Synthesis and Characterization of Fe_2O_3 Particulate Reinforced Aluminum Alloy: A Review

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Abstract: ***Aluminum alloy composite is the most widely used material because of its advantages over other composites. In this review, different methods of synthesis and characterization of Fe_2O_3 particulate reinforced aluminum alloy were discussed. It was observed that stir casting is the most commonly used process of synthesis over other processes. Large variation was found in RPM (CV = 0.39) of the stirring process but the time of stir was the same in all studies. It was also observed that characteristics of the composite were improved by the addition of Fe_2O_3 up to a certain limit. Very limited studies discussed the exact mixture proportion for optimum properties. The effect of the addition of pure Fe_2O_3 in the aluminum alloy is least studied.***

Keywords: characterization, synthesis, aluminum composite, particulate reinforced

1. Introduction

Aluminum (Al) and aluminum alloys, as one of the most widely used structural materials, havemany applications in aerospace, automotive, and naval industries due to their high specific strength, easy processing, low density, and no requirement of surface protection [1]. Al - 7xxx series alloy is many times called aluminum - zinc alloy because of maximum zinc quantity between 5.1 and 6.1 percent. Because of many applications of Al - 7xxx alloy further improvement in properties is required. Metal matrix composites have become a material of choice in aerospace and automotive industries due to requirements like weight reduction in their components while promoting properties such as strength, corrosion, and wear resistance among others. Al_2O_3, TiC, SiC, C, B, BN, and B_4C are the materials most extensively studied for application in strengthening metal matrices. Powder metallurgy, spray atomization and co - deposition, plasma spraying, stir casting, and squeeze casting are some methods for creating metal matrix composites [2]. Stir casting is the most popular technique for creating aluminum and magnesium - based matrix composites because it is very inexpensive, straightforward, and effective [3]. Currently, the high demand for composite materials with improved properties ata low cost necessitates research in this area. Here in this review literature search was done only for the aluminum alloy with at least Fe_2O_3 as a reinforcement of with other materials.

2. Materials and Method of synthesis

Here in this section different types of reinforcement in aluminum alloy and production methods are discussed. Most of the studies use stirred casting method while some studies used different production methods and are discussed in detail.

In a study [4] the fabrication and evaluation of the mechanical properties of hybrid aluminum matrix composites were reported. Aluminum 7075 (Al7075) alloy was reinforced with particles of boron carbide (B_4C) and coconut shell fly ash. Chemical compositions of coconut shell fly ash and their weight percentage are, SiO_2 - 45.36, Al_2O_3 - 21.82, Fe_2O_3 - 18.58, MgO - 12.32, Na_2O - 0.73, CaO - 0.67, ZnO - 0.32, MnO - 0.20. Al7075 matrix composites were fabricated by the stir casting method. The mixture of reinforcing particles was stirred at 800 rpm for 10 min using a coupled electric stirrer with the motor. In research [5] mechanical properties and microstructures of two different particulates reinforced hybrid composites of Aluminium 7075 - Flyash (SiO_2 - 55 % weight, Al_20_3 - 26% weight, Fe_2O_3 - 7% weight, CaO – 9% weight, MgO - 2% weight, SO_3 - 1% weight), and Zircon was conducted using a stir casting process. The rpm used for the stirrer was up to 500 rpm and then the mixture was kept constant for 5 minutes.

In the [6] research work, aluminum7075 alloy composites containing different volume fractions of basalt fiber (SiO_2 - 69.51% weight, Al_2O_3 - 14.18 % weight, Fe_2O_3 - 3.92 % weight, MgO - 2.41 % weight, CaO - 5.62 % weight, Na_2O - 2.74 % weight, K_2O - 1.01 % weight, TiO_2 - 0.55 % weight, MnO - 0.04 % weight) were developed using the stir casting process. Preheated reinforcements were poured at 800 ℃ and the slurry was stirred for 10 minutes at 400 RPM. In a study [7] where rice husk ash was used in A7075 was an Aluminum alloy series, stir casting was successfully implemented. Rice husk ash used in the study consists of SiO_2 – 67.3, Al_2O_3 - 4.9, Fe_2O_3 – 0.95, and C - 12.9 percent by weight.

