FATIGUE PROPERTIES OF BONDED COMPOSITE JOINTS

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Abstract. Nowadays, composite materials are often used in aircraft structures. The most common method of jointing the individual parts is sticking. Therefore, it is necessary to known the properties of bonded joints in terms of static and fatigue strength. The following article represents the results of experimental tests to determine fatigue properties of bonded joints. The test sample was composed of several parts, which were made of carbon/epoxy and glass/epoxy laminate. For the bonded joints were used glue Araldit and different ways of surface treatment. This type of bond can be found in joints flanges and webs. Measured data can be used for design of bonded joints in terms of service life or to calculate the lifetime for different load spectrum.

Keywords. Fatigue, bonded joint, S-N curve, durability

1 Introduction

This article deals with the fatigue of composite bonded joints, and originated on the basis of information and knowledge from fatigue tests performed at Institute of Aerospace Engineering VUT Brno. The motivations for testing bonded joints were just prior static and fatigue tests of the wing segment, where was bonded joint identified as a critical point.

Segment represents a typical wing design of composite glider wing with a one beam. The beam consisted of two flanges made of carbon/epoxy rowing and glass/epoxy web with foam core. The remaining structure was a sandwich type, where the facesheet was formed glass/carbon fabric epoxy resin and the foam core. It was made several identical segments of the wing for static test and two pieces for fatigue test. The first segment of the wing designed for the fatigue test is marked with X06 and cyclic load with spectrum KoSmos. In this wing the test was discontinued after the double life of 6000 hours without any disorders. The second segment of the wing is marked with X07 and loaded by constant amplitude R=-0,47 (stress ratio R is ratio of minimal and maximum load) with a force equal to the maximum limit load equal maximal and minimal load factor on which was the wing designed. Failure occurred after nearly 60600 cycles and critical point was bonded joint. Damage of the bonded joint was so great, that flange was pulled from the spar boom. The bonded joint flange and a web interface have been identified as a weak point on the basis of previous static tests. Fatigue tests using real load spectra are very time consuming. For shortening the test can be used higher load spectrum, as has been applied to the sample X07. To convert the measured results to the normal spectrum and expressions of life, we need the S-N curves of bonded joints. These curves are not many, and therefore it was necessary to test adhesive bonds for their findings. The resulting S-N curves can also be used to design the wing. Figure 1 shows the scheme of the test segment of the wing and includes a description of each part.

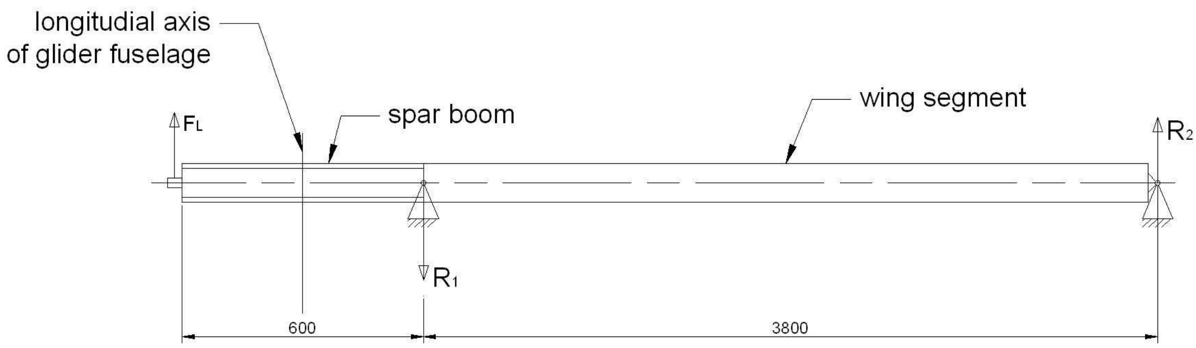

Figure 1: Scheme of wing segment test.

Glued joint is designed to achieve similar conditions as in the wing segment interface flange and web. The test specimen was made by hand lamination and the individual parts are made of glass/epoxy and carbon/epoxy laminate. For glued joints were used Araldite glue, that can be used for this type of connection.

2 Specimen configuration and materials

2.1 Geometry and preparation of test specimens

The test specimen was designed as an adhesively double lap composite joint. Specimen consists of two main load-bearing parts (carrier), and two splice bars. Carrier is marked with number 1 on Figure 2 and ensures transfer of load from the test machine into the glued joints. Splice bars marked with number 2 in the figure implements glued joint and transfer the load between the two parts of carrier.

