PRODUCTION & CHARACTERIZATION OF AL 2024-SiC<sub>p</sub> METAL MATRIX COMPOSITE USING STIR CASTING

ATUL KUMAR<sup>1</sup>, SUDHIR KUMAR<sup>2</sup> & ROHIT GARG<sup>3</sup>

<sup>1</sup>Research Scholar, Suresh Gyan Vihar University, Jaipur, Rajasthan India
<sup>2,3</sup>Professor in ME Department, (GNIT), Greater Noida, Uttar Pradesh, India

ABSTRACT
The substantial use of aluminum reinforced with silicon carbide composites in various structural applications has led to the need of finding a efficient technical production techniques for these composites. Uniformity, machinability and intra-grain reactions of the constituents represent the most problems related to these composites. Production of uniform and strong components made from aluminum-silicon carbide composites can be achieved with the help of stir casting. Metal Matrix Composites (MMCs) have developed a high interest in modern times for potential applications in aeronautical and automobile industries. Achievement of a uniform distribution of reinforcement in the matrix is difficult and it has direct effect on the properties of the composite. Present thesis attempts to develop aluminum based silicon carbide particulate Metal Matrix Composites. Aluminum (Al2024) has been chosen as matrix and SiC (320-grit) as reinforcement material. Trials are done by changing the weight fraction of SiC (10% &15%), while other parameters are kept constant. An increase in hardness and strength has been observed with the increase in weight percentage of SiC. The results were further justified by comparing with other investigators.

KEYWORDS: Stir Casting, Microhardness, Light Optical Microscopy, SEM-EDS, XRD

INTRODUCTION
As defined by Jartiz, [13] Composites are multifunctional materials that give properties not obtained from any individual material. They are embedded structures made by combining two or more suitable materials, different in composition and properties and form. Van Suchetelan [12] defines composite materials as heterogeneous materials having multiple solid phases & the combination has its own distinctive properties. Metals are extremely versatile engineering materials. The broad use of metallic alloys in engineering shows not only their strength and toughness but also the relative simplicity and low cost of fabrication of engineering components by a wide range of manufacturing processes. The necessity of achieving better properties that those obtained in monolithic metals has allowed the development of different kinds of MMCs. However, the cost of achieving appropriate improvements remains a challenge in many potential MMC applications. The goal is to combine the required characteristics of metals with ceramics. Metals have properties such as high strength, ductility and high temperature resistance, whereas ceramics are stiff and strong but brittle. The Aluminum has Young's moduli of 70 GPa, coefficients of thermal expansion of 24 × 10-6 °C, and yield strengths of 35 MPa while value of same properties for silicon carbide are 400 GPa,4 × 10-6/°C and 600 MPa. The main function of the reinforcement is to bear most of the applied load, whereas the matrix fastens the reinforcements together, and imparts the external loads to the individual reinforcement [5]. One of the main problems is focused on ensuring the optimum degree of
chemical contact (or wetting) between the fibers or reinforcements and the matrix. Composites consist of one or more discontinuous phases embedded in a continuous phase. The discontinuous phase namely reinforcement is harder and stronger than the continuous phase, while the continuous phase known as the ‘matrix’. A few advantages of MMC are high strength and toughness, low thermal shock, improved fabricability. Aluminum metal matrix composites are advanced materials due to its light weight, high strength, high specific modulus and good wear resistance. These types of properties are not present in a conventional material. [1] The application of aluminum metal matrix composites has been limited to aerospace and military weapon because of high processing costs. In recent times, aluminum matrix composites have been used for engine pistons, cylinder liners, brakes etc. Composite are classified in many ways [15]. The three broad classes of composites are:

- Metal Matrix Composites (MMC)
- Ceramic Matrix Composite
- Polymer Matrix Composites (PMC)

MATERIALS OF FABRICATION

- Matrix Material

Aluminum alloy Al 2024 was used as matrix material. The main alloying element of Al 2024 alloy is copper. The second is magnesium, which is predominantly added to increase the wetting between matrix and reinforcement. Composition of Al 2024 is tabulated in table 2.

