THE PROCESSING TECHNIQUES AND BEHAVIOUR OF ALUMINUM METAL MATRIX WITH DIFFERENT REINFORCEMENT MATERIALS

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ABSTRACT

Improvement in the mechanical properties and retainment of properties is an essential requirement for the industrial application. The properties of the composite not only depend on reinforcement materials but it also depends on the manufacturing technique adopted for processing of the composites. This paper discusses various fabrication techniques of composite. This paper summarizes the various aluminium grades used in the industry and how its properties can be improved using different reinforcement materials like carbides, oxides, organic compounds and industrial agro waste. It reviews the influence of different reinforcement material on mechanical properties like hardness, tensile strength, density, and percentage elongation. This also paper reviews comprehensive data related to the research work carried with different various weight percentage reinforcement material.

KEYWORDS: Metalmatrix Composite, Industrial Waste, RHA & Casting

INTRODUCTION

The industrial revolution has also led to the development of new materials in the automobile, aerospace and various processing industries. Composite are one among the developing materials due to its improved properties which satisfied the requirements of the various industries. Composites are made of several parts or element. Composite materials are defined as a material which is made of two or more materials at a microscopic scale and has chemically distinct phases. Composite materials can also be defined as the combination of two or more materials to enhance the properties of the parent material. The composite material constitutes of two materials viz. Reinforcing materil and Matrix material. Properties of composite materials can be modified according to required final properties of a component or the product. Metal matrix composite (MMC), polymer matrix composite (PMC), ceramic matrix composite (CMC), and other inorganic composites are glass and carbon composite, these above composites are classified based on the matrix material used during processing of composite materials. Composites can also be classified based on the structure and geometry of reinforcement materials – dispersive composites, particulate composite and fibrous composite.

MMC are defined as the composite with at least two constituent materials with one being a metal and the other being metals, ceramics or organic compounds. The purpose of manufacturing of composites is not only
concerned to increase the firmness or strength, it also has to serve the various other purposes like improved temperature range, mechanical properties, abrasion resistance, dimensional stability and reduce specific weight compared with pure metal. The most widely used metal matrices, mainly for their price and variability. Aluminium alloys are most preferred material for engineering application due to its advantage of low weight and excellent thermal properties over other material [1]. Aluminium matrix composite is the most competitive composite in emerging industrial era. Aluminium matrix improves its properties when it is reinforced with hard ceramic materials like Al₂O₃, SiC, and B₄C etc [2].

Properties of Matrix and Particles Reinforcements

Aluminium and its alloys have a excellent industrial applications due to its properties, however there are some of the drawbacks of the material can be overcome by addition of reinforcement material. Choosing of appropriate aluminium alloy with characteristic alloying elements for desired industrial application where the mechanical properties are taken into consideration [3]. The aluminium alloy composite materials have high strength, high stiffness, high thermal stability, more corrosion and wear resistance and high fatigue life hence aluminium has found to be best alternative for industrial applications [4]. The property of MMC mainly depends on the processing method adopted for producing the composites. Aluminium alloys are normally identified by a four figure system which is now universally accepted. Table 1 describes the designation for aluminium wrought alloys.

Table 1: Designation of Aluminium Alloys

| Designation | Principle Element        |
|-------------|--------------------------|
| 1xxx        | Unalloyed (Pure)         |
| 2xxx        | Copper                   |
| 3xxx        | Manganese                |
| 4xxx        | Silicon                  |
| 5xxx        | Magnesium                |
| 6xxx        | Magnesium+ Silicon       |
| 7xxx        | Zinc                     |
| 8xxx        | Lithium/Tin              |

Oxides, carbides and other organic compounds can be used as reinforcement materials in the metal matrix composites. Reinforcement particle changes the structural and mechanical properties of the matrix material. The most commonly used reinforcement materials are listed in table 2. Selection of reinforcement materials mainly depends on the required properties for industrial application. For operation like toughening mechanisms, the microstructure should be homogeneous; it means the metal particles should be uniformly distributed in the ceramic particles [5].