In research [8] where the impacts were investigated on the reinforced Al6061 composite with 5 wt% of Fe_2O_3 in addition to 2 %, 4 %, and 6 % weight of B_4C being madeup by stir casting technique. In research [9] stir casting was been followed for preparing the composites. In stir casting process was carried out by adding 5gms of reinforcement with 1 kg of Aluminum. The Aluminumwas in a muffle furnace at 800°C for 1 hour. In a study [10], aluminum was used as a matrix and coconut shell ash was used as reinforcement. The aluminum coconut shell ash particulate composites were fabricated by using the stir casting technique at 5, 10, and 15 % by volume. In research [11] Wear characteristics of Fe_2O_3 reinforced Aluminum 6061 Metal Matrix Composites were studied. The stir casting technique was used to fabricate composite. A molten metal bath was created and rotated at a speed of 300 to 350 rpm to create a vortex. Preheated hematite powder was then added to the melt and stirring was continued till uniform mixing of the reinforcement in the molten matrix. In a study [12], Aluminium LM6 Metal Matrix Composites Reinforced with Iron Oxide and MWCNTs two particulates are compared using the stir casting method.

In one novel technique [13] In - situ preparation of particle reinforced Al matrix composites (PRAMCs) by laser powder bed fusion (LPBF) was used to strengthen Al - based alloys. The laser - driven thermite reaction can be a practical mechanism forthe in - situ synthesis PRAMCs. However, the addition of Fe_2O_3 makes the powder mixture particularly susceptible to the formation of porosity and Al_2O_3 film during LPBF, creating obstacles to the preparation of dense products. Research [14] was further carried out to investigate the material behavior and processing windows for selective laser melting and it was observed that in situ material reaction between aluminum and Fe_2O_3 helps to melt. It was also observed that [15]using low layer thickness, high laser power, and low scanning speed promising result can be achieved. In their further study [16]it was found that the SLM process not only can produce the three - dimensional parts but also was capable of activating an in situ reaction in the powder mixture, producing particles mainly from alumina (Al_2O_3) and iron combinations (such as Fe2þAl2O4) in the Al matrix. Under controlled circumstances, these particles can be disseminated uniformly with a good particle/matrix contact and serve as reinforcements.

3. Characterization

The tensile strength [4] of the composites increased 66% by the addition of 9 % weight B_4C and 3 % weightcoconut shell fly ash in aluminum 7075 alloys. The hardness of the composites increased 33% by reinforcements of 12 % weight B_4C and 3 % weight coconut shell fly ash in aluminum 7075 alloys. Further addition of reinforcements decreased the tensile strength of the composites. Elongation of the composites decreased while increasing B_4C and coconut shell fly ash reinforcements in the matrix. The impact energy of the composites increased up to 2.3 J with 9 weight % B_4C and 3 weight % coconut shell fly ash addition in aluminum alloy. Further addition of reinforcement decreased the impact strength of the composites. Microstructure examination shows that the reinforced particles are randomly oriented, and their distribution in the matrix was uniform.

The results [5] indicate that the tensile strength of the fly ash reinforced composite increases with an increase in weight % of reinforcement, but hardness declines beyond 7% addition of reinforcements. It was also observed that reinforcing Flyash and Graphite into Al 7075 produces more strength than Zircon and Graphite reinforcement. Microstructure examination shows better dispersion of particles in a uniform manner of Flyash compared to zirconium. Fly ash tends to homogeneously spread over the matrix avoiding cluster formation.

