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Experimental and Testing Mechanical Properties of Al 7075–Zrb–Sic–Gr Composites Using for Advanced Heat Sink Applications

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Abstract
This study Experimental and Testing Mechanical Properties of Al 7075–Zrb–Sic–Gr Composites Using for Advanced Heat Sink Applications focuses on the development and characterization of a hybrid metal matrix composite (MMC) using Aluminium 7075 (Al 7075) as the base matrix reinforced with Silicon Carbide (SiC), Zirconium Diboride (ZrB_2), and Graphite (Gr). Generally, a heat sink is a passive thermal management device that dissipates heat from electronic components (like CPUs, GPUs, power transistors, LEDs, etc.) into the surrounding air or liquid. The primary objective is to enhance the mechanical and tribological performance of Al 7075 through the synergistic effect of ceramic and solid lubricant reinforcements. SiC provides improved hardness and strength, ZrB_2 offers high thermal stability and wear resistance, while Gr contributes to reduced friction due to its solid lubricating properties. The composites were fabricated using the stir casting process to ensure uniform distribution of the reinforcements. Mechanical properties such as compressive strength and hardness were evaluated, along with wear behavior under dry sliding conditions. The results indicated a significant improvement in all properties compared to the unreinforced Al 7075 alloy. The combined effect of SiC and ZrB_2 enhanced load-bearing capacity and thermal resistance, while the presence of Gr reduced the coefficient of friction and wear rate. The aim of the project is perform the 89%AL7075+8%Sic+2%ZrB2+1%Gr,90%AL7075+7%Sic+2%ZrB2+1%Gr,91%AL7075+6%Sic+2%ZrB2 +1%Gr, 92% AL7075+ 5%Sic+2%ZrB2+1%Gr these compositions of Mechanical testing was perform to evaluate hardness, compressive strength, and wear resistance, while micro structural analysis was conducted, heat treatment after which composition have better results use the real time application created the heat sink using CATIA software and perform the Thermal analysis using ANSYS software and here find out the temperature distribution and Total heat flux. Finally concluded the material is best based on the testing.
Keywords: *AL 7075, Sic, Zrb2, CATIA, ANSYS, temperature distribution, Heat flux, Heat sink, compressive strength, Hardness, Sem.*

1. Introduction
1.1. Composite Materials
Composite materials are specially designed by combining two or more distinct components, typically consisting of a durable reinforcement phase and a continuous matrix phase that are bonded together through a clearly defined interface. Each component maintains its own properties but works together to achieve enhanced characteristics that neither could accomplish independently. The reinforcement phase, which is generally stronger and stiffer, plays a crucial role in improving mechanical performance, while the matrix phase holds the structure together and facilitates load distribution. Composites are created for specific uses, offering a balance of strength, lightness, thermal stability, and resistance to wear. Engineers have the ability to tailor these materials for optimal performance, cost-effectiveness, or particular electrical or mechanical requirements. The key advantage of composites lies in their adaptability, providing properties like conductivity, corrosion resistance, or low weight, depending on the chosen

materials. Naturally occurring composite materials, such as wood, are also found in nature, where cellulose fibers are reinforced by lignin, forming a sturdy and enduring structure.

1.2. Aluminum Heatsinks

Aluminum heat sinks are essential components in thermal management systems, commonly used in electronic and electrical devices that generate significant heat during operation. Their primary role is to transfer excess heat away from sensitive components, such as CPUs, LEDs, power transistors, and battery packs, helping to prevent overheating. This heat dissipation ensures that devices maintain peak performance and extend their operational life.The popularity of aluminum as the material for heat sinks stems from its impressive thermal conductivity, approximately 205 W/m•K, which allows it to efficiently spread heat across its surface. Beyond its thermal properties, aluminum is also lightweight, resistant to corrosion, affordable, and easy to process. These characteristics make it an ideal choice for manufacturing heat sinks in high volumes, with the flexibility to create intricate shapes to meet specific design needs. Whether through extrusion or machining, aluminum allows for versatile and cost-effective solutions in thermal management.

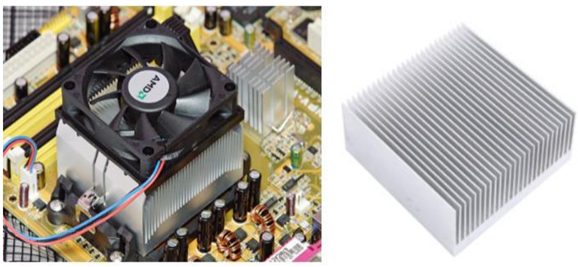

Figure 1 Aluminum Heat Sink

These heat sinks are used in a broad range of devices, including computers, power electronics, LED lighting, inverters, and electric vehicles. Surface treatments like anodizing are commonly applied to enhance both corrosion resistance and thermal radiation efficiency, with black anodized finishes being particularly effective at improving heat dissipation. While aluminum heat sinks may have lower thermal conductivity than copper, they are much lighter, more resistant to corrosion, easier to process, and more affordable. These characteristics make aluminum the preferred choice for a wide variety of industrial and consumer applications.