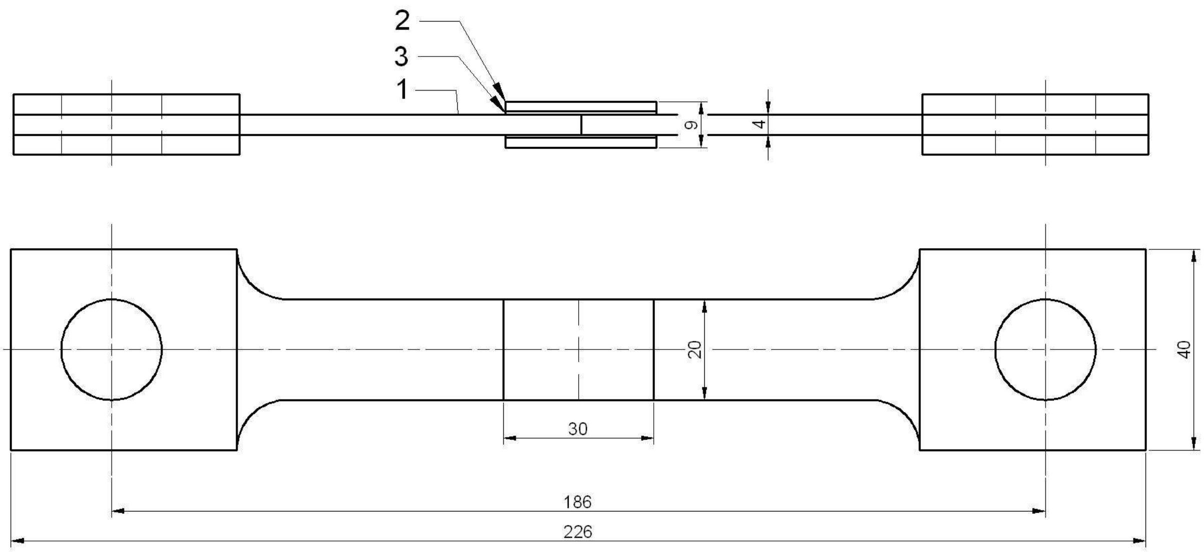

Figure 2: Geometry of specimen.

For fatigue tests were made two series of samples labeled BA and OA. These samples were identical except for different surface roughness of adhesive surfaces. The surface roughness of carrier was created by peel ply fabric. Changes were made at the splice bars. In the series of OA was also the surface roughness created by peel ply fabric. The series BA was created as well, but bonded surface was subsequently finished by abrasive paper with grain size 80.

Adhesive Araldite was applied manually to the prepared and dry joint surface. On both parts were applied thin layer of glue and then one of the areas was deposited layers about 1 mm thick. Subsequently, components were attached to him and gently pressed. All specimens were heated 16 hours at 55°C.

2.2 Material of test specimens

Main load-bearing parts (carrier)

This part (labeled 1 in Figure 2) was made by wet lamination of glass fabric reinforce and epoxy matrix. Was used 10 layers 92140 (390g) 45° and one surface layer 92110 (163g) 45°.

Splice bar

This part (labeled 2 in Figure 2) was made by wet lamination of carbon rowing fiber reinforce and epoxy matrix. Was used rowing TENAX HTA 5131 800tex pulled twice for 24 bands. Followed by pressing at 75% weight ratio.

Adhesive Araldite

This glue is a two component, room temperature curing paste adhesive giving a resilient bond. It is particularly suitable for CFRP and GRP bonding with high shear and peel strength. The strongest and most durable joints are obtained by either mechanically abrading the degreased surfaces. The resin/hardener mix may be applied manually or robotically to the pretreated and dry joint surfaces. A layer of adhesive 0.05 to 0.10 mm thick will normally impart the greatest lap shear strength to the joint.

Material informations	Value	Unit
Max shear strength	17	[MPa]
Tensile strength at 23° C (ISO 527)	30	[MPa]
Tensile modulus	2000	[MPa]
Elongation at break	4,4	[%]
Roller peel test (ISO 4578)	5	[N/mm]
Mix ratio	1:1	[-]
Gel time	35	[min]
Max service temperature	80	[°C]

Table 1: Published material properties of adhesives Araldite [3].

3 Tests

3.1 Static test

Previous static strength values are taken from [3]. Figure 3 shows the static strength for different materials, including GRP and CFRP. Bonded joint cured for 16 hours at 40°C end tested at 23°C. Bonded surfaces were lightly abraded and degreased.

