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A FRAMEWORK FOR WELDING OF DISSIMILAR POLYMERS BY USING METALLIC FILLERS

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Abstract: Friction welding is one of the commercially established processes for welding of similar or dissimilar metallic or polymeric materials. In the present research, two different technique of friction welding namely: rotary friction welding and friction stir welding have been performed to check the feasibility of joining of different polymeric materials with the use of metallic fillers of Fe and Al. Rotary friction welding was performed on center lathe by controlling input parameters such as rotational speed, feed rate and time taken to perform welding, whereas friction stir welding was performed on CNC vertical milling cutter by controlling input parameters of specimen thickness, rotational speed and feed rate. The results of study suggested that for rotary friction welding, similarities in melt flow index (MFI) is a prominent factor whereas for friction stir welding, MFI was not a significant factor.

Keywords: Friction welding, ABS, Nylon-6. HDPE, LDPE, dissimilar plastics

1. INTRODUCTION

Friction welding is a process of joining of materials and structures below their melting points. When these materials come in contact with relative motion to each other, with the action of friction, heat is produced and deformation takes place, due to this intermolecular diffusion is occurred between their faces and thus welding is performed. Friction welding concept was originally come for similar metal joining, but it was further applied for similar thermoplastic composites [1]. Later on this concept was used for the dissimilar materials like steel-aluminum and steel-copper and aluminum-magnesium cylindrical piece joining [2-3] and for dissimilar plastic welding of ABS to HDPE [4]. The number of studies has been reported to check the mechanical, thermal and metallurgical properties of friction welded piece [5-7]. Interface properties were examined to check the fusion, deformation mechanisms and microstructure characteristics of friction welded interface [8-9]. ABS and Nylon6 are commonly used thermoplastics with excellent mechanical properties and are used generally for friction welding application. The joining of ABS or Nylon 6 to itself or welding of ABS to HDPE is feasible [10], but, there is a limitation of joint strength (for friction welded joints) of these thermoplastics that hinders its use in different engineering applications.

Some studies have highlighted the use of a tool in the form of a ring which is rotated in between the interface of two pipes. This is getting heated deformed by friction created due to rotation of ring, so welding of pipeline is possible [11]. In the aerospace, the friction inertia welding concept is most applicable concept with high precision of joining [12-14]. The fillers in the form of carbon nanotubes can be reinforced with polymeric materials can result into the better joint made by friction stir welding. The studies also highlight that friction spot welding of polymethyl-methacrylate and polymethyl-methacrylate-Sio_2 is feasible [15-16]. Use of fillers like carbon Nano-composites and non-metallic fillers can be treated as the medium to enhance the mechanical, metallurgical as well as thermal properties of rotary friction welded or friction stir welded polymers. [17]-[18].

The literature review reveals that joint strength properties of rotary friction welded joints of ABS with Nylon6 are not good enough because of difference in their rheological properties (like: MFI and glass transition temperature) [19-23]. But with reinforcement of metal powder in different proportions with these polymers results into similar MFI, which in turns may contribute to better joint strength. So in this study effort has been made to investigate the weld properties of rotary friction welded joints of ABS with Nylon6 after metal filler reinforcement. Whereas in the case of friction stir welding of LDPE and HDPE, contribution of rheological properties were negligible and higher rotational speed were responsible for joining.

2. MELT FLOW INDEX

Melt flow index (MFI) can be considered as one of the rheological properties like glass transition temperature, melting point, which characterized the flow-ability of polymer based materials [24]. MFI of any polymer or polymeric composites is considered as the deposition/10min though melt flow tester as ASTM D1238-95, applying standard weight of 3.8 Kg at standard temperature of 230 Degree centigrade. The similarities in MFI offer the possibility of joining of two different polymeric materials in the case of rotary friction welding..

The melt flow tester is consist of cylindrical barrel which is wrapped and surrounded by a heater coil, heater have an outer periphery of insulation material to restrict the losses of heat and this heater is controlled automatically by process control box. This set-up is also consisting of a standard weight applied through the piston, a piston head and dies to deposit the materials.

The material is collected in 10 minute is further subjected to weighing balance to determine its mass. So, deposition of material through melt flow tester in 10 minute is considered as melt flow index.

3. TOOL, TECHNIQUES AND MATERIALS

This research deals with experimental feasibility of friction welding for two dissimilar polymeric materials with the use of metallic fillers. There were two variant of friction welding technique performed in this attempt, first rotary friction welding and other friction stir welding.