2. Literature Survey

R Kartigeyan et.al.[2022], has efficaciously evolved Al 7075 alloy and Short Basalt Fibre composite via liquid metallurgy technique. The boom in brief basalt fibre maximizes the remaining tensile energy, yield energy and Hardness. The composite containing 6% wt of brief basalt fibre indicates better hardness fee of 97.1 Mpa while examine to base matrix hardness 92Mpa. TheAl-7075/brief basalt fibre bolstered 6 vol % maximizes the remaining tensile energy via way of means of 65.51%. The distribution of reinforcements in steel matrix is truly uniform. From the above studies paper I concluded that, beneathneath anxiety loading with out affecting the tensile ductility, values of tensile energy increases. Experimental values of brief basalt fiber deliver the excellent end result for the Al-MMC`s Pradeep P et.al [2023], has fabricated Al 7075 and Titanium DI Boride (Tib2) thru the sir casting technique. The amount fraction of TiB2 brought about are %, 6% and eight% . They evaluated the microstructure, put on, hardness residences. At eight% wt of TiB2 notices the most hardness of 126 VHN and strengthens the bottom matrix. Explicit put on charge diminishes because the sliding charge increments as much as rotation pace (1.6 m/s) and weight, in mild of labor solidifying of the cloth surface. Minimal impact of the wear and tear charge were given from the eight Wt. % of TiB2 fortified composite. The pace and the sliding distance are in maximum intense with the insignificant weight. The micro photograph shows the Aluminum particles are unvaryingly dispersed inside the maximum extent fraction of particulate matrix of 8Wt. %. From the above studies paper I presumed that put on and abrasive region residences of MMCs having aluminum as base cloth particularly is based upon the particulate applied for filler, its length and weight department of particles. If the particulates delivered for strengthened nicely to the lattice, the wear and tear obstruction increments with increasing extent department of help materials. Arunkumar D T et al. [2018] used the stir casting technique to successfully create Al-7075 composites with mica and kaolinite reinforcements. They performed a wear test at constant load for different time intervals using equal volume percentages of mica and kaolinite, which are [(2+2)%, (4+4%%), (6+6%%), and (8+8%). Composites containing 8% volume of mica and kaolinite show a slower rate of wear loss reduction. The composite's SEM microstructure shows no signs of agglomeration and a uniform distribution of reinforcement into matrix. I deduced from the aforementioned study that by enhancing wear resistance, the inclusion of mica and kolonite in the matrix reduced wear loss. Rajesh Kumar Bhushan et.al [2019], and colleagues investigated the creation of Al7075 composites reinforced with SiC particulates. They used a fluid vortex casting technique to prepare specimens with various SiC particle sizes (20-40 μm) and volume fractions (10% and 15%). Their detailed analysis using EPMA, XRD, SEM, EMPA, and DTA showed that while SiC oxidation can hinder interfacial reactions, adding 2.52 wt.% Magnesium (Mg) to the Al alloy significantly prevented the formation of Al4C3 at the interfaces. This Mg effectively improved wetting between the base material and SiC, ensuring uniform particle dispersion as confirmed by SEM. The absence of Al4C3, validated by XRD, means these composites have no adverse chemical reactions. Consequently, these Al7075-SiC composites are ideal for demanding applications in the automotive, aerospace, and defense sectors. Madhuri Deshpande et al. (2016): They developed pitch-based carbon fiber reinforced AA7075 composites using the Powder Metallurgy technique. The study found that uncoated carbon fibers resulted in lower hardness compared to nickel-coated fibers, which showed improved hardness. Hot pressing helped enhance the density of the composite. Conclusion: Nickel coating improves the interfacial bonding between fibers and aluminum, enhancing hardness. Manoj Singla et al. (2009): Their experiments with Sic (Silicon carbide) reinforced Al matrix composites revealed that increasing Sic content raised hardness and impact strength, with the best results at 25% Sic. Conclusion: The homogenous dispersion of Sic particles in the Al matrix led to an increase in mechanical properties. Jamaluddin Hindi et al. (2016): Al 7075 reinforced with gray cast iron (GCI) showed increased tensile strength and hardness with higher GCI content. Wear rate also decreased with GCI addition. The increase in GCI reduces inter-particle spacing and enhances the composite's strength and durability. Mohan Kumar S et al. (2014): Electro less nickel coating on Al 7075-T6 enhanced its crack resistance. The study found significant increases in yield strength and fracture toughness when the Al alloy was coated. Conclusion: The nickel coating improves the composite's ability to resist crack propagation due to stronger bonding between the coating and the Al matrix. Gururaj Aski et al. (2017): Reinforcing LM13 alloy with ZrSiO4 at varying percentages (2%, 4%, 6%) increased tensile strength, with the highest tensile strength observed at 6% ZrSiO4 The homogeneous distribution of ZrSiO4 in the matrix significantly improved the mechanical properties, including impact strength. Shivannah & V. S. Ramamurthy et al. (2012): In their study on A356-ZrSiO4 composites, they found that adding ZrSiO4 increased hardness but also increased wear rates. The reinforcement of ZrSiO4 particles contributed to higher hardness, but also led to higher wear rates at higher concentrations. R.S. Raveendra et al. (2016): In experiments on Al6061 with α-Al2O3 particles, the addition of Al2O3 improved the hardness and ultimate tensile strength of the alloy, particularly at 6% wt. The incorporation of nano-Al2O3 improved the composite's mechanical properties by restricting bending and stress. Miss. Laxmi & Mr. Sunil Kumar et al. (2017): Their study on Sic reinforced Al6061 composites showed that increasing Sic content improved hardness, but beyond 15%, the hardness decreased. The optimal Sic content for enhancing hardness was found to be 15%. Z. Hasan et al. (2011): They studied the wear characteristics of 2124

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Al alloy reinforced with Sic particles and observed that wear increased with load. The wear rate in Al-Sic composites increased with load due to abrasive and cutting actions of the Sic particles. Gopal Krishna U B et al. (2013): This study investigated the effect of Boron Carbide (B4C) particles of varying sizes (37µ-250µ) in aluminum matrix composites. The largest B4C particles at 12wt% showed the highest hardness. Conclusion: The hard B4C particles increase the composite's resistance to plastic deformation and improve its mechanical properties. Shivraja H B et al. (2012): In their hybrid composite study of Al356 with ZrSiO4 and Sic, the addition of both reinforcements improved strength and toughness. The combination of ZrSiO4 and Sic particles enhanced the composite's toughness and resistance to crack propagation. Z. Konopka et al. (2006): The addition of short carbon fibers to Al-Si composites improved toughness, with higher fiber content (12.5%) showing the best results. Higher fiber content in Al-Si composites improves crack resistance and durability. Ajay Kumar et al. (2016): The study on Al356 with graphite, boron carbide, and fly ash showed significant improvements in tensile strength and hardness. The uniform distribution of fly ash particles enhanced the mechanical properties, especially tensile strength. Niranjan K.N et al. (2017): Their research on hybrid composites with Sic and graphite in Al6061 indicated that while increasing graphite decreased hardness, it improved tensile and compressive strength. Graphite's impact on mechanical properties depends on the ratio of Sic and graphite reinforcements. Avinash Patil et al. (2017): Their investigation into the fracture toughness of Al alloy A384 indicated moderate crack strength and fracture toughness values. The fracture toughness of Al A384 was moderate, with crack resistance improving with applied stress.

