Characterization of aluminium / (SiC+B4C) ceramic particles reinforced hybrid Surface Composites (SC) fabricated by friction stir processing

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Abstract. Friction stir processing (FSP) has advanced as a novel method used for the fabrication of surface composite (SC), refinement of microstructure and enhancing the mechanical properties. In this paper, aluminium surface matrix composite (SMC+ B(C) was fabricated on the surface of aluminium alloy (6082) with ceramic (SiC+B(C) reinforcement using friction stir processing technique. In order to analyze the effect of SiC+B(C particles, its percentage fraction on the microstructure, mechanical and the sliding wear behaviour. A single pass FSP was carried out using a tool with 1000 - 1200 rpm rotational speed, whose travel speed of 45 to 60 mm/min and a vertical force to produce the composite. Aluminium Matrix Composites with different percentile combinations were synthesized. The microstructure of the AA6082/SiC+B(C AMCs was studied using optical and scanning electron microscopy. The micro hardness was measured and the sliding wear behaviour was evaluated using a pin-on-disc apparatus. Thus, the results revealed that the effect of SiC+B(C particles significantly influenced the area of the composite, dispersion, grain size of matrix, micro hardness, and sliding wear behaviour of the AA6082/SiC+B(C AMCs. With this the effect of SiC+B(C particles on fracture surface and worn surface is also reported in this paper.

1. Introduction:

A composite material could be a material made up of two or more essential materials with considerably partially unique internal or thermo mechanical properties that possess by its nature. When both of them mixed and joined, they end up with a new material with its features totally changed from the parent materials. The two different individual elements stay separately with unique properties within the processed structure.

The processed material is most well-liked for numerous reasons. Common parameters comprises materials that are strong and light in their mechanical properties and more cost-effective when compared to the unprocessed standard materials. The applications of metal matrix composites in the space research has improved significantly from 1970s. There was a drastic growth since its invention. In a motorised vehicle manufacturing industries they are facing countless unfeasible difficulties, with increased world-wide survival fitness, the requirement for improved-performance vehicles, a drop in costs and improved eco-friendly and personal safety needs. The similar method has initiated for the advancement in the area of the composite materials with their exceptional as said stuffs. Different methods and techniques had been evolving for production and construction of surface composite (SC), however Friction Stir Processing was known as the foremost hopeful method.

FSP is introduced by Mishra.et.al [1, 2], which has the working principle as same as the principle of friction stir welding (FSW). Traditional and age old liquid based manufacturing techniques were affected by the limitations like, development of midway detrimental phase and creates volume of
pores and fractures due to increased temperature process parameters, and requires considerable control of process parameters to have the control on the solidified condition. To avoid the above said drawbacks, the process has to be undertaken out at a temperature less than the melting point of the matrix and reinforcement as done in solid phase surface alteration methods. As, being one of the solid type surface changing method, it has been widely used in the current experimentation for fabrication of Surface Composites. First SC has been synthesized via FSP route by Mishra et al. [1].

Fabrication of MMC is the primary processing method of its production. A basic arrangement, about the technological methods for Metal Matrix and Ceramic Matric Composites, takes consideration of the state where the processing materials during the initial cycle of production. Preparation of Metal Matrix Composites can be widely divided into three types of fabrication methods. There are several fabrication methods existing for producing MMC materials. A powder metallurgy (PM) method is the most widely method for the production of reinforced MMC with break, because no melting and casting is present.

Liquid state fabrication of Al-based surface composites is highly reduced by the low wettability of ceramic particles into the semi-solid combination of metal; as a result, even though the processed composites would allow the creation of difficult profile shape parts, conventional liquid processing methods such as casting are typically connected with particle grouping, high amounts of casting shortcomings related to the incorporation of ceramic particles and particle isolation convinced by the unique specific gravity of the base metal and the add on particles [2, 3].

Semi liquid casting has been introduced as a likely production method to remove such problems and difficulties, by improving the particle wettability because of the higher viscosity of the semi-liquid matrix when comparing with the the liquid state. This would also help enabling the mechanical set-up of the reinforcing stage [4, 5]. The incorporation of reinforcing particles to the parent at the semi-liquid state in connection with mechanical mixing is always called as compo casting.

2. Experimental Procedure
Experiments was carried out on standard vertical milling machine. As proposed by Badheka.et.al, a traditional standard vertical milling machine also be utilised for friction assisted stir welding and processing of commercial aluminium and for surfacing also. The size of the Matrix plate used in this experiment for processing of composites is 10 mm thick Aluminium alloy 6082-T6 material with the cross section dimension of 100mm in larger dimension and of 50 mm in shorter dimension. The chemical properties of the parent material is mentioned in table 1. In order to fill the reinforcement with the matrix metal, a longitudinal pocket of 6(W) × 5(D) × 100(L) mm was created using grooving tool in the using shaper machine and same was filled with reinforcement of Silica Carbide (SiC) and Boran Carbide (B4C)

![Figure 2.1 as received AA6082](image1.png)  ![Figure 2.2 Cylindrical Tool](image2.png)
The different percentile combinations of SiC and B₄C were used in this experiment is listed below.

