LAP SHEAR STRENGTH OF SIMILAR GF/PP ADHERENDS BONED WITH TWO-PART ACRYLIC-BASED ADHESIVE

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Abstract

The lap shear strength and fracture behavior of two-part acrylic-based adhesive was investigated. Shear tests were carried out using single lap joints. Commercially available acrylic adhesive was used as adhesive. Glass fabric reinforced polypropylene matrix composite (GF/PP) was used as adherends. Aluminum alloy (5052-H34) was also used as adherends for comparison purpose. Three types of surface treatment were prepared: as-received with ethanol cleaning, as-received with acetone cleaning, sandblasted with acetone cleaning.

Lap shear tests were performed using a universal testing machine. Strain gauges were used to obtain the elastic modulus and Poisson's ratio of adherend, and deformation behavior of lap joint for adhesive and adherend parts. It was found that the lap shear strength for as-received with acetone cleaning treatment was highest in the other treatment and was almost similar to that for aluminum alloy adherend one. The release agent of GF/PP could not be removed by ethanol cleaning and the surface of GF/PP was damaged by sandblasting.

1. Introduction

Aluminum alloy and fiber reinforced polymer matrix composites (FRP: fiber reinforced plastic) have become a dominant lightweight structural material in the aerospace, high-performance automotive industries [1].

Adhesive bonding is formerly applied for such lightweight structural materials [2]. However, most commercial adhesives cannot adhere properly for fiber reinforced PP matrix composites. This is caused by their nonpolar, nonporous, and chemically inert surfaces. Recently, two-part acrylic adhesives were developed for low surface energy materials, including PP.

The traditional evaluation of adhesive joints by strength measurements was utilized in the study. The adhesive strength was determined by utilizing the single-lap shear test [3].

The objectives of the present work are to fabricate the adhesive bonded joints using two-part acrylic-based adhesive with glass fabric reinforced polypropylene matrix composite (GF/PP) of adherends and to show the shear mechanical properties of two-part acrylic-based adhesive under static loading. Especially, the attention of this paper is focused to obtain the effect of surface treatment on the shear strength for single lap joint of two-part acrylic-based adhesive.

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2. Experimental procedure

2.1. Materials and specimen

Tensile shear tests were carried out using single lap joint specimen. **Figure 1** shows the shapes and dimensions of the specimen used in this study.

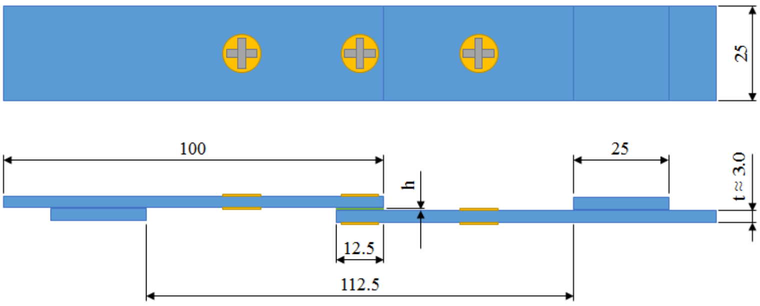

Figure 1. Shapes and dimensions of the single lap joint (Unit: mm).

Commercially available two-part acrylic-based adhesive (Scotch-Weld™ Structural Plastic Adhesive, DP-8005, 3M) was used as an adhesive. The DP8005 can bond many low surface energy plastics, including many grades of polypropylene, polyethylene, and thermoplastic polyolefin (TPO)'s without special surface preparation. Aluminum alloy (5052-H34, t ≈ 3.0) and Glass fabric reinforced polypropylene matrix composite (GF/PP: TEPEX dynalite 104-RG600(6)/47 %, t ≈ 3.0, Bond laminate) were used as adherends.

2.2. Specimen preparation

For the aluminum alloy adherend, two pieces of adherends were prepared and the surfaces of the adherends were treated with sandblast. The treated adherends were cleaned and degreased by acetone and dried at room temperature under the laboratory environment (at 23±3 °C and 50±5 % relative humidity) before bonding. For the GF/PP adherend, three types of specimens were prepared; (G1) the adherends were cleaned and degreased by ethanol without sandblast treatment. (G2) the adherends were cleaned and degreased by acetone without sandblast treatment. (G3) the surfaces of the adherends were treated with sandblast, and were cleaned and degreased by acetone. They were dried at room temperature under the laboratory environment (at 23±3 °C and 50±5 % relative humidity) before bonding.

The adhesive was spread in both adherends. The adhesive was cured according to the manufacturer's recommended procedure (it was kept under the laboratory environment (at 23 ± 3 °C and 50 ± 5 % relative humidity for more than 12 hour)).

After curing, squeeze-out of adhesive at both sides of the specimens were carefully removed with a knife and sandpaper.

