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Jig design and manufacturing for adhesive thickness control in adhesive joints

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Abstract

Adhesives and adhesive bonding is a material group and joining technique with a long history. There are many parameters that affect performance in the bonded joints. Factors such as the type of adhesive, the force applied to the joints, the shape of the joint, the surface preparations, the material to have adhered, the working conditions, and the adhesive thickness change the characteristics of the process (adhesion). Researchers use different methods to keep or change the adhesive thickness. In this study, an apparatus was designed and manufactured, which allows for keeping the adhesive thickness constant during sample preparation by focusing on the adhesive thickness in single lap joints. As a result of the tests, it was determined that the adhesive thickness was 0.2 mm in the joints obtained using this apparatus.

Keywords: Adhesive bonding process, adhesive, bond line thickness, jig design, PLA plus material.

1. Introduction

The bonding process is one of the traditional joining methods from ancient times to the present day. Some process parameters must be considered in order for the adhesive joints to be reliable and stable. These; adhesive selection, working conditions of the connection, material to be adhered, surface treatment and adhesive thickness. The success of the process depends on the balance of these parameters. Keeping the adhesive thickness constant throughout the process is one of the challenges faced in academic studies in the field of bonding. Examining the studies in the literature reveals that various designs and techniques are used to modify the adhesive thickness. Some methods for regulating adhesive thickness [1-4] include incorporating micro glass beads, and applying wires, tape or pressure.

With the help of two opposing rods and five joint samples stacked on top of one another, Arrowsmith and Maddison [5] created the assembly mechanism depicted in Figure 1. 250-300 µm spherical glass was fixed to the joint area with spring clips and added to the adhesive at a rate of 1% by weight in order to control the adhesive thickness. Guo et al. [6] applied a metal pressure block (Figure 2) to the overlap region of the adhesive joints until the adhesive was cured. With the symmetrical distribution of weight, they tried to avoid the unevenness of the adhesive layer.

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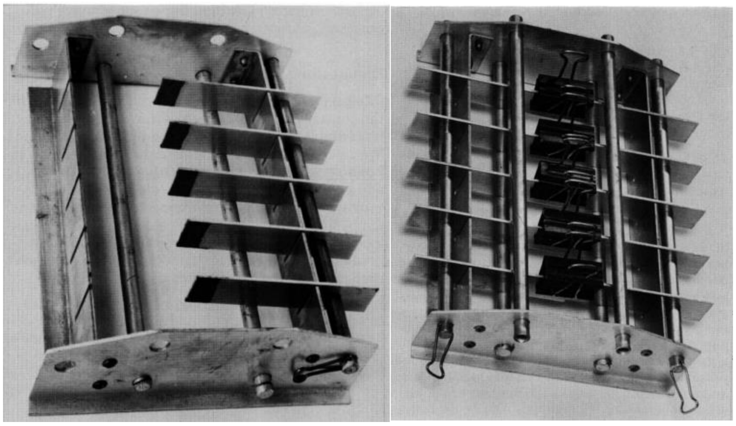

Fig. 1. Fixing mechanism (assembly jig) [5].

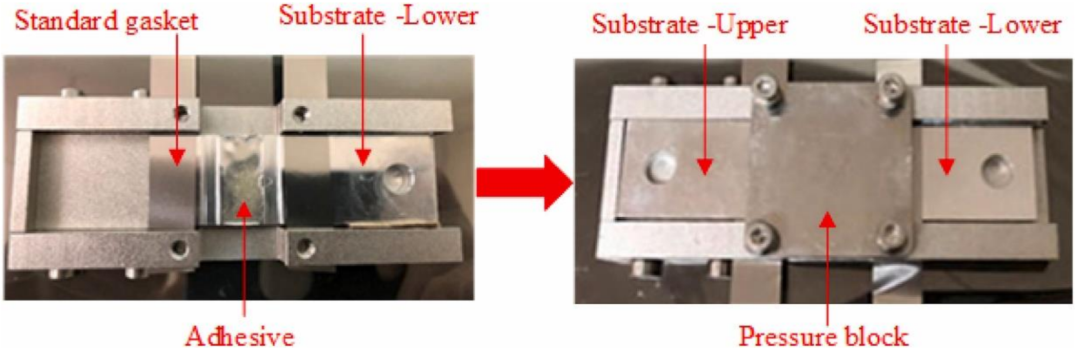

Fig. 2. Preparation of single lap joint [6].

