Fracture of new joints of aero structures

Marek A. Debski [1], Krzysztof M. Golos [2], Daniel K. Debski [2]

[1] Institute of Aviation, Al. Krakowska 110/114, 02-256 Warsaw, Poland, tel.: (+48-22) 846 00 11 in. 630, fax.: (+48-22) 846 44 32, dedal@ilot.edu.pl
[2] Institute of Machine Design Fundamentals, Warsaw University of Technology, Narbutta 84, 02-524 Warsaw, Poland.

ABSTRACT: *The conception, tests and applications of composite joints as a new, alternative kinds of joints of structures are presented in this paper. This paper presents results of tests made within the confines of research project sponsored by of the State Committee for Scientific Research and of work on new structures, especially on the sport airplane DEKO-9 Magic and the ultra light airplane DEKO-6 Whisper.*

INTRODUCTION

Structures of high manoeuvrable airplanes are the most loading structures. A factor of safety ν is very low, for airplane's structures a primary factor of safety $\nu=1.5$. It means that a failure load is only 50% higher than a safe load – which can occurre during exploitation. Joints are one of important and difficult points in structures. Especially if it is concerning truss. Welded, pin, riveted, screw and glue joints are the most popular joints. Welded joint of an airplane truss, connecting steel or duralumin truss members, is a primary kind of a joint. The manufacturing of welded joint leaves residual stresses and micro cracks. Riveted joints are an alternative solution but this kind of joints is requiring of additional sheets. In very sophisticated, multi truss members structures this requirements complicate the construction.
The chose of the optimal kind of joint, connecting principal bearing elements, is a primary problem for a designer. Joints are the points of the structure where concentrate forces are loaded into and distributed by a structure. These forces cause a complex state of internal loads of the structure. The problem is very expressive in trusses and thin-walled constructions. Our result of years of aerostructures designing is the composite joint. The conception of the composite joint is an alternative solution for a classical kind of joints.

THE CONCEPTION

The conception of composite joint based on connecting principal bearing elements by composite materials as a main load transmitting material. If we use roving to connect elements we receive a kind of an anatomical joint. The possibility of construction of the joint in an optimal way for load transmitting is the one of the most important design feature. It is also possible to join elements separately. The destruction or the pulling out one of the connected element does not have to mean the damage of the joint. The composite joint, characterized by high structural strength, allow to connect the elements made by different materials. The example connecting of a landing gear beam and a duralumin truss is showed below (Figure 1).

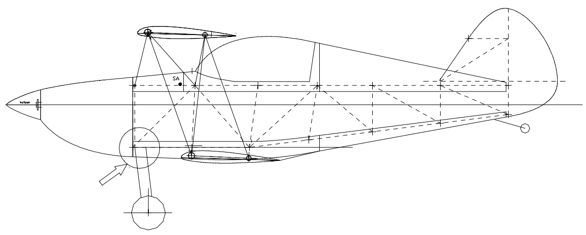


Figure 1: The example of the composite joint in the aircraft structure of the DEKO-9 Magic airplane

FATIGUE AND STATIC TEST OF ISOLATED COMPOSITE JOINTS

A joint, connecting two coaxial pipes ϕ 30x1.5 made of PA7ta duralumin, has been tested. In joint structure three kind of roving material have been used: glass, Kevlar and carbon. Epoxy resin Epidian 53 has been a matrix.
Tests have been carried out, using a MTS test machine, in the laboratory of the Institute of Machine Design Fundamentals of the Warsaw University of Technology. The one of the test joints, during tests, is presented on Figure 2 (the composite joint connecting two coaxial pipes ϕ 30x1.5 made of PA7ta duralumin). Figure 3 shows the damage of the joint.
The result of pulling out next bundles of roving is the gradual profile of damage process with increasing load and high joint extension as a characteristics for composite joints. The damage is not a violent process,

and it is indicated by high joint extension (Figure 4). The composite joint keeps capacity to transmit load, it is the very positive feature.