3. Selection of Material

3.1 Processing of Al7075 Matrix Composites

The primary methods for manufacturing Aluminum Matrix Composites (AMCs) can be divided into two key categories based on the material state during processing. Liquid State Processes: This group involves working with molten metal to incorporate reinforcement materials. The most common techniques include:

- **Stir Casting:** Reinforcement particles are mixed into molten aluminum, ensuring uniform dispersion before being cast into molds.
- **Squeeze Casting:** Molten aluminum is injected into a mold under high pressure to achieve better reinforcement distribution and enhanced material properties.
- **Ultrasonic Assisted Casting:** Ultrasonic vibrations are used to improve the dispersion of reinforcement particles in the molten aluminum, leading to finer, more uniform composites.
- **Solid State Processes:** These techniques occur without the material reaching its melting point. They typically produce composites with superior mechanical properties and include:
- **Powder Metallurgy (PM):** Metal powders and reinforcements are mixed, compacted, and then sintered to form a solid composite with controlled properties.
- **High-Energy Ball Milling:** Metal powders are combined with reinforcement particles and subjected to high-energy milling, resulting in a fine, homogeneous mixture.
- **Friction Stir Processing (FSP):** A rotating tool mixes aluminum with reinforcement material under heat and pressure, refining the composite’s microstructure for improved mechanical performance.

Table 1 Composition of Aluminum-7075

Al	Zn	Cr	Ti	Mn	Si	Fe	Cu	Mg
88.85%	5.5%	0.15%	0.2%	0.3%	0.4%	0.5%	1.6%	2.5%

3.2. Liquid State Process

The **Stir Casting** process is a liquid-state technique in which aluminum alloy serves as the matrix phase, and ceramics act as the reinforcing phase. In this

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method, the aluminum alloy is first heated to a molten state, and the reinforcing materials, typically in powder form, are evenly distributed throughout the molten aluminum by mechanical stirring. The key element of this process is the mechanical stirring that occurs within the furnace, which ensures uniform dispersion of the reinforcement in the aluminum matrix. The **Squeeze Casting** process combines gravity die casting and closed-die forging. This technique involves applying pressure to the solidifying molten metal to improve the material's density and mechanical properties. The steps in this process include:

1) Pouring a metered quantity of liquid metal, with adequate superheating, into a die cavity.
2) Applying pressure to the liquid metal and maintaining it until the metal solidifies.
3) Removing the solidified casting and preparing the die for the next cycle.

4. Ultrasonic Assisted Casting

Combines conventional solidification techniques with the innovative approach of ultrasonic cavitation. In this process, ultrasonic waves generate rapid "hot spots" within the molten metal, reaching temperatures of up to 5000°C and pressures surpassing 1000 atmospheres. These extreme conditions are accompanied by ultra-fast heating and cooling rates, which can exceed 10^10 K/s. The intense energy from the ultrasonic cavitation aids in the efficient dispersion of nanoparticles throughout the molten metal, resulting in enhanced material properties.

5. Properties of Al Composites Materials

The factors that determine properties of composites are microstructure, volume fraction isotropy and homogeneity of the system and these are strongly influenced by proportions and properties of the matrix and the reinforcement.

5.1. Physical Properties

Density is a physical property of matter, as each element and compound has a unique density associated with it. Density defined in a qualitative manner as the measure of the relative "heaviness" of objects with a constant volume. Density plays very important roles in the composite material study. These materials using in space crafts and automotive industry, they must be light weight. So, the density should be reduced by adding some reinforced material like Al2O3, Sic, GR AND SIC, etc., in Aluminum alloy. In a composite, the volume fraction (v), which is commonly used in property calculation. Density can be calculated by dividing the mass of specimen by the volume displaced by that specimen in the water beaker

5.2. Low Density

Density ranges between 2.6 – 2.9 g/cm³ depending on the type and content of the reinforcement. AMCs are 20–30% lighter than steel, making them suitable for aerospace and automotive applications.

5.3. Low Thermal Expansion Coefficient (CTE)

The CTE of AMCs is lower than pure aluminum due to the presence of low CTE reinforcements. This improves dimensional stability under varying **thermal conditions.**

5.4. High Thermal Conductivity

AMCs exhibit excellent thermal conductivity, making them suitable for heat sinks and electronic packaging. The thermal conductivity depends on the matrix and the type of reinforcement.

5.5. Improved Damping Capacity

AMCs have better vibration damping properties compared to pure aluminum, making them useful in reducing noise and vibration in automotive applications.

5.6. Zirconium Diboride (ZrB_2)

Zirconium diboride (ZrB_2) is an ultra-high temperature ceramic (UHTC) material composed of zirconium and boron. It is known for its exceptional thermal, mechanical, and chemical properties, making it a strong candidate for aerospace, defense, and high-performance industrial applications. ZrB_2 has a hexagonal crystal structure and a very high melting point (approximately 3245°C), which allows it to maintain structural integrity in extreme environments. Additionally, its good electrical and thermal conductivity, combined with strong covalent bonding, sets it apart from many other ceramics. In

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terms of mechanical performance, ZrB_2 exhibits excellent hardness, wear resistance, and stiffness. It is often used in applications such as hypersonic vehicle leading edges, cutting tools, and nuclear reactor components. One of the challenges with ZrB_2 is its relatively poor fracture toughness and oxidation resistance at high temperatures, which researchers often address by incorporating additives like silicon carbide (SiC). Despite this, its overall mechanical profile remains impressive, as summarized in the table below.