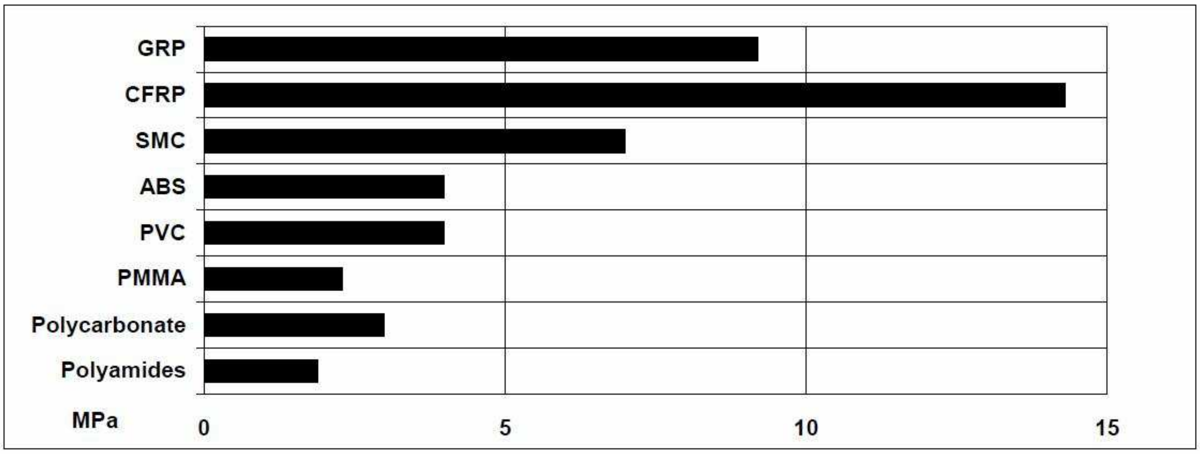

Figure 3: Shear strengths of typical plastic-to-plastic joints [2].

3.2 Fatigue test

These fatigue tests were conducted to determine the specific S-N curves of the bond and to determine the influence of surface treatment on the number of cycles to failure. To create these S-N curves is necessary to carry out tests on several stress levels. Samples were loaded with a hydraulic machine INOVA ZUZ 200. Applied load was made by constant amplitude and was driven by force. Frequency of loading was chosen smaller with regard to the heating of the sample and ranged from 3Hz to 5Hz. The loading cycle was chosen tension-tension with a stress ratio R = 0,1. The test specimen was clamped in the preparation, which allows simultaneous testing of up to 6 samples. Preparation and clamped sample are shown in Figure 4. Load cell is an essential part, because the load is driven by force. In this case, was used load cell HBM type S9 with nominal force 20kN.

Fatigue tests were conducted at six levels of stress. Depending on the size of the levels occurred crack nucleation during cyclic loading. This nucleation occurred at the corners of loose ends, because there is the greatest stress concentration. From these places, the fatigue crack spread, which can be monitored by eye. Another spreading was towards the center of the sample and thus there was a reduction in bonded area. This surface reduction increases shear stress and achieve to the limit values in breach of the bond. In a few cases occurred fatigue failure of the basic composite material outside the glued joint. These results can not be included in the results. For other samples, where were a failure of the bond was a failure on the interface of glass/glue or carbon/glue. Fatigue failure modes were adhesive and interlaminar delamination. Interlaminar delamination shows that have not been fully utilized adhesive properties, but there was a damege of basic material and glued joints.