Table 2: Reinforcement Materials and its Properties

| Reinforcement | Melting | Density Point °C/cm³ | Hardness Gpa |
|---------------|---------|----------------------|--------------|
| SiC           | 2730    | 3.21                 | 32.0         |
| B₄C           | 3500    | 2.52                 | 38.0         |
| TiC           | 3250    | 4.93                 | 31.4         |
| Al₂O₃         | 2045    | 3.97                 | 20.7         |
| TiB₂          | 2980    | 4.52                 | 25.0         |
| Si₃N₄         | 1900    | 3.17                 | 15.5         |

Apart from oxides, carbides and other compounds industrial agro wastes can also be used as reinforcement material in the manufacturing of MMC. Fly ash, red mud, palm oil clinker, rice husk ash, coconut shell and sugarcane bagasse are some of the examples of industrial agro waste material [6]. The chemical compositions of some of the
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industrial waste are listed in the tables 3-7.

### Table 3: Chemical Composition of Fly Ash [7]

|        | SiO$_2$ | Al$_2$O$_3$ | Fe$_2$O$_3$ | TiO$_2$ | Carbon/LOI |
|--------|---------|-------------|------------|---------|------------|
|        | 56.92   | 29.9        | 8.44       | 2.75    | 1.99       |

### Table 4: Chemical Composition of Bagasse Ash [8]

|        | SiO$_2$ | Al$_2$O$_3$ | Fe$_2$O$_3$ | CaO | MgO | SO$_3$ | K$_2$O | Na$_2$O | Others | LOI |
|--------|---------|-------------|------------|-----|-----|--------|-------|--------|--------|-----|
|        | 77.29   | 10.95       | 3.66       | 2.09| 1.49| 0.49   | 3.16  | 0.38   | Balance| 3.28|

### Table 5: Chemical Composition of Coconut Shell Ash [9]

|        | SiO$_2$ | MgO | Al$_2$O$_3$ | Fe$_2$O$_3$ | CaO | K$_2$O | Na$_2$O | ZnO | MnO |
|--------|---------|-----|-------------|------------|-----|-------|--------|-----|-----|
|        | 45.05   | 16.2| 15.6        | 12.4       | 0.57| 0.52  | 0.45   | 0.3 | 0.22|

### Table 6: Chemical Composition of Palm Oil Clinker [10]

|        | SiO$_2$ | Fe$_2$O$_3$ | K$_2$O | Al$_2$O$_3$ | CaO | MgO | P$_2$O$_5$ | TiO$_2$ | Na$_2$O |
|--------|---------|------------|-------|-------------|-----|-----|------------|---------|---------|
|        | 81.8    | 5.18       | 4.66  | 3.5         | 2.3| 1.24| 0.76       | 0.17    | 0.14    |

### Table 7: Chemical Composition of Rice Husk Ash [11]

|        | SiO$_2$ | Al$_2$O$_3$ | MgO | Fe$_2$O$_3$ | K$_2$O | SO$_3$ | Na$_2$O | CaO | LOI | Others |
|--------|---------|-------------|-----|------------|-------|--------|--------|-----|-----|--------|
|        | 97.095  | 1.135       | 0.825| 0.316      | 0.181| 0.146  | 0.092  | 0.073| 0.965| Balance|

Manufacturing Techniques

The property of MMC not only depends on the type of reinforcement but it also mainly depends on the manufacturing technique adopted for producing the composites. The manufacturing technique plays an important role in improving the physical appearance and developing different mechanical properties of the composite. The manufacturing techniques of the composite are classified based on the nature and behaviour of raw material. The various techniques for processing a composites are-

- Stir casting
- Friction stir processing
- Squeeze casting
- Chemical vapour deposition
- Physical vapour deposition
- In-situ fabrication technique
- Powder metallurgy
Impact Factor (JCC): 7.6197

