Processing and Testing of Aluminum based Hybrid Surface Composites by Friction Stir Processing

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Abstract. The ever increasing service necessities in industries like automobile and aerospace demands the engineers to use the aluminium based composites which are reinforced by either single or mixture of ceramic particles. When hybrid reinforcements are used, the resulting composites are having superior mechanical properties. In the present experimental work, the Al 5083 was reinforced by Titanium oxide and aluminium oxide to the depth of 2mm and processed by solid state friction stir processing technique. To prepare the surface composites, three non-consumable rotating tools were used with different tool pin profile such as square, straight cylinder and taper cylinder. The other parameters like tool rotational speed, tool traverse speed, number of passes were maintained uniform. Totally three workpieces were processed in order to inspect the ultimate tensile strength, yield strength and micro hardness. The test results shown that the square tool pin has delivered the highest strength and hardness than the other tool pin profile. The micro hardness test results showed that the hardness of the reinforced zone is higher than unreinforced region.

Keywords: Hybrid Composites, Friction Stir Processing, Tool pin profile, Ultimate tensile strength, Micro hardness

1. Introduction

Over the last few decades, in the area of metal joining techniques, friction stir welding was created a revolutionized development. Friction stir processing is a technique invented by Mishra and his team as a modification of friction stir welding and was initially used for developing ultra-fine grained super plastic aluminum alloys. The process was emerged as an efficient tool for processing and developing the materials, for modifying the microstructure of the materials.

Hybrid surface composites are the group of materials which contains more than one type of reinforcement particles dispersed in the matrix. Hybrid composite takes the benefits of all the reinforcements and therefore exhibits the improved properties than the other materials [1,2]. In general hybrid composites are prepared by various methods like powder metallurgy, plasma spraying technique, pressure infiltration method, and squeeze casting. In this list friction stir process is added as a unique technique for manufacturing surface composites by means of modifying the grain structure.

The major approaches found in literature for developing surface composites are groove method, drilled hole method, cover plate method. In all three methods non consumable rotating tool is used to ensure the proper stirring of reinforcement in to the matrix material. The main function of the
tool is heating and deforming the workpiece material. Friction stir processing technique has different process parameters which are grouped as machine related variables, tool related variables, and material properties based variables as shown in the Figure1.

2. Experimental methods:

The aluminum 5083 was selected as base material with 4mm thickness. The small groove of size 1mm width and 2mm depth was cut on the base material to fill the reinforcement particles. Titanium oxide and aluminum oxide were taken equal amount as reinforcement particles, mixed thoroughly and filled in the machined groove.

The tool is considered as a heart of the process, because it produces the heat and ensures the proper mixing of the reinforcement particles in to the matrix aluminum. In the present work, three different tools were machined with different pin profiles namely taper cylinder, square of side 4mm, and straight cylinder with 6mm diameter. The tool is made from H13 steel and heat treated to improve the hardness. The other process parameter like tool rotational speed, traverse speed and number of passes were fixed constant. The details of the process parameters were given below in Table 1.
Table 1. Details of Process Parameters

| S.No | Process Parameter          | Details                      |
|------|---------------------------|------------------------------|
| 01   | Tool rotational speed     | 1000 rpm                     |
| 02   | Tool traverse feed        | 100 mm/min                   |
| 03   | Tool pin profile          | Square, Straight cylinder, Taper cylinder |

Totally three experiments were conducted on vertical milling machine for analyzing the mechanical properties like ultimate tensile strength, yield strength, and micro hardness. The machine used, tool and sample specimen prepared were shown in the Figure 2 as [A], [B], [C] respectively.

![Figure 1: Machine Used, FSP tool, workpiece with groove](image1)

**Figure 2** [A] Machine Used, [B] FSP tool, [C] workpiece with groove

The friction stir processed workpiece using all the three tools are shown in the Figure 3.

![Figure 3: Processed Specimen](image2)

**Figure 3**: Processed Specimen
3. Results and discussion

In order to analyze the tensile strength and yield strength of the friction stir processed workpieces, the dog bone like sample was prepared as per ASTM E8 standard. The shape and dimensions to be followed for preparing the specimen is given in the Figure 4.

![Figure 4: ASTM E8 standard for tensile test](image)

From each workpiece three samples were cut using Wire Electrical Discharge Machining method. The samples were tested for its tensile strength, yield strength on Computerized Universal Testing Machine. From the samples it was observed that the specimens were failed at processed zone. The specimen after the tensile test was shown in the Figure 5.

![Figure 5: Tensile specimen after test](image)

The computer controlled UTM was used to plot the curve between stress and strain. The sample result produced for one of the square pin profiled tool is shown in the Figure 6. All the details like dimensions of the specimen prepared, the standard followed was given above the curve and the results obtained after the test were mentioned bottom of the report.

![Figure 6: Sample test result for square tool](image)
The ultimate tensile strength and yield strength of the specimens were given in the Figure 7. From the sample prepared it was observed that cylindrical and tapered pin were had a tunnel like defect throughout the length. The specimen prepared using square pin had slightly better processed surface. It was proven by the test results that when compared with the other two profiles the square pin tool had better tensile strength and yield strength.

![Figure 7: UTS and YS of FSP specimens](image1)

Micro hardness testing is a type of finding a material hardness or resistance to penetration when the samples were thin foil or small region of the composite materials. The samples were prepared and tested as per ASTM E384 standard. The prepared samples from the friction stir processed specimen are shown in the Figure 8.

![Figure 8: Micro hardness sample specimen](image2)

The hardness values were measured at base material and processed zone at different locations. The average hardness of the materials are considered and given in the Figure 9. For all the three tools, the processed zone had higher hardness than the base material. This is due to inclusion of reinforcement particles in to the base materials.
Figure 9: Micro hardness of FSP specimens

Based on the available literature, this is because in the stir zone the material recrystallization occurs due to the stir of the material by rotating tool. Among the three tool considered for study, square pin tool had produced better hardness values in all three zones than the other two tools by means of pulsating stirring action.

4. Conclusion

As a unique material processing method, Friction stir processing has great advantages in preparation of surface composites and modification of materials due to solid state processing method. This article presents the details of the aluminium based hybrid surface composites prepared by three different tools via square, cylinder and tapered. The composites were tested for its mechanical properties such as ultimate tensile strength, yield strength and micro hardness.

The test results revealed the ultimate tensile strength reached maximum of 221.92 MPa for square pin tool profile followed by cylindrical tool and tapered tool of 106.64 Mpa and 100.27 Mpa respectively. The yield strength was obtained maximum as 204.73 Mpa for square tool. The results of the micro hardness test showed that at stir zone the hardness was high for all three different tool pin. This was due to stirring action of the tool ensures the proper distribution of reinforcement particles in to the base material.

References

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