



沈阳建筑大学学报(自然科学版)

Journal of Shenyang Jianzhu University (Natural Science)

卷 : 39 期 : 06  
Vol: 39 No. 06

doi: 10.11717/j.issn: 1671-2021.2023.06.19

## Investigations On the Mechanical Properties of Tungsten Carbide Reinforced Aluminium and Fly Ash Metal Matrix Composites by Stir Casting

<sup>1</sup>B. Bala, <sup>2</sup>D.R. Srisan

Department of Mechanical Engineering,

Jawaharlal Nehru Technological University Anantapur, College of Engineering

*Received: 16<sup>th</sup> November 2023 Accepted: 17<sup>th</sup>  
December 2023 Published: 19<sup>th</sup> December 2023*

**Abstract:** In the present world, metals play a pivotal role in manufacturing industries. The requirements for various metals have been growing exponentially over the last few centuries resulting in the exploitation of natural resources. As the applications and technical specifications of metals are different and very large. There is an urgent need to develop methods to suit the specific requirements of the metals and the combination of metals. Also, various techniques have been developed over the year and metal matrix composites are one of them. It has an inherent advantage that all the constituents need not be processed to their melting points instead they are processed to the lowest melting temperatures of their constituents thereby ensuring better bonding and structural stability. The main objective of this work is to employ aluminium alloy-fly ash-tungsten carbide metal matrix composites as they possess light-in-weight characteristics with improved corrosion and hardness properties. The workpieces shall be manufactured by stir casting and corresponding mechanical properties are determined.

**Keywords:** Mechanical properties like Impact, Hardness, Corrosion and Wear.

## **I. Introduction**

The majority of composite materials, including metal matrix composites (MMCs), offer improved qualities in comparison to monolithic materials. These improvements include increased strength, stiffness, and hardness, as well as a reduction in weight. Aluminum-based metal matrix composites are becoming increasingly important in the engineering industry. This is due to the fact that these composites belong to a class of lightweight and high-performance aluminum-centric materials system. Al6061 is a type of aluminium alloy that is typically used in aerospace applications, maritime applications, cycling and automotive applications, and for the production of gas cylinders. Magnesium and silicon play a significant role in the alloying process of Al6061. It is possible to heat treat Al6061, and it has extremely strong corrosion resistance and finishing properties. Additionally, it can be easily welded. It possesses a strength and a hardness that are around average.

Stir casting is the most popular choice among the several processing techniques that are available for fabricating composites. This is due to the fact that stir casting is the most straightforward and economical form. sources. According to the references, tungsten carbide can be found as a reinforcement material in Al6061 matrix composites of various weight percentages. Stir casting is a technique used to fabricate the object. The mechanical properties of the matrix material, such as its hardness and tensile strength, were shown to significantly improve when the amount of WC inside the matrix material was increased. The amount of tungsten carbide increases along with density, according to the reference. The reference claims that higher WC concentrations result in higher levels of wear resistance.

References provide information on the use of fly ash as a reinforcing ingredient in aluminium composites. The fabrication process employs the stir-casting technique. Casting and powder metallurgy are the procedures that are utilised in the production of MMCs more frequently than any other processes. Powder metallurgy is a highly developed way of making reliable net shaped components by mixing together elements or pre-alloyed powders, compacting this blend in die, and then sintering in a controlled furnace atmosphere to bind particles. This process is known as "powder metallurgy."

## **Literature Review**

**V. V. Kondaiaha, P. Pavanteja, P. A. Khan, S. A. Kumar, R. Dumpala, and B. R. Sunil, "Microstructure, hardness and wear behavior of AZ31 Mg alloy – fly ash composites produced by friction stir processing," *Materials Today: Proceedings*, vol. 4, no. 6, pp. 6671–6677, 2017,** recent research has demonstrated that improving a material's ductility and

mechanical qualities by adding reinforcements such SiC, Al<sub>2</sub>O<sub>3</sub>, MgO, and ZrO<sub>2</sub> can have a positive impact. Fly ash is the most easily available and inexpensive substance, and if it is used correctly, it can help minimise the amount of pollution that is caused to the land. It has a significant impact on the environmental effect of thermal power plants and other combustion processes that are used by enterprises that use coal as fuel.

