

Investigation of Fracture Toughness on FSW Joints of Nano Fly Ash Reinforced Aluminium Composites

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ABSTRACT

The fracture toughness is a desirable structural property which governs the life of materials and impact strength is the measure of toughness in terms of absorbed energy. In this research work, nano fly ash (NFA) reinforced Al6063 matrix based composites are prepared with different %wt. of NFA and consequently the friction stir weld (FSW) joints of composites are fabricated with tool rotational & traverse speeds as welding process parameters. The energy absorption behavior is studied on FSW joints by Charpy impact test. Higher toughness values were observed on the FSW joints compared to base Al6063 alloy due to the influence of FSW process parameters. Reduced impact strength on FSW joints was observed with increased NFA reinforcement in the fabricated composites. The NFA particles acts as obstacles to dislocation motion thereby decreases the ductility of fabricated composites. The increased brittleness with hard NFA particle inclusion in the composites leads to the reduction in fracture toughness.

KeyWords: NFA; FSW; Toughness; Charpy impact strength

INTRODUCTION

Aluminium Metal matrix Composites (AMCs) are advisable structural materials for most of the aerospace applications due to their low density property. There is an increasing demand for AMCs in transportation sector due to improved properties and low cost of production. Several researchers studied AMCs to investigate their behavior in different aspects [1]. The manufacturing conditions are highly influencing the properties of resulting AMCs. Stir casting is the most adoptable method to produce AMCs at cheaper rates with ease of production [2]. The parameters like stirring speed, stirring time and pouring temperature are important casting parameters for producing sound castings of AMCs. Aluminium matrix materials can accommodate most of the particulate reinforcement materials [3] like SiC, TiC, TiB₂, Al₂O₃ etc., in micro and nano sizes to produce AMCs. Fly ash is an industrial waste material [4] which can replace the expensive reinforcements to produce sound castings of AMCs.

The study of secondary manufacturing processes like forming, machining, joining etc., of composite materials is very much

essential to suggest for several applications. Friction Stir Welding is one of the best joining process suitable for AMCs. Different process parameters of FSW are highly influential on the properties of joint obtained [5]. The rotational speed of tool and its traverse speed are important FSW parameters which effecting the weld joint properties. The FSW tool position and its profile are other important considerations for producing sound weld joints [6, 7]. The dynamic recrystallization is the major phenomenon of FSW process which influencing the behavior of weld joint [8]. The reinforcing material and its size of AMCs are most effective on properties of FSW joints. The fracture toughness is an essential property of weld joints to adopt the welding process for several structural applications. The reinforcement material is so crucial for influencing the energy absorption capability on FSW joints of AMCs.

Based on available literature, limited work has done on inexpensive NFA, Al6063 matrix based composites and FSW joints of Al6063 matrix based composites with NFA as reinforcement. Now in this work, the research was focused on producing the AMCs with Al6063 alloy as matrix material & NFA as reinforcement material. And consequently FSW joints of

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fabricated composites were obtained to study the influence of NFA on FSW joints. The FSW joints were tested to evaluate the fracture behavior of the joints.

METHODOLOGY

The standard methodology in the experimentation gives acceptable results to perform proper evaluation. In this work, experimentation carried in two stages i.e., stir casting of Al6063/NFA composites and joining of fabricated composites by FSW process. The materials used in the stir casting process are Al6063 alloy ingots and different %wt. of NFA to produce Al6063/NFA composites. The ultrasonic assisted stir casting process was adopted for producing Al6063/NFA composite castings with 0, 1, 2 and 3% wt. of NFA as reinforcement material. The stirring speed 400 rpm, stirring time 4-5 minutes and pouring temperature 6700C were considered as casting parameters. Vortex method was used to reinforce the preheated NFA particles in to the Al6063 melt [9]. The vibrating sonicator probe at 20 kHz was kept in the melt to separate the clusters formed in the NFA and argon gas shielding was provided to avoid the atmospheric contamination. The melt was poured in to the preheated moulds and Al6063/NFA composites were obtained in the form of plates for the consequent fabrication of FSW butt joints.

