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JOINING OF PLASTICS BY FRICTIONAL VIBRATION

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ABSTRACT

Plastics are the possessors of superior properties such as extreme strength to weight ratio, corrosion resistance, higher impact strength and dimensional stability. Owing to these exotic properties, they are finding applications in advanced industrial applications. To exploit the complete advantages of plastics, they have to be integrated suitably with similar and dissimilar materials. Conventional methods of joining such as mechanical fastening, adhesive bonding and hot knife joining are available for plastics. However the continuous thrust to satisfy the industrial requirements such as high productivity and improved quality necessitate an improved method of joining. Present study emphasizes on joining of plastics by an innovative idea of utilizing the principle of friction stir welding process. Translational vibration of a tool induces frictional heat at the interface of the joining members. The generated heat is harnessed to form the joint. The processed joints by this method are analyzed by metallurgical and mechanical studies in order to assess the quality and performance of the joints.

Keywords: friction, plastics, vibration, strength and microstructure.

1. INTRODUCTION

Joining of plastics finds applications in medical, aerospace, electronic and automotive areas. Recently, researchers are using the non conventional energy sources to join plastics. Microwaves are focused using a specially designed ridged wave guide device, on the joint zone to obtain good quality joints [1]. High speed lasers are used to process joints of plastic films for optical devices [2]. Polypropylene and polyethylene joints are processed by concentrating solar energy by a specially designed solar energy concentrator [3]. Though the above mentioned methods are highly productive, the cost associated with the initial set-up is costly. Present idea of utilizing the frictional heat for joining of plastics is of a lower cost and a high through put method.

In Friction Stir Welding (FSW), a welding tool moves along the area to be joined while rotating at a high speed. The action between the tool and the parent materials creates frictional heat. This causes the work material to soften without reaching its melting point. Plasticizing, mixing and forging of the plasticized material to the weldment are the three stages of FSW. The initial plunging frictional contact heats the adjacent material around the probe as well as a small region underneath the probe, but once in contact with the top surface of the substrate the shoulder contributes significant additional heat to the weld region. In addition to the contacting shoulder, which can be profiled to provide improved coupling, prevents highly plasticized material from being expelled from the welding region [4-6]. If you examine the machined surface of plastics by a saw blade, you will be observing the molten layer. The oscillation of the saw blade during cutting melted the plastics due to the friction between the plastics and the saw blade. Though friction stir welding process finds innovative applications in joining of metals, it does not suit well for thermoplastic joining. Instead of retaining the softened plastic at the joint zone, the shoulder of friction stir tool expels the material. Due to this there is a depletion of material at the joint zone, which results in voids. Suitable design of an additional element is needed to retain the softened plastics at the weld zone [7]. In this study a combined analogy of frictional heating in FSW (third body vibration) and machining of plastics by a saw blade have been utilized for this welding process.

2. EXPERIMENTAL PROCEDURE

Acrylic sheets of 25x25x2 mm were used as parent materials in this study. The saw blade of cutting saw machine is changed to a specially fabricated thin wire made of High Speed Steel (HSS). This thin wire is oscillated at the interface of the plastic sheets to be joined. The machine set up and arrangements of tool and work materials are presented in Fig.1 (a & b) respectively. The friction processed joints were analyzed by mechanical and metallurgical examination methods. To understand the joining mechanism, optical microscopical studies were performed on the joints. Tensile test was carried out to evaluate the strength of the joints. For comparison, adhesive (epoxy) bonded joints also were fabricated.

3. RESULTS AND DISCUSSION

3.1. Microstructural Studies

As explained in Fig.1 (a & b), the plastic parts to be joined are secured by a clamp on the table and the thin wire is oscillated in between the present members. Due to this third body vibration, frictional heat is generated. The materials to be joined were fed towards the thin wire. The generated heat softens the material and makes them to flow which facilitates the consolidation of joint. Unlike cutting, we can get joined parent members on the other end of the thin wire. Typical macrographs of the plastic joints processed by vibration of thin wire are presented in the Fig.2(a & b).

The macrographs presented in the figure confirm the applicability of this method to various configurations of joints and various thickness of material. The feed rate of parent members towards the thin wire, oscillation of the thin wire and design of this thin wire (Friction tool) are the important parameters of this process. Some joints processed initially were of defective. At the joint zone porous sites and lack of flow of material were observed. Typical optical micrograph of poorly fabricated joint is presented in Fig.3. The porous sites observed at the interface of joints are illustrated in figure. This may be due to the improper flow of molten layer. This weakens the joint's performance and most of these poor joints failed during the preparatory activities of tensile test specimens. By way of repeated trials, good quality joints are processed. Typical micrograph of good joints processed by this method is presented in Fig. 4.

