MECHANICAL AND MICROSTRUCTURE ANALYSIS OF 2050 SERIES ALUMINIUM ALLOY USING SQUEEZE CASTING

LOKESH RV, GUGASARVANAN D, HARIKRISHNA N
UG – BE MECHANICALENGINEERING, BANNARI AMMAN INSTITUTE OF TECHNOLOGY, SATHYAMANGALAM, TAMIL NADU
lokesh.me20@bitsathy.acin, gugasaravanan.me20@bitsathy.ac.in, harikrishna.me20@bitsathy.ac.in

ABSTRACT
Squeeze casting is a potential manufacturing method that combines the advantages of casting and forging, making it particularly ideal for difficult-to- form alloys such as the 2050 series aluminium alloys. The mechanical characteristics and microstructure studies of 2050 series aluminium alloys, specifically 2024 and 2014, made utilizing the squeeze casting technique are the focus of this research. The goal is to comprehend the impact of this novel manufacturing process on the mechanical and microstructural properties of the alloys, which are crucial for their future uses, notably in the aerospace industry. This study provides useful insights into improving the performance and application breadth of 2050 series aluminum alloys utilizing squeeze casting. The mechanical properties of the squeeze cast 2050 series aluminium alloys were rigorously tested, including hardness testing, hardness testing, and impact testing. Hardness testing revealed the alloys' ultimate hardness strength, yield strength, and elongation, demonstrating the squeeze casting process's improved mechanical performance. Hardness testing provided useful information on the alloys' resistance to deformation and abrasion, highlighting the benefits of squeeze casting in refining material qualities. Impact testing revealed the metals' toughness and resistance to sudden loading, which is critical for applications requiring durability and reliability. Hardness testing revealed useful information about the alloys' resistance to deformation and abrasion, emphasizing the advantages of squeeze casting in refining material properties. The metals' toughness and resistance to abrupt loading were revealed by impact testing, which Is crucial for applications demanding durability.

Keywords: *Hardness testing - revealed useful information about - the alloys' resistance to deformation and abrasion, - emphasizing the advantages of squeeze casting - in refining material properties.*

INTRODUCTION

Aluminum and its alloys are essential in modern engineering and industry, with the 2050 series aluminum alloys, such as 2024 and 2014, standing out for their remarkable strength-to-weight ratio and fatigue resistance. These alloys are especially important in applications that require high strength while remaining lightweight, such as the aerospace sector. However, using typical production processes, getting appropriate mechanical characteristics and microstructure in these alloys remains a substantial issue. Conventional procedures, such as casting or forging, frequently struggle to precisely control the microstructural characteristics and mechanical qualities, prompting the development of novel production techniques to overcome these constraints. Squeeze casting, a prospective hybrid technique that combines casting and forging aspects, appears to be a promising method for improving the characteristics and microstructure of 2050 series This research aims to extensively analyses the impact of the squeeze casting method on the mechanical characteristics and microstructure of 2050 series aluminum alloys, with a particular emphasis on alloys such as 2024 and 2014. By thoroughly examining this manufacturing procedure, useful insights into optimizing these alloys for a wide range of high-performance applications particularly in the aerospace industry, can be gleaned. The investigation began with the selection of suitable 2050 series aluminum alloys, primarily 2024 and 2014, based on their importance and broad use in aerospace and related applications. The squeeze casting method was then used to create samples of these alloys. The procedure entailed preparing a warmed die and then melting the aluminum alloy at the desired temperature. The molten metal was 2 then fed into the die under tremendous pressure and held there until solidification occurred.