3.1. Rotary friction welding

Rotary friction welding technique can be considered as variant of friction welding where stationary

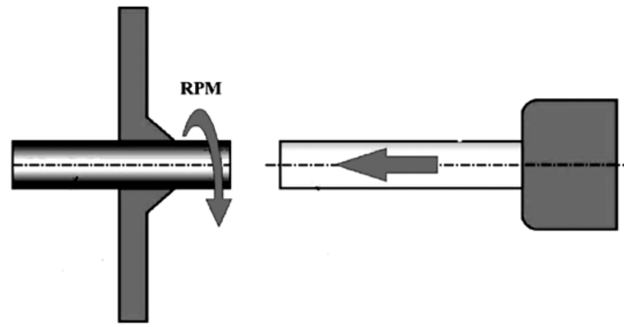

Figure 1: Mechanism for rotary friction welding [25]

cylindrical part is provided by linear motion for creation of friction between two specific workpiece specimens. Rotary friction welding was performed of center lathe by reinforced specimen of ABS and Nylon-6. These materials were selected upon the similarities in their melt flow index. Fig. 1 shows schematic of rotary friction welding process.

3.2. Friction stir welding

Friction stir welding is another variant of friction welding in which consumable or non-consumable tool is taken and rotates in between two dissimilar polymeric sheet to create the friction between then, resulted in the formation of heat which will responsible for the easy bonding of two different sheets. In this experimentation workpiece of HDPE and LDPE was taken with some reinforcement of iron metal powder to make the joint with the help of Non consumable tool of mild steel. CNC vertical milling cutter was selected as tooling apparatus. Fig. 2 shows the mechanism of friction stir welding of two dissimilar plastics.

4. EXPERIMENTATION

As discussed above, there were two different processes have been selected to check the

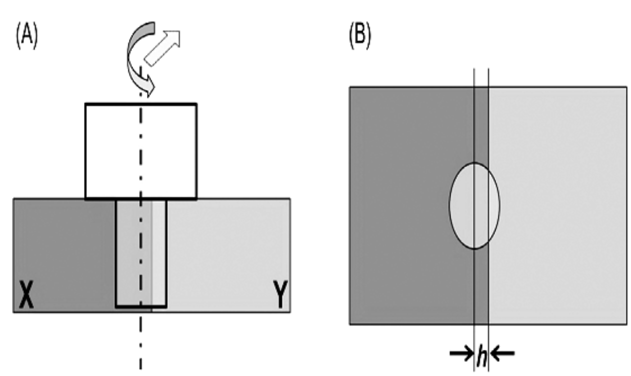

Figure 2: Schematic of friction stirs welding (A), Top view of process (B) [21]

feasibility of joining of two different polymers. Concept of rotary friction welding and friction stir welding were applied on joining of ABS with Nylon-6 and joining of HDPE with LDPE with reinforcement of metallic fillers.

4.1. Rotary friction welding

ABS and Nylon-6 were selected for the pilot experimentation. In this pilot study, the center lathe was selected as tooling apparatus which has input variables like feed rate and rotational speed. Center lathe has the configuration of feed rate ranges of 0.045-18mm/rev whereas rotational speed ranges of 50-1200rpm. As literature review reveals, the welding of polymeric materials can be best suited under the range of 500-1500 rpm [1], [6]-[7], [18], so rotational speed of 1200rpm was selected for the pilot study. Cylindrical pieces of ABS and Nylon of 55mm length and 25mm diameter were prepared on the specimen hot mounting machine with using concept of powder metallurgy. The welding of ABS to Nylon-6 was unsuccessful because their dissimilarities in rheological properties such as melt flow index. So, controlling the melt flow index by using addition of metallic fillers resulted in similar melt flow index. So, these similarities in melt flow index offered the possibility of joining of two dissimilar polymeric materials. Two different metallic fillers of Fe and Al were taken to control the melt flow index. At metallic proportion of 40% for both cases, the melt flow index was nearly similar.

Table 1
MFI with different polymer and metallic filler proportion and feasibility of joining
MFI with Al metal powder reinforcement

Wt. % of Al filler	*MFI with ABS*	*MFI with Nylon 6*	*Characteristics of joint*
0	8.898	9.972	unsuccessful
10	9.722	10.622	unsuccessful
20	11.114	12.285	successful
30	13.091	13.664	successful
40	14.613	14.656	strong joint
50	15.250	16.214	Broken by handling

MFI with Fe metal powder reinforcement

Wt. % of Fe filler	*MFI with ABS*	*MFI with Nylon 6*	*Characteristics of joint*
0	8.898	9.972	unsuccessful
10	10.344	11.249	broken by handling
20	11.973	12.615	successful
30	13.681	14.208	successful
40	15.075	15.006	strong joint
50	16.141	16.786	successful

Table 1 shows the feasibility of rotary friction welding at different polymer and metallic filler composition. At 40% metallic filler proportion, the welding of ABS to Nylon-6 was possible for both cases. Next experimentations were performed to cross-check this similar MFI concept, in which ABS-10%Fe and Nylon-6 were selected and performed the welding operations. The welding was successful and given a strong joint of these polymers with using similar MFI concept. Fig. 3 shows the obtained welded joint of ABS with 10% Fe filler and Nylon-6 materials.