In these joints, rarely porous sites are observed at the interface. The molten layer by the frictional heat generated can be observed at the joint zone. Wavy structured interface observed at the joint zone, promoted mechanical locking and high integrity of the parent materials and thereby improved strength of joints.

3.2. Mechanical Testing

The performance of joints during service can be usually tested by mechanical testing methods. The quality of the joints can be evaluated by mechanical testing methods**.** The joints were subjected to tensile testing. The adhesive joints also were subjected to tensile testing for comparison. The ultimate load withstood by the joints and the percentage strength when compared with the strength of parent materials are presented in Table 1.

The adhesive bonded joints exhibited 37% whereas friction processed joints possessed of 80% strength to that of parent material's. The failure of adhesive joints is exactly at the interface, whereas the failure of the friction processed joints were observed in the parent members, away from the interface. From the Table1, it can be observed that the joints confirm the potential applicability of this frictional vibration method for high technology applications.

4. CONCLUSIONS

This technology is still in the early stages of development. In this paper, we confirmed the possibilities of getting sound joints of plastics by the frictional heat developed by the vibration of thin wire between the members to be joined. We could demonstrate the high potentials of this method such as simpler design, lower cost associated with equipment and the better strength of the processed products. However, the effects of parameters such as tool profile, frequency of the wire tool and work feed rate on the characteristics of joints are yet to be explored. In the near future, those things will be achieved and this method will be highly suited for joining of plastics and composites for commercial and industrial applications.

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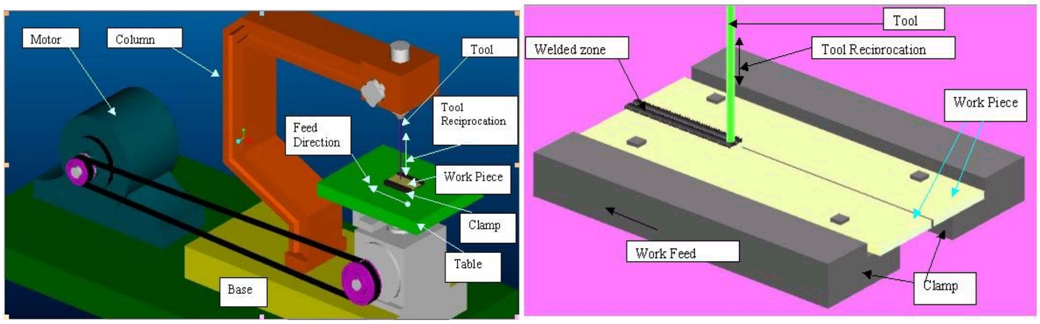
TABLES

Table 1 Strength properties

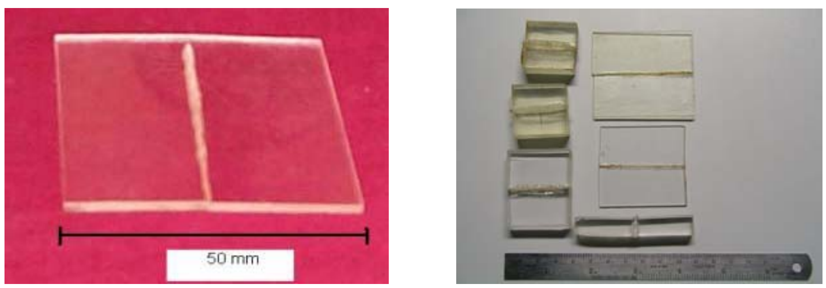
S.No.	Nature of joint	Maximum Load (N)	% Strength (compared with parent material)
1	Adhesive joint	260	37.142
2	Friction processed joint	560	80

FIGURES



(a) (b)

Fig.1 (a & b) The machine set-up and arrangement for welding.



(a) (b)

Fig.2. (a & b) Different configurations of friction processed joints

Fig. 3. Porous sites at interface of a poor joint.

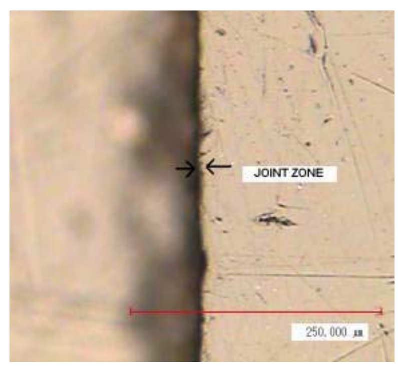


Fig.4.Typical micrograph of a good joint.