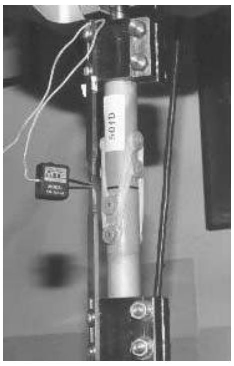
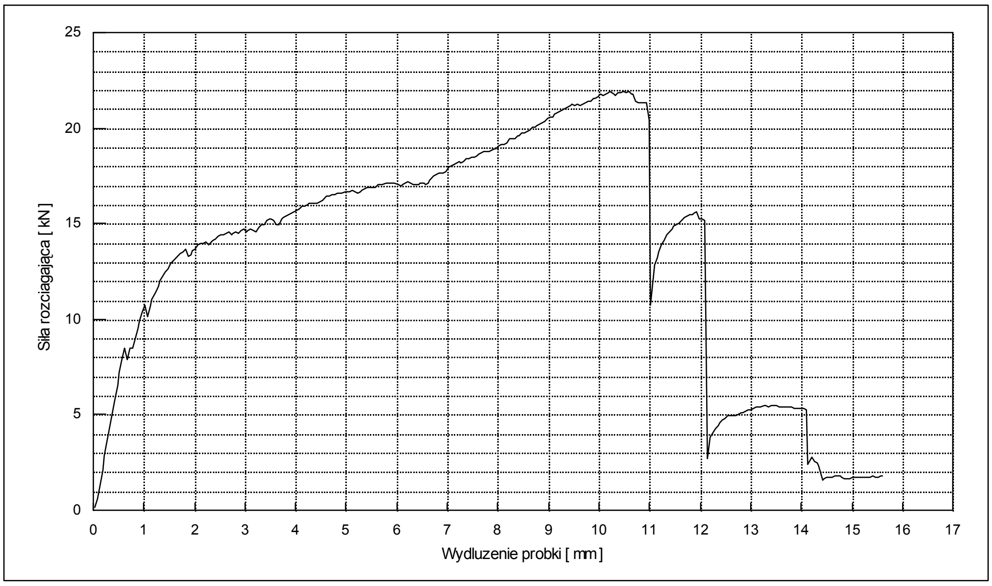


Figure 2

Figure 3

Force [kN]

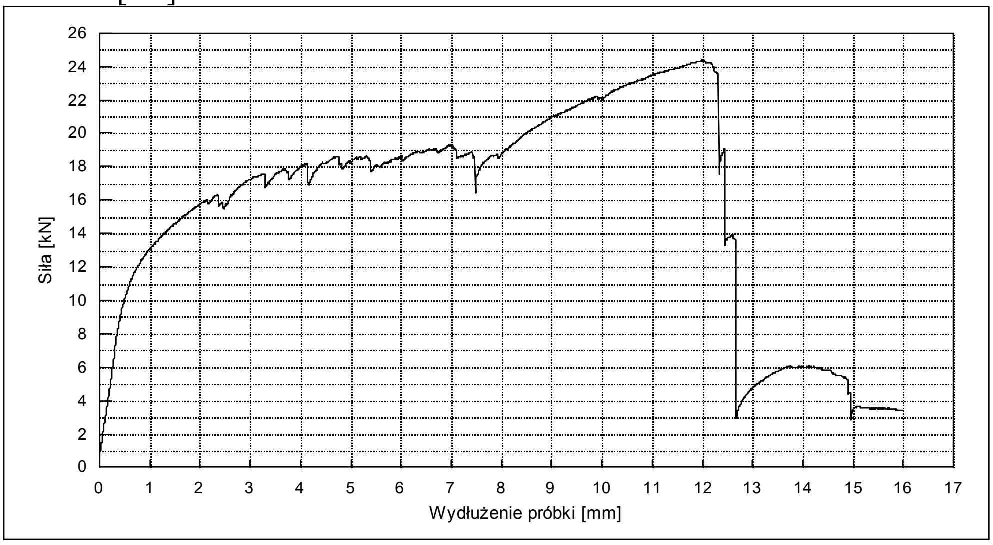


Extension [mm]