<table>
<thead>
<tr>
<th>Si</th>
<th>Fe</th>
<th>Cu</th>
<th>Mn</th>
<th>Mg</th>
<th>Cr</th>
<th>Zn</th>
<th>Ti</th>
<th>Others (Each)</th>
<th>Others (Total)</th>
<th>Balance</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>0.5</td>
<td>3.8-4.9</td>
<td>0.30-0.9</td>
<td>1.2-1.8</td>
<td>0.1</td>
<td>0.25</td>
<td>0.15</td>
<td>0.05</td>
<td>0.15</td>
<td>Aluminum</td>
</tr>
</tbody>
</table>

Al 2024 alloys have high strength and excellent machining properties. They possess low formability and corrosion resistance in the heat treated state. They are not suitable for fusion type welding. Archetypal uses include higher strength parts of aircrafts and machinery, fuselage structural wing tension members, shear webs and ribs and structural areas where stiffness, fatigue performance and good strength are required, including gears and bolts and for security vans where strength is critical. Alloy 2024 plate products are used in sheet metal products like Alclad, having applications for fuselage and wing skins and engine parts subjected to high temperatures.

- Reinforcement Material

Silicon carbide powder in the form of particles is used as reinforcement material. Silicon carbide was purchased from Thermo-Technologies, Ghaziabad. The grade of the silicon carbide used was F320. Density of silicon carbide ranges in 1.29-1.35 g/cm³ while the mesh size is 29.2 ± 1.5 µm. The figure 4 shows the Al-2024 slabs while figure 5 shows the SiC powder.

EXPERIMENTAL DETAILS

- Stir Casting

The silicon carbide (SiC) is used as the reinforcement material in the preparation of the Al-2024 SiC metal matrix
particulate composite. The process involves heating up of the Al-2024 metal to a temperature higher than the melting point about 850°C. This was done in an underground furnace and once aluminum melts; the SiC is added to the molten aluminum. It was degassed by purging hexachloro ethane tablets. The furnace is then enclosed by the cover and a stirrer is introduced upon the cover of the furnace. The stirrer is attached to the motor which rotates the stirrer blades which are inserted into the molten metal. The motor rotates the blades at the speed of 500 rpm for about 5 minutes. The molten composite is then poured into the mould made by sand moulding of pattern 11” x 7” x 1”. The molten composite is then allowed to solidify which takes some 25 minutes and then the solidified composite is then allowed to cool in atmospheric temperature and pressure.

- **Characterization of Al 2024- SiC<sub>p</sub> Plates**

  - **Metallographic Examination and Characterization:**

    Microstructures of stir cast aluminum composite samples were examined by metallography. The photographs of samples were taken. Samples were firstly cut and mounted. Then they were grinded, polished and etched with Keller solution which contains 1.5% HCl, 2.5% HNO3, 1% HF and 95% H2O. At the end, micrographs were taken by a metallurgical microscope fitted with a digital camera.

- **SEM, EDX& XRD Testing of the Prepared Composite Plates**

  In order to get detailed and close views of interior structures of aluminum samples SEM studies were done. Especially the precipitates that should form after casting were examined. The percentages of alloying elements were analyzed and their graphs were obtained. SEM studies were done with JSM-6400 Electron Microscope (JEOL). XRD Analysis was carried out on X-ray diffraction machine of Shimadzu make (model XRD 6000) whereas SEM EDAX was carried out on Oxford instrument’s ZEISS EVO 18 series EDAX machine.
Figure 5: Stir Cast Plates of Al2024-SiC
Figure 6: Cut Samples from Cast Plate

Figure 7: LOM of Al 2024-15% SiC @10X
Figure 8: LOM of Al 2024-10% SiC @10X

Figure 9: Arrangement for LOM

Figure 10: SEM Setup
XRD Data

Table 1: XRD Data

<table>
<thead>
<tr>
<th>Sl No.</th>
<th>Peak No.</th>
<th>2Theta (Deg)</th>
<th>d (Å)</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>1</td>
<td>38.5993</td>
<td>2.33065</td>
</tr>
<tr>
<td>02</td>
<td>2</td>
<td>39.0200</td>
<td>2.30649</td>
</tr>
<tr>
<td>03</td>
<td>3</td>
<td>44.5400</td>
<td>2.03261</td>
</tr>
<tr>
<td>04</td>
<td>4</td>
<td>44.8451</td>
<td>2.01948</td>
</tr>
<tr>
<td>05</td>
<td>5</td>
<td>65.2552</td>
<td>1.42866</td>
</tr>
<tr>
<td>06</td>
<td>6</td>
<td>65.5800</td>
<td>1.42237</td>
</tr>
<tr>
<td>07</td>
<td>7</td>
<td>78.4419</td>
<td>1.21823</td>
</tr>
</tbody>
</table>