Figure 1: Stir Casting

Figure 2: Friction Stir Processing

Figure 3: Squeeze Casting

Figure 4: Chemical Vapour Deposition

Figure 5: Physical Vapour Deposition

Figure 6: In-Situ Fabrication Technique
Influence of Reinforcement on MMC’s

The different reinforcement materials used in developing the metal matrix are carbides, oxides, organic compounds, industrial agro waste and so on. The properties of reinforcement also play an important role in deciding the property of the composite along with manufacturing technique used. The different factors such as density, hardness, tensile test, and percentage elongation are considered in the study of various reinforcement materials for developing the composites. Present paper mainly focuses on the stir casting technique for manufacturing of composite.

Gaurav A et al. [38] did a comparative study of AA6351 reinforced with SiC/RHA the results showed that the density of the composite increased with the increased content of SiC while with the increase in content of RHA the density of composite decreased. The micro hardness of the composite with SiC and RHA as reinforcement increased from 52.82 VHN to 72.5 and 61.3 VHN respectively for 8% reinforcement; this is due to uniform distribution of reinforcement in the matrix melt & dislocation density. The presence of hard particles in the in the reinforcement transferring of load from matrix to reinforcement has improved the tensile strength of the composite developed. S Nayaket, al. [39] studied tensile and hardness characterization for the composite, lower the percentage of zirconia higher the tensile strength and lowers the hardness value of the composite. PB Pawaret, al. [4] studied the hardness value of silicon carbide particle based aluminium composite and found highest hardness value of 60.3 BHN for 10% SiC reinforcement which is better than the aluminium metal. P Ashwathet, al. [40] evaluated the property of Al 2xxx with Al2O3 and SiC, alumina as reflected the better mechanical properties when compared with SiC. Table 8 gives the various different reinforcement aluminium metal matrix and its behaviour with and without reinforcement.

CONCLUSIONS

This paper presents the various aspects regarding the manufacturing of metal matrix by stir casting with different combination of reinforcement materials used in synthesis of MMC or Hybrid MMC and how it influences the mechanical properties has been reviewed. This paper also focuses on the use of industrial Agro waste as reinforcement material and its influence on the properties of the matrix material for manufacturing of the green composite. The data results showed that
with the addition of the agro waste as reinforcement material the mechanical properties like tensile strength, hardness has been increased and the weight of the prepared composite has been reduced due to less density of the reinforcement material. This paper provides the future scope for the researcher to study the behaviour of the reinforcement material on different grades of aluminium matrix composites.

