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Influence on tensile and yield strength in composites of heat-treated AA6463 alloy by copper oxide nano particles

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Highlights

- AA6463 alloy/ Copper oxide (CuO) nanoparticle was synthesised using stir casting.
- Cuo nano particle concentration increased from 2% to 10%.

- Temperature of the melt was maintained at 500°C 300rpm for 5 min.
- AA6463 with 6% of CuO have higher tensile and yield strength.
- 6 % of CuO is recommended to mix with AA6463 alloy.

Abstract

The strength-to-weight ratio provided by AA6XXX alloys and their improved mechanical characteristics have emerged as key requirements for their use in light weight military vehicles, rockets, missiles, aircrafts, and cars, employed for both defense and civil purpose. The effects of the alloying elements that are often utilized for forged AA6XXX alloys are addressed while taking into account their interactions. We address the importance of alloying as well as processing to generate certain qualities and the underlying strengthening mechanisms. These AA6XXX alloys are often and effectively used in structural applications for both civil and military purposes. In this experimental investigation mainly focused on ultimate tensile strength and yield strength variations in AA6463 alloy by Copper oxide (CuO) nanoparticle. There are five composites of aluminium alloy and CuO nano particle combinations were created by stir casting method for the comparison with the individual AA6463 alloy specimen. CuO nano particle concentration increased from 2% to 10% with 2% of variation in volume of material basis in the composite. Individual specimens were prepared and tested as per standards. 94 % of AA6463 with 6% of CuO nano particle mixed composite have the greatest tensile and yield strength among the composites in this investigation.

Introduction

In mechanical industries need the properties enhancement of the materials [1]. The characteristics of AA6XXX wrought alloys, such as their high strength-to-weight ratio, plasticity, capacity for critical shape forming, ease of joining, and good corrosion resistance, have drawn more attention for a variety of applications, including the design of armour structures, rocket and missile casings, light-weight defense vehicles, automobiles, and marine structures [2]. By modifying their compositions and adjusting the manufacturing method

for the aforementioned purposes, different AA6XXX wrought alloys have been created [3]. Precision alloy design, the development of cutting-edge processing technologies, and the improvement of mechanical qualities are inextricably linked to the requirements for creating high-quality AA6XXX wrought alloys [4]. Due to their high strength-to-weight ratio, excellent creep and chemical resistance, and quick and affordable manufacturing techniques, alloys and composites based on aluminium are frequently utilised in aerospace, automotive, marine, and defence applications [5]. However, their load bearing and abrasion applications are restricted by their increased coefficient of thermal expansion (CTE), weak hardness, and poor wear performance. Therefore, to enhance its qualities, the Al matrix must constantly be reinforced with suitable ceramics as SiC, Al₂O₃, TiO₂, and B₄C [6]. However, using micro-sized reinforcements in many applications hasn't been able to deliver the necessary strength. Therefore, in order to enhance the cermet in accordance with applicational criteria, researchers have leaned toward nanoparticles that require particular reinforcing mechanisms such as the Orowan mechanism, thermal discrepancy, and load transfer mechanisms.

Using single reinforcements like SiC and TiO₂, many researchers have sought to strengthen aluminium alloys [7]. According to Bobic et al., the reaction between SiC and aluminium alloys at high temperatures produced aluminium carbide, which boosted the mechanical qualities of cermet but did not improve its corrosion resistance [8]. The basic alloy's wear resistance and density were also shown to rise with the addition of TiO₂ nanoparticles, but the thermal expansion was significantly reduced [9]. Several publications claim that only one reinforcement is necessary to improve all of the qualities of aluminium alloys. As a result, a hybrid composite may be a good alternate strategy for improving the various properties of the alloys.

Several studies have examined the impact of adding extra reinforcements to the aluminium alloys and successfully improved characteristics. In their comparison of the stir-cast composite Al7075/SiC with and without Al₂O₃ reinforcement, Kannan et al. [10] provided evidence to support their claim that SiC reinforcement increased the cermet's UTS and hardness by 17.4% and 13.7% in comparison to base alloy and by 60.1% and 80%, respectively. Similar to this, Altinkok et al. claimed that the wear resistance of hybrid cermet (SiC/ Al₂O₃) was greatly improved from single composite due to fine particle and interfacial bonding strength of alumina which hardened the cermet [11].

According to studies, hard reinforcements and other reinforcing mechanisms may be to blame for the increase in hardness and other mechanical properties of cermets. These mechanisms are primarily responsible for the accumulation of reinforcing particles into molten alloys as well as the rise in cermet dislocation density [12].

