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COMPOSITES THEORY AND PRACTICE

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INFLUENCE OF SURFACE PREPARATION IN COMPOSITE BONDED JOINTS

One of the basic methods for joining composites are adhesive joints. In contrast to traditional methods used in connecting metal structures (bolting, riveting), bonding ensures uniform stress distribution. Bonding requires appropriate technological conditions and proper surface preparation. In the case of bonding composites, surface preparation methods are based on mechanical processing. The authors conducted a study to compare the different methods of surface preparation used in the adhesive bonding of composites. As a parameter defining the efficiency of the method, stress failure in a tensile test was used. Specimens were made based on the ASTM-D1002 standard using a carbon-epoxy prepreg and DP-490 3M adhesive. The article contains the results of tensile tests for three types of surface treatment.

Keywords: composites, adhesive joints, surface preparation

WPŁYW PRZYGOTOWANIA POWIERZCHNI NA POŁĄCZENIA KLEJOWE KOMPOZYTÓW

Jedną z podstawowych metod łączenia kompozytów jest klejenie. W odróżnieniu do tradycyjnych metod stosowanych w łączeniu konstrukcji metalowych (skręcanie, nitowanie) zapewnia równomierny rozkład naprężeń. Klejenie wymaga zachowania odpowiednich warunków technologicznych oraz właściwego przygotowania powierzchni. W przypadku połączeń klejonych kompozytów metody przygotowania powierzchni bazują głównie na obróbce mechanicznej. Autorzy przeprowadzili badania mające na celu porównanie różnych metod przygotowania powierzchni stosowanych podczas klejenia konstrukcji kompozytowych. Jako parametr określający skuteczność danej metody przyjęto naprężenia niszczące w próbie rozciągania połączeń klejowych. Próbki wykonano, wykorzystując normę ASTM-D1002 z prepregu węglowo-epoksydowego. Jako spoiwo zastosowano klej DP-490 firmy 3M. Artykuł zawiera wyniki badań dla trzech rodzajów przygotowania powierzchni.

Słowa kluczowe: kompozyty, połączenia klejowe, przygotowanie powierzchni

INTRODUCTION

Surface preparation plays the main role in the adhesive bonding process. In the case of composites the cleanness and roughness of the bonded surfaces are very important. It is well known that increasing the roughness means an increase the total area of the joint and as a consequence a better bond quality is achieved [1, 2]. In the case of metal bonding generally chemical surface treatment and mechanical surface preparation are used [3-5]. For composites the most common method is peel-ply removal, hand grinding and also sandblasting. Those methods give satisfactory results. Their particular influence on bonding strength is often investigated because the whole mechanism is not yet known [6, 7]. The mentioned methods are well known from the knowledge of metal joining. Composite materials are much more susceptible to damage which can take place during sanding as an effect of using too sharp sand or too high operating pressure. In the worst cases it may cut fibers which leads to delamination. Nowadays, laser surface pre-treatment also gives great effects. This method is promising and is applied increasingly more often [8, 9]. This article is focused on traditional methods.

AIM OF RESEARCH

The aim of this research was to determine the influence of surface pre-treatment on the strength of adhesive bonded joints. One of the most standardization oriented documents for composites, MIL-HDBK 17-3F [10], contains information that some peel plies leave a residue on the bonding surfaces that makes adhesion poor (However, some manufacturers have obtained satisfactory results from surface preparation consisting only of peel ply removal). Lack of clear guidance in the literature led the authors to carry out tests. The investigations were focused on mechanical methods (peel--ply removal, sandblasting and hand sanding). These methods are appropriate to put into use in the aviation

industry in bonding operations. of The treatment parameters were based on literature [11] and procedure [12], developed in the Air Force Institute of Technology (AFIT) for the purposes of the consortium KOMPOTECH.

SPECIMEN PREPARATION

The assumption of the research is a bonded joint of two composite elements made of an OOA carbon fiber prepreg bonded with epoxy adhesive DP490. The adhesive is intended for use without a high temperature curing cycle (Fig. 1). The specimens were prepared according to standard test method ASTM - D1002. The ASTM standard specified the dimensions of the panels which are bonded together. Four set of panels were made. The surface for bonding was prepared in four different ways:

1. Peel ply
2. Sandblasting - 0.8 MPa pressure
3. Sandblasting - 1 MPa pressure
4. Hand sanding with sandpaper 240

After manufacturing the specimens, the tensile test was realized in the AFIT Material Strength Laboratory.