Table 8: Properties of MMC with Different Reinforcement Materials

| Composition References | Fabrication  | Hardness (MPa) | Tensile/Yield (MPa) | Density (g/cm²) | % | Elongation |
|------------------------|--------------|----------------|--------------------|-----------------|----------|-----------|
| AI6082                 | Stir casting | 31.6           | 161.5              | 2.69            | 8.6      | [12]      |
| AI6092 - 3wt.% Gr      |              | 31.0           | 160.0              | 2.67            | 8.0      |           |
| AI6082 - 6wt.% Gr      |              | 30.2           | 158.0              | 2.64            | 7.4      |           |
| AI6082 - 9wt.% Gr      |              | 29.0           | 155.0              | 2.62            | 7.0      |           |
| AI6082 - 12wt.% Gr     |              | 28.3           | 152.0              | 2.58            | 6.8      |           |
| AI6061 - 5wt.% SiC     | Stir casting |                |                    | 132.3           | 6.7      | [13]      |
| AI6061 - 10wt.% SiC    |              | 143.4          |                    | 2.71            | 2.66     |           |
| AI6061 - 15wt.% SiC    |              | 150.9          |                    | 2.73            | 2.66     |           |
| AI6061 - 5wt.% SiC/Gr  |              | 144.7          |                    | 2.66            | 2.66     |           |
| AI6061 - 10wt.% SiC/Gr |              | 173.3          |                    | 2.64            | 2.64     |           |
| AI6061 - 15wt.% SiC/Gr |              | 192.4          |                    | 2.63            | 2.63     |           |
| AI7075 - 2wt.% A3h + 1wt. % Gr | Stir casting | 87.3          | 259.3              |                | 6.7      | [16]      |
| AI7075 - 2wt.% A3h + 3wt. % Gr |              | 92.4          | 255.4              |                | 6.4      |           |
| AI7075 - 2wt.% A3h + 5wt. % Gr |              | 94.3          | 272.3              |                | 5.8      |           |
| AI7075 - 4wt.% A3h + 1wt. % Gr |              | 87.3          | 267.3              |                | 6.3      |           |
| AI7075 - 4wt.% A3h + 3wt. % Gr |              | 94.2          | 283.4              |                | 5.9      |           |
| AI7075 - 4wt.% A3h + 5wt. % Gr |              | 95.4          | 290.3              |                | 5.2      |           |
| AI7075 - 6wt.% A3h + 1wt. % Gr |              | 88.3          | 294.2              |                | 5.9      |           |
| AI7075 - 6wt.% A3h + 3wt. % Gr |              | 95.4          | 296.3              |                | 5.4      |           |
| AI7075 - 6wt.% A3h + 5wt. % Gr |              | 99.6          | 299.4              |                | 4.9      |           |
| AI6051 - 2wt.% MoS2 + 4wt. % Al2O3 | Stir casting | 94.5          | 201.5              | 201.5 N/mm²     | 6.7      | [14]      |
| AI6051 - 2wt.% MoS2 + 8wt. % Al2O3 |              | 98.0          | 221.4              | 221.4 N/mm²     | 6.4      |           |