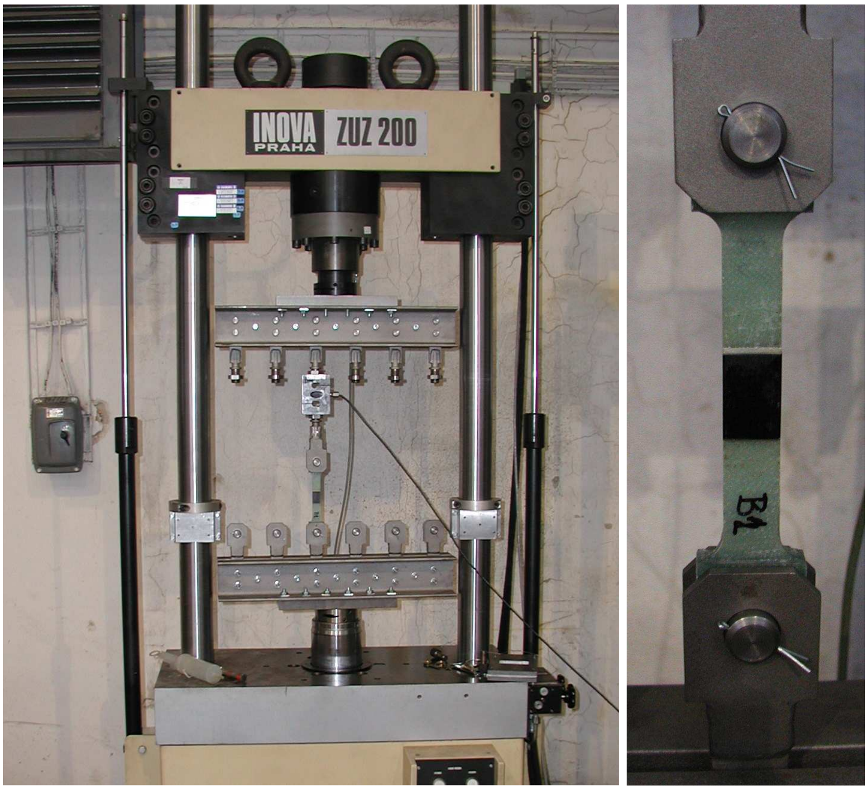

Figure 4: Testing Machine details and clamped specimen.

The following Figure 5 shows the measured S-N curves of two series of bonded joints. On the vertical axis of the graph is ratio τ_f/τ_{st}, where τ_f is the fatigue shear stress at fracture a τ_{st} is the static shear strength. The horizontal axis is the logarithm of the number of cycles N. Red color square indicates a series of OA samples (surface roughness created by peel ply fabric) and the blue color triangle indicates a series of samples BA (cemented surface grinding). On Figure 5 is easy to see a significant difference between these series. Abrade surface reaches the same number of cycles significantly higher levels of stress that leads to the failure.

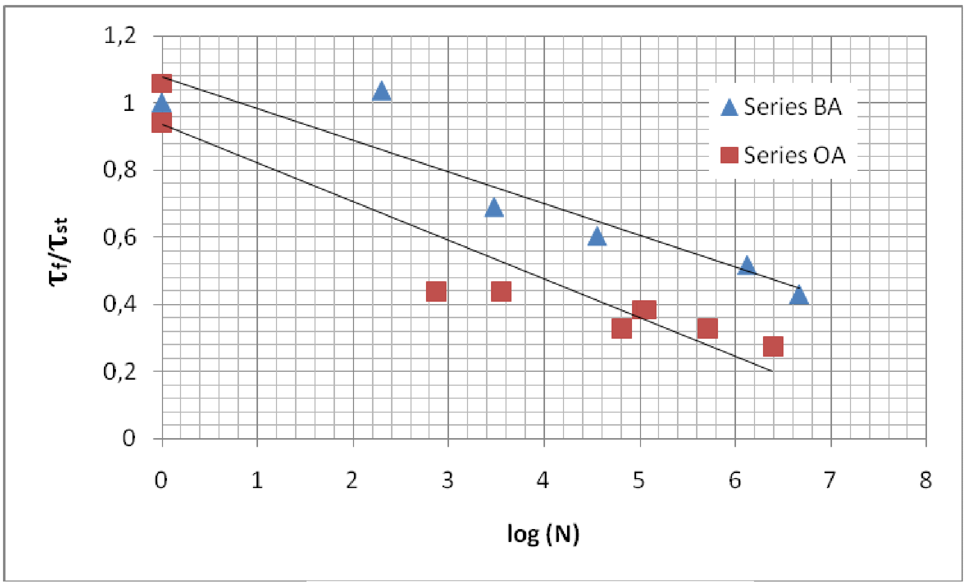

Figure 5: The resulting S-N curves of bonded joints.

The following Figure 5 shows the test specimens after fatigue tests. There is clearly noticeable adhesive debonding and interlaminar delamination failure.