| S.No | Case   | Combination       |
|------|--------|-------------------|
| 1    | Case 1 | SiC 0% & B₄C 0%   |
| 2    | Case 2 | SiC 25% & B₄C 75% |
| 3    | Case 3 | SiC 50% & B₄C 50% |
| 4    | Case 4 | SiC 75% & B₄C 25% |
| 5    | Case 5 | SiC 100% & B₄C 100% |

2.1 Tool Introduction
Different types of tool geometries were used for friction stir processing. Studies say that the pin height of the tool should be less than that of the thickness of the material to be joined. Heat is formed through direct contact between the rotary motion tool shoulder and surface of the matrix material and hence the neighbouring distortion and mechanical property losses happening in the composite material. The shoulder diameter is the one that determines the heat produced since the friction is produced by the rubbing motion of the tool shoulder over the metal. It is agreed that material is displaced from the leading side of the tool pin to the trailing side of the tool pin under rotational and translational action of the tool.

2.2 Tool Geometry
The tool geometry affects the heat generation rate in the surface, traverse force in the longitudinal direction, torque in the tool and the thermo mechanical atmosphere absorbed by the tool. The flow of semi liquid state material in the work piece is changed by the tool shape and size as well as the straight and rotary motion of the tool. Significant features are shoulder diameter of the tool, tool tilt angle on the tool post, pin shape, size and profile, and the property of the tool material.

2.3 Tool Diameter
The broadness of the tool shoulder is playing a vital role in heat generation in the surface of the matrix material, which is influenced the plasticised materials mostly forms the material flow field. Slipping and clogging together produces the heat, whereas material flow is affected only from clogging. During the practice the material should be sufficiently softened for movement, the tool should have acceptable grip on the plasticised material and the total turning effect and longitudinal force should not be more than expected. Practical results have revealed that only a tool with a correct shoulder diameter produces the highest strength of the composites. Even the necessity to see a best shoulder diameter being recognized within the survey, most of the researcher is now looking for the acceptable principle for the determination of tool material and tool geometry.

2.4 Materials & Processing Details

| Table 2.1 | Properties of AA6082 |
|-----------|----------------------|
| Element   | Mg   | Si    | Fe    | Mn    | Cu    | Cr    | Zn    | Ti    | Aluminium |
| Wt %      | 0.78 | 1.06  | 0.21  | 0.55  | 0.09  | 0.03  | 0.06  | 0.01  | Balance   |

2.4.1 Properties of SiC
Silicon carbide (SiC) ceramics consists of a group of different physical properties and chemical properties, like improved hardness and mechanically stable at increased temperatures, good thermal movement and low coefficient of thermal expansion, high degree of resistance to corrosion and oxidation. Silicon carbide is consists of tetrahedra structure of carbon and silicon atoms along with
strong attachments in the crystal structure. This forms SiC as a very hard and strong material with good mechanical and chemical properties. They can maintain their hardness and strength with small amount of change in grain boundary or without grain boundary at high temperature above 1500°C.

3. Microstructure

The following figure shows the micrograph of the as received AA6082:

![Micrograph of as received AA6082](image)

**Figure 3.1** as received AA6082

The mechanically polished sample was analyzed before chemical etching using a FE-SEM microscope to study the structure of precipitates and secondary phases. Figure 3.1 shows the microstructure of the as received AA6082 with the magnification of 200 times. Figure 3.2 (a) to Figure 3.6 (b) shows the micrographs of the FSPed AA6082 aluminum alloy. The figures show the distribution of particles in both the stir zone and also in the Heat affected zone. The different zones of FSPed AA6082 with different combinations of ceramic particles were observed using microscope such as Transition Zone (TZ), Heat Affected Zone (HAZ) and Stir Zone (SZ). The refined grain size is observed in the SZ.

![Micrographs of FSPed AA6082](image)

**Figure 3.2 (a)** Heat affected zone (SiC 0% & B₄C 0%)

**Figure 3.2 (b)** Stir Zone (SiC 0% & B₄C 0%)

**Figure 3.3 (a)** Heat affected zone (SiC 25% & B₄C 75%)

**Figure 3.3 (b)** Stir Zone (SiC 25% & B₄C 75%)
3.2 Micro Hardness

The micro hardness of FSPed plates were measured using Vickers micro hardness tester with the load of 300g for 5 seconds. The average hardness of as-received AA6082 was 56Hv. The micro hardness of FSPed aluminium plate is increased to 89HV.

Figure 3.7 Micro hardness of FSPed plates

Figure 3.7 shows the distribution of micro hardness in the three different zones namely base metal, stir zone and heat affected zone. The hardness value varies in all the three zones. It can be seen that the hardness is fluctuated between 56Hv to 89Hv. The hardness value considerably increased on 75%-25% refinement.
4. Conclusion

AA6082-T6 as a parent material mixed and processed with different percentage of (SiC + B4C) particulates as reinforcements was produced using stir processing method. Based on the experiments the following decisions were collected. The microstructural images shows the standardised and even distribution of the reinforcements in the processed stir zone and decent amount of attachment with the parent material.

Micro-hardness of the processed composites shows an increment significantly to 89 HV for hybrid composite with 75% - 25% combination; 10% improvement in hardness was recorded compared to all other combinations.

In this experiment the reinforcements were mixed in solid state and then fed into the groove created for processing, additionally the reinforcements can be mixed along with the binder materials like resin and some other so that the properties may enhance.

5. References

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