| AI6051 - 2wt.% MoS2 + 12wt. % Al2O3 |              | 106.23        | 243.4              | 243.4 N/mm²     | 5.8      |           |
| AI6051 - 4wt.% MoS2 + 4wt. % Al2O3 |              | 98.7          | 219.3              | 219.3 N/mm²     | 5.4      |           |
| AI6051 - 4wt.% MoS2 + 8wt. % Al2O3 |              | 104.7         | 237.2              | 237.2 N/mm²     | 4.9      |           |
| AI6051 - 4wt.% MoS2 + 12wt. % Al2O3 |              | 107.5         | 259.5              | 259.5 N/mm²     | 4.5      |           |
| AI6051 - 8wt.% MoS2 + 4wt. % Al2O3 |              | 97.37         | 207.4              | 207.4 N/mm²     | 3.7      |           |
| AI6051 - 8wt.% MoS2 + 8wt. % Al2O3 |              | 101.2         | 227.8              | 227.8 N/mm²     | 3.2      |           |
| AI6051 - 8wt.% MoS2 + 12wt. % Al2O3 |              | 104.5         | 251.3              | 251.3 N/mm²     | 2.9      |           |
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| Composition References | Fabrication | Hardness | Tensile/Yield | Density | %  |
|------------------------|-------------|----------|---------------|---------|----|
| AA6062                 | Stir casting| 49.5 VHN | 2.69 g/cm³    | [15]    |
| AA6062 + 3wt.% Si₃N₄ |             | 82.0 VHN | 2.70 g/cm³    |
| AA6062 + 6wt.% Si₃N₄ |             | 85.0 VHN | 2.72 g/cm³    |
| AA6062 + 9wt.% Si₃N₄ |             | 91.0 VHN | 2.74 g/cm³    |
| AA6062 + 12wt.% Si₃N₄|             | 91.5 VHN | 2.75 g/cm³    |
| A7075                  | Stir casting|         | 157N/mm²      | [17]    |
| A7075 + 1wt.% BaC     |             | 250N/mm² |
| A7075 + 2wt.% BaC     |             | 255N/mm² |
| A7075 + 3wt.% BaC     |             | 270N/mm² |
| A7075 + 4wt.% BaC     |             | 285N/mm² |
| A2024                  | Hot-extrusion| 489 MPa  | 1.17          |
| A2024 + 10vol.% BaC   |             | 573 MPa  |
| A2024 + 20vol.% BaC   |             | 626.7 MPa|
| A7075 + 5%BaC+35%Gr+6%Al₂O₃| Stir casting| 140 BHN  |
| A7075 + 35%BaC+45%Gr+75%Si₃N₄| Hot-extrusion| 162 BHN  |
| AL25                   | Stir casting| 37.8 BHN | 452 MPa       |
| LM25 + 3wt.% Al₂O₃ + 2wt.% Al₂O₃ | Stir casting| 33.4 BHN |
| LM25 + 2wt.% Al₂O₃ + 3wt.% Al₂O₃ | Stir casting| 48.5 BHN |
| A2024 + 5% SiC + 5% FA | Powder metallurgy| 138.9 BHN |
| A2024 + 10% SiC + 10% FA|             | 167.6 BHN |
| A2024                  | Stir casting| 80 BHN 236N/mm² | 19.4 |
| A2024 + 5% SiC         |             | 83 BHN 248N/mm² | 19.0 |
| A2024 + 10% SiC        |             | 87 BHN 265N/mm² | 18.2 |
| A2024 + 5% FA          |             | 80 BHN 243N/mm² | 10.3 |
| A2024 + 10% FA         |             | 83 BHN 263N/mm² | 15.8 |
| A2024 + 5% SiC + 5% FA |             | 88 BHN 276N/mm² | 14.4 |
| A2024 + 5% SiC + 10% FA|             | 90 BHN 278N/mm² | 13.8 |
| A2024 + 5% SiC + 5% FA |             | 93 BHN 285N/mm² | 12.3 |
| A2024 + 10% SiC + 10% FA|             | 95 BHN 293N/mm²| 11.9 |