PROPOSED SOLUTION:

Squeeze casting, a new hybrid process that combines casting and forging aspects, has gained attention as a viable option for improving the characteristics and microstructure of 2050 series aluminium alloys. Squeeze casting involves pouring molten metal under pressure into a prepared die, allowing for a more controlled and homogeneous filling of the mould than standard casting procedures.During solidification, the pressure is maintained, resulting in a fine-grained, dense structure with superior mechanical properties. This method has the advantage of producing high integrity and near-net shape components with improved mechanical properties, making it a viable technology for improving the performance of 2050 series aluminium alloys. Given the importance of these alloys in the aerospace industry and the possibility for squeeze casting to improve their qualities, the purpose of this research is to explore deeper into the impacts of the squeeze casting method on the mechanical properties and microstructure of 2050 series aluminium alloys.

OBJECTIVE OF THE PROPOSED:

The objectives of this work might be stated sincerely based totally at the findings from the Literature survey. The minimal wide variety of goals could be equal to the wide variety of college students within the batch, and each scholar’s person contribution may be based totally on these targets. Understand the fundamental houses of the 2050 aluminium alloy, along with its Mechanical homes (together with energy, ductility, hardness, and fatigue resistance) and microstructural capabilities (inclusive of grain size, phase composition, and defects). Aluminium alloy 2050 is being considered for the fabrication of cryogenic propellant tanks to reduce the mass of destiny heavy-deliver launch vehicles. The alloy is available in section thicknesses more than that of the incumbent aluminium alloy,2195, a good way to permit Designs with extra structural performance. While ambient temperature layout allowable Residences are available for alloy 2050, cryogenic houses are not to be had. To decide its Suitability for use in cryogenic propellant tanks, hardness, compression and fracture assessments Have been executed on 4-inch thick 2050–T84 plate at ambient temperature and at -320°F. Diverse metallurgical analyses have been also completed as a way to offer a know-how of the Compositional homogeneity and microstructure of 2050. Synthetic procedure: Acquire 2050 aluminium alloy material. Reduce or form the cloth into samples or specimens suitable for testing and assessment. Squeeze Casting: put together the squeeze casting setup along with the Mold. Warm the 2050 aluminium alloy to its molten state. Inject or squeeze the molten alloy into the Mold below the strain. Permit the solid additives to solidify and become funky. Sample training: reduce or section. 21 the squeeze-stable components to acquire smaller samples for assessment. Polish the samples to attain a flat and easy surface for microscopy. Microstructure analysis: perform optical microscopy (OM) to have a look at the macrostructure and famous grain shape of the samples. Optionally, etch the samples to show unique microstructural skills, which encompass grain barriers, degrees, and inclusions. Conduct scanning electron microscopy (SEM) to take a look at microstructural records, which encompass grain obstacles, phases, and defects. Use electricity- dispersive X-ray spectroscopy (EDS) together with SEM to investigate the essential composition of diverse microstructural areas. Mechanical locating out: perform hardness attempting out to assess mechanical houses like hardness electricity, yield energy, and elongation. Behavior hardness is tested using a Vickers or Rockwell hardness tester to assess fabric hardness. Carry out impact checking to determine the cloth's resistance to impact or shock loading. Heat treatment (non-compulsory): situation decided on samples to warmth treatment techniques, which include solution warm temperature remedy and growing older to adjust the microstructure and mechanical residences. Signify the microstructure and mechanical houses of heat-handled samples. Records evaluation: look at the information obtained from microstructure evaluation and mechanical locating out. Correlate microstructural abilities with mechanical houses, which include grain length consequences for power. Examine the influence of the squeeze casting
method of the cloth’ house.

METHODOLOGY AND PROPOSED WORK:

The research methodology adopted for this project is rooted in a holistic approach to comprehensively explore the novel composite material, which integrates aluminum 2050 as the matrix and limestone as the reinforcement, produced through the stir casting technique. The chosen methodology revolves around the synergistic integration of mechanical testing, microstructural analysis, and sustainability assessment to derive valuable insights into the material's properties and potential industrial applications. A pivotal element of the methodology entails the application of established ASTM standards for mechanical testing, encompassing hardness, compressive, and Rockwell hardness assessments. These tests serve as fundamental components for analyzing the composite's mechanical behavior under different loading conditions. The results obtained from these assessments contribute to a profound understanding of the material's mechanical properties. In addition to mechanical testing, the methodology incorporates advanced analytical Techniques such as Field Emission Scanning Electron Microscopy (OPTICAL MICROSCOPY) and X-ray Diffraction (XRD) analysis to delve into the microstructure and crystalline properties of the composite. OPTICAL MICROSCOPY provides high-resolution imaging capabilities, enabling detailed insights into the distribution and morphology of reinforcing particles within the matrix. XRD analysis assists in identifying the crystalline structures and phases within the material, enhancing the comprehension of its microstructure.

