Property Enhancement of Aluminium Alloy 2000 Series Strengthened by Synthetic, Self-Lubricant and Natural Reinforcements

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Abstract - Wider usage of aluminium alloy composites can be seen in several sectors like automobile, aerospace and marine application. Current article clearly explains the property enhancement of aluminium alloy composites reinforced with natural materials and is compared with synthetic as well as hybrid reinforcements. AA2219 is taken as a base metal and BC, WC, Al2O3, MOS2, Graphite, Sea shell powder (SSP) are taken as reinforcing agents. Stir casting technique is adopted to fabricate a test specimen since it is flexible and easy to cast among remaining casting methods in metal matrix composite. Above mentioned reinforcements are taken with a weight percentage of 1, 2 and 3. For property enhancement evaluation, hardness test is carried out. It is observed from the evaluation, natural reinforcement result in better enhancement than the synthetic reinforcements.

Keywords - AA2219, seashell powder, Stir casting, Hardness

1. Introduction

Blending of more than one material is named as composites. Metal matrix composite is widely applied due to its several usages in various areas like aircraft, ship and heavy vehicles. Aluminium matrix plays a vital role due to its low weight to density ratio in manufacturing field. 2000 series of aluminum matrix applied in brake pad and motors which is subjected to both mechanical and tribological property. Strengthening of metal matrix by means of ceramic particles results in enhancing a properties of engineering materials which adds strength, stiffness resistance to wear and corrosion with excellent elastic constants [1]. Mixing of matrix and strengthening elements which combines both mechanical and strength properties which results more effects in tangential and contraction force effects for thermal applications [2]. Metal matrix composites possess very good improvement in science and technology and also in marketable purpose. In recent years, metal matrix composites are widely adopted for both aircraft and automotive industry due to this reason [3]. Many of the research work has been carried out in aluminium matrix composites strengthened by synthetic ceramics like alumina and silicon carbide [4]. Coefficient of friction and frictional force are the major factors for the aluminium matrix composites strengthened by synthetic ceramics like alumina and silicon carbide which is used to fabricate a piston and cylinder heads [5]. Significant weight age of enhancing the properties of aluminium composites widely considered in many industrial field. It is observed that reinforcing of robust particulate materials with metal alloy matrix is most economical and benefited [6]. Manufacturing related issues during machining resolved by metal matrix composites strengthened by ceramic particles. So to overcome this problem many research work is carried out to introduce near-net-shape production techniques in which the initial production of the item is very close to the final (net) shape, decreasing the requirement for finishing of surface. Plenty of manufacturing techniques of fabricating metal matrix composite is accessible recently. Particularly particle-reinforced composites fabricated by liquid phase and solid phase [7]. Another name of solid phase processing technique is powder metallurgy is having poor cohesion between base metal and particles. Liquid state technique which is known as a melting process results in good cohesion bonding among the base metal and reinforcing element. So liquid state manufacturing technique is chosen widely for aluminium metal matrix composites. This technique is also beneficial for flexible regulation for structure of base metal and reinforcing element, cheaper in cost and decreasing the extra work for surface finishing [8]. Some demerits also observed from liquid state processing which are poor wet ability, non-uniform dispersion of a strengthening agent which are less effect in solid state processing [9]. Issues observed from liquid state processing is eliminated by preheating the reinforcing particles used to increase the wet ability of a composites and melting of stirring temperature is applied with a maximum blending speed with a value of 900 revolutions per minute. Major objective of obtaining homogeneous distribution of particulates with matrix material is under examination in metal matrix composite [10]. Maintaining homogeneous distribution of particulates with matrix is still tricky because of its weak ability for wet among the strengthening element and base metal [11]. From the different manufacturing methods for fabricating the aluminium matrix composites, stir casting is recommended widely due to its flexibility and cheaper price. Stirring speed, time, velocity, melting temperature of the base metal and furnace, preheating temperature of the particulates are major factors considered for fabricating metal matrix composites [12]. Main objective of current work majorly focuses the comparative study of mechanical property enhancement to the aluminium matrix composites with synthetic, hybrid and natural reinforcing elements. Several researches are going on by reinforcing those composites by using synthetic materials. Replacing synthetic reinforcement with natural materials or hybridizing results in enhancement of properties of the aluminium alloy composites [13].
2. Fabrication of Composites

Stir casting method is used to fabricate aluminum metal matrix composites. This method is cheap and flexible to fabricate a composite [14]. Factors majorly included for stir casting technique are position, speed, time and size for stirring, angle of blade, rate of feed for reinforcements. For evaluation of hardness property, several combinations of reinforcement with base metal are taken. AA2219 is chosen as a base metal and tungsten carbide, Graphite and Sea shell powder are chosen as reinforcement [15]. Stir casting method comes under the melting state process in which ceramic particles are blended uniformly with molten base metal of aluminum alloy to get uniform dispersion which is achieved by complete mechanical stirring process [16]. That molten state mixture is casted by traditional casting process to obtain required specimen for testing.

Advanced technique in stir casting is two step processes [17]. Melting of a base metal with its reinforcing agent to its above critical temperature is the primary process [18]. The wet ability of the matrix composite is attained by using stir casting setup.