The plates with 100 mm X 60 mm X 5 mm were used to fabricate FSW joints of Al6063/NFA composites with different %wt. of NFA. A numerically controlled 3 ton capacity with 415V, 3 phase, 50Hz, 6000 kgf FSW machine was used to obtain FSW joints for all four composite plates. Based on literature and trial runs performed on the plates, tool rotational speeds 800, 1000, 1200 & 1400 rpm and tool traverse speeds 50, 60, 70 & 80 mm/min were considered as FSW process parameters [10]. The standard Charpy impact test specimens with sub size were cut on the FSW joints perpendicular to the direction of welding. The energy absorbed during impact loading was obtained on standard Charpy impact testing machine with standard loading conditions on standard Charpy impact test specimen.

RESULTS AND DISCUSSION

The various results obtained from Charpy impact testing were obtained and shown in the figures 1 to 4. The FSW parameters and the amount of added NFA in the Al6063/NFA composites impart changes in the fracture toughness of FSW joints. A decrease in energy absorbed during impact test was observed with increased %wt. of NFA in the Al6063/NFA composites.

Higher Charpy impact strength was observed in weld bead of pure Al6063 alloy samples compared to weld beads of Al6063/NFA composites with different %wt. of NFA, as shown in figures 1 & 2. The amount of absorbed energy during fracture was decreased drastically with an increased %wt. of NFA reinforcing particles in the Al6063 alloy. It was observed that the decreased energy absorption capability in the Al6063/FA composites due to the brittle nature of the reinforced FA particles, reduced ductility, and deformation capabilities of the fabricated cast composites [11 - 14]. A similar

trend was observed in the weld beads of Al6063/NFA composites on toughness values.

The NFA particles reduce the grain size, which causes limited space for dislocation movement and leads to reduced ductility in the weld bead of Al6063/NFA composites with increased brittleness. In this investigation, reduced toughness values were observed on the weld beads of Al6063/NFA composites with increased NFA, and weld beads of pure Al6063 alloy exhibit high impact strength when compared to NFA, reinforced composites.

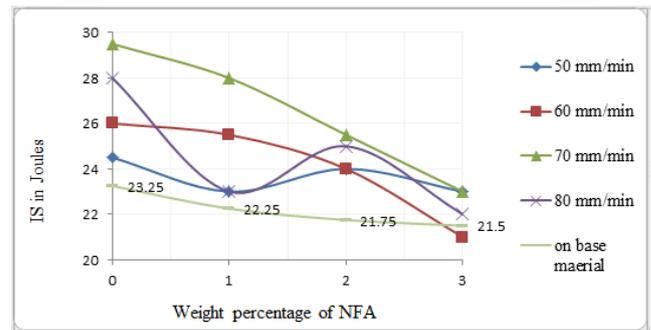


Figure 1: Influence of NFA on impact strength of FSW joints of Al6063/NFA composites at different tool rotational speeds

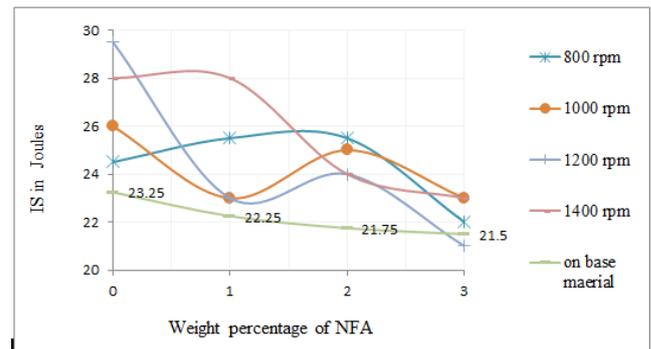


Figure 2: Influence of NFA on impact strength of FSW joints of Al6063/NFA composites at different tool traverse speeds

An increase in impact strength was observed in the weld beads of Al6063/NFA composites with an increase in tool rotational speed, as shown in figure 3. The rotational tool speed was responsible for generating enough heat input to the weld zone of Al6063/NFA composite, which results in the recrystallization of microstructure due to the stirring of material during FSW tool rotation.

The fine microstructure obtained due to rotation of the FSW tool improves the impact strength. Comparatively, increased toughness was observed in the weld beads of Al6063/NFA composites, increasing tool rotational speed.