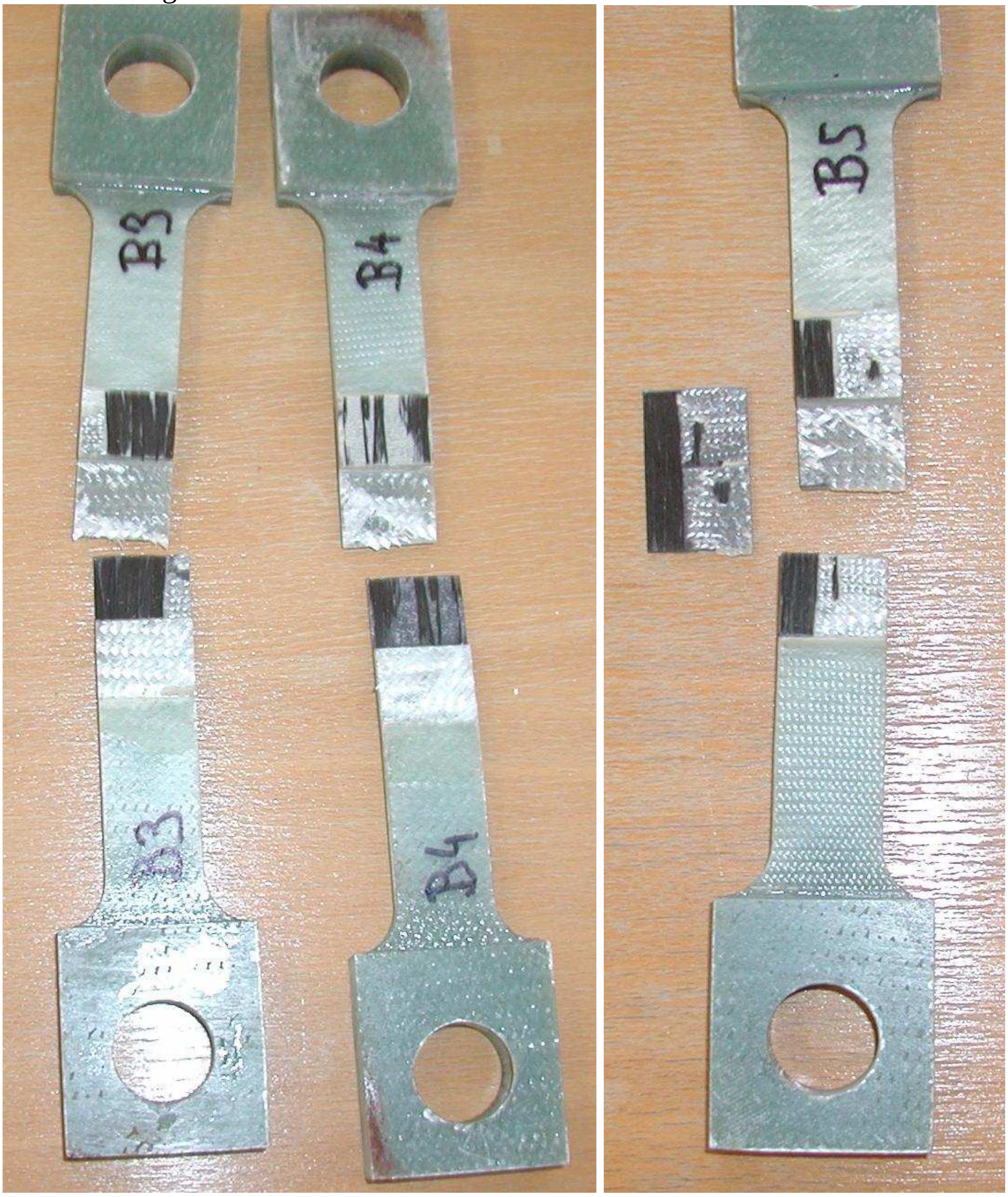

Figure 5: Specimens after fatigue tests.

4 Conclusion

Fatigue testing of bonded joints were made for two series of samples. On the basis of fatigue tests was demonstrated relatively strong influence of surface roughness on the number of cycles to failure. From Figure 5, this effect is clearly visible as the number of cycles increases the difference between the two measurement series. If we compare the two series, for example, 2.5 million cycles we find that failure occurs in a series of OA in 27% of static shear strength and polished surface with a series of lines, this value is 47% of shear strength.

The surface roughness has great influence on life time. Even at the abrade surface there were abrasive and interlaminar failure. Fatigue stress failed to reach the cohesion failure. It follows that the fatigue properties of glue are better than the adhesion properties of adhesive surfaces.

Comparison is done only for one type of glue. It is necessary to continue the fatigue tests and also take into account other adhesives. One possibility is thickened epoxy. We can examine the influence of the volume of cotton or Aerosil on the resulting fatigue properties. Fatigue tests are very time consuming, but necessary for durable construction.

References

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