The mechanical [6] properties evaluation reveals an improvement in hardness and tensile strength with the fiber addition without significant loss in ductility. Ultimate tensile strength increased by 65.51 % with 6% reinforcement of short basalt fibers. Here continuous fiber, continuous fiber, and random distribution were compared up to 6 % volume distribution only. The effect of the further addition of fiberswas not discussed. The microstructure shows a uniform distribution of fibers. Uniform distribution and enhanced mechanical properties were found in a study [7] with 5% rice husk ash where experimental data was compared with simulations.

Results of a study [8]indicate the tensile strength of the metal composites was enhanced by increasing the fraction of Fe_2O_3 and B_4C particles without a significant decrease in elongation. With the increase in the weight percentage of B_4C from 0 % to 6 % with constant Fe_2O_3 (5 weight %), the hardness, ultimate tensile strength, and compressive strength were increased from 112 VHN to 139 VHN, 324 MPa to 421 MPa, and 283 MPa to 352 MPa respectively, whereas the impact strength was reduced from 23 J to 11 J but elongation decreased from 15.1% to 11.2 %. It was observed that The microstructure of newly prepared composites was shown a regular spreading of reinforcements in the matrix by an optical microscope.

It provides [9]high elastic properties, high service temperature, and fracture toughness. Fracture toughness was significantly increased by the addition of reinforcements and the addition of Fe_2O_3 has more significant fracture toughness compared to SiC. Moreover, the grain size of the samples increased due to the effect of reinforcement bonding with the aluminum matrix. The tensile strength [10] and hardness both increase with increases inthe percent of CSAp whereas percent elongations and density decrease. The wear behavior of the composite wasanalyzed considering three quality attributes with three input process parameters such as load, % of CSAp, and sliding distance. It was observed that the wear was increased from 191 to 268 µm, the wear rate was reduced from 5.556 to 1.936 and the coefficient of friction was improved from 0.298 to 0.372. Results of the study [11] it was observed that the Hardness and Ultimate Tensile Strength of the composite due to the addition of Fe_2O_3 as reinforcement. It was also observed thatthe wear rate of the Al6061 - Fe_2O_3 Metal Matrix Composites has decreased with the increase in the percentage of reinforcement. The Microstructural study reveals the uniform distribution of reinforcement particles in all the compositions. Here also the effect of further addition of reinforcement was not studied. A study [12] shows no change in hardness, Impact strength and wear rate using Iron Oxide and multi - wall carbon nano

Tube (MWCNTs) but MWCNT composit had less density which can be reasoned due to the hollow structure of CNTs.

The fine [13]microstructure, nano - structured dispersion strengthening, and high - level densification strengthen the prepared in - situ PRAMCs, reaching a yield strength of 426 ± 4 MPa and tensile strength of 473 ± 6 MPa. Furthermore, the results also provide valuable information to process other powder mixtures with severe porosity/oxide - film formation potential considering the evidenced contribution of laser melting/remelting strategy to densify material and obtain good mechanical properties during LPBF. The fine [16] microstructure and nano - structured dispersion strengthening prepared in - situ, having a yield strength of 426 ± 4 MPa and tensile strength of 473 ± 6 MPa.

4. Conclusion

With a fairly uniform dispersion of basalt fiber, stir casting - based liquid processing can be used to successfully create aluminum alloy and its composites. Tensile ductility is unaffected by the increase in strength values under tensile loading. Composites become harder as the amount of reinforcement in the matrix increases. As a result of the numerous reinforcements, the porosity level is reduced, and the interface bonding is improved, providing resistance to crack propagation. The impact energy of composites can be increased by increasingthe reinforcement content in the matrix. In all studies, improvement in properties was observed up to a certain limit, and properties degradation after that limit. Optimization of aluminum alloy and reinforcement mixture proportion can be a topic for further research. The effect of variation of RPM in stir casting will be an ambitious future direction. Very few research studies were carried out on the effect of pure Fe_2O_3 particulate reinforcement in Aluminum 7075 alloy.

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