| Composition References | Fabrication | Hardness | Tensile/Yield | Density | %  |
|------------------------|-------------|----------|---------------|---------|----|
| A10602                 | Stir casting| 31.6 BHN | 151.3 MPa     | 2.69 g/cm³ | 8.6 |
| A10602 + 3wt.% Cr      |             | 31.0 BHN | 160.6 MPa     | 2.67 g/cm³ | 8.0 |
| A10602 + 6wt.% Cr      |             | 30.2 BHN | 158.0 MPa     | 2.64 g/cm³ | 7.4 |
| A10602 + 9wt.% Cr      |             | 36.0 BHN | 155.0 MPa     | 2.62 g/cm³ | 7.0 |
| A10602 + 12wt.% Cr     |             | 38.3 BHN | 152.0 MPa     | 2.58 g/cm³ | 6.8 |
| A6061 + 5wt%SiC        | Stir casting| 133.9 MPa| 2.70 g/cm³    | [23]    |
| A6061 + 5wt%SiC        |             | 143.4 MPa| 2.71 g/cm³    |
| A6061 + 10wt%SiC       |             | 150.9 MPa| 2.73 g/cm³    |
| A6061 + 15wt%SiC       |             | 144.7 MPa| 2.68 g/cm³    |
| A6061 + 30wt%SiC       |             | 173.3 MPa| 2.64 g/cm³    |
| A7075 + 2wt% Ash + 1wt% Cr | Stir casting| 87.3 BHN | 259.3 MPa     | 6.7 |
| A7075 + 2wt% Ash + 3wt% Cr |             | 92.4 BHN | 265.4 MPa     | 6.4 |
| A7075 + 2wt% Ash + 5wt% Cr |             | 94.3 BHN | 272.5 MPa     |
| A7075 + 4wt% Ash + 2wt% Cr |             | 87.3 BHN | 267.5 MPa     | 6.3 |
| A7075 + 4wt% Ash + 3wt% Cr |             | 94.2 BHN | 283.4 MPa     | 5.9 |
| A7075 + 4wt% Ash + 5wt% Cr |             | 95.7 BHN | 293.0 MPa     | 5.2 |
| A7075 + 6wt% Ash + 1wt% Cr |             | 86.3 BHN | 294.2 MPa     |
| A7075 + 6wt% Ash + 3wt% Cr |             | 95.4 BHN | 296.3 MPa     |
| A7075 + 6wt% Ash + 5wt% Cr |             | 99.6 BHN | 299.4 MPa     |
| A6061 + 2wt% MoS₂ + 4wt% Al₂O₃ | Stir casting| 94.5 BHN | 261.5 N/mm²  | [14]    |
| A6061 + 2wt% MoS₂ + 8wt% Al₂O₃ |             | 98.0 BHN | 221.4 N/mm²  |
| A6061 + 2wt% MoS₂ + 12wt% Al₂O₃ |             | 102.5 BHN | 243.5 N/mm²  |
| A6061 + 4wt% MoS₂ + 4wt% Al₂O₃ |             | 96.5 BHN  |
| A6061 + 4wt% MoS₂ + 8wt% Al₂O₃ |             | 104.7 BHN | 237.2 N/mm²  |
| A6061 + 4wt% MoS₂ + 12wt% Al₂O₃ |             | 107.7 BHN | 256.5 N/mm²  |
| A6061 + 8wt% MoS₂ + 4wt% Al₂O₃ |             | 97.3 BHN  | 207.4 N/mm²  |
| A6061 + 8wt% MoS₂ + 8wt% Al₂O₃ |             | 103.3 BHN | 237.8 N/mm²  |
| A6061 + 8wt% MoS₂ + 12wt% Al₂O₃ |             | 104.2 BHN | 251.3 N/mm²  |
| Composition References | Fabrication | Hardness | Tensile/Yield | Density % | Technique |
|------------------------|-------------|----------|---------------|-----------|------------|
| AA6082 - 3 wt. % Si3N4 | Stir casting | 45.5 HVN | 2.69 g/cm³ | [5]       |            |
| AA6082 - 6 wt. % Si3N4 |            | 82.0 HVN | 2.70 g/cm³ |            |            |
| AA6082 - 9 wt. % Si3N4 |            | 86.0 HVN | 2.72 g/cm³ |            |            |
| AA6082 - 12 wt. % Si3N4|            | 91.0 HVN | 2.74 g/cm³ |            |            |
| AA6082 - 15 wt. % Si3N4|            | 93.5 HVN | 2.75 g/cm³ |            |            |
| A17075 - 3 wt. % B4C  | Stir casting| 157 N/mm²|              | [7]       |            |
| A17075 - 6 wt. % B4C  |            | 230 N/mm²|              |            |            |
| A17075 - 9 wt. % B4C  |            | 232 N/mm²|              |            |            |
| A17075 - 12 wt. % B4C |            | 285 N/mm²|              |            |            |
| A1024 - 7 wt. % B4C  | Hot-extrusion| 450 MPa | 14.7          | [18]      |            |
| A1024 - 10 vol. % B4C |            | 573 MPa | 1.73          |            |            |
| A1024 - 20 vol. % B4C |            | 626 MPa | 1.84          |            |            |
| A10705 - 7 wt. % B4C  | Stir casting| 378 BHN | 64.24 MPa  | [20]      |            |