Parameters used in stir casting

Several factors considered for fabricating aluminium matrix composites [19]. These factors mostly helpful for property development of composites as shown in Table 1.

| Parameters/Reinforcements | BC | WC | Al₂O₃ | MOS₂ | Graphite | SSP |
|---------------------------|----|----|-------|------|----------|-----|
| Stirring speed (rpm)      |    |    | 500   |      |          |     |
| Stirring temperature (K)  |    |    | 1023  |      |          |     |
| Stirring time (min)       |    |    | 10    |      |          |     |
| Preheating time (min)     | 30 | 30 | 30    | 30   | 45       | 45  |
| Preheating temp (K)       | 400| 400| 400   | 400  | 300      | 300 |

Composition of specimens

Various composition of the specimen were used for the hardness testing of the aluminium alloy composites [20]. Table 2 shows various composition of reinforcements mixed with AA2219.

| S. No | AA2219% in % | AA2219 alloy weight (gm) | Reinforce-ent in % | Reinforce-ment weight (gm) | Name of the reinforce-ment |
|-------|--------------|--------------------------|--------------------|----------------------------|----------------------------|
| 1     | 99           | 742.5                    | 1                  | 7.5                        | BC                         |
| 2     | 98           | 735                      | 2                  | 15                         |                            |
| 3     | 97           | 727.5                    | 3                  | 22.5                       |                            |
| 4     | 99           | 742.5                    | 1                  | 7.5                        | WC                         |
| 5     | 98           | 735                      | 2                  | 15                         |                            |
| 6     | 97           | 727.5                    | 3                  | 22.5                       |                            |
| 7     | 99           | 742.5                    | 1                  | 7.5                        | Al₂O₃                      |
| 8     | 98           | 735                      | 2                  | 15                         |                            |
| 9     | 97           | 727.5                    | 3                  | 22.5                       |                            |
| 10    | 99           | 742.5                    | 1                  | 7.5                        | MoS₂                       |

Tests Conducted

For evaluating mechanical properties of aluminium matrix composites, hardness test is taken for all the samples [21]. Brinell hardness testing equipment is chosen for testing hardness for metal matrix composites. ASTM E-10 is taken as standard for a test specimen as per American Society for Testing [22].

3. Results and discussions

Hardness test is taken for all the 18 samples with an applied force 250 N as shown in Table 3 and Figure 1. Intender ball diameter is 5mm [23]. three trials is taken for approximate result. The following table shows the collective hardness value for all 18 specimens.

Table 3: Hardness value for synthetic, self-lubricant and natural reinforced aluminum 2219 composites

| Weight fraction of reinforcement (wt. %) | AA2219-BC (BHN) | AA2219-WC (BHN) | AA2219-Al₂O₃ (BHN) | AA2219-MoS₂ (BHN) | AA2219-Graphite (BHN) | AA2219-SSP (BHN) |
|-----------------------------------------|-----------------|-----------------|--------------------|-------------------|----------------------|------------------|
| 1                                       | 49.4            | 42.6            | 23.68              | 27.09             | 22.65                | 29.5             |
| 2                                       | 53.2            | 46.78           | 28.84              | 27.49             | 24.8                 | 39.1             |
| 3                                       | 60.7            | 54.02           | 34.43              | 28.30             | 27.14                | 48.5             |

Fig.1: Hardness test values of AA2219 reinforced with synthetic, self-lubricant and natural materials

AA2219 base metal is reinforced with synthetic ceramic, self-lubricant material and natural ceramic with the weight percentage of 1, 2, and 3 by using stir casting setup [24]. AA2219 reinforced with boron carbide given the increased value of brinnell hardness by increasing the boron carbide weight percentage [25]. Similar result is observed for tungsten carbide but the hardness values are lesser than the boron carbide reinforced matrix [26]. The reason behind this is boron carbide is harder material than the tungsten carbide and the particle size of the WC is low quantity of grain size deviation. Formation of strange inter
metallic state is also the reason even both are having a spherical structure [27]. AA2219 reinforced with alumina powder given the decreased hardness values than both boron and tungsten carbide powders. The reason is alumina is a fine course ceramic material which is blended completely with AA2219.

AA2219 reinforced with molybdenum di sulphide and graphite powder shows an increased hardness value compared to alumina powder. MOS₂ and Graphite are the self-lubricating materials which can distribute uniformly with the AA2219 alloy [28,29]. So the hardness value of these two powders showed slight increment than the alumina powder. AA2219 reinforced with sea shell powder which a natural ceramic material is shown a gradual increment of hardness value than the AA2219 which is not reinforced (27 BHN) and hardness increased by adding weight percentage of sea shell powder. The reason for increment is, it contains calcium carbonate which helps to improve the hardness value.

4. Conclusion
The experimental study reveals the following conclusions

- AA2219 reinforced with boron carbide and tungsten carbide shown dramatically increment in hardness since those two are hard materials.
- AA2219 reinforced with alumina powder shown very low values for hardness since it is a fine course ceramic material.
- AA2219 reinforced with self-lubricating materials like MOS₂ and Graphite shown increased hardness values than the alumina reinforced composites.
- AA2219 reinforced with natural ceramic material like sea shell powder shown a gradual and nearer value with AA2219 non reinforced alloy. The gradual increment will not affect the originality of the composites and those alloys reinforced with sea shell powder can be applied where hardness plays an important role. The application includes brake pad, cylinder and piston rods.

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