Procedures:

(i) Procurement of Aluminum 2050 The research journey commences with the meticulous procurement of Aluminum 2050, a pivotal step that sets the foundation for our composite material.

(ii) Precision Cutting using EDM With the high-quality Aluminum 2050 at our disposal, we employ Electrical Discharge Machining (EDM) for precise cutting. This precise machining technique ensures that our specimens conform to the dimensions required.

(iii) Squeeze Casting Process The process of squeeze casting involves applying pressure on closed dies to cause molten alloy to solidify. As soon as the liquid alloy begins to solidify, pressure is applied and maintained until the entire casting has done so. The principle behind squeeze casting is to reduce both gas compression and solidification shrinkage.

(iv) Addition of Limestone Reinforcement: At this juncture, approximately 10% by weight of limestone reinforcement is carefully introduced into the molten Aluminum 2050. This step is critical in achieving a uniform dispersion of the reinforcement material within the matrix.

(v) Squeeze Casting Process Parameters: Usually, the die temperature is kept at a setting appropriate for the particular aluminium alloy being used. This could range from about 200 °C to 450 °C for alloys made of aluminium. The alloy and required characteristics can affect the 27-injection pressure used during squeeze casting. Typically, it lies between 20 to 200 MPa. As the solidifies and after injection, the squeeze pressure is applied. It aids in increasing density and mechanical qualities while lowering porosity. Depending on the alloy, the pressure and time can vary from 20 to 200 MPa and a few seconds to a few minutes, respectively.

(vi) Crucible at 630 Degrees Celsius: Throughout the stir casting process, the crucible is maintained at a precise temperature of 630 degrees Celsius. This controlled thermal environment is essential to facilitate the homogeneous mixing of the aluminum matrix and the limestone reinforcement.

(vii) Pouring into Desired Die: As the stir casting process concludes, the composite material is meticulously poured into a pre-designed die, meticulously crafted to adhere to ASTM standards. The die dimensions are integral to the fabrication of standardized specimens for mechanical testing.

(viii) Preparation of Hardness, Compressive Testing Specimens: After the composite material cools and solidifies within the die, we embark on the precise preparation of specimens that meet the dimensional requirements outlined in ASTM standards.

(ix) Crucible Preparation The process commences with the selection of a suitable crucible, typically constructed from high-temperature-resistant materials, to contain and maintain the molten aluminum matrix. The crucible's interior is meticulously cleaned to ensure the absence of impurities that could adversely affect the quality of the composite.

(x) Preheating the Crucible, A controlled heating mechanism is employed to preheat the crucible to a specific temperature. For this research, the crucible is maintained at 630 degrees Celsius. This precise thermal environment is pivotal as it guarantees the molten state of the aluminum 2050, a fundamental requirement for effective stir casting.