However, the manufacturing methods used to create hybrid cermets that contain the alloys also affect their general properties [13]. For the manufacture of hybrid cermets, a variety of fabrication techniques are used, including infiltration and casting processes. The reduced cost, quick structure development, and easier mass manufacturing of casting processes, however, make them more popular than infiltration.

More often used methods use molten metal as the casting medium, including stir casting, compo casting, squeeze casting, and more recent methods like Rheo or vacuum die casting [14]. But adding oxide powders to molten metals results in non-homogeneous dispersion, aggregation, and cluster formation of the powders on the surfaces [15]. Many researchers developed various approaches, such as impellers, stirrers, and ultrasonication procedures before to fabrication, to get around this prevalent issue with stir casting methods. In order to reduce cavitation on alloys, methods like Rheo-casting were used in place of stir casting, and the ultrasonication process improved things even more [16].

With the aid of a magnetic stirrer, Shamsipour et al. evaluated the fractures on several casting techniques used to create Al/Al₂O₃ - based cermets and found that compo casting resulted in fewer dimples and a more uniform distribution than sand casting [17]. However, when the financial element of mass manufacturing was impacted, electromagnetic stirrers were further used to address the issues connected with magnetic stirrers. Shamsipour et al. used electromagnetic stirrers to create aluminium matrix nanocomposites by optimising the parameters that resulted in superior wear behaviour in order to get around this issue [18]. Further research revealed that when using electromagnetic stirrers, the intermetallic particles were equally dispersed with lower stress concentration locations throughout the Al-Si metal matrix [19].

Even with these methods, there are a few reports that claim that the lack of external pressure prevented ultrasonic assisted double casting processes from completely eliminating porosity. As a result, Hajjari et al. used squeeze casting to fabricate hybrid Al alloys and demonstrated that the surfaces had apparent microstructural refinement and decreased porosity. However, the particle distribution over the surfaces was insufficiently homogeneous [20].

The development of these improved Taylor-made features necessitates an understanding of the underlying mechanisms that control the strengthening phenomena [21]. It leads to encourage the creation of the new material composite by different combination of varies of materials (Al, SS, MS, Fe, Cu, Mg, Mn, Ti, Si, CuO, MgO, MnO, CNT and etc.) [22] and their preparing techniques (molding, casting, sintering and etc.), consideration parameters variations (Temperature, Pressure, Volume, mass, Etc.) [23] and other

considerations of fabrication techniques (input parameter variations) [24]. These all variation help to create the new material composite with desirable properties [25].

The aluminium is the most commonly desirable material based on their application in different field like automotive vehicles, industrial application, domestic purpose product things and etc. AA6xxx series contains the pure Aluminium alloy (Al), Magnesium (Mg) and Silicon (Si) concentration combination [26].

Fly ash, quarry dust, asphalt, and red mud are just some of the industrial wastes that have been reinforced in an aluminum matrix as part of a growing trend toward recycling and conservation [10]. Waste catalysts, or “spent catalysts,” are a common byproduct of the global petroleum industry. Catalysts that are used up during the cracking of crude oil can be recycled and reused. With continued use, the regenerated catalyst eventually dies and must be disposed of as a large land fill [12]. Useful byproducts like alumina, silica, molybdenum, vanadium, etc. [27] can be salvaged from the wasted catalyst. Recently, these metals have been extracted using a variety of hydrometallurgical, pyrometallurgical, and biohydrometallurgical processes [28].

By using the double stir casting method, Kenneth Kanayo Alaneme and colleagues created an aluminum matrix composite with SiC and QD reinforcements at varying ratios. The mechanical characteristics and wear behavior of a composite made with a matrix of Al6063 (Al-Mg-SiC) were investigated. The density of the composite decreased as the proportion of QD rose, and it was lower than the density of the composite having more SiC. The toughness of SiC reinforced composite was not matched by QD. Maximum tensile strength was achieved with an equal volume of SiC and QD in all composites tested. Researchers found that raising the QD of a composite improved its resistance to wear. The goal of reinforcing QD was achieved, as its tensile strength was found to be comparable to SiC's and its resistance to abrasive wear was found to be greater [29].

The effects of micro and nano Al₂O₃ reinforcement in the LM25 aluminum alloy matrix were compared by S.M.Suresh et al. Stir casting composites were made with micro and nano Al₂O₃ added at 10%wt each. Tensile strength and hardness varied slightly between the two samples. Mechanically, nano alumina outperformed micro alumina of the same proportion [30].

