass," Journal of Materials Engineering and Performance, vol. 27, no. 4, pp. 1544–1554, 2018.
5. N. M. Anas, T. E. Abioye, A. S. Anasyida, B. K. Dhindaw, H. Zuhailawati, and A. Ismail, "Microstructure, mechanical and corrosion properties of cryorolled-AA5052 at various solution treatment temperatures," Materials Research Express, vol. 7, no. 1, Article ID 016535, 2020.
6. V. Mohanavel, K. Ashraff Ali, S. Prasath, T. Sathish, and M. Ravichandran, "Microstructural and tribological characteristics of AA6351/Si3N4 composites manufactured by stir casting," Journal of Materials Research and Technology, vol. 9, no. 6, pp. 14662–14672, 2020
7. P.M. Aneesh, K.A. Vanaja, M.K. Jayaraj, Synthesis of ZnO nanoparticles byhydrothermal method. in Proc. SPIE 6639: 66390J, 2007, pp. 1–7
8. J.J. Reinosaa, T.P. Lere, C.M. Álvarez-Docio, A.D. Campo, J.F. Fernández, Enhancement of UV absorption behavior in ZnO–TiO2 composites. boletín de la sociedad española de cerámica y vidrio. 55, 55–62 (2016)
9. E. Galoppinin, J. Rochford, H. Chen, G. Saraf, Y. Lu, A. Hagfeldt, G. Bosochloo, Fast electron transport in metal organic vapor deposition grown dye-sensitized ZnO nanorod solar cells. J. Phys. Chem. B 110(33), 16161–18159 (2006)
10. Y. Hong, J.H. Li, L.L. Chen, D.Q. Liu, H.Z. Li, Y. Zheng, Synthesis surface modification and photocatalytic property of ZnO nanoparticles. J Ding. Powd. Technol. 189, 426–432 (2009)
11. X. Zhao, R. Zhou, Q. Hua, L. Dong, R. Yu, C. Pan, Recent progress in ohmic/schottky-contacted ZnO nanowire sensors. J. Nanomater. Hindawi 20, 20–29 (2015)
12. J. Al-Sabahi, T. Bora, M. Al-Abri, J. Dutta, Controlled defects of zinc oxide nanorods for efficient visible light photocatalytic degradation of phenol. Mater. MDPI 9(4), 238–247 (2016)
13. Z.L. Wang, Zinc oxide nanostructures: growth, properties, and applications. J. Phys. Condens. Matter 16, R829–R858 (2004)
14. N. Raghukiran, R. Kumar, Effect of scandium addition on the microstructure, mechanical and wear properties of the spray formed hypereutectic aluminum–silicon alloys. Mater. Sci. Eng. A 641, 138–147 (2015)
15. N. Belov, A. Naumova, N. Alabin, A. Matveeva, Effect of scandium on structure and hardening of AleCa eutectic alloys. J. Alloy Compd. 646, 741–747 (2015)
16. L. Hengcheng, B. Juanjuan, Z. Min, D. Ke, J. Yunfeng, C. Mingdong, Effect of strontium and solidifi cation rate on eutectic grain structure in an Al-13 wt% si alloy. China Foundry 6(3), 226–231 (2009)

17. I.S. El-Mahallawi, A.Y. Shash, A.E. Amer, Nanoreinforced cast Al-Si Alloys with Al2O3, TiO2 and ZrO2 nanoparticles. Metals 5, 802–821 (2015)
18. K. Nithesh, M. C. Gowrishankar, R. Nayak, and S. Sharma, “Effect of light weight reinforcement and heat treatment process parameters on morphological and wear aspects of hypoeutectic Al-Si based composites - a critical review,” Journal of Materials Research and Technology, vol. 15, pp. 4272–4292, 2021.
19. S. Muthukumar, “Mechanical behaviour of silicon carbide-fly ash hybrid Aluminium alloy composites subjected to age hardening,” International Journal of Vehicle Structures & Systems, vol. 11, no. 2, pp. 196–198, 2019.
20. Hegde, Dinesha Vasanta, Mahesha C. Bhavanishankar, Gowtham G. Kariyappa, Thejas G. Urs, Nandaprakash M. Basavaraju, Mahadevaiah Dasaiah, and Somashekar Rudrappa. "Studies on physical properties of wine palm and Roselle natural fibers." *Journal of Natural Fibers* (2018).
21. Urs, Thejas Gopal Krishne, Karthik Bharath, Sangappa Yallappa, and Somashekar Rudrappa. "Functional data analysis techniques for the study of structural parameters in polymer composites." *Journal of Applied Crystallography* 49, no. 2 (2016): 594-605.
22. Gowtham, G. K., G. Thejas Urs, S. Raghavendra, D. Mahadevaiah, H. Somashekarappa, and R. Somashekar. "Investigation on optical switching behaviour of regenerated and non-regenerated silk by nanosecond Z-scan technique." *Physica Scripta* 96, no. 12 (2021): 125873.
23. Urs, G. Thejas, Radhika V. Hurkadli, R. V. Basavaraj, M. Niranjana, A. Manjunath, and R. Somashekar. "Study of optical and conducting properties of FeCl3 doped PVA polymers." *Progress in Crystal Growth and Characterization of materials* 60, no. 3-4 (2014): 87-93.
24. Ananda, H. T., G. Thejas Urs, and R. Somashekar. "Preparation and characterization of conductive PVA/Gly: Na2SO4 polymer composites." *Polymer Bulletin* 73, no. 4 (2016): 1151-1165.
25. Thejas, Urs G., and Y. Sangappa. "Stochastic analysis of experimentally determined physical parameters of HPMC: NiCl {sub 2} polymer composites." In *AIP Conference Proceedings*, vol. 1731, no. 1. 2016.
26. Khan, Bharvez, M. U. Rosli, H. Jahidi, Muhammad Ikman Ishak, M. S. Zakaria, Mohd Riduan Jamalludin, C. Y. Khor, W. M. Faizal, W. M. Rahim, and M. A. M. Nawi. "Effect of zinc addition on the performance of aluminium alloy sacrificial anode for marine application." In *AIP conference proceedings*, vol. 1885, no. 1, p. 020074. AIP Publishing LLC, 2017.