5.7. Silicon Carbide (SiC)

Silicon Carbide (SiC) is a robust ceramic material made of silicon and carbon, renowned for its remarkable hardness, exceptional thermal stability, and strong chemical inertness. It comes in various crystalline structures, with the most prevalent being hexagonal (α-SiC) and cubic (β-SiC). As a wide-bandgap semiconductor, SiC possesses unique electrical properties that make it ideal for use in high-voltage, high-frequency, and high-temperature electronics.Beyond electronics, SiC is highly valued in structural applications due to its ability to maintain strength and integrity at extreme temperatures, often exceeding 1600°C. This makes it an excellent choice for components such as armor, wear-resistant parts, and high-temperature applications.In terms of mechanical properties, SiC boasts impressive hardness (22–23 GPa), moderate fracture toughness (3–4 $MPa \cdot m^{1/2}$), and outstanding wear and oxidation resistance. Its excellent thermal conductivity (up to 120 W/m·K) and low thermal expansion make it especially suitable for thermal shock-resistant applications. Additionally, SiC's low density (around 3.2 g/cm^3) is advantageous for weight-sensitive industries such as aerospace and automotive.

5.8. Reinforcement Choice (Graphite, AL2O3 and Magnesium)

Reinforcing Aluminum 7075 (Al 7075), a high-strength, heat-treatable alloy mainly composed of aluminum, zinc, and magnesium, with materials such as Graphite, Al_2O_3 (Aluminum Oxide), and Magnesium, can substantially improve its mechanical properties and broaden its potential uses. Each of these reinforcing materials brings distinct features and benefits, which impact the composite's performance in various applications. For instance, Graphite enhances lubrication and wear resistance, while Al_2O_3 boosts hardness, strength, and corrosion resistance. Adding Magnesium can further improve the alloy's overall toughness and fatigue resistance, making the composite more versatile and reliable in demanding environments.

5.9. Graphite Reinforced AL 7075

Graphite, known for its exceptional lubricating properties, high thermal conductivity, and electrical conductivity, can significantly improve the wear resistance and reduce friction within the aluminum matrix. When incorporated into Al 7075 composites, graphite enhances self-lubricating qualities, making the material ideal for tribological applications such as bearings, pistons, and other high-friction components. Additionally, graphite contributes to better thermal conductivity, making the composite suitable for heat-dissipating applications like heat sinks and cooling systems.

5.10. Zrbr Reinforced AL 7075

Reinforcing Al 7075 with ZrB_2, a ceramic material, significantly improves the hardness and wear resistance of the composite. ZrB_2 particles provide excellent abrasion resistance, making the composite suitable for applications that involve high wear and tear, such as automotive engine components, cutting tools, and industrial machinery. Additionally, ZrB_2 enhances the thermal stability and high-temperature strength of ZrB_2, making it a good candidate for aerospace and defense applications, where both high strength and resistance to elevated temperatures are crucial. However, ZrB_2 $_3$ can also make the composite more brittle, reducing its ductility and fracture toughness, making the material prone to cracking under impact or high-stress conditions.

5.11. Silicon Carbide Reinforced Al 7075

Silicon Carbide (SiC) being a lightweight and highly reactive element can be used to reinforce Al 7075 to further reduce its density while enhancing strength and ductility. Silicon Carbide (SiC) particles in Al 7075 composites improve the tensile strength and fatigue resistance, which is especially beneficial for

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high-performance applications in the aerospace and automotive industries where both strength and weight reduction are critical. Silicon Carbide (SiC) also helps improve the corrosion resistance of the composite, particularly in environments where exposure to moisture and chemicals is common. However, excessive amounts of Silicon Carbide (SiC) can lead to alloy instability or poor formability due to its reactive nature, which may compromise the overall performance of the composite. The choice of reinforcement material for Al 7075 depends largely on the specific performance characteristics required for a given application. Silicon Carbide (SiC) is ideal for friction reduction, Al_2O_3 enhances wear and hardness properties, and Silicon Carbide (SiC) helps balance strength, weight, and corrosion resistance.

6. Material Ad Measurement

The fabrication process is carried out as two stages one is composite and hybrid composite. The composite measurements are carried as given table for both composites. The AL7075, Sic, ZrB2, GR alloy which is used forms metal matrix composition and where the AL7075 is mixed with using 1% GR, 2% ZrB2 in all compositions and SIC in the ratio of (8%,7%,6%,5%) to form compositions and these alloys are mixed thoroughly in the ball mill for 30 minutes to form the fine mixture (or) mixing in pestle motor thoroughly and the compositions are prepared. In this particular The AL7075, Sic, ZrB2, GR alloy as reinforcement for composite, increases the mechanical properties of aluminium7075.in the same way for The AL7075, Sic, ZrB2, GR alloy and graphite as reinforcement for hybrid composite. Many researches were done through powder metallurgy by incorporating ceramic particles as reinforcements on pure aluminium7075 whereas, in this work, a novel idea of reinforcing ceramic particles in aluminium7075 alloy is attempted. Powders of aluminium7075 were generated through ball milling for this work. This paper focuses on further enhancement of the properties of aluminium7075 alloy through powder metallurgy process by incorporation AND SIC and as hybrid reinforcement.

Table 2 Composition of Hybrid-Composite

S. No	AL 7075 Matrix	SiC	ZrB2	Graphite
	% in composition	% of Reinforcement	% of Reinforcement	% of Reinforcement
1	100	0	0	0
2	89	8	2	1
3	90	7	2	1
4	91	6	2	1
5	92	5	2	1

7. Stir Casting Process

Stir casting is a cost-effective and mass-production suitable process for creating metal matrix of the composites. It involves using a mechanical stirrer in a furnace to mix reinforcement material into a molten

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matrix, allowing for easy control of the composite's structure.