Figure 4: The gradual profile of damage process of the composite joint (glass roving / epoxy resin = 0.5)

The composite joint (with glass roving), connecting two coaxial pipes, passed 100 000 cycles of load (0, +7 kN). Composite joints, in Kevlar and carbon version, have been destroyed by damage of pipes in the area of roving fastener elements. An influence of a fatigue load on a static strength became very important problem after carrying out our fatigue tests. To define this influence the static test of the residual strength has been done. We could not found out the influence of the fatigue load on the static strength (Figure 5).

Force [kN]



Extension [mm]

Figure 5: The residual strength after 100 000 cycles (load 0, +7 kN)

TESTS OF A TRUSS

Data analysis [1, 2] and results of fatigue and static tests [3, 4, 5, 11] let us to make a high-complicated truss. The truss (Figure 6) is similar to the real aerostructure of the sport airplane DEKO-9 Magic. We had all load dates of this high manoeuvrable airplane [6, 7].

The capacity to transmit test loads, in condition of maximum effort and minimum mass of the structure is a fundamental criterion in aviation. The minimum factor of safety $\nu = 1.5$. The fatigue test station, designed and made in the Institute of Aviation, is shown on Figure 7.

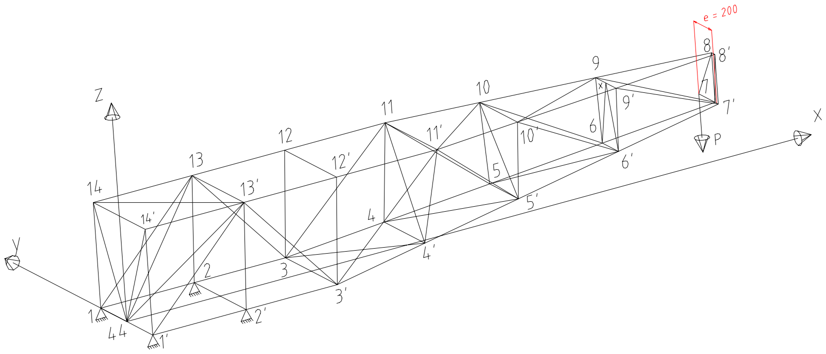


Figure 6: The test truss.
Points 1, 1`, 2, 2` are fixed points, P – load force, e- an arm of the force

