EVALUATION OF SURFACE TREATMENTS FOR ADHESION OF THERMOPLASTIC COMPOSITES FOR AUTOMOTIVE USE

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Abstract

Methods for treating the surface of thermoplastic composites before adhesion have experimentally been investigated. Specimens comprising of glass fiber reinforced plastics, which have matrix resins of polyamide or polypropylene, were prepared, bonded with an acrylate adhesive after several types of surface treatments, and tested. It is concluded that almost all the surface treatment methods examined in this research are effective to increase the bonding strength with the adhesive even for the thermoplastic composites.

1. Introduction

Fiber reinforced thermoplastics (FRTP) are promising materials for car structures in terms of reducing the weight. For fiber reinforced thermosetting plastics, adhesively bonded joints have widely been used instead of mechanical fasters or welding because the materials are weak for local stress concentrations and are difficult to weld. Adhesive joining of the FRTPs is, however, more difficult than thermosetting composites because of the low surface energy. Surface treatment is, therefore, indispensable for good adhesion of FRTPs. In this research, the improvement of adhesion strength for FRTPs by several types of surface treatments has experimentally been investigated. Single lap joint specimens comprising of glass fiber reinforced thermo plastic (GFRTP) bonded adhesively were prepared with several types of surface treatment methods and were tested to measure the lap shear strength. In addition, the surface roughness and surface tension of the material were measured using a roughness measurement device and a contact angle tester. For some treatments, surface analyses were carried out by X-ray Photoelectron Spectroscopy (XPS).

2. Specimens

Two types of glass fiber reinforced plastics (TEPEX-102 and 104), which have matrix resins of polyamide 6 or polypropylene, were used as the adherends of specimens for the research. In this research, the polyamide 6 based GFRP and the polypropylene based GFRP are denoted as GFRPA and GFRPP respectively. The adherend materials were treated on the surfaces by IR laser, plasma, plasma CVD, flame, frame CVD, or vacuum UV. The treatment by IR laser irradiation was mainly utilized for surface abrasion to remove release agent on the surface, but it had functions of surface activation and surface modification. Plasma, plasma CVD, flame and flame CVD treatments were utilized in order to enhance the surface energy. These treatments were applied after sand blasting by which the release agent was removed in advance. Vacuum UV irradiation is a novel method to improve the surface conditions of thermoplastics for adhesion, by which ozone or oxygen radicals are produced and attack chemically the surface of thermoplastics. For the vacuum UV treatment, sand blasting was also applied prior to the treatment because decomposition of the release agent is difficult even by the method. After these treatments, the adherends were bonded with an acrylate adhesive whose curing time was very short at an ambient temperature, and single lap joint (SLJ) specimens were obtained.

Small size specimens of the GFRTPs were also prepared to measure the surface tensions, the contact angles, the surface roughness and the chemical decomposition of the surfaces. These specimens were treated on the surfaces by the same methods as the SLJs were done before the surface analyses.

3. Experiments

The SLJ specimens were tested by a hydraulic testing machine and the lap-shear strengths of the specimens were measured under a quasi-static condition. The lap-shear strengths are shown in Figs.1 and 2. In these figures, the ordinates and the abscissas indicate the strength and the intensity of treatments respectively and notations of SB and NB indicate sand blasted and not sand blasted specimens respectively.

Using treated small specimens, surface analyses were carried out to measure the surface tension, the roughness and the chemical change or decomposition of the specimens. The surface roughness was measured with a surface roughness tester. For measurement of surface tension, a contact angle tester shown in Fig.3 was used and a contact angle was calculated from an image obtained with the tester, as shown in Fig.3. The image was taken as soon as possible after the treatment because surface conditions might change in a short time. XPS was used to detect the chemical components on the surface to investigate the chemical change or decomposition caused by the treatments.

4. RESULTS AND DISCUSSION

Almost all the treatments are effective to improve the joint strength of the specimens. For the GFRPA, the adhesion strengths were higher than 10 MPa, however, the improvements by the treatments were not significant because cohesive fractures in the adhesive layers dominantly occurred. In other words, the interfacial strengths between the adhesive and the adherends were higher than the intrinsic strength of the adhesive. In contrast, the adhesion strength of the GFRPP without any treatment was low such as 1-2 MPa, but the improvement by the treatments is significant. Sand blasting was quite effective to increase bond strength and it became about two times in average. The Si peak in a spectrum by the XPS decayed with respect to the intensity of sandblasting, so that the increase of bond strength is due to removal of the release agent including silicone. Among the surface treatment methods, flame treatment exhibits the highest adhesion strength for the GFRPP and flame CVD exhibited similar strength. Plasma, Plasma CVD and vacuum UV treatments were also effective but not more than the lame treatment. In contrast, the bond strengths by laser treatments were similar to those of sandblasted specimens. It seems that the main reason of strength increase by the laser treatment is removal of the release agent and it leaded to the strengths similar to those of sandblasted specimens. In other words, the method is not suitable for surface energy enhancement for polypropylene based composites. All the treatment methods except for laser abrasion did not exhibit the drastic change in roughness but in contact angle on the surfaces. Therefore, it can be concluded that treatments such as plasma, plasma CVD, flame, flame CVD and UV influenced the surface energies without drastic change of roughness.

