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Friction welding of dissimilar plastic/polymer materials with metal powder reinforcement for engineering applications

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ABSTRACT

Friction welding is one of the established processes for joining of similar as well as dissimilar polymer/plastics and metals. In past 20 years numbers of application in different areas using this process have been highlighted, but very limited contributions have been reported on properties of friction welded joints of dissimilar polymer/plastic materials after reinforcement with metal powder. In the present work an attempt has been made to perform friction welding of dissimilar plastic based materials by controlling the melt flow index (MFI) after reinforcement with metal powders. The present studies of friction welding for dissimilar plastic were performed on Lathe by considering three input parameters (namely: rotational speed, feed rate, and time taken to perform welding). Investigations were made to check the influence of process parameters on mechanical and metallurgical properties (like: tensile strength, Shore D hardness and porosity at joint). The process parameters were optimized using Minitab software based on Taguchi L9 orthogonal array and results are supported by photomicrographs.

1. Introduction

The joining of composite materials and structures is a topic of high technological interest; since it is well know that traditional joining techniques are usually not directly exportable to composite elements (refer, e.g. to [1–4] and references therein). Attention is increasingly being given to the following research areas, both experimentally and numerically: fusion bonding [5,6]; welding-based joining techniques [7–14]; friction spot and friction lap joining [15·16],; and ultrasonic joining [17]. 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 [18]. Later on this concept was used for the dissimilar materials like steel-aluminum and steel-copper and aluminum-magnesium cylindrical piece joining [19,20] and for dissimilar plastic welding of ABS to HDPE [21]. The number of studies has been reported to check the mechanical, thermal and metallurgical properties of friction welded piece [22–24]. Interface properties are examined to check the fusion, deformation mechanisms and microstructure characteristics of friction welded interface [20,25–26]. ABS and Nylon6 are commonly used thermoplastics with excellent mechanical properties and are used generally for friction welding application [21]. The joining of ABS or Nylon 6 to itself or welding of ABS to HDPE is feasible [27], 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 [28]. Friction inertia welding concept is widely accepted in aerospace applications [29,30]. Reinforcement of polymer with nano-composite is the technique to make the feasibility of friction welding process. The studies also highlight that friction spot welding of polymethyl-methacrylate and polymethyl-methacrylate-Sio_2 is feasible [31]. The reinforcement of nano-composite with polymers is responsible for the improved mechanical and metallurgical properties [32–36].

The literature review reveals that joint strength properties of friction welded joints of ABS with Nylon6 are not good enough

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because of difference in their rheological properties (like: melt Flow Index (MFI) and glass transition temperature) [37–41]. 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 friction welded joints of ABS with Nylon6 after metal powder reinforcement.

2. Experimentation

In pilot experimentation of friction welding for dissimilar plastic/polymer materials, two different materials were judicially selected (namely: ABS and Nylon6). Cylindrical discs of dimension length 50 mm and diameter 25 mm were prepared on hot mounting machine (by pressure moulding). After preparation of cylindrical discs, friction welding was performed on center lathe at 500, 775 and 1200 rpm. Two cylindrical discs were mounted on the center lathe (see Fig. 1), and were put in contact with each other (to generate friction/heat) for duration of 10 s along with automatic feed of 0.045 mm/rev. for 6 s. Welding of these pieces were unsuccessful because ABS and Nylon 6 was not having similar MFI or glass transition temperatures. So, again an experiment was performed with the 10% Fe powder (by weight) as reinforcement of ABS and Nylon6 (without Fe powder reinforcement) work pieces. This time welding was successful. This may be because of attainment of MFI in similar range between two different polymers. Fig. 2 shows friction welded work piece of ABS with 10% Fe powder as reinforcement and Nylon6.

The main objective of this pilot study was to check the possibility of welding for ABS and Nylon6 for engineering applications. For possibility of welding it was necessary to establish MFI of two components in a particular range. So testing was performed on melt flow tester (as per ASTM D 1238 standard) to check the MFI of ABS and Nylon6 with reinforcement of Fe and Al metal powder (see Table 1).

After establishing MFI, for mentioned combination of metal powder with polymers, it was observed that melt flow index of ABS and Nylon 6 are very similar at 40% reinforcement of both metal powder. So, this combination of composition/proportion of metal powder with polymer matrix have been selected for further investigations, with design of experimentation based on Taguchi L9 orthogonal array (see Table 2). Based upon Table 2, Table 3 shows control log of experimentation.

The output parameters for the present study are tensile strength,

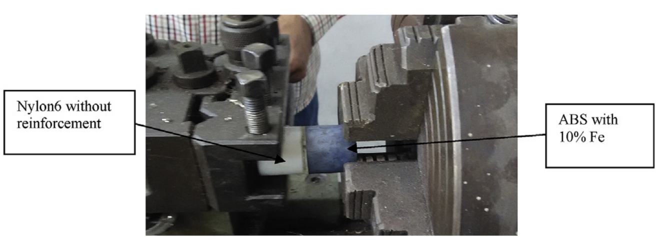

Fig. 1. Pilot experimentation on Center lathe.

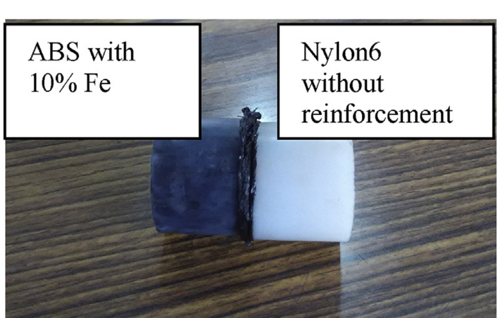

Fig. 2. Obtained welded piece of ABS-10%Fe to Nylon6-10%Fe.

Table 1 MFI of ABS and Nylon6 with reinforcement of Fe and Al metal powder.

MFI with Al powder reinforcement		
Wt% of Al	MFI with ABS	MFI with Nylon 6
0	8.898	9.972
10	9.722	10.622
20	11.114	12.285
30	13.091	13.664
40	14.613	14.656
50	15.250	16.214
MFI with Fe powder reinforcement		
Wt% of Fe	MFI with ABS	MFI with Nylon 6
0	8.898	9.972
10	10.344	11.249
20	11.973	12.615
30	13.681	14.208
40	15.075	15.006
50	16.141	16.786

Table 2
Parameters selected for experimentation Based on Taguchi L9 orthogonal array.

Levels	A Rotational speed (RPM)	B Feed rate(mm/rev)	C Time for welding (s)
1	500	0.045	4
2	775	0.090	6
3	1200	0.180	8

Table 3
Control log of experimentation.

Parametric conditions	A Rotational speed (RPM)	B Feed rate (mm/rev)	C Welding time(s)
1	500	0.045	4
2	500	0.090	6
3	500	0.180	8
4	775	0.045	6
5	775	0.090	8
6	775	0.180	4
7	1200	0.045	8
8	1200	0.090	4
9	1200	0.180	6

Table 4
Shore D hardness value at obtained weld interface (Al metal powder reinforced).

Parametric conditions	Batch run 1	Batch run 2	Batch run 3
1	78.5	78.0	77.5
2	77.5	77.5	78.0
3	77.0	77.5	77.5
4	79.0	78.5	78.0
5	78.0	78.0	77.5
6	77.5	78.0	78.0
7	78.5	78.0	79.0
8	78.0	78.5	78.0
9	78.0	77.5	77.5