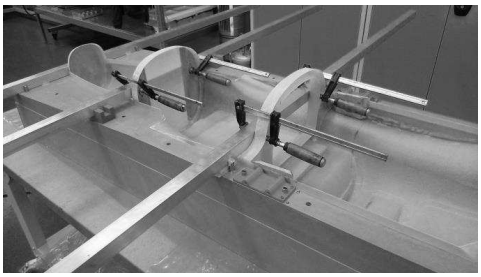

Fig. 1. UAV Fuselage bonding process

Rys. 1. Proces klejenia kadłuba samolotu bezpilotowego

Fig. 2. Test stand

Rys. 2. Stanowisko do badań

TEST RESULTS AND DISCUSSION

The results of the tests present the stress characteristics. Sets of five specimens for every kind of surface preparation were tested.

In the case of specimens bonded only after peel ply removal, adhesive destruction was observed. The adhesive layer clearly separated from the composite is shown Figure 3. The peel ply imprint on the surface without adhesive was visible. Figure 4 shows the stress characteristics. The average ultimate tensile strength value for five specimens is 11.91 MPa.

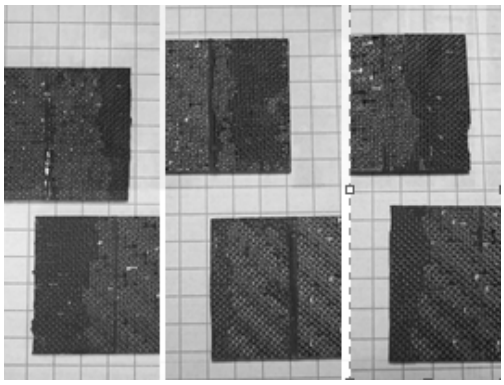

Fig. 3. Bonded surfaces after test

Rys. 3. Powierzchnie klejone po próbie

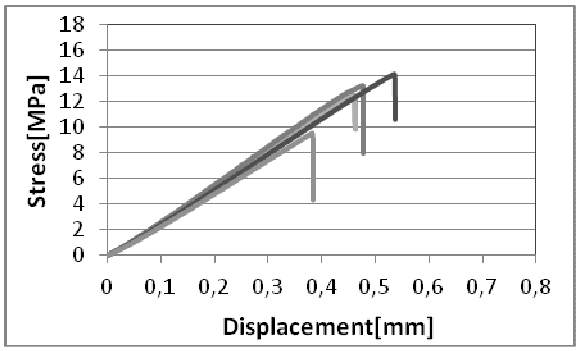

Fig. 4. Stress - displacement characteristic - bond made after peel ply removal

Rys. 4. Charakterystyka naprężnia - przemieszczenia dla skleiny wykonanej po zdjęciu delaminażu

Figure 6 shows the stress value for sandblasted specimens (pressure 0.8 MPa). On average, the ultimate tensile strength is 16.19 MPa. Cohesive destruction of the bond line is presented in Figure 5.

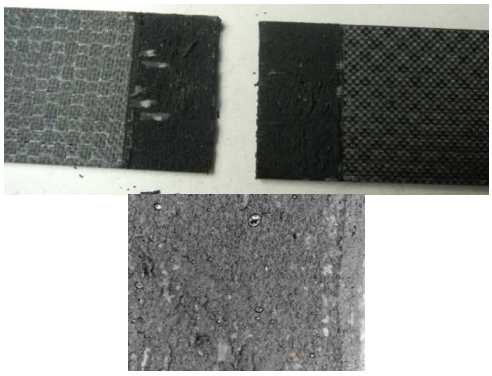

Fig. 5. Bonded surface after test. Visible adhesive layer on both connected elements

Rys. 5. Powierzchnia klejenia po zerwaniu próbki. Widać wyraźnie warstwę kleju na powierzchni dwóch elementów łączonych

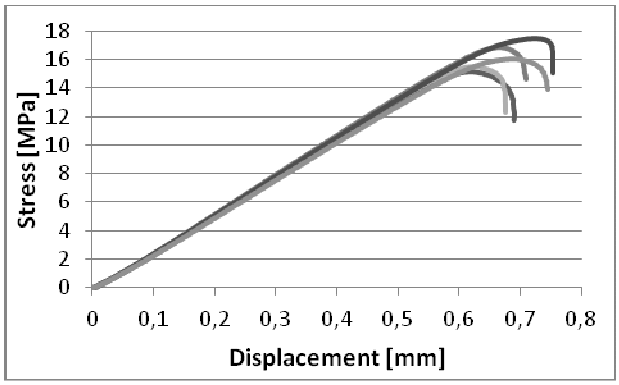

Fig. 6. Stress – displacement characteristics - bond made after sandblasting, pressure 0.8 MPa

Fig. 6. Charakterystyka naprężenia - przemieszczenia dla próbki piaskowanej pod ciśnieniem 0,8 MPa

Results of the test with sandblasted specimens under pressure 1 MPa shows Figure 7. Strength of these specimens is slightly lower. It is caused by fiber breakage due to pressure above 0.8 MPa.