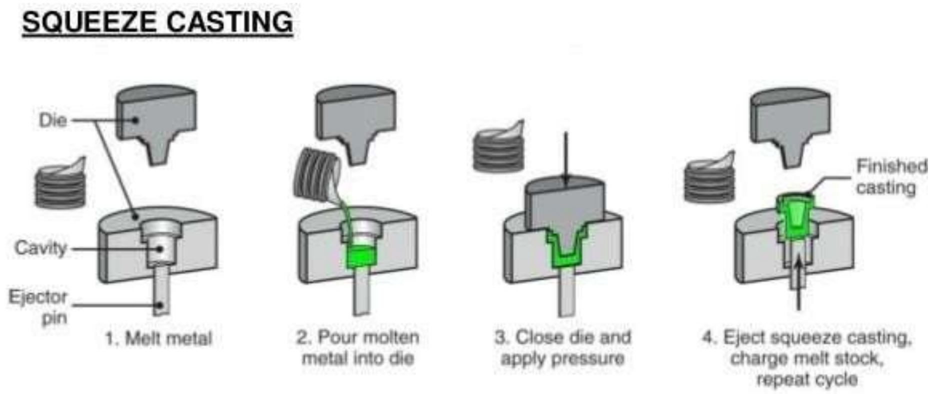
(xi) Molten Aluminum Preparation: Aluminum 2050, a high-strength aluminum alloy, is prepared for the stir casting process. The alloy is carefully weighed and introduced into the preheated crucible, where it undergoes the transition from its solid to molten form. The precise temperature control ensures that the alloy reaches the desired consistency, crucial for subsequent steps.

(xii) Addition of Limestone Reinforcement: A defining characteristic of stir casting is the introduction of reinforcement materials into the molten matrix. In this project, approximately 10% by weight of 29 limestone is added to the molten Aluminum 2050. This addition is executed with precision to ensure a homogeneous dispersion of the reinforcement material within the matrix, a pivotal step in achieving a composite with uniform properties.

(xiii) Controlled Agitation: One of the distinguishing features of stir casting is the agitation applied to the molten material. In this research, the process parameters call for a specific rotation per minute (RPM) set at 100 and a defined process timing of 10 minutes. These parameters are meticulously controlled to guarantee an even and consistent distribution of the limestone reinforcement material throughout the aluminum matrix.

(xiv) Homogenization and Mixing: During the squeeze phase, the combination of RPM and time is orchestrated to promote the uniform mixing of the aluminum alloy and limestone reinforcement. This controlled homogenization ensures that the composite exhibits consistent properties throughout, a crucial factor for reliable mechanical testing.

(xv) Material Transfer: When the squeeze casting process is complete, the composite material is carefully and promptly transferred from the crucible. It is then ready for the next phase: pouring into a pre-designed die, which adheres to ASTM standards and features dimensions necessary for the creation of standardized specimens for mechanical testing.



Sequence of operations in the squeeze-casting process. This process combines the advantages of casting and forging.

CONCLUSION:

In conclusion, this research project, centered on the development of a composite material with Aluminum 2050 as the matrix and limestone as the reinforcement using stir casting, represents a significant stride in the realm of materials science. The journey from material selection to manufacturing, testing, and advanced analysis has unveiled a wealth of insights and potential applications. The amalgamation of Aluminum 2050 and limestone as an unconventional reinforcement has shown promise in enriching the mechanical properties of the resulting composite material. While the outcomes may vary based on manufacturing parameters and material quality, the potential for enhanced tensile and compressive strength, wear resistance, and lightweight characteristics is evident. The strict adherence to ASTM standards throughout the project ensures the credibility and reliability of the data generated from the mechanical tests, further reinforcing the material's suitability for various applications.

The application of advanced analytical techniques, including Field Emission Scanning Electron Microscopy (FESEM) and X-ray Diffraction (XRD), has unraveled the microstructural and crystalline intricacies of the composite, offering valuable insights forfuture refinement and optimization. This project is more than a scientific endeavor; it symbolizes innovation, adaptability, and the potential for sustainability. The versatility of the composite, coupled with its ability to be customized for specific industry requirements, makes it a valuable addition to the materials landscape. As the journey of this project concludes, it leaves a trail of possibilities in industries as diverse as aerospace, automotive, construction, and machinery manufacturing. The composite 'Combination of properties promises to address specific needs, enhance performance, and contribute to sustainable solutions. In essence, this research project echoes the spirit of exploration and innovation, affirming that the quest to push the boundaries of materials science is an ongoing and evolving journey. The future holds the promise of even more groundbreaking developments in the ever-expanding universe of composite materials.