Table 3: Interpretation

<table>
<thead>
<tr>
<th>Sl No</th>
<th>Peak</th>
<th>Reference Peak</th>
<th>Measures Peak</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Al, SiC</td>
<td>38.452</td>
<td>38.5993</td>
</tr>
<tr>
<td>2</td>
<td>Al</td>
<td>44.8451</td>
<td>44.8451</td>
</tr>
<tr>
<td>3</td>
<td>Al</td>
<td>65.004</td>
<td>65.2552</td>
</tr>
</tbody>
</table>

From the above table it is confirmed that Aluminum, Silica and Carbon are present in the sample.

RESULTS AND DISCUSSIONS

Microscopy, Density and Hardness Measurement

In order to know the dispersion of SiC in Al2024, the samples were analyzed by scanning electron microscope (SEM). The hardness of the composites and matrix alloy were measured after polishing. The magnification of the images was 500x. Hardness of all samples was measured by Micro hardness tester and mean of at least five readings was taken to represent the sample.

SEM & X-Ray Diffraction Analysis of Composite

Samples, for X-ray diffraction analysis, were prepared by following standard procedures. Figure 15 shows an X-ray diffraction (XRD) pattern taken for aluminum, SiC powder and composites to verify its quality. The aluminum10%SiC composites prepared by stir casting were subjected to X-ray diffraction analysis for the constituents present and X-ray Cu-

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editor@tjprc.org
K radiation was passed through these composite samples and X-ray patterns were obtained. The X-ray diffraction pattern shows that three highest intensity peaks, namely, (111), (200) and (220), are distinctly visible for aluminum while many peaks are visible for SiC powder. This is owing to lower purity of aluminum and the better purity of SiC, as well as due to the preferred orientation in the aluminum and SiC powder. Different constituents, such as aluminum and SiC were identified after matching experimental peaks obtained with those of the standard peaks.

Figure 12: SEM & EDS (Energy Dispersive Spectroscopy) of Al 2024-10% SiC

Figure 13: XRD Plot

CONCLUSIONS

- The aluminum silicon carbide composites were successfully fabricated by stir casting technique at stirring speed of 300 rpm.
- The results of LOM, SEM-EDAX and XRD showed that:
  - There is proper dispersion of SiC reinforcement in Aluminum matrix material as per LOM.
  - Mechanical characterization proved that there is increase in hardness and strength after reinforcement.
  - XRD and EDX showed the presence of SiC in alloy matrix.
  - The different peak heights were found at different 2-theta scale for different compositions.
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APPENDIXES

About the Authors

Mr. Atul Kumar

Atul Kumar is Assistant Professor in Mechanical Engineering Department at the Mody University of Science & Technology, Lakshmangarh (Rajasthan). Atul Kumar is pursuing PhD from Suresh GyanVihar University, Jaipur. He has a number of publications in some journals of well repute. His research area is machining of aluminium metal matrix composite. He has more than 15 years of experience in industry and in teaching mechanical engineering and guiding projects at Graduate and Post-Graduate levels.

Dr. Sudhir Kumar, PhD

Professor & HOD, Mech. Engg. Deptt. Faculty of Engineering and Technology, GNIT, Greater Noida (U.P.) He has got 20 years of experience in teaching mechanical engineering and guiding projects at Graduate and Post-Graduate levels. He has completed his Ph.D. from IIT Roorkee. Experienced in guiding Ph.D. students and associated with various universities. He has many papers to his credit in various journals of repute. His research area is Evaporative Pattern Casting Process, Capacity Waste Management.

Dr. Rohit Garg, PhD

Dr. Rohit Garg, Director, GNIT, Greater Noida, obtained his M.E. in CAD/CAM and Robotics from Thapar Institute of Engineering and Technology, Patiala (TIET) in the year 2002 and Ph.D. in Mechanical Engineering from National Institute of Technology (NIT), Kurukshetra in the year 2011. He has a vast and rich experience of 17 years in teaching, research and administrative field. He has been a member of board of studies to Kurukshetra University. He has published various research papers in the International/National Journals and Conferences. He is Life member of Indian Society for Technical Education and Institution of Engineers.