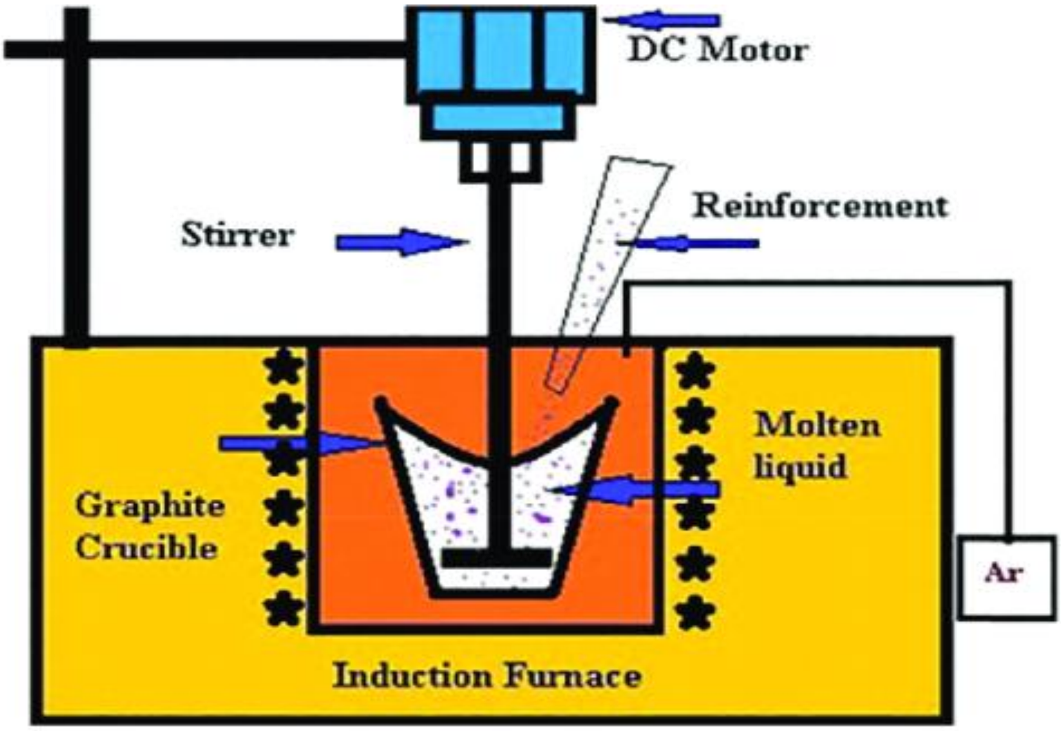

Figure 2 Schematic of Stir Casting Setup

In stir casting, a bottom-pouring furnace is ideal for immediate pouring after mixing, preventing solid particle settling. A mechanical stirrer, featuring a stirring rod and impeller blade (preferably a three-flat-bladed design for efficient axial flow and low power consumption), creates a vortex to evenly mix reinforcement powder, fed by an attached feeder, into the molten metal. The stirrer's speed is controlled by a variable speed motor. The resulting slurry can then be cast into permanent, sand, or lost-wax molds. It's involves stirring of melt, in which the melt is stirred continuously which exposes the melt surface to the atmosphere which tend to continuous oxidation of aluminum melt. As a result of continuous oxidation, the wet ability of the aluminum reduces and the reinforcement particles remain unmixed.

7.1. Stir Casting Machine Components

- Furnace
- Crucible
- Stirrer rod
- Stirrer impeller
- Mold
- Feeder
- Motor

7.2. Experimental Procedure and Equipment

- Aluminum powders of 50µm size are mixed with GR AND SIC and aluminum powder and GR AND SIC mixed in above given table powders are prepared.
- The mixture was carried out in pestle mortar to ensure uniform distribution of GR AND SIC withAluminum.
- Stir casting is a liquid state method for the fabrication of composite materials, in which adispersed phase is mixed with a molten matrix metal by means of mechanical stirring.

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Figure 3(a) Weighing of AL7075
3(b) Weighing of Graphite and Silicon Carbide for 4 Specimens

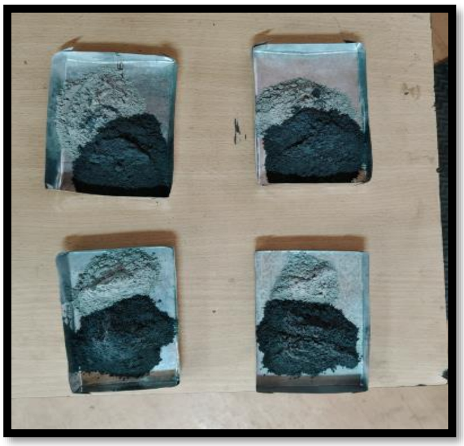

Figure 4 Compositions of Graphite and Silicon Carbide

Figure 5(a) Stir Casting Machine Operating Values 5(b) Stir Casting Heat Process

8. Testing of Specimens

8.1. Scanning Election Microscope

A typical SEM instrument, showing the electron column, sample chamber, EDS detector, electronics console, and visual display monitors. The scanning electron microscope (SEM) uses a focused beam of high-energy electrons to generate a variety of signals at the surface of solid specimens. X-ray generation is produced by inelastic collisions of the incident electrons with electrons in discrete orbital's (shells) of atoms in the sample. As the excited electrons return to lower energy states, they yield X-rays that are of a fixed wavelength (that is related to the difference in energy levels of electrons in different shells for a given element).

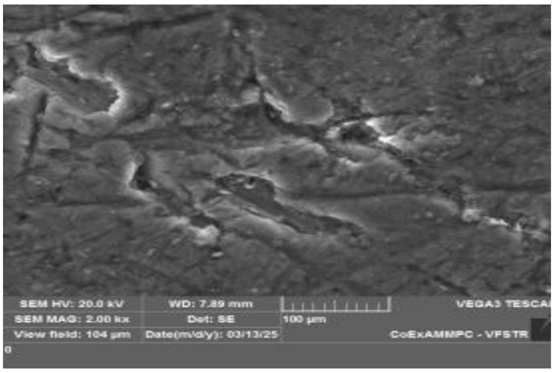

Figure 6 SEM Analysis on the 92% AL7075+ 5%Sic+2%ZrB2+1%Gr

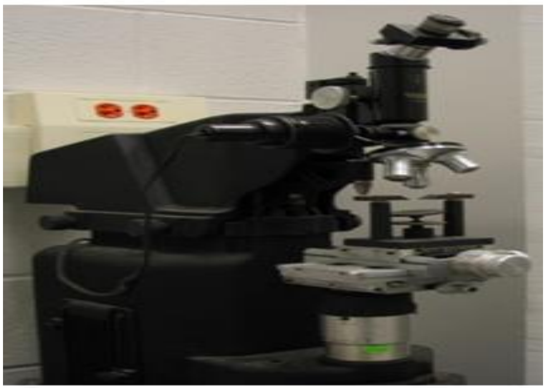

Figure 7 Vicker Hardness Tester

8.2. Compression Test

Compression testing is conducted to determine the behavior of materials under crushing loads, which helps evaluate the compressive strength, elastic limit, and modulus of elasticity of the specimen. 89% AL7075 + 8%Sic + 2%ZrB2 + 1%Gr, 90%AL7075 + 7%Sic + 2%ZrB2 + 1%Gr, 91%AL7075 + 6%Sic + 2%ZrB2 + 1%Gr, 92% AL7075+