**M. Viswanath, H. Dieringa, K. K. Ajith Kumar, U. T. S. Pillai, and B. C. Pai, “Investigation on mechanical properties and creep behavior of stir cast AZ91-SiCp composites,” Journal of Magnesium and Alloys, vol. 3, no. 1, pp. 16–22, 2015,** a friction stir procedure was used by Kondaiah et al. to create AZ31/fly ash composites, and they reported that the composites had enhanced hardness and superior wear properties. Stir casting was utilized by Viswanath et al. in the development of AZ91/SiC composites with weight percentages of 5, 10, 20, and 25% respectively. They found that composites containing 15, 20, and 25 weight percent of SiC had enhanced creep resistance. Stir casting was utilized by Matina et al. in order to create pure magnesium/SiC and AZ80/SiC composites.

**M. Hassan, A. T. Mayyas, A. Alrashdan, and M. T. Hayajneh, “Wear behavior of Al-Cu and Al-Cu/SiC components produced by powder metallurgy,” Journal of Materials Science, vol. 43, no.15, pp. 5368–5375, 2008,** die casting was the process that Lim et al. used to develop their AZ91/D-flyash composites. According to what they found, the composite density declined as the amount of fly ash grew, and the maximum tensile strength was reached in composites that had 5 weight percent of reinforced fly ash. Hassan and colleagues looked into the wear behaviour of composites that were reinforced with magnesium and silicon carbide. They were able to demonstrate that the composites’ outstanding load-bearing capacity led to an increase in wear resistance of between 15 and 30 percent.

## **Material’s Compositions & Methods**

The following composition was chosen for characterization:

Composition-1: 94% Aluminium Alloy – 3% Tungsten Carbide – 3% Fly Ash

Composition-2: 94% Aluminium Alloy – 2% Tungsten Carbide – 2% Fly Ash

Composition-3: 94% Aluminium Alloy – 1% Tungsten Carbide – 1% Fly Ash

### **Aluminium Alloy**

**Aluminium alloys** are alloys in which aluminium (Al) is the predominant metal. The typical alloying elements are copper, magnesium, manganese, silicon and zinc. There are two principal

classifications, namely casting alloys and wrought alloys, both of which are further subdivided into the categories heat-treatable and non-heat-treatable. . The most important cast aluminium alloy system is Al–Si, where the high levels of silicon (4.0–13%) contribute to give good casting characteristics. 6111 aluminium and 2008 aluminium alloy are extensively used for external automotive body panels, with 5083 and 5754 used for inner body panels. Hoods have been manufactured from 2036, 6016, and 6111 alloys. Truck and trailer body panels have used 5456 aluminum. Automobile frames often use 5182 aluminium or 5754 aluminium formed sheets, 6061 or 6063 extrusions.

## **Tungsten Carbide**

Tungsten carbide (chemical formula: WC) is a chemical compound (specifically, a carbide) containing equal parts of tungsten and carbon atoms. In its most basic form, tungsten carbide is a fine gray powder, but it can be pressed and formed into shapes for use in industrial machinery, cutting tools, abrasives, armor-piercing rounds, other tools and instruments, and jewelry. Tungsten carbide is approximately two times stiffer than steel, with a Young's modulus of approximately 530–700 GPa (77,000 to 102,000 ksi), and is double the density of steel—nearly midway between that of lead and gold.

Tungsten carbide has a high melting point at 2,870 °C (5,200 °F), a boiling point of 6,000 °C (10,830 °F) when under a pressure equivalent to 1 standard atmosphere (100 kPa), a thermal conductivity of  $110 \text{ W}\cdot\text{m}^{-1}\cdot\text{K}^{-1}$ , and a coefficient of thermal expansion of  $5.5 \mu\text{m}\cdot\text{m}^{-1}\cdot\text{K}^{-1}$ . Tungsten carbide is extremely hard, ranking about 9 on Mohs scale, and with a Vickers number of around 2600. It has a Young's modulus of approximately 530–700 GPa, a bulk modulus of 630–655 GPa, and a shear modulus of 274 GPa.<sup>[16]</sup> It has an ultimate tensile strength of 344 MPa, an ultimate compression strength of about 2.7 GPa and a Poisson's ratio of 0.31.

## **Fly Ash**

Fly ash, also known as flue-ash, is one of the residues generated in combustion, and comprises the fine particles that rise with the flue gases. Ash which does not rise is termed bottom ash. In an industrial context, fly ash usually refers to ash produced during combustion of coal. Fly ash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys of coal-fired power plants, and together with bottom ash removed from the bottom of the furnace is in this case jointly known as coal ash. Since the particles

solidify rapidly while suspended in the exhaust gases, fly ash particles are generally spherical in shape and range in size from 0.5  $\mu\text{m}$  to 300  $\mu\text{m}$ .