Similarly many cross-check examinations have been performed and it was concluded that similarities in MFI resulted into better joining of polymeric materials.

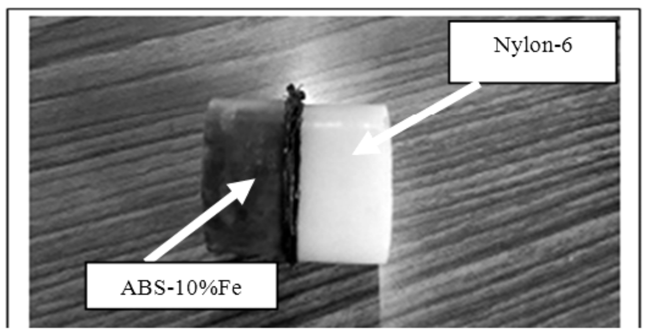

Figure 3: Rotary friction welded joint of ABS-10%Fe and Nylon-6

4.2. Friction stir welding

Friction stir welding is also an economical technique for joining of sheets of similar metallic or polymeric materials. Some researchers have attempted friction stir welding of dissimilar materials. Cylindrical discs of HDPE and LDPE materials were prepared on specimen hot mounting machine of different thickness and 25mm diameter. The prepared cylindrical pieces were cut down by their half to make it semi-circular shape, then the friction stir welding were performed on different rotational speed of 1800rpm to check the feasibility of joining of such polymeric materials. Firstly the welding of LDPE and HDPE were performed on the CNC VMC

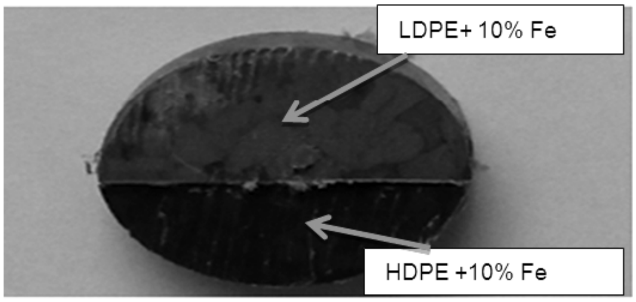

Figure 4: Friction stir welded LDPE-10%Fe and HDPE-10%Fe

without using any fillers, the welding was unsuccessful because of their difference in molecular structure, carbon chain, glass transition temperature, intermolecular bonding and melt flow index. When metallic filler of 10%Fe reinforced with both LDPE and HDPE , resulted into successful joining of these polymer. Fig. 4 shows the welded piece of HDPE and LDPE with using metallic fillers.

Next experimentation were performed to see the feasibility of welding with similarities in their melt flow index, it was observed that the melt flow index not contributed in the case of friction stir welding, this is may be due to high rotational speed conditions, resulted into the better het generation and better mixing of samples.

Table 2
Different MFI conditions and characteristics of welded joints

Wt. % of Fe	*MFI of LPDE*	*MFI of HPDE*	*Characteristics of joining*
0	2.37	17	unsuccessful
10	2.69	23.64	successful
20	3.07	22.86	successful
30	3.01	24.64	successful
40	2.85	26.98	successful

Table 2 shows the melt flow index of LDPE and HDPE at different proportions of metallic filler and there characteristics of joint after welding. The above study has been suggested that there is a possibility of welding of dissimilar polymeric materials with use of metallic fillers. Melt flow index is not a significant phenomenon for joining of dissimilar polymers in the case of friction stir welding.

5. CONCLUSIONS

This study highlighted the difference in basic mechanism of joining dissimilar polymeric materials with two different variants of friction welding process and role, contributions of different process variables for feasibility of dissimilar plastic welding. Both the techniques like, rotary friction welding and friction stir welding was found feasible for joining dissimilar polymeric materials. Following conclusions have been made from present study:

5.1. For rotary friction welding

The similarities in the melt flow index offered the rotary friction welding; this may be due to attainment of similar rheological properties by using metallic fillers. At 40% of metallic fillers in both the cases of Fe fillers and Al fillers, welded pieces were appeared as good joint. Rotary friction welding is nearly not possible when two materials do not have similar melt flow index.

5.2. For friction stir welding

Friction stir welding of LDPE and HDPE was not possible, without using Fe metal fillers; this may be due to different bonding characteristics of these two materials. The melt flow index was not considered as the significant parameters in the case of friction stir welding of LDPE and HDPE. The welding is possible without similarities in their MFI, but a very high rotational speed of about 1800rpm is needed in this variant of friction welding.

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