The Al7075/Al₂O₃ nano composite was created by Amit Raturi and colleagues via double stir casting. Composites with 3, 5, and 7 percent nano alumina were evaluated for their mechanical and tribological properties. Nano alumina improved the material's mechanical qualities. In terms of hardness, tensile strength, impact strength, and flexural strength, 5% wt nano Al₂O₃ was superior.

Due to particle dispersion effects, mechanical characteristics dropped at 7%wt nano Al₂O₃. SEM scans revealed that 3% and 5% wt nano alumina were evenly dispersed throughout the matrix, while the remaining 7% were visible as clusters [31].

Nano copper oxide and micro silicon carbide were investigated as potential reinforcements for an aluminum matrix by T.Rajmohan et al. Powder metallurgy was used to create the composites, with 10% SiC and either 1% or 2% nano CuO depending on the desired properties. The micro hardness of the composites was determined with a Vickers Hardness Tester, and their microstructure was analyzed using scanning electron micrographs and X-ray diffraction patterns. Ten percent SiC and two percent nano CuO were discovered to be the optimal ratio for greatest hardness in a composite. The percentage of nano CuO added to the aluminum matrix results in a greater tensile strength. The reinforcing particles were evenly dispersed throughout the aluminum matrix. Inclusion of nano CuO enhances hardness and tensile strength, and porosity was also seen in the composites [32].

Al-12Si-xCu-1Ni-1Mg (x=2%, 4%, 6% wt.) composite with 20vol% SiC reinforcement was developed by Weng Zhenzhen et al. Mechanical properties were analyzed based on the microstructural analysis of the composites, which were produced using the stir casting method. Composite hardness increased with increasing Cu content, reaching a maximum of 100BHN at 6%Cu. The optimal amount of copper for tensile strength was 4%, while the optimal amount for wear resistance was 6%. According to the microstructure, the SiC was strongly bound and evenly distributed throughout the sample. Based on the enhanced mechanical and wear qualities, it was determined that adding 4% Cu to the composite might be utilised in the automotive sector [33].

From above literature it is obvious that copper oxide reinforcement in aluminum metal matrix composite related studies is very limited and need to investigate more. In this investigation heat treated Aluminium alloy of AA6463 taken to identify the influence of the copper oxide nano particle in the major mechanical property such as the ultimate tensile strength and yield strength. As considering the merits of CuO this investigation novelty approaches the reinforcement of CuO in the matrix of AA6463 alloy to modify the tensile strength as well as the yield strength. Hence the research aims to modify the tensile strength and the yield strength of AA6463 alloy by reinforcing the CuO nanoparticles with a suitable proportion. This aim is achieved by synthesizing the AA6463/ CuO composite samples by varying the CuO nanoparticles from 2wt% to 10wt%. and optimizing the reinforcement quantity based on the maximum tensile and yield strength.

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Experimental procedure

The AA6463 alloy and 50nm sized CuO particles were purchased in the market and the quality of the materials were tested which meet the standards of that materials [34]. The composites were prepared with stir casting method it contains the muffle furnace. The initial step involved uniformly blending the reinforcing nanoparticles in a ball mill (SPEX 8000D, Ukraine) for 60min at 300rpm. In addition, the base aluminium alloy ingot was heated in a stir casting machine to 650°C, and C₂C₁₆ was ...

Results and discussion

According to the research plan the control specimen (100AA6463) and composite specimens such as 98AA6463+2CuO, 96AA6463+4CuO, 94AA6463+6CuO, 92AA6463+8CuO and 90AA6463+10CuO were prepared through stir casting process. Prepared specimens were characterized mechanically by tensile test as illustrated in Fig. 1. Standard Instron wedge-type knurled grips were used to hold the samples, and no pre-test machining or polishing was performed. The materials were subjected to tensile testing ...

Conclusions

AA6463 alloy is well known though its wide applications. Most of the failures were reported due to tensile load. So, this investigation carried out to investigate the potential possibilities of improving the tensile properties by reinforcing the CuO nanoparticles in various proportions and found that the CuO reinforcement is one of the promising solutions to alter the tensile property in the AA6463 alloy. Even small or excess reinforcement there was a significant improvement tensile property in ...

CRediT authorship contribution statement

Satyanarayana Gupta: Visualization. ...

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. ...

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