## **Experimental Procedure of Stircasting**

In a stir casting process, the reinforcing phases are distributed into molten matrix by mechanical stirring. Stir casting of metal matrix composites was initiated in 1968, when S. Ray introduced alumina particles into aluminum melt by stirring molten aluminum alloys containing the ceramic powders. Mechanical stirring in the furnace is a key element of this process. The resultant molten alloy, with ceramic particles, can then be used for die casting, permanent mold casting, or sand casting. The matrix that has been used here is Aluminium 6081. The alloy composition and mechanical properties of Aluminium was studied. A micron size of boron carbide was used as the first reinforcement. Two different compositions, taking 2%, 4% and boron carbide as a constant required composites are fabricated. The fabrication of composites are done by stir casting method, Due to its suitability in producing uniformly distributed reinforcements. Aluminium was purchased in the form of rods and then were cut into pieces to as per requirement of the crucible.

## **Conclusion**

- The stir-casting method was used to manufacture Al6061 metal matrix composites, and tungsten carbide and fly ash particles (with varying compositions of volume percentage) were used as reinforcements. The process was simple and cost-effective. The results of the tests on mechanical qualities such as impact and hardness are improved.
- The findings of the impact test showed that the amount of energy in Joules absorbed was proportional to the amount of reinforcement content in the matrix and the weight percentage of the matrix. However, the ductility of the composites decreased as the amount of reinforcement content in the matrix increased.
- When compared to the enhanced effect of fly ash reinforcement, the effect of tungsten carbide reinforcement on mechanical strength and hardness qualities is significantly greater.
- In addition, the results of the corrosion and wear characterisation showed that there was no void formation and that the reinforcing content (tungsten carbide

and fly ash particles) was distributed evenly throughout the Al6061 matrix composites. As a result of these experimental investigations, it was observed that the mechanical strength, along with other features such as corrosion and wear resistance, rose when there was a greater quantity of tungsten carbide and fly ash. This was one of the findings that was acquired.

## References

- [1] M. Gupta and S. N. M. Ling, *Magnesium, magnesium alloys, and magnesium composites*, John Wiley & Sons, Inc. Publication, 2011.
- [2] N. Singh and R. M. Belokar, "Tribological behavior of aluminum and magnesium-based hybrid metal matrix composites: a state-of-art review," *Materials Today: Proceedings*, vol. 44, pp. 460–466, 2021.
- [3] L. Ceschini, A. Dahle, M. Gupta et al., *Aluminium and Magnesium Metal Matrix Nano Composites*, Springer, 2017.
- [4] E. Friedrich and B. L. Mordike, *Magnesium Technology Metallurgy, Design Data, APPLICATIONS*, Springer, 2006.
- [5] R. Liu, M. Zhang, and B. Jia, "Inhibition of gas explosion by nano-SiO<sub>2</sub> powder under the condition of obstacles," *Integrated Ferroelectrics*, vol. 216, no. 1, pp. 305–321, 2021.
- [6] I. Dinaharan, S. C. Vettivel, M. Balakrishnan, and E. T. Akinlabi, "Influence of processing route on microstructure and wear resistance of fly ash reinforced AZ31 magnesium matrix composites," *Journal of Magnesium and Alloys*, vol. 7, no. 1, pp. 155–165, 2019.
- [7] V. V. Kondaiaha, P. Pavanteja, P. A. Khan, S. A. Kumar, R. Dumpala, and B. R. Sunil, "Microstructure, hardness and wear behavior of AZ31 Mg alloy – fly ash composites produced by friction stir processing," *Materials Today: Proceedings*, vol. 4, no. 6, pp. 6671–6677, 2017.
- [8] A. Viswanath, H. Dieringa, K. K. Ajith Kumar, U. T. S. Pillai, and B. C. Pai, "Investigation on mechanical properties and creep behavior of stir cast AZ91-SiCp composites," *Journal of Magnesium and Alloys*, vol. 3, no. 1, pp. 16–22, 2015.
- [9] A. Matina, F. F. Saniee, and H. R. Abedi, "Microstructure and mechanical properties

of Mg/SiC and AZ80/SiC nanocomposites fabricated through stir casting method,”  
Materials Science and Engineering, vol. 625, pp. 81–88, 2015.