| A10705 - 10 wt. % B4C |            | 52.8 BHN| 51.75 MPa  |            |            |
| A10705 - 15 wt. % B4C |            | 46.5 BHN| 54.60 MPa  |            |            |
| A1 - 5 wt. % B4C     | Powder metallurgy | 112.8 BHN | 371 MPa | [21]     |            |
| A1 - 10wt % B4C     |            | 138.0 BHN | 483 MPa |            |            |
| A1 - 15 wt. % B4C   |            | 197.6 BHN | 482 MPa |            |            |
| A1024 - 3 wt. % SiC  | Stir casting| 80 BHN | 2.60 g/cm³ | [22]      |            |
| A1024 - 5 wt. % SiC  |            | 81 BHN | 2.40 g/cm³ |            |            |
| A1024 - 7 wt. % SiC  |            | 87 BHN | 2.39 g/cm³ |            |            |
| A1024 - 9 wt. % SiC  |            | 89 BHN | 2.39 g/cm³ |            |            |
| A1024 - 11 wt. % SiC |            | 90 BHN | 2.10 g/cm³ |            |            |
| A1024 - 13 wt. % SiC |            | 95 BHN | 2.10 g/cm³ |            |            |
| A10705 - 5 wt. % SiC | Stir casting| 70 BHN | 224 N/mm² | [23]      |            |
| A10705 - 10 wt. % SiC|            | 100 BHN | 146 N/mm² | 3.00 g/cm³|            |
| A10705 - 15 wt. % SiC|            | 135 BHN | 135 N/mm² | 3.10 g/cm³|            |
| A10705 - 20 wt. % SiC|            | 110 BHN | 148 N/mm² | 3.16 g/cm³|            |
| A1-MgSi          | Stir casting| 67 BHN | 2.81 g/cm³ | [24]      |            |
| A1-MgSi + 10% SiC  |            | 77 BHN | 2.74 g/cm³ |            |            |
| A1-MgSi + 20% SiC  |            | 74 BHN | 2.69 g/cm³ |            |            |
| A1-MgSi + 30% SiC  |            | 72 BHN | 2.63 g/cm³ |            |            |
| A1-MgSi + 40% SiC  |            | 67 BHN | 2.64 g/cm³ |            |            |
| A1-MgSi          | Stir casting| 67 BHN | 2.81 g/cm³ | [25]      |            |
| A1-MgSi + 10% Al2O3|            | 75 BHN | 2.79 g/cm³ |            |            |
| A1-MgSi + 20% RHA  |            | 69 BHN | 2.66 g/cm³ |            |            |
| A1-MgSi + 30% RHA  |            | 66 BHN | 2.66 g/cm³ |            |            |
| A1-MgSi + 40% RHA  |            | 64 BHN | 2.62 g/cm³ |            |            |
| A1               | Stir casting| 65 BHN | 2.72 g/cm³ | [26]      |            |
| A1-MgSi + 20% SiC  |            | 74 BHN | 2.70 g/cm³ |            |            |
| A1-MgSi + 30% SiC  |            | 83 BHN | 2.70 g/cm³ |            |            |
| A1-MgSi + 50% SiC  |            | 96 BHN | 2.69 g/cm³ |            |            |
| A1-MgSi          | Stir casting| 67 BHN | 2.72 g/cm³ | [27]      |            |
| A1-MgSi + 3% B4C  |            | 77 BHN | 2.69 g/cm³ |            |            |
| A1-MgSi + 5% B4C  |            | 82 BHN | 2.54 g/cm³ |            |            |
| A1-MgSi + 7% B4C  |            | 85 BHN | 2.54 g/cm³ |            |            |
| A1-MgSi + 10% B4C |            | 88 BHN | 2.54 g/cm³ |            |            |
| A1-MgSi         | Die casting| 65 BHN | 199 MPa  | [28]      |            |
| A1-MgSi + 3% Ba    |            | 70.2 BHN | 215 MPa | 1.75 g/cm³|            |
| A1-MgSi + 5% Ba    |            | 67.5 BHN | 208 MPa | 1.75 g/cm³|            |
| A1-MgSi + 7% Ba    |            | 67.4 BHN | 210 MPa | 1.75 g/cm³|            |
| A1-MgSi         | Stir casting| 70.4 BHN | 164 MPa | 2.84 g/cm³| [29]      |
| A1 + 5% Ba        |            | 73.6 BHN | 174 MPa | 2.67 g/cm³|            |
| A1 + 10% Ba       |            | 77.5 BHN | 176 MPa | 2.60 g/cm³|            |
| A1 + 15% Ba       |            | 84.7 BHN | 155 MPa | 2.54 g/cm³|            |
| A1 + 20% Ba       |            | 90.7 BHN | 144 MPa | 2.46 g/cm³|            |
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