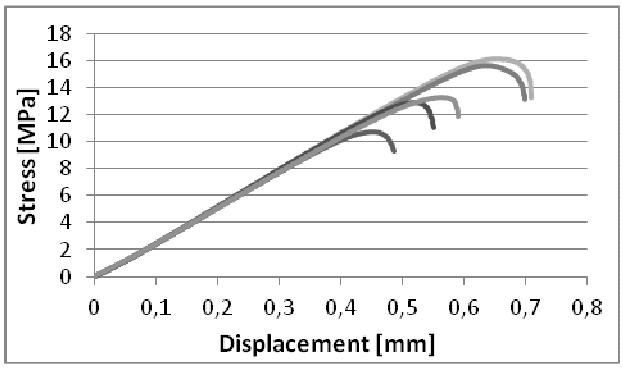

Fig. 7. Stress - displacement characteristics - bond made after sandblasting, pressure 1 MPa

Rys. 7. Charakterystyka naprężenia - przemieszczenia dla próbki piaskowanej pod ciśnieniem 1 MPa

The last samples series was prepared by hand sanding. The characteristics for this series is summarized in Figure 8. A high value of repeatability can be observed. The average value of damage stress amounts 16.04 MPa.

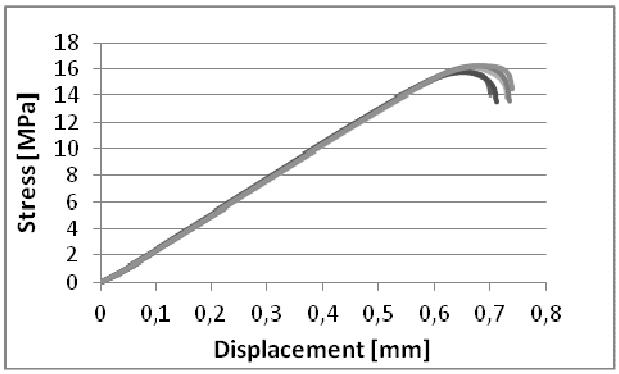

Fig. 8. Stress - displacement characteristics - bond made after hand sanding

Rys. 8. Charakterystyka naprężenia - przemieszczenia dla próbki szlifowanej papierem ściernym

The summary of the results is presented in Figure 9. It shows the ultimate stress values. The method based on joints made without pre-treatment - only peel ply removal are significantly different than the others. Also noticeable is advantage 0.8 MPa sandblasting over hand sanding, but all the three methods feature practically similar stress value.

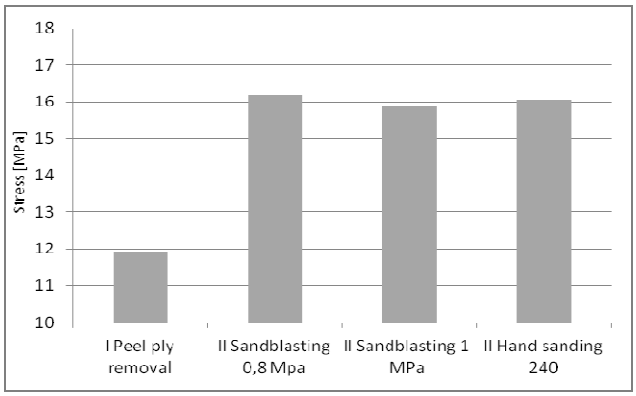

Fig. 9. Summary of results

Rys. 9. Zestawienie wyników

CONCLUSION

The study clearly showed the influence of surface preparation in bonding of composites on the strength of the joint. Suitable treatment performed before bonding is necessary to make a strong joint. The investigations proved that peel ply is the weakest method, despite the fact that the bonded surface has a certain roughness. Adhesion type destruction was observed. Hand sanding gives a better effect but effect strongly depends on personnel experience. The highest ultimate strength was recorded for sandblasting. For that method the key parameters are: sandblasting pressure, distance between nozzle and composite and nozzle feed. It is significant because incorrect selection of those parameters can cause damage of the material (fiber breakage) causing weakening of the joint.

The observed difference in the strength values obtained for the mechanical treatments and peel ply only, may be due to presence of the contaminants in the resin layer on the outer surface of the composite after peel ply removal [13]. The strength of the specimens with additional surface pre-treatment after peel ply removal are higher.

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