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Optimization of squeeze casting process parameters for the production of Al composite reinforced with bone powder

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Abstract

Al6061 alloy is most commonly used in automotive, marine, and aerospace applications to reduce weight and improve the strength of the composite. Al6061 alloy is a precipitation-hardened aluminium alloy used as a matrix material. Beef bone is a bio-waste which pollutes the environment and the people who live in the vicinity of its manufacturing and disposal sites. Bio-waste has been used in a variety of ways by researchers in recent years, including activated carbon, water purification, reinforcement in composites, fillers, medicines, food products and additives etc. Recycled beef bones that had been abandoned as waste were collected, cleaned, and ground into a fine powder with a particle size ranges between 5 and 50μm and used as reinforcement to produce the Al composite. Because, beef bone has good tensile and compression strength and is light in weight, which helps improve the strength without much increase in cost of the Al composite. The aluminium composite are fabricated using squeeze casting process and the design of experiment based on Taguchi design are imposed to produce the high quality Al composite. The aluminium composite is fabricated and nine samples were successfully obtained for testing and analysis. The prepared substrates are analysed for

hardness and tensile strength. Based on the experimental run the optimized process parameter conditions are found also regression equation is provided for the design. The optimized process parameters are found for melt temperature, squeeze pressure, reinforcement percentage, stirring speed as 700°C, 100MPa, 5%, 600rpm respectively. Also, the highest contribution for improving the strength of the material is percentage of reinforcement.

Introduction

Metal matrix composites (MMC) are kind of compounds mixed with reinforcing components including fibres, whiskers, or particles. MMC are primarily categorized into Aluminium based composite, Mg based composite, Copper based composite, and Titanium based composite [1], [2]. Lightweight composite materials are becoming more and more in demand as a manner of enhancing the overall performance of automotive and aeronautical components. Composite materials of aluminium alloy metal matrix composites are frequently employed to suit industrial demand among the various types of composites on the market because they have qualities such as cost effective, low weight, resistance to corrosion, high wear resistance, and superior electrical conductivity [3]. The most fascinating engineering material that can satisfy the requirements of current engineering applications employed in industries including the automotive, defence, aerospace, and marine sectors is AA6061 composites. This need is brought on by scale economies, better mechanical properties, formability, and better production methods. The most crucial aspect of a material's performance is choosing the precise blend of reinforcing elements [4]. Fly ash, breadfruit seed hull ash, sugarcane bagasse, coconut shell ash, palm oil clinker, ash of rice husk red mud from the soil are used to prepare the MMC to reduce the cost of the final product [5]. The various reinforcing materials utilised in the formation of Aluminium Matrix Composites (AMCs) can be divided into three broad categories industrial,wastessynthetic ceramic granules, and derivatives from agricultural/natural waste. Individual characteristics of the chosen reinforcement and the matrix alloy determine the hybrid reinforcement's ultimate attributes [6]. Because of the altering or change in mechanical behaviour due on the percentage fluctuation of reinforcement and composition of matrix material, Aluminium Metal Matrix Composites (AMMCs) demonstrated efficacy in several engineering disciplines as well as structural and functional applications [7]. Aluminium alloys who have been reinforced with ceramic particles exceed unreinforced Al alloys in terms of mechanical properties, allowing them candidates for applications in engineering. Nowadays, the majority of research is focused on creating composites from diverse recycled wastes, particularly when it comes to creating composites that utilize the most environmentally benign agricultural wastes (lignocellulosic materials) as the reinforcing fillers [8], [9].

The earlier researchers are focused to improve the strength using many techniques the few articles are discussed here: The process parameters must be optimised in order to produce products with improved qualities. load (P), Speed (N),and percentage of reinforcement (%) are typically the parameters used in experiments to optimise wear behaviour [10]. Victor et al studied the Al_2O_3 dispersion and porosity in the Al matrix revealed a variety of morphologies depending on the treatment parameters, according to microstructural measurements. The optimal process parameters were then discovered using the Taguchi Grey Relational Analysis (GRA) method, which was then empirically validated. The sample displayed the least amount of porosity (5.29%) and a much greater final compression strength (433 MPa) [10]. The optimal Graphene nanoplatelets (GNP) addition was 0.9 wt%, while the optimal ultrasonic runtime was 12 min. The composite's hardness, yield strength and tensile strength were all higher than those of the matrix by 30.5%, 42.7%, and 34.8%, respectively, and were HV 126.0, 210.6 MPa, and256.8 MPa respectively, at the optimal conditions[11].Srivastava and Pankaj Kumar Gupta reported that there are several fabrication techniques available today, but stir casting is the best option because it is easy to use, flexible, and can be applied to large production while still being reasonably priced. In stir casting, the various measures are taken to refine the grain size of the composites. Few examples are electromagnetic generation in the molten metal, ultrasonic device instead of stirring set up, heat treatment after the production of material etc. Additionally, the effect of particle size and the proportion of reinforcement on the mechanical characteristics of composite materials, such as hardness, tensile strength, and reduced percentage ductility, was investigated [12]. Adithiya et.al ↗. prepared the cylindrical shape specimens examined under different melting temperature and die preheating temperatures that are maintained at 800 °C and 400 °C and a squeeze pressure of 100 MPa during each stage of production. After fabrication, mechanical testing is done to check the manufactured specimen qualities under loading circumstances. On a universal testing machine, the material tensile strength and hardness are assessed, and Brinell hardness is evaluated using an intender ball with a 5 mm diameter under a 250 kg loading condition [13]. Natrayan et al reported that the squeeze casting was utilized to produce hybrid metal matrix composites reinforced with AA6061 & Al_2O_3/SiC. The investigations were carried out using a L16 orthogonal array. The optimal process parameters with the yield strength, ultimate tensile strength (UTS), and maximum hardness were found using the Taguchi technique. The contribution ratio was demonstrated using ANOVA. Hardness, UTS, and yield strength were best accomplished with the process parameters of 100 MPa, 20 s, 750 °Cfor squeeze pressures, holding time, and melt temperature respectively [14]. The squeeze casting parameters were subjected to a Taguchi analysis by karthikeyan et al. to identify the most significant process variable influencing hardness and density. A confirmatory test was run using a reduced version of the regression equation. Squeeze pressure of 650 MPa, die preheating temperature of 225 °C, and melt temperature of 700 °C have been the squeeze casting

