EXPERIMENTAL STUDY ON MANUFACTURING AND FRICTION STIR WELDING OF AA 2014 BASED METAL MATRIX COMPOSITES

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Chapter 06: Conclusion

6.1 Introduction

The present chapter discusses the conclusions drawn from this research work. The research work makes use of the stir casting process for manufacturing of Aluminium Matrix Composites (AMC) having three different compositions i.e. AA 2014 + 5% SiC, AA 2014 + 10% SiC and AA 2014 + 15% SiC. The manufactured composites were evaluated on the basis of metallurgical, mechanical and tribological properties. These characteristics of as-cast composites were compared with that of as-received AA 2014. To further enhance the characteristics of as-cast composites, Friction Stir Processing (FSP) was performed. The characteristics of composites processed under two different conditions were evaluated and compared with that of as-cast composites. Lastly, the present research work demonstrates Friction Stir Welding (FSW) and characterization of welded as-cast composites.

6.2 Thesis Contribution

AA 2014 reinforced with different weight percent of SiC particles were successfully manufactured using the stir casting process. The considered weight percent of SiC particles in AA 2014 was 5%, 10% and 15%. The presence of reinforcement particles in the manufactured composites was evaluated using Optical Microscope (OM). Owing to the carefully selected stir casting process parameters, the microstructure of all as-cast composites were not having any traces of intermetallic or deleterious phases. It can be concluded that the increase in weight percent of reinforcement particles reduces the particle free region but increases the dendrites formation, agglomeration of reinforcement particles and casting defects. Among three composites, the microstructure of AA 2014 + 10% SiC revealed a comparatively uniform and homogenous distribution of broken SiC particles having irregular shape and size.

Compared to as-received AA 2014, the manufactured composites revealed enhancement in microhardness and tensile strength. The observed microhardness and tensile strength of as-received AA 2014 were 73.45 Hv and 175.58 MP. With reference to this, the microhardness and tensile strength of as-cast composites in the increasing order of weight percent of reinforcement particles were 85 Hv, 86.76 Hv and 86.16 Hv and 213.71 MPa, 225.76 MPa and 200.25 MPa respectively. It can be said that with the increase in weight percent of reinforcement particles from 5% to 10%, both hardness and tensile strength increase and achieves maximum value. Further increase in weight percent of reinforcement beyond 10% was found to have an adverse effect on both properties of as-cast composites. Lastly, it was observed that with the increase in weight percent of reinforcement particles from 5% to 15%, both wear resistance and coefficient of friction (COF) was found to increase. Thus, it can be said that among three compositions, AA 2014 + 10% SiC revealed maximum microhardness and tensile strength with the acceptable value of wear and COF. Looking at the microstructure, mechanical and tribological properties, it is recommended that the weight percent of SiC particles in AA 2014 must not exceed 15%. Exceeding the weight percent of SiC particles by 15% will ultimately increase the slag formation which will result in more casting defects and lower mechanical properties.

To avoid the casting defects and further enhance the characteristics of as-cast composites, FSP was performed. Irrespective of the processing condition and composition of as-cast composites, the nugget zone (NZ) of processed composites revealed a homogeneous distribution of fine and equiaxed grains of SiC particles having rounded boundaries. Apart from a few exceptions, post processing, enhancement in microhardness and wear resistance was observed. The resulting microstructure of processed composites was either found to have a banded structure or the presence of particle rich and particle deficient zones.

Composites processed at a rotational speed of 270 rpm and transverse speed of 78 mm/min (T7 processed) showed satisfactory microscopic results for all fabricated composites. The average grain size in the NZ of T7 processed composites showed a drastic reduction from 61.95 µm for as-cast composite to 5.45 µm, 5.50 µm and 7.75 µm for AA 2014 + 5% SiC, AA 2014 + 10% SiC and AA 2014 + 15% SiC respectively. Corresponding average microhardness was 81.25 Hv, 88.56 Hv and 86.97 Hv respectively. Apart from AA 2014 + 5% SiC, the average microhardness of other compositions revealed noticeable enhancement compared to as-cast composites. The wear of T7 processed composites in increasing order of weight percent of reinforcement was 376 microns, 230 microns and 247 microns, which was comparatively lower than the respective wear of as-cast composites.