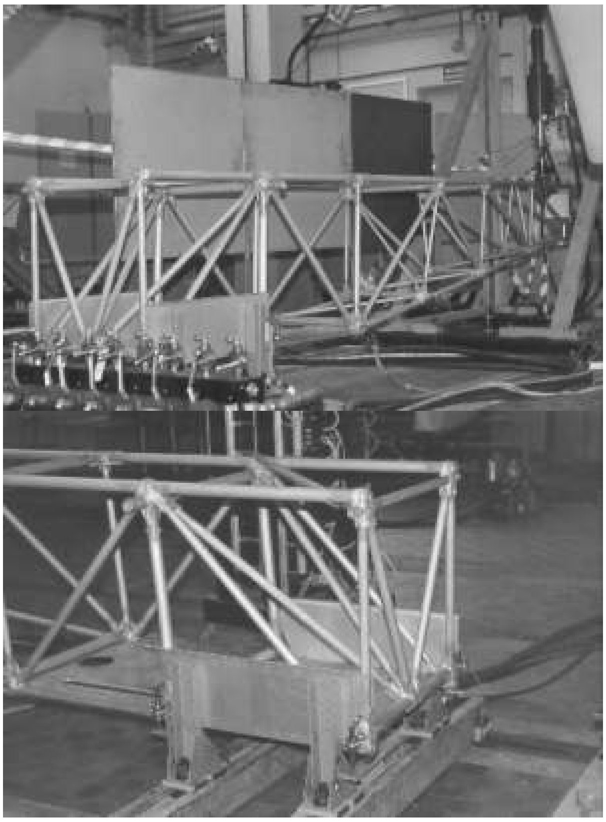
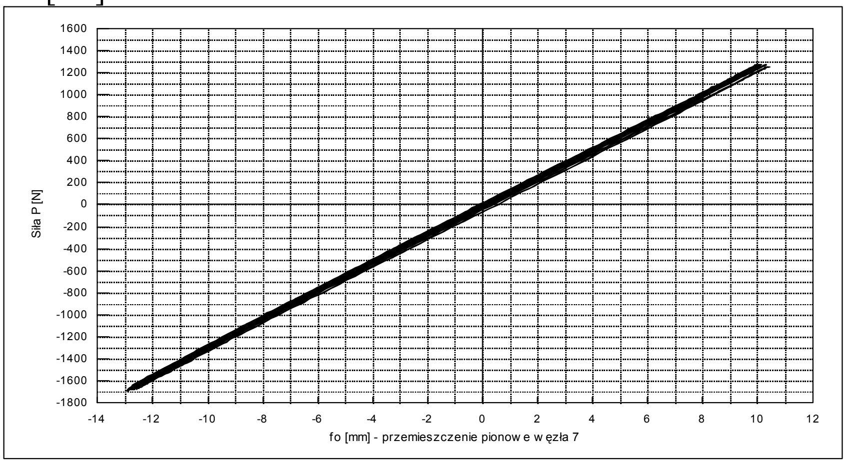


Figure 7: The fatigue test station (Institute of Aviation)

The tests have been realised according to test program [9]. 70 000 cycles (load force P=+1680N, -1270N with 1Hz frequency) of load have been made. This is an equivalent of 10 600 flight hours [8]. The truss favourable passed all tests without any defects and changing of stiffness. Linear displacement has been measured in point 7. After each 2000 of cycles that displacement bas been recording (Figure 8, 3 recorded profiles). The recorded profile of P=P(fo), where fo - displacement in 7 [mm] after 10 000, 20 000, …, 70 000, has linear characteristic. Figure 9 shows an angle of torsion, section between points 2 and 6 recorded after 50 000 cycles.

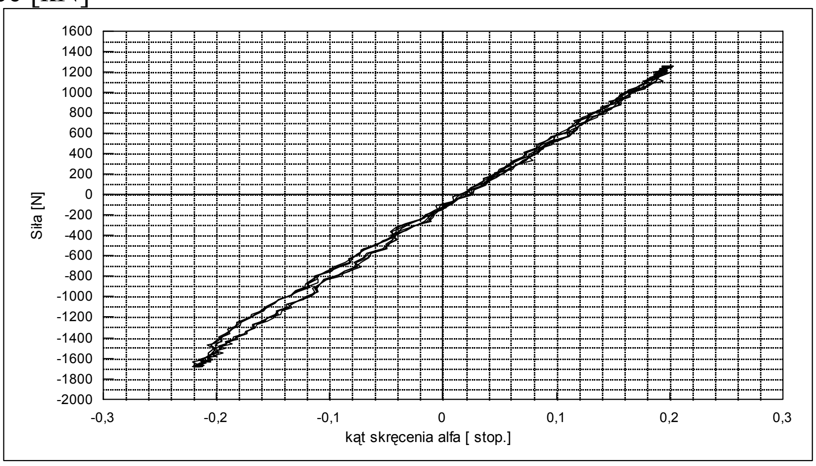
Force [kN]



fo - displacement in point 7 [mm]

Figure 8: Recorded profiles P[N]=function (fo[mm]) measured in point 7 after 10 000, 20 000, 30 000, 40 000, 50 000, 60 000, 70 000 cycles of loading

Force [kN]