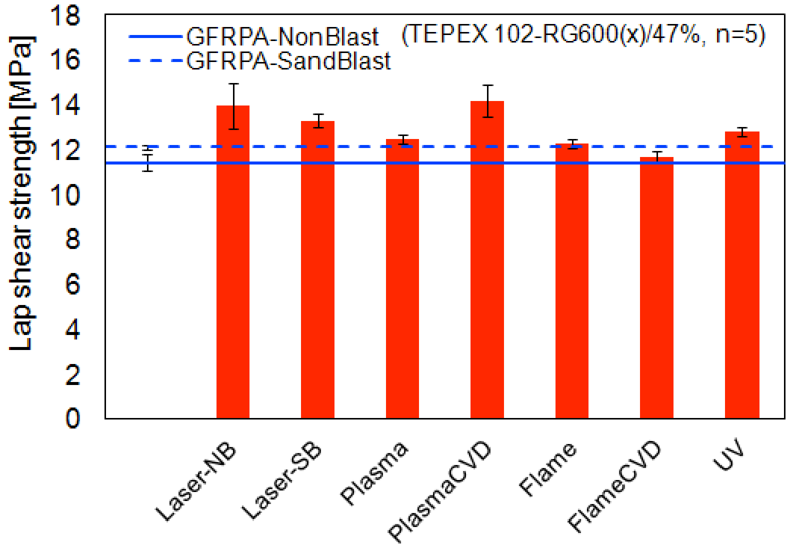

Figure 1. Adhesion strength of GFRPA treated by several treatment methods

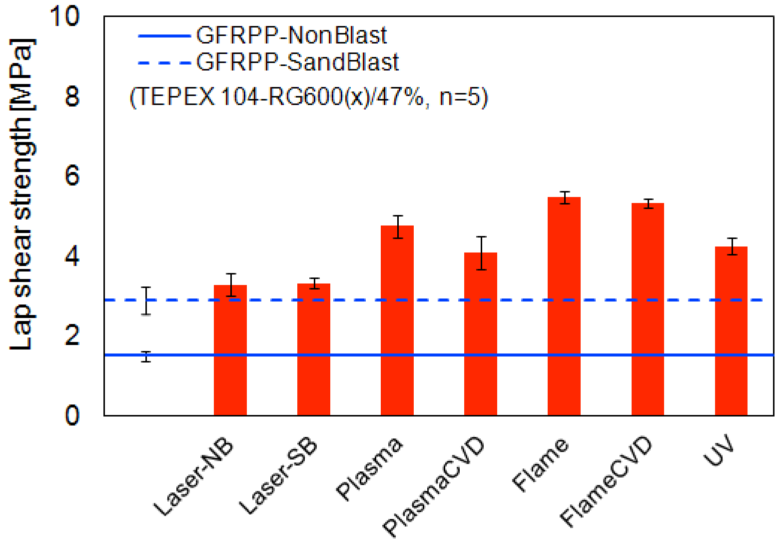

Figure 2. Adhesion strength of GFRPP treated by several treatment methods

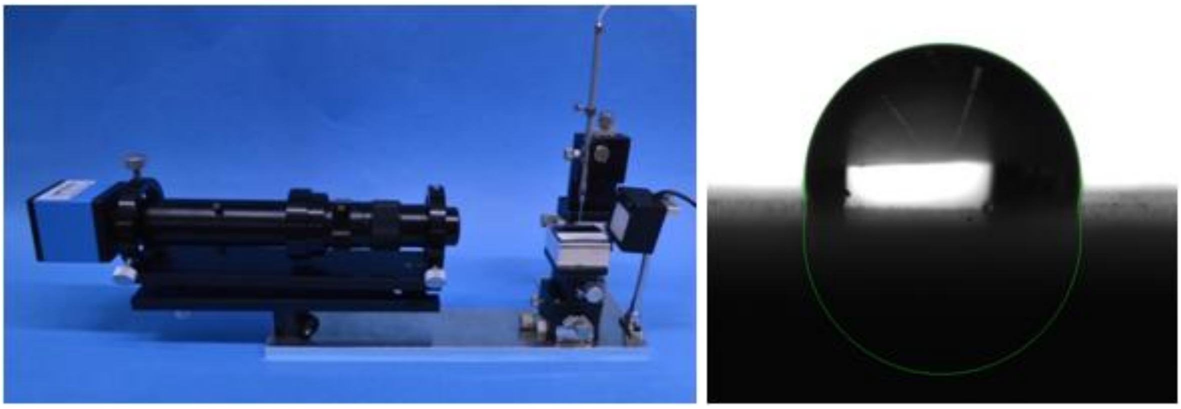

Figure 3. Contact angle tester used for experiments and image of water drop on surface

5. Conclusion

All the treatments examined in the experiments are effective to improve the adhesion strength of glass fiber reinforced thermoplastics. The most suitable method for the polypropylene based GFRP is the flame treatment so far. Laser abrasion is also effective, but it may have only a function of removing release agents for the material. In contrast, the polyamide 6 based GFRP has a much better nature for adhesion than the polypropylene based one and higher strengths were able to be obtained by all the treatment methods. By laser abrasion, the surface roughness increased, but did not change by other methods. Surface energies calculated from contact angles increased with respect to the intensity of treatments, but their change was not connected directly to the increase of bond strengths.

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