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Effect of Feeding Technique in Mechanical Behaviour of Sic/Tio$_2$ Reinforced AA 6082 Composites

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***Abstract**: In this study, SiC and TiO$_2$ nanoparticles reinforced AA 6082 composites were prepared by stir casting technique. The optimized quantities of reinforcement particles used in composites was 6 Wt.%. The mechanical properties such as tensile strength, compressive strength and hardness of prepared composites were improved significantly about with novel multi-encapsulate feeding as compared normal feeding technique. Also, the drastic improvement was noted with microstructure in order to form of health clusters and homogeneous distribution under novel feeding than normal feeding. The testing shows that the micro hardness and tensile strength was improved about 10% and 5% than normal feed process. Lesser blow holes and good matrix materials dispersion was found in multi encapsulate feeding process. From this experimentation, it was confirmed that multiple encapsulate feeding of reinforcement particles can increase the mechanical strength and microstructure properties than normal feed technique.*

***Keywords** : Characterization; Mechanical properties; Multi Encapsulate feed; Stir Casting*

I. INTRODUCTION

Belittle the mass to might ratio is a basic requirement in many applications especially like aeronautical and aerospace industries. In modern airframe industries, new and novel materials have an endless invention on the base of increasing load bearing capacity with reducing the weight percentage. Due to light mass to might ratio, wear resistance, better modulus of elasticity, more stiffness and specific strength, the aluminium-based metal matrix composites (MMC) plays a huge role in aviation industries. The quality of aluminium alloys enhanced by adding the hard particles such as TiO_2, SiC, Gr, TiB_2, B_4C, Al_2O_3, Si_3N_4. etc... [1-2]. Based on applications and other requirements, selecting the suitable fabrication technique like stir casting, squeeze casting etc, can make aluminium alloy into aluminium metal matrix composites with enhanced mechanical properties such as tensile strength upto 20% and hardness upto 15% [3]. Among various casting, the stir casting technique has widely used by many researchers due to greater reinforcement dispersion and good surface morphology and micro structure. Beyond this versatility, stir casting is low cost process and ease of processing [4]. The hard ceramic Silicon carbide (SiC) on aluminium alloy enhances the mechanical tensile strength about 8% and hardness about 5% by stir casting method of fabrication [1, 2 & 5]. It denigrates the elongation and density; also it enhances the hardness, tensile and compressive strength and porosity [6]. Aluminium base metal matrix composites (AA6086-T6 with silicon nitride particles) casted by conventional stir casting method, the ultimate tensile strength, hardness, density and porosity have improved when increase of silicon nitride particles. Along with this, cost of production has reduced in order to ductility [7, 8]. Most of properties of AA6061 are very analogous to AA6082, and AA6061 has reinforced with aluminium nitride (AIN). Also, it enhances the hardness and tensile strength with increasing content of AIN particles [9]. Likewise AA 6082-T6 are casted with TiC particles, the hardness, tensile strength and other mechanical properties were raised than AA 6082 [10]. The addition of graphite (Gr) particles on AA6082 by stir casting process, uninformed materials Gr particle dispersion found in all the weight percentages. The hardness is reduced up to 11.1% at all the case of Gr addition. In concern with tribological properties, it was found that better wear and friction resistance by providing the lubricant effect from Gr particles [7]. In stir casting process, the aluminium alloy has kept at crucible and it reacts with moisture from atmosphere which creates the oxidation layer on top side. Also this layer can stop further reaction with atmosphere. In order to avoid unwanted reaction with oxygen and reduction in wettability, sometimes whole process has carried in inert gas environment [11]. Apart from oxidation layer problems, attaining the homogenous dispersion throughout molten state aluminium metal matrix composites (AMMC) is highly challengeable issue due to non Newtonian fluid nature of molten state metal. Also mechanical stir plays important role in particle dispersion and it has been controlled based on particle nature. To attain extraordinary properties, uniform dispersion and avoiding agglomeration are important task in stir casting process [12-13].

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A single encapsulate feeding of reinforcement particle of cubic boron nitride (CBN) on AA 6061 was improved the mechanical and thermal properties and it was produced better surface morphology than normal feeding [14]. The oxide layer while oxidization can shields and arrests the furthermore reactions in atmospheric conditions. After setting temperature, the mechanical stirrer starts to create a vortex; also ceramic particles were fed into middle of vortex. This induces the continuous oxidization which results in wettabilty reduction. To avoid this conditions, inert gas used throughout the process [15-16]. In other way, adding wetting agents such as TiK2F6, borax and magnesium improves the wettability between matrix material and reinforcement ceramic powders [17- 18]. Also, the mechanical stirrer plays vital role in micro structure and mechanical properties of composites. The parameters such as stirrer time and speed control the materials dispersion and materials strength [19]. This research focused on fabricating the aluminium base metal matrix composites using AA6082 with SiC (6 Wt.%) and TiO_2(6 Wt.%) by stir casting technique. It was processed both normal feeding and multi encapsulate particle feeding methods. Based on aircraft structural application, the mechanical properties such as ultimate tensile strength, compressive strength, hardness and flexural strength were found and compared each other. The surface morphology was analyzed by scanning electron microscope (SEM), and it compared with other.