Arenas et al. [7] used an adjustable polyethylene mounting mold (Figure 3) with plastic parts, which allowed the desired adhesive thickness to be achieved, in order to repeat the experiments and to keep the geometric parameters (overlap length and adhesive thickness) constant. After the adhered samples were placed in the mold, a weight of 250 g was applied over the overlap zones for 2 hours.

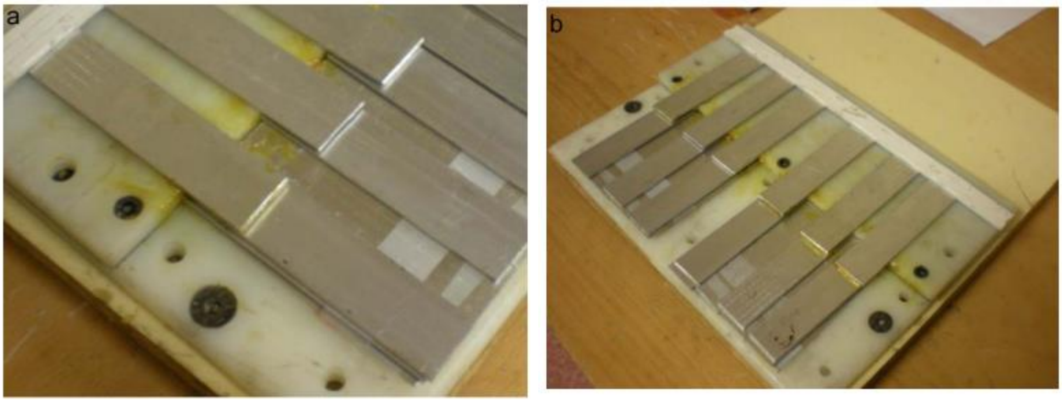

Fig. 3. The apparatus used in the production of six samples [7].

Abdullah et al. [8] used special apparatus and part plates as shown in Figure 4 to control the adhesive thickness during the fabrication of specimens joined with the T-joint type.

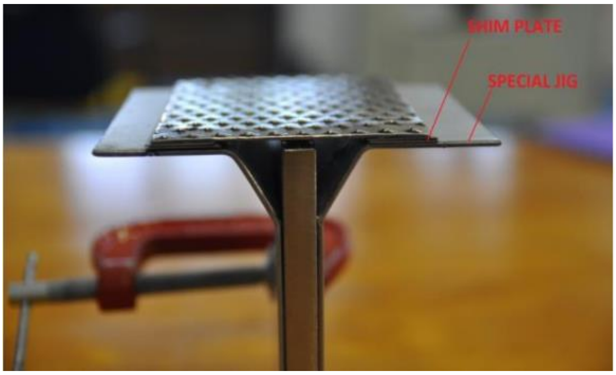

Fig. 4. Special apparatus design [8].

An apparatus created by B. Soltannia and Taheri [9] produces fully aligned joints with uniform and consistent adhesive thickness. Figure 5 shows the layout of this mold, which has two parts.

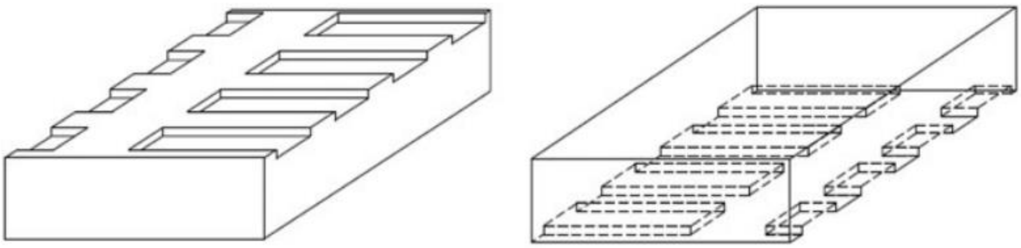

Fig. 5. Two-piece apparatus design [9].

Boutar et al. [10] designed and manufactured a special apparatus which has adjustable wedges that allows changing the adhesive thickness as desired.