The stir zone material was converted to the soft sponge-like material due to elevated temperatures developed by the rotating tool. Proper mixing of the material was carried through the stirring action of the rotating tool. The homogeneity in weld bead material was achieved through a rotating tool, which leads to enhanced impact strength of the FSW joints.

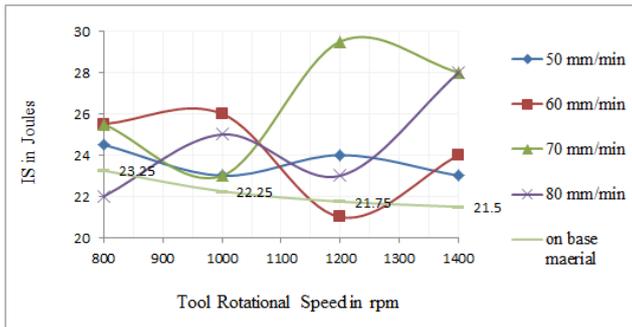


Figure3: Influence of tool rotational speed on impact strength of FSW joints of Al6063/NFA composites at different %wt. of NFA

The tool traverse speed influences the impact strength on weld beads of Al6063/NFA composites, as shown in figure 4. The material transfer from the advancing side to the retrieving side was handled by tool movement along the weld line. Slow tool traverse speed develops high heat inputs in the stir zone, which leads to large TMAZ & coarse microstructure results in poor impact strength. On the other hand, too high traverse speeds lead to improper mixing of material in the stir zone and impart defects like pinholes in the weld bead.

A comparatively increase in impact strength was observed in the weld beads of Al6063/NFA composites with increased tool traverse speeds. The maximum Charpy impact strength on the weld bead of Al6063/NFA composite was 29.5 Joules, obtained at tool traverse speed 50 mm/min, rotational tool speed 1400 rpm, and 0%wt. of NFA. The Al6063/NFA composite base materials exhibit lower impact strengths than weld beads of Al6063/NFA composites due to the increased bonding achieved in the FSW joint of the composites.

Beyond 2%wt. of NFA reinforcement, the impact strength on weld bead of Al6063/NFA composite was further decreased below the Al6063/NFA composite base material. The NFA inclusion reduces the toughness values on account of increased brittleness, and tool rotational & traverse speeds improved the impact strength of the weld beads of Al6063/NFA composites.

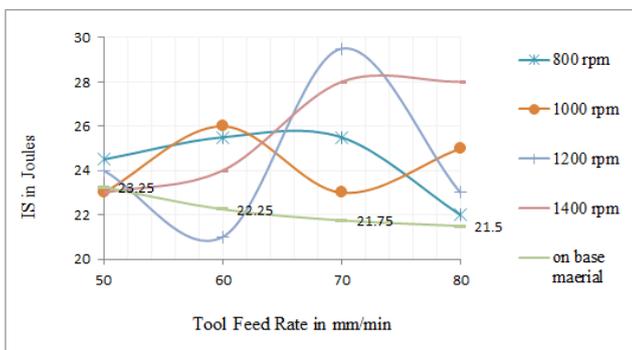


Figure4: Influence of tool traverse speed on impact strength of FSW joints of Al6063/NFA composites at different %wt. of NFA

CONCLUSION

The following are the conclusions drawn from the observations from the experimental results and discussions carried in the previous section.

The NFA was successfully reinforced in to the Al6063 matrix material through stir casting method.

The FSW process was successfully carried on Al6063/NFA composites with different %wt. of NFA and FSW parameters.

The impact strength was decreased on the FSW joints of Al6063/NFA composites with increased NFA. The Charpy impact strength on FSW joints of Al6063/NFA composite was further decreasing below the base Al6063/NFA composite with an increase in NFA reinforcement.

The maximum Charpy impact strength of FSW joints of Al6063/NFA composite specimen is 29.5 Joules, obtained at tool traverse speed 50 mm/min, rotational tool speed 1400 rpm, and 0% wt. of NFA.

The tool's rotational and traverse speeds were influencing parameters in improving the impact strength on FSW joints of Al6063/NFA composites.

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