II. MATERIALS AND METHODS

Table 1 Chemical Composition of AA6082

Element	Composition
Si	0.7-1.30
Fe	0.0-0.5
Cu	0.0-0.1
Mn	0.4-1.0
Mg	0.6-1.2
Zn	0.0-0.2
Ti	0.0-0.1
Cr	0.0-0.25
Al	Balance

Due to poor cluster formation, irregular materials dispersion and agglomeration in few sites of materials in stir casting technique, the novel multiple encapsulate feeding has carried out for reinforcement particles on AA6082. Based on availability of surface area, More than 4 holes were drilled around the AA6082 square shaft with the depth of 5mm and mixed SiC and TiO_2 were packed in each hole given in Fig.1

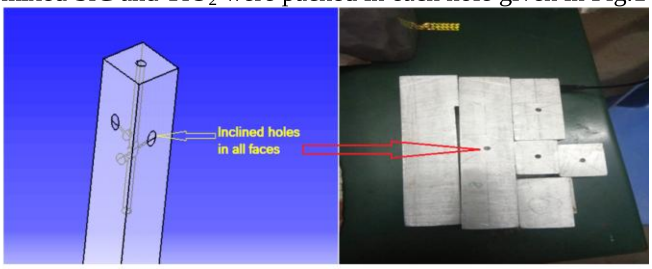

Fig. 1, Multiple holes around faces for encapsulating the reinforcement particles

After packing, the materials were placed inside the heater and it heated up to 850°C. The coated metallic stir was started and maintained the RPM about 500 RPM for 5-6 minutes after molten stated attained. Due to multiple encapsulate feeding and stirring, the reinforcement particles are dispersed throughout the molten state. This process was carried out in the presence of inert gas to avoid the oxidation during the heating process. The molten state metal matrix composites have poured into preheated (up to 450°C) square chamber. The two different test specimens were prepared for normal feeding and multiple encapsulate feeding methods.

Both test specimens were cut into dimensions of 5x5x10mm by an abrasive cutter. Emery paper (220-320-400-600-800 1000-1200-1500) and burnishing with the diamond paste of 0.5–1 µm are used to prepare test specimen for surface morphology analysis by Scanning Electron Microscope (SEM) make TESCAN-VEGA3 attached with Energy-dispersive spectroscopy (EDS). The EDS has taken at two different places for ensuring the quality of microstructure and degree of variability in samples.

The Vickers hardness tester (make "HMV microhardness tester Shimadzu") used to measure the microhardness of both specimens with dimensions of 10x10 mm. The averaged value of hardness has taken from 5 different values measured at different places. Each test carried out under atmospheric temperature, applied a load of 235mN for 20 time seconds. Also, the worn surface of all the samples was scanned by an optical microscope.

III. RESULTS AND DISCUSSIONS

A. Surface Morphology

In the visual inspection of both SEM images from Fig.2, more poor/ unusual reinforcement clusters were formed at normal feeding which has denoted by yellow circles. Also, the presences of defects and below holes (indicated in red circles) are little more in normal feed casting than multiple encapsulating feed casting. Due to poor clusters and below holes formations in normal feed, the casted specimen were found lesser quality and get breaks in many times during secondary operations like cutting, drilling and machining during sample preparation. By using the encapsulate feed methods at multiple places around AA 6082, the poor cluster formations and blow holes are reduced significantly. This is mainly due to increases of reinforcement particle dispersions meanwhile reduction in particles agglomerations.

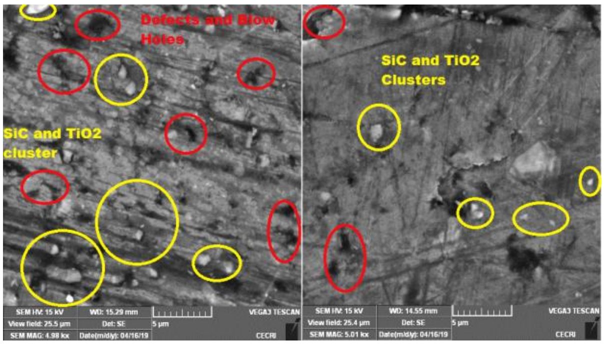

Fig.2 SEM images of AA6082 with SiC+TiO_2, i) Normal feeding, ii) multiple encapsulate feeding

Moreover, energy dispersive spectroscopy (EDS) analysis given in Fig.3 confirms that all the elemental presence in the tested sample especially Si and Ti.