2.3. Static test

Static shear test was conducted using a universal testing machine (Shimadzu, Autograph AG-series) with a load cell of 50 kN at a constant crosshead speed of 1.0 mm/min. Twelve strain gages were used to measure longitudinal and transverse strains (as shown in Figure 1). All tests were conducted under

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the laboratory environment at room temperature (at 23±3 °C and 50±5 % relative humidity). The fracture morphology of these adhesive joints was examined using a digital microscope (VHX-5000 and VH-ZST, Keyence).

3. Results and discussion

3.1. Strain gage response

Figure 2 shows the stress ($\sigma = P/A_1$(width*thickness))-strain (σ-ε) curves for the G3 specimen.

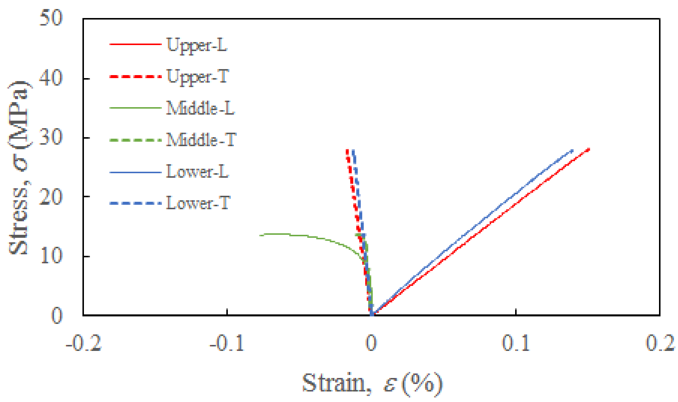

Figure 2. Stress-strain curves for the G3 specimen.

Elastic modulus and Poisson's ratio of GF/PP were 20 GPa and 0.094. In the adherend part, the GF/PP of lap joint showed almost linear behavior until failure. In the adhesive part, however, the strain gauges had complex nonlinear behavior. The secant modulus was transited from positive to negative value.

3.2. Shear strength

Figure 3 shows the lap shear strength ($\tau = P_{max}/A_2$(width*lap length)).

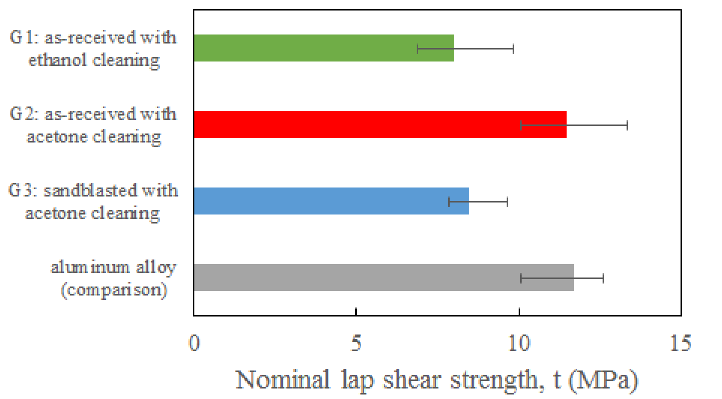

Figure 3. Lap shear strength.

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It was found that the lap shear strength for as-received with acetone cleaning treatment (11.5 MPa) was highest in the other treatment (8.0 MPa for as-received with ethanol cleaning, 8.5 MPa for sandblasted with acetone cleaning) and was almost similar to that for aluminum alloy adherend one (11.7 MPa). The release agent of GF/PP could not be removed by ethanol cleaning and the surface of GF/PP was damaged by sandblasting.

3.3. Fracture morphology

The fractured surfaces of the lap joints in as-received and sandblasted with acetone cleaning (G2 and G3 specimens) showed cohesive fracture with some delamination of GF/PP. However, the lap joint in the as-received with ethanol cleaning (G1 specimen) had adhesive/interfacial fracture with original fiber surface feature.

4. Conclusions

Lap shear tests of two-part acrylic-based adhesive for glass fabric reinforced polypropylene matrix composite (GF/PP) adherends were performed. Strain gauges were used to obtain the elastic modulus and Poisson's ratio of adherend, and deformation behavior of lap joint. The results can be summarized as follows.

(1) The lap shear strength for as-received GF/PP with acetone cleaning treatment (11.5 MPa) was highest in the other treatment (8.0 MPa for as-received GF/PP with ethanol cleaning, 8.5 MPa for sandblasted GF/PP with acetone cleaning) and was almost similar to that for aluminum alloy adherend one (11.7 MPa).
(2) Elastic modulus and Poisson's ratio of GF/PP were 20 GPa and 0.094.
(3) The fractured surfaces of the lap joints in as-received and sandblasted with acetone cleaning showed cohesive fracture with some delamination of GF/PP. However, the lap joint in the as-received with ethanol cleaning had adhesive/interfacial fracture with original fiber surface feature.

Acknowledgments

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