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5%Sic+2%ZrB2+1%Gr MMCs, a high-strength aluminum alloy primarily used in aerospace, automotive, and structural applications, is known for its excellent strength-to-weight ratio and corrosion resistance. The specimens are prepared using the Stir Casting Process, a widely used liquid-state fabrication technique that ensures uniform distribution of reinforcements by stirring molten aluminum and then pouring it into a mold to solidify.

- **Machine Type:** Universal Testing Machine (UTM) with Compression Fixture
- **Load Capacity:** 100 kN or higher
- **Strain Rate:** 0.5 – 1 mm/min (as per ASTM E9)

Table 3 **Compression Test Results**

S.No	Compositions	Ultimate Compressive Strength(N/mm2)
Sample - 1	AL7075	315.333
Sample - 2	89% AL7075+ 8%Sic+2%ZrB2+1%Gr	400.958
Sample - 3	90%AL7075+7%Sic+2%ZrB2+1%Gr	633.12
Sample - 4	91%AL7075+6%Sic+2%ZrB2+1%Gr	603.658
Sample - 5	92% AL7075+ 5%Sic+2%ZrB2+1%Gr	522.043

The compression test of AL7075 specimens prepared by the stir casting process provides valuable insights into the material's strength, deformation behavior, and failure characteristics. The results can be used for validating simulation models and optimizing processing parameters for improved mechanical performance. The below graph is about the compression test on all AL7075.

8.3. Wear Test

Wear resistance is defined as the ability of stone to resist comprehensive external forces such as abrasion, edge cutting and impact etc. during service. The wear tests were conducted on 89% AL7075 + 8%Sic + 2%ZrB2 + 1%Gr, 90%AL7075 + 7%Sic + 2%ZrB2 + 1%Gr, 91%AL7075 + 6%Sic + 2%ZrB2 + 1%Gr, 92% AL7075+ 5%Sic+2%ZrB2+1%Gr MMCs as per ASTM G99-95 standard at room temperature using a computerized pin on disk wear test. The sliding wear test samples were machined of 8 mm nominal diameter and gauge length of 30 mm. The sliding wear test was conducted in Pin-on-disc wear testing machine with data acquisition system, which was used to evaluate the wear behavior of the 89% AL7075 + 8%Sic + 2%ZrB2 + 1%Gr, 90%AL7075 + 7%Sic + 2%ZrB2 + 1%Gr, 91%AL7075 + 6%Sic + 2%ZrB2 + 1%Gr, 92% AL7075+ 5%Sic+2%ZrB2+1%Gr MMCs against the toughened steel disc (En-32) with hardness of 60 HRC and surface roughness (Ra) 0.5 pm. The sliding wear occurs when the test samples were slide over rotating disc. The disc is coupled to a 1000 rpm capacity DC motor and the disc of 120 mm diameter. The load can be applied to test sample adding the dead weight up 200N through steel wire and pulley arrangement. The test sample was fitted to the collect

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and placed at a particular track diameter. The track diameter is to be changed for each sample and test conditions the machine is having the facility to vary the sliding wear parameter through controller. The particular parameters like sliding velocity, applied and time are selected. The experiment was conducted and after completing the time, the wear in microns and frictional force in Newton's were, recorded. From, the materials the we have done a three load conditions and three distances in machine

There are:

- Wear at 1kg load 200mts
- Wear at 1kg load 400mts
- Wear at 1kg load 600mts

Figure 9 wear test machine

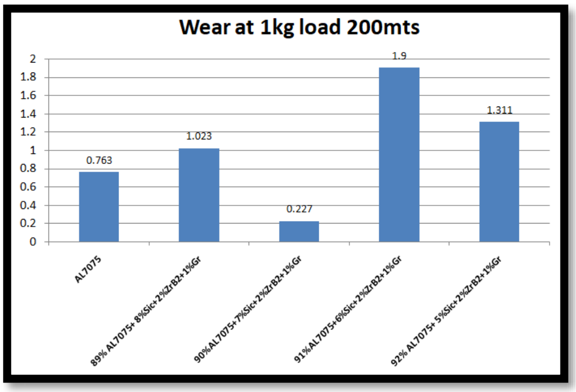

Figure 10 Graph Wear at 1 kg load 200mts

Figure 8 wear test specimens

Table 4 Wear at 1kg Load 200mts

Material	Initial weight	Final weight	Loss of weight
AL7075	17.998	17.235	0.763
89% AL7075+ 8%Sic+2%ZrB2+1%Gr	18.035	17.012	1.023
90%AL7075+7%Sic+2%ZrB2+1%Gr	18.125	17.898	0.227
91%AL7075+6%Sic+2%ZrB2+1%Gr	17.832	15.932	1.9
92% AL7075+ 5%Sic+2%ZrB2+1%Gr	17.023	15.712	1.311

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The graph is the wear analysis of the all 5 samples of AL7075 specimens with load of 1kg and 200mts displacement on rotating disc will have been shown the reduced in the final weight of specimen. The specimen of composition 90%AL7075+ 7%Sic+2%ZrB2+1%Gr shows the lesser wear rate on comparing with the remaining compositions. Higher rate of wear may arise at the Al 7075.

8.4. Design Procedure in CATIA

A thermal issue was identified in a desktop CPU, where the processor unit was frequently overheating due to an ineffective active cooling system. To address this, a passive heat sink was designed to enhance heat dissipation and maintain optimal operating temperatures.