Composites processed at a rotational speed of 190 rpm and transverse speed of 50 mm/min (T9 processed) were found to have a comparatively higher number of defects. Few locations of processed composites revealed void or agglomerated SiC particles. Thus, it can be concluded that this combination of process parameters tends to generate improper stirring action and poor processing of composites. At the same time, NZ of AA 2014 + 5% SiC, AA 2014 + 10% SiC and AA 2014 + 15% SiC were found to have an average grain size of 7.75 µm, 9.20 µm and 7.90 µm which were higher than that of T7 processed composites. Due to the same, the reduction in average microhardness was observed for T9 processed composites. Along with this, all the composites processed by T9 condition revealed higher wear when compared to T7 processed composites. In the increasing order of weight percent of reinforcement particles, the average wear of T9 processed composites was 405 microns, 227 microns and 402 microns respectively. Thus, to enhance the characteristics of as-cast composites, the combination of the rotational speed of 270 rpm with a transverse speed of 78 mm/min can be preferred over the other combination.

Compared to as-cast, weld nugget (WN) of Friction Stir Welded composites revealed the presence of fine, equiaxed and homogenous grain structure. With the increase in weight percent of SiC particles, defects such as voids and porosity were found to increase in welded zones. Due to the higher weight percent of reinforcement particle, the microstructure of AA 2014 + 15% SiC revealed a comparatively larger size of reinforcement particle along with a particle free region. In increasing order of weight percent of SiC particles, the tensile strength of welded composites was found to reduce by 31.16%, 22.90% and 18.55% respectively, when compared to as-cast composites. On the other side, the elongation of welded composites was found to decrease with the increase in weight percent of reinforcement particles. In the increasing order of weight percent of reinforcement particles, the microhardness of as-cast composites was 95.16 Hv, 123.68 Hv and 133.36 Hv respectively. Post FSW, enhancement in the microhardness of weld zone was observed and the respective values were 127.2 Hv, 140.12 Hv and 150.19 Hv.

6.3 Future Scope

The present investigation shows that there is a scope for further work. The study can be extended in the following areas:

- The AMC AA 2014 + 5%, 10% and 15% SiC has been manufactured using the manual stir casting process. An attempt should be made for manufacturing AMC using a more sophisticated stir casting setup or powder metallurgy. Also, manufacturing of composites having minimum casting defects and agglomeration of reinforcement particles can be attempted.
- As a result of slag formation, the weight percent of SiC particles in AA 2014 was restricted to 15%. Thus, a suitable way of manufacturing AA 2014 reinforced with a higher weight percent of SiC particles can be explored for further research.
- In the present investigation, a comparatively smaller range of rotational speed and transverse speed was observed during the FSP. Interested researchers should work upon the ways of processing as-cast composites with greater control on process parameters having a larger range. Apart from this, the effect of other processing parameters such as axial load, number of passes, the orientation of workpiece and different tool profiles can be studied elaborately.
- The present investigation demonstrates the FSW process carried out for butt joint configuration. This investigating can be extended by attempting different joint configurations. As a result of this, the FSW process will get more acceptances in various industries associated with welding.
- Experiments can be attempted by considering different tool profiles and in different welding conditions such as immersed water and under the presence of liquid nitrogen. This will increase the acceptance of manufactured composites in various industries.
- Furthermore, dissimilar welding i.e. welding of AA 2014 + 5% SiC with AA 2014 + 10% SiC can be targeted. Along with this, welding of manufactured composites with different grades of aluminium alloy can also be explored.
- Lastly, a similar type of study can be attempted for AMC manufactured using a different grade of alloy (such as aluminium, copper magnesium, etc.) reinforced with ceramic particles other than SiC.