BENEFITS

The benefits, which involves creating a composite material with Aluminum 2050 as the matrix and limestone as the reinforcement using stir casting, are diverse and can have several applications across various industries:

Enhanced Mechanical Properties: The composite material may exhibit improved tensile and compressive strength compared to the base material (Aluminum 2050). This enhancement can make it suitable for applications where high-strength materials are required.

Lightweight Construction: Aluminum is known for its low density, and by incorporating limestone as a reinforcement, you may retain this lightweight property while improving strength. This is valuable in industries that demand lightweight yet robust materials, such as aerospace and automotive.

Wear Resistance: Limestone reinforcement can enhance the wear resistance of the composite. This feature is advantageous in manufacturing components for machinery, where materials need to withstand abrasive forces.

Cost-Effective Manufacturing: Stir casting is a relatively cost-effective manufacturing process. This makes the composite material appealing for applications where affordability is a significant factor.

Corrosion Resistance: Aluminum inherently possesses corrosion resistance. The project may result in a composite that retains this attribute while gaining other favorable properties, making it useful in environments where corrosion is a concern, such as marine applications.

Sustainability: Depending on the sourcing of materials and the environmental impact of the manufacturing process, the composite may offer sustainability advantages, making it suitable for eco-friendly initiatives.

Diverse Industry Applications: Potential industries for the application of this composite material include aerospace, automotive, construction, marine, and machinery manufacturing, among others.

Research Contribution: Beyond practical applications, your project contributes to the field of materials science. The innovative combination of materials and the use of advanced analysis techniques can lead to valuable insights and potentially inspire further research and development in the domain of composite materials.

The project's benefits are extensive and offer the potential to provide solutions in multiple industries, from improving the performance of structural components in aerospace to enhancing the durability of automotive parts and machinery. The versatility and customization options of the composite make it a versatile candidate for a wide array of applications.

REFERENCE

1.Ding-ding LU, Jin-feng LI, Hong NING, Peng-Cheng MA, Yong-Lai CHEN, Xu-hu ZHANG, Kai ZHANG, Jian-mei LI, Rui-feng ZHANG (2020). Effects of microstructure on hardness properties of AA2050-T84 Al−Li alloy. The Nonferrous Metals Society of China, 31(2021),1189−1204.

2.Y. Li, J. Lin, Y.-L. Yang, B.-M. Huang, T.-F. Chung, J.-R. Yang (2016). Experimental investigation of tension and compression creep- ageing behavior of AA2050 with different initial tempers. Materials Science and Engineering A,657, 299-308

3. Jianyu Li, Yu Pan, Shusen Wu, Lu Chen, Wei Guo, Shilong Li, Shulin Lu (2023). Precipitates strengthening mechanism of a new squeeze-cast Al–Cu–Li– Mn alloy with high strength and ductility. Tate Key Lab of Materials Processing and Die & Mould Technology, 25, 1334-1343.

4.Jian-Yu LI, Shu-Lin LÜ, Lu CHEN, Qiao LIAO, Wei GUO, Shu-Sen WU (2023). Influence of squeeze casting pressure on nanoparticle distribution and mechanical properties of nano-SiCp/Al−Cu composites assisted with ultrasonic vibration. The Nonferrous Metals Society of China,33(2023) ,1977−1987.

5. M. Guérin, J. Alexis, E. Andrieu, C. Blanc, G. Odemer (2015). Corrosion fatigue lifetime of Aluminium–Copper–Lithium alloy 2050 in chloride solution. Materials & Design,87,681-692.

6.Chen L, Sergiu P. A, Xiaorong Z, Zhihua S, Xiaoyun Z, Zhihui T, George E (2016). Continuous and discontinuous localized corrosion of a 2050 aluminium–copper–lithium alloy in sodium chloride solution. Journal of Alloys and