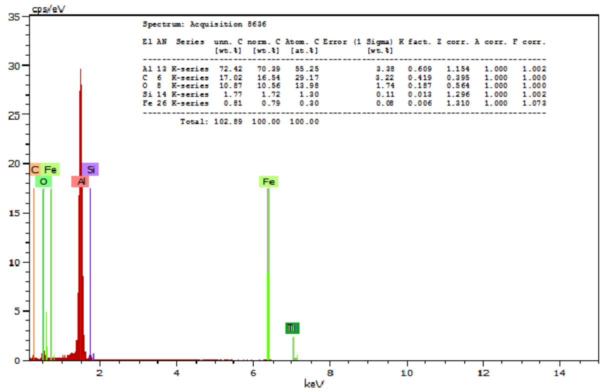

Fig.3 EDs of AA6082 with SiC+TiO_2

B. Mechanical Properties

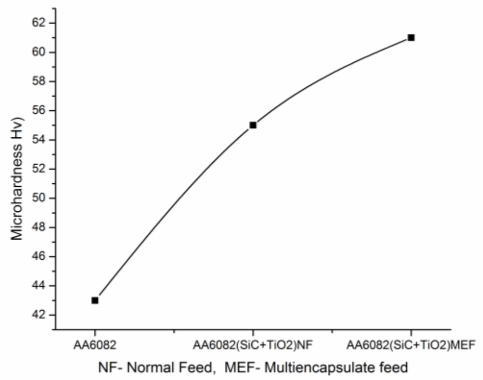

Fig.4, Micro-hardness Vs different samples

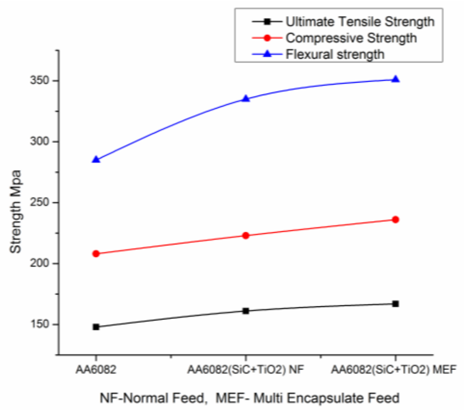

Fig.5 Ultimate tensile strength, Compressive strength and Flexural strength Vs different samples

Fig.4 shows that the microhardness of AMMC on both normal feeds and multi encapsulate feed of reinforcement particles. The increased hardness has found with AMMC under encapsulate feed technique about 10% than normal feed, 30% than AA 6082. This is because of better dispersion of reinforcement particles and the addition of SiC and TiO_2 particles.

Fig.5 indicates that the ultimate tensile strength of the mentioned samples. Similar to hardness, tensile strength found maximum with encapsulating feed technique about 5% than normal feed and 12% than AA 6082. In many places of aircraft, most of the structural members are experienced with a high compressive load than tensile and another kind of loads. Keeping this in mind, TiO_2 and SiC have added with AA 6082 to elevate the mechanical properties. The compressive strength has increased with the addition of SiC and TiO_2 particles about 7.5% normal feeding method. In case of multi encapsulate feeding, further increase of compressive strength was found about 6% than the normal feeding method. The flexural strength is property to find the maximum stress at the time of yield during the flexural test. In addition to this, flexural strength was found maximum with AA6082 with SiC and TiO_2 due to better binding between the reinforced particles and base metals given in Fig.5. In the case of encapsulating feed, binding is improved further which cause of little increment of flexural strength about 5-6%.

IV. CONCLUSION

The aluminium-based metal matrix composites are prepared in order to both normal feed and multiple encapsulate feed methods in stir casting technique.

- ❖ The surface morphology by Scanning electron microscope shows that the better reinforcement dispersion and reduced blow holes and defects with encapsulating feeding found compared to the normal feeding method.
- ❖ The mechanical properties such as microhardness, ultimate tensile strength, compressive strength and flexural strength found little increment as 10%, 5%, 6% and 5% than normal feeding technique.

Form this investigation, multi encapsulate feeding in stir casting method could increase the materials dispersions, lesser agglomeration and blow holes, hence it could be recommended for airframe structural industries especially in compressive loading applications.

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