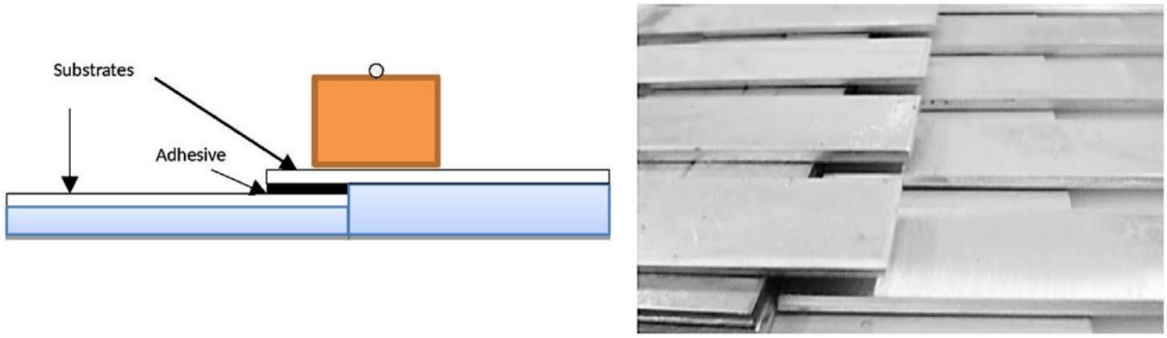

Fig. 6. The tool used in sample preparation [10].

The study's aim is to design and produce a device that can maintain the same (fixed) bonding thickness for each test group in bonding joints. By maintaining a constant bonding thickness in single overlap joints, a faster and more precise bonding thickness is thus targeted. Single overlay joints, a joint model that is frequently employed in studies of a similar nature, were used in this study.

2. Material and method

To maintain a constant adhesive thickness in the joints, an apparatus has been designed and produced for use with adhesive bonding methods.

2.1 Materials

Samples for the study were produced using an Anycubic 3 Mega S 3D printer and Esun brand PLA Plus filament. Figure 7 shows the printer that was employed.

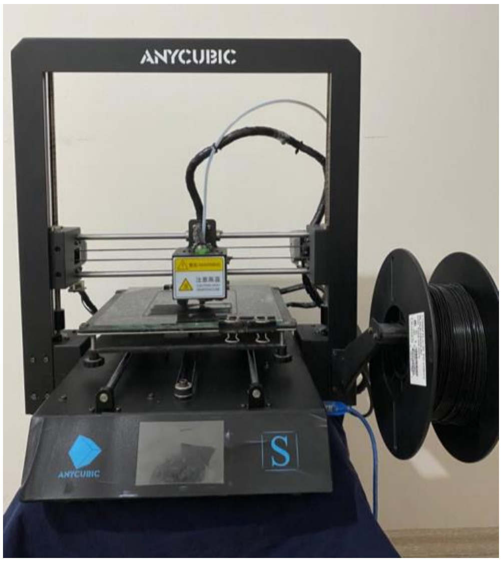

Fig. 7. 3D printer

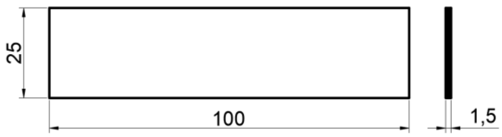

Fig. 8. Sample dimensions

Figure 8 shows the sample dimensions for the preferred single lap joints in bonding tests. Table 1 lists the mechanical and physical properties of the filament used.

Table 1. Physical and Mechanical Properties of PLA Plus Material [11].

Mechanical Properties	PLA Plus
Filament Diameter (mm)	1.75
Colour	Black
Tensile Strength (MPa)	63
Elongation at Break (%)	20
Density (g/cm^3)	1.23
Melting Point (°C)	205-225

JB Weld brand Kwik Weld adhesive was used to join the samples. The properties of this adhesive, which is preferred because it is suitable for bonding plastic materials, are given in Table 2.

Table 2. Kwik Weld (epoxy) properties [12].

Fixing time (minute)	6
Curing time (hours) 22 ◦ C	4-6
Tensile strength (MPa)	14.51
temperature resistance	150 °C
Mixing ratio	1:1

The samples' adhesion surfaces were best prepared by sanding, which is a mechanical surface treatment. 240 SiC sandpaper was employed for this. To completely cover the bonding region, sanding was done horizontally and perpendicular to the part axis.