process parameters which generated the optimal mechanical response and metallographic structure for the AA2219 alloy. With the assistance of an optical microscope, the microstructure of the squeeze-cast sample was examined along the radial direction. Microstructure analysis demonstrates the presence of fine grains, which is only possible at the process parameter that is optimised [15]. In comparison to gravity die casting, the castings produced under ideal squeeze casting conditions had better grain growth in the microstructure and a tensile yield strength gain of almost 65%. Squeeze pressure was found to be crucial methods for determining for creating castings that are sound, high-quality, and free of defects. The experimental findings indicate that squeeze casting, which involves applying and sustaining level compression straight to the melt until the moment of complete solidification, is recognized to be practical for processing this alloy [16]. Junhong Li et alto assess the significance and predictive power of mathematical models produced by regression analysis, ANOVA was used. According to the data, the shrinkage porosity is at its minimum when the mould temperature, melt temperature, and squeezing pressure are all 341.74°C, 697.33°C, and 107.03MPa, correspondingly. The squeeze casting machine SCH-1000 underwent a trial production test to confirm the ideal parameters. Additionally, an X-ray analyses revealed that the lid has no casting flaws [17]. Arunachalam and Vijian published that three level orthogonal array has been utilised in the Taguchi method to calculate the S/N ratio. The most important process variables influencing the surface roughness are identified using analysis of variance and the results of the “F” test [18]. Ramanathan Arunachalam et al. determined the optimized process parameters to be100 MPa for squeeze pressure, 45sfor squeeze time, 250°Cfor die preheating temperature, and 525 RPM for stirrer speed for the production of brake discs. Additionally, a confirmatory evaluation was conducted to assess these ideal process parameters. The outcomes showed that the composite had improved compressive strength and decreased pores [19].

Thus, in this research work, a new material composition is formulated and developed using the squeeze casting process. Al6061 alloy is a used matrix material, which is the most commonly used material in sports applications. For the first time, bone powder is prepared and used as reinforcement to produce the new Al composite. A hardness tester and universal testing machine is used to determine the hardness value and tensile strength of the developed component.

Section snippets

Matrix and reinforcement materials

The matrix material, aluminium Al6061, was procured from the metal market from NEXTGEN STEELS AND ALLOYS, India. Composites were developed using waste cow bone, which was gathered from a butcher market and used as reinforcing material Table 1 shows the composition of reinforced waste beef bones. …

Production of MMCs using squeeze casting method

Using the squeeze casting procedure, the composites were made, and the parameters employed in this study are obtained from the literature survey. In order to eliminate filth and oil, an aluminium rod was …

Result and discussions

Fig. 3 depicts the mean effect plot for the response of hardness. It can be observed that the hardness value of the material increases with respect to incremental order of process temperature. This fact may be due to the effect of fine grain refinement and extrusion ratio. During extrusion process the increasing in extrusion ratio result in conversion of coarse grain to finer grains this helps controls the localised deformation brought on by the indentation, raising the hardness value. Also …

Conclusions

Based on the Taguchi design, experiments are conducted and analysed for improving the response such as hardness and tensile strength of the squeeze casting process for aluminium composite. The conclusions are derived from the data obtained through this analysis. The optimum values of process parameters are found to be melt temperature 700°C, squeeze pressure 100MPa, Percentage of reinforcement 5%, stirring speed 600rpm.The rank of contribution towards the improvement of responses rank …

CRediT authorship contribution statement

R. Muthu Kamatchi: Investigation, Validation. **R. Muraliraja:** Conceptualization, Methodology. …

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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References (19)

Z. Zhao *et al.*
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Carbon N. Y. (2020)

A. Chauhan *et al.*
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Mater. Today Proc. (2021)

S. Raja *et al.*
A review on tribological, mechanical, corrosion and wear characteristics of stir cast AA6061 composites
Mater. Today Proc. (2020)

M.O. Bodunrin *et al.*
Aluminium matrix hybrid composites: a review of reinforcement philosophies; Mechanical, corrosion and tribological characteristics
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J. Mater. Res. Technol. (2019)

S.D. Saravanan *et al.*
Effect of mechanical properties on rice husk ash reinforced aluminum alloy (AlSi10Mg) matrix composites
Procedia Eng. (2013)

V. Bhuvaneswari *et al.*
Influence of bioceramic reinforcement on tribological behaviour of aluminium alloy metal matrix composites: experimental study and analysis
J. Mater. Res. Technol. (2021)

J.V. Christy *et al.*
Processing, properties, and microstructure of recycled aluminum alloy composites produced through an optimized stir and squeeze casting processes
J. Manuf. Process. (2020)

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