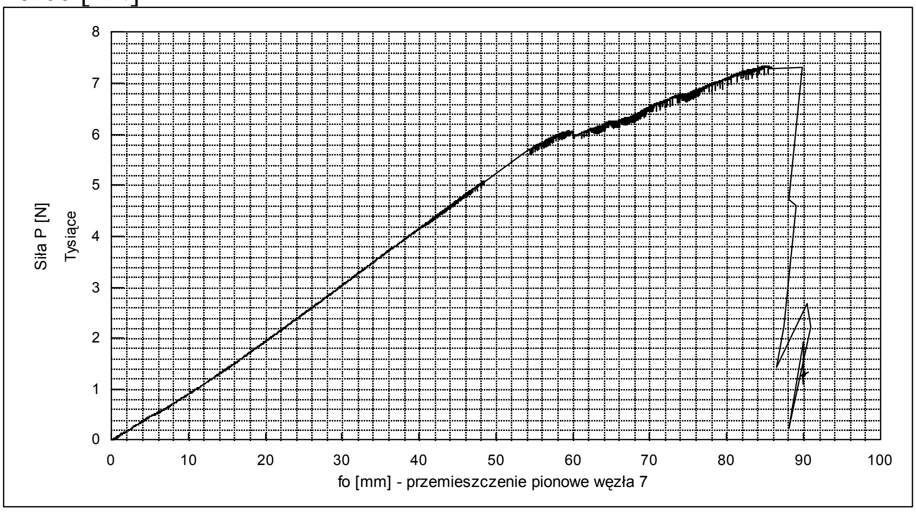
angle of torsion

Figure 9: An angle of torsion, section between points 2 and 6 recorded after 50 0000 cycles

After 70 000 data recording has stopped. After 150 000 cycles fatigue test has been interrupted because of that this safe life of the truss is sufficient.

Next, the static test has been made to determine a residual strength of the truss. During the test composite joint in point 13 has been destroyed. It happened under force P=7339[N], (Figure 10).

Force [kN]



fo - displacement in point 7 [mm]

Figure 10: The residual strength of the truss after 150 000 cycles

---

Composite joints conception has been applied to manufacture an aerostructure of the new sport airplane DEKO-9 Magic (www.Kaiser-Flugzeugbau.de, WZL-3 Deblin). Actually the Magic is testing in flight.

Mr Krzysztof Kotlinski M.Sc.Eng is the forerunner of composite joint using in Poland. He has designed a lot of modern ice-boats where he has used composite joints to connect bearing elements.

Copyright of Composite joints reserved by K. Kotlinski, M. Debski [10].

REFERENCES

1. Agarwal, B.D. (1982): *Analysis and performance of fiber composites*, J.Wiley & Sons, New York.
2. (1986) *Data manual for Kevlar49 aramid, Du Pont*, Wilmington.
3. Debski M., Golos K., Debski D**.** (1999): *Composite joints of structures – static and fatigue strength tests*, Transactions of the Institute of Aviation, 158.
4. Osinski Z., Golos K.M., Debski M. (1997): *Tests of composite joints*, III Scientific Conference, Experimental Methods in machines' building and exploitation, Szklarska Poreba, Poland.
5. Debski M., Golos K.M., Kotlinski K., Debski D. (1997): *Stand for static and fatigue test of joints*, III Scientific Conference, Experimental Methods in machines' building and exploitation, Szklarska Poreba, Poland.
6. *Regulations **JAR – VLA,*** 26.04.1990.
7. Urbaniak W., Debski M. (1998): *Loads of the DEKO-9 airplane,* DK9/OB/3/98.
8. Test Report, *Fatigue test of the truss*, Institute of Aviation, W-21/RPT/06/99.
9. Debski M.: *A Program of fatigue test of the truss*, Institute of Aviation.
10. Kotlinski K., Debski M.: *Joints of structures* - Patent: UP RP nr PL 173 997.
11. Osinski Z., Golos K.M., Debski M., Debski D. (May 2001): *Composite joints of lifting structures in point of strength tests,* Mechanics of Material Failure Symposium, Białystok University of Technology.