1) Design Specifications

- **Base Plate Dimensions:** The heat sink's base measured **80 mm (width) × 75 mm (depth)** with a **thickness of 10 mm**. This base serves as the contact surface with the CPU and is critical for efficient thermal conduction.
- **Fin Configuration:** Mounted on the base were **six parallel lateral fins** designed to maximize surface area for convective heat transfer.
- **Fin Dimensions:** Each fin measured **40 mm in height × 5 mm in thickness × 75 mm in length**.
- **Fin Spacing:** A **10 mm gap** between each fin was maintained to promote better airflow and atmospheric heat exchange.
- **Design Software:** The heat sink was designed using **CATIA V5**, a powerful CAD software well-suited for precision modelling in mechanical engineering applications.
- **Manufacturing Readiness:** The final model was exported as an **IGES (Initial Graphics Exchange Specification) file**, enabling compatibility with CNC machinery. A **three-axis Vertical Machining Centre (VMC)** can now be used to manufacture the heat sink directly from the digital design.

2) Results and Discussions of Heat Sink in ANSYS

Heat sink serves as an essential element in a computer's thermal management system, engineered to dissipate heat from the CPU and other high-temperature components. By maximizing its surface area through the use of extended structures like fins or ridges, the heat sink facilitates greater thermal exchange with the surrounding air. This design encourages efficient heat transfer, especially when paired with active airflow from fans, helping to maintain safe operating temperatures and ensure system reliability. Igs file imported after perform the steady state thermal analysis using two materials AL7075 and (90%AL7075+ 7%Sic+ 2%ZrB2 +1%Gr) Finally find out the temperature distribution and Total heat flux as shown below figures.

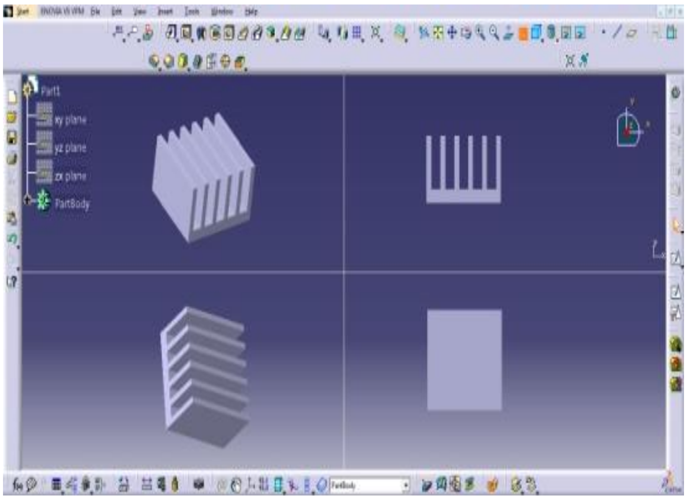

Figure 11 3D representation of 90%AL7075+7%Sic+2%ZrB2+1%Gr Material

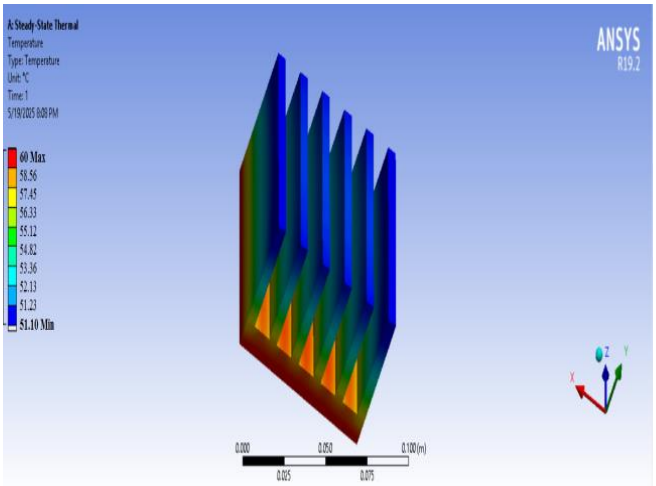

Figure 12 Temperature distribution of AL7075 Material

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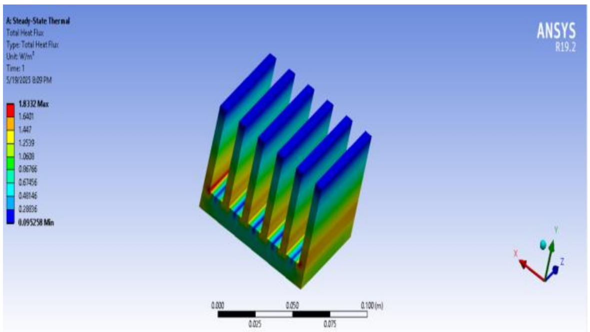

Figure 13 Total heat flux of AL7075 Material

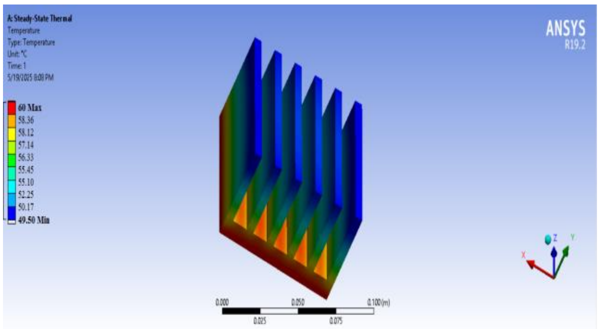

Figure 14 Temperature distribution of 90%AL7075+7%Sic+2%ZrB2+1%Gr Material

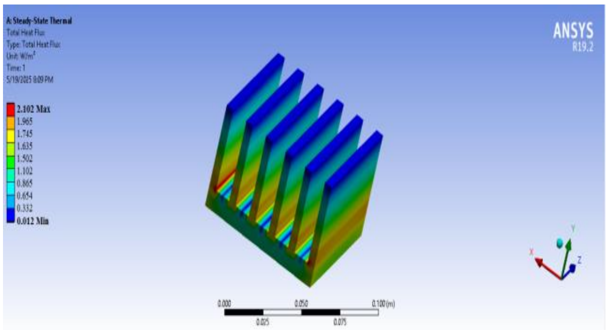

Figure 15 Total heat flux of 90%AL7075+7%Sic+2%ZrB2+1%Gr Material

8.5. Graph

This bar chart illustrates the temperature distribution in degrees Celsius for two different materials: "90% AL7075+ 7%SiC+2% ZrB2+1%Gr" and "AL7075". The composite material, "90%AL7075+7%SiC+2%ZrB2+1%Gr", shows a temperature of 49.5°C. In contrast, the "AL7075" material exhibits a higher temperature of 51.1°C. This indicates that the addition of SiC, ZrB2, and Gr to AL7075 results in a lower operating temperature compared to pure AL7075 under the conditions represented by this graph.