2.2 Printer process parameters

The values recommended by the filament and printer manufacturer were used for the printing of PLA Plus parts (Table 3).

Table 3. Sample printing parameters.

Parameters	PLA Plus
Table Temperature	55 °C
Extruder Temperature	210 °C
Solidity ratio	%100
Layer thickness	0.2 mm
Print speed	50 mm/s

2.3 Design of jig

To ensure homogenous distribution of the adhesive in the glued test samples and to maintain a constant bonding thickness, five weights (800 gr) of equal mass were positioned side by side on the steel skeleton using the gap-fit method on a single axis with the aid of bolts and springs. The upper and lower portions of the joint samples were set on two Teflon pieces for the apparatus's floor (Figure 9).

As a result, measures were taken to prevent the possibility of adhesive leakage from the test samples' joint area. Also, teflon pad was used to prevent the adhesive flowing from the adhered parts from sticking to the designed apparatus. Five samples can be used with the particular apparatus. Each compartment will be filled with a sample of an adhesive joint. A weight of 800 gr was applied to each of the single lap joints (while accounting for the adhesive's characteristics) in order to position the adhesive on the overlap area. The test samples were taken out of the apparatus after 24 hours, and the parts' adhesive thickness was measured.

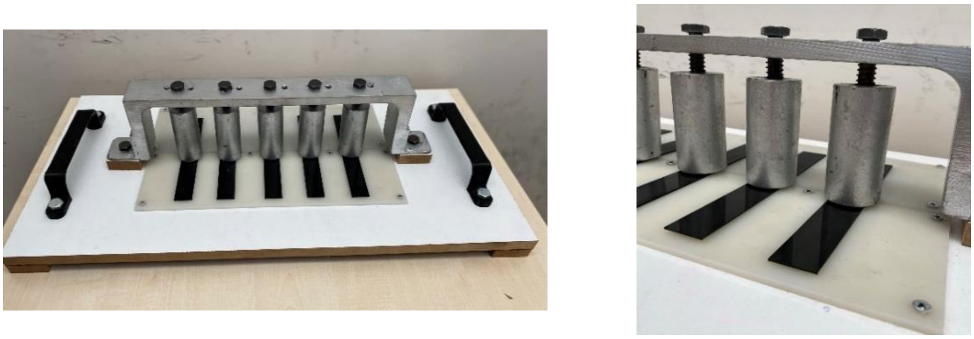

Fig. 9. View of the manufactured mold and test piece.

3. Results and discussions

Using a digital caliper, the bond thicknesses at the bonding joints were measured. According to measurements made from samples prepared in accordance with the test parameters and placed in side-by-side compartments, the value was 0.2 mm, respectively (for joints with 240 SiC sandpaper surface preparations). Some pieces of the sanded material are removed during surface preparation using sandpaper. The measured bond thickness values fall within the bounds set by the adhesive bonding method. It will be easier to maintain the bond thickness parameter constant in bonding studies if each sample has the same thickness.

4. Conclusions

The adhesion process of the PLA Plus materials created by additive manufacturing was carried out, and the adhesion thicknesses were evaluated, yielding the following results;

- Five parts could be joined simultaneously in single overlap joints using the devised apparatus.
- Maintaining a constant adhesive thickness is one of the key components of the bonding joint. The manufacturing tool allowed for the achievement of the same bonding thickness.
- After being prepared with 240 SiC sandpaper, the PLA Plus material's bonding thickness was discovered to be 0.2 mm.
- During the tests conducted for various surface preparation processes, the groups belonging to the surface preparation process should be evaluated for the adhesion thickness within themselves.
- It is anticipated that the apparatus under study will be improved so that different adhesive thickness values can be obtained in subsequent research. With the manufactured apparatus, it can be made usable with different weights to achieve various bonding thicknesses. This will give it an advantage over other thickness adjustment methods.

Author Contribution Statement

Conceptualization, N.A. and O.K.; methodology, N.A and O.K.; investigation, B.Ş., K.Ç., S.N.Ü, and N.A.; data curation, B.Ş., K.Ç. and S.N.Ü; writing—original draft preparation, N.A. and O.K.; writing— review and editing, N.A. and O.K. All authors have read and agreed to the published version of the manuscript.

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