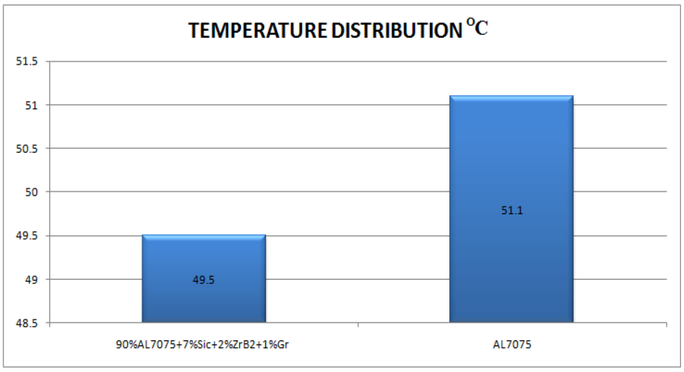

Figure 16 Temperature distribution

8.6. Total heat flux:

This bar chart illustrates the total heat flux, measured in W/mm², for two different materials: "90% AL7075+7%SiC+2%ZrB2+1%Gr" and "AL7075". The composite material, "90% AL7075+ 7%SiC+ 2%ZrB2+1%Gr", shows a higher total heat flux of 2.102 W/mm². In contrast, the "AL7075" material exhibits a lower total heat flux of 1.833 W/mm². This indicates that the addition of SiC, ZrB2, and Gr to AL7075 leads to an increase in the total heat flux compared to pure AL7075 under the conditions represented by this graph.

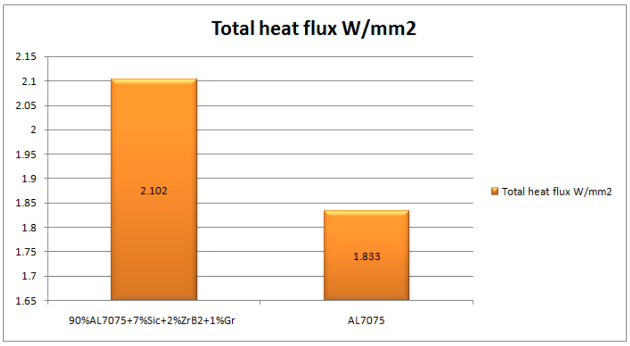

Figure 17 Total heat flux

Conclusion

The conclusions of the research work undertaken are;

- The AL7075, Sic, ZrB2, Graphite nano metal matrix composite materials have been fabricated by stir casting method followed by extrusion process.

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- The nano AL7075, Sic, ZrB2, Graphite particulates are evenly dispersed in the matrix alloy. The micro hardness of AL7075, Sic, ZrB2, and Graphite nano metal matrix composite material is superior to the matrix material. The micro hardness increases by the addition of 90% AL7075+ 7%Sic+2% ZrB2+1% Gr nano particulates in aluminum (AL7075) matrix alloy.
- The wear analysis on the all 5 compositions is tested at different displacements like 200mts, 400mts and 600mts respectively. All the wear analysis results at various displacements are shows very lesser wear rate on the 90%AL7075+7%Sic+2%ZrB2+1%Gr composition on comparing with remaining compositions.
- The inclusion of AL7075, Sic, ZrB2, Graphite nano particulates in AL7075 matrix alloy significantly enhanced the ultimate tensile strength and yield strength of the AL7075, Sic, ZrB2, Graphite nano metal matrix composite materials. The 90%AL 7075+7% Sic+2% ZrB2+1%Gr reinforced aluminum nano composite shows better increase in the ultimate tensile strength as compared to ultimate tensile strength of remaining compositions.
- The Scanning Electron Microscopy (SEM) on the all 5 compositions is tested at different 100 µm respectively. All the Scanning Electron Microscopy (SEM) at at 100 µm are shows very good and clean picture for the 90%AL7075+7%Sic+2%ZrB2+1%Gr composition on comparing with remaining compositions.
- Based on the all the testing's conducted on the aluminum (AL7075) alloy as discussed in above chapters, finally we are concluded that 90%AL7075+7%Sic+2%ZrB2+1%Gr MMCs possess grater mechanical behavior among the remaining all compositions of aluminum alloy MMC as specified and tested in this project.
- After fabrication and testing best material and existing material AL7075 using these properties enter in ansys software create the heat sink in CATIA.
- The composite material "90%AL7075+7% SiC+2%ZrB2+1%Gr" having a lower temperature of 49.5°C compared to pure AL7075 at 51.1°C, indicating a reduced operating temperature due to the additions. Conversely, the second bar chart reveals that the same composite material exhibits a higher total heat flux of 2.102 W/mm² compared to pure AL7075 at 1.833 W/mm², signifying an increased heat transfer capacity.
- The composite material 90%AL7075+7%SiC+ 2%ZrB2+1%Gr" has a higher total heat flux of 2.102 W/mm² compared to pure AL7075 at 1.833 W/mm². This indicates that adding SiC, ZrB2, and Gr to AL7075 increases its total heat flux.

Scope of Future Work

There is a very wide scope for future scholars to explore this area of research, this work can be further extended to study other aspects of such composites like use of other potential fillers for development of hybrid composites and evaluation of their mechanical and erosion behavior and the resulting experimental findings can be similarly analyzed.

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