FATIGUE INVESTIGATIONS INTO A COMPOSITE GLIDER STRUCTURE

Miroslaw Rodzewicz, Krystyna Majorkowska-Knap
Warsaw University of Technology, Institute of Aeronautics and Applied Mechanics, Nowowiejska 24, PL 00-665 Warszawa, Poland

Summary The authors present the results of fatigue investigations into the primary structure of composite glider undertaken at the Institute of Aeronautics and Applied Mechanics (IAAM) of WUT. The specimens representing the main joints of wings and fuselage, as well as the wing spar root were tested, since they form a most representative part of the glider primary structure. The integral fatigue tests of the wings-fuselage system were finally performed.

Introduction

Composite materials are primary candidates in the construction of the next generations of advanced aeronautical and aerospace vehicles. The design for primary and secondary structure of modern gliders will rely on FRPs to meet the structural weight criteria. Due to the economic and safety criteria, the structure of them must be durable over an expected life time at environmental conditions. From the survey of literature plenty of results are published in the field of fatigue of composite (e.g. recently published [1 ÷ 5]) and new smart [6] materials [7].

For several years the education and design program of light composite gliders has been developed at the IAAM, bringing about the "PW" family of six manufactured and tested glider prototypes, together with the widely known PW5 "Smyk" – the winner of FAI international technical competition for a new mono-type class - called the World Class glider. One of the main aims of the investigations undertaken after making successful tests of the PW-5 consisted in proving that its operation life was 9 000 hours, which was the level required for the World Class Glider. The investigations were conducted in the following three stages: 1st - fatigue tests of the main wing-fuselage joints, 2nd – fatigue tests of the root part of wing spar, and 3rd – integral fatigue tests of the wings-fuselage system. Before making the fatigue tests - the estimation the glider load spectrum was performed by means of calculations and in-flight load recording.

Fatigue tests of the main wings-fuselage joints

A special type of joints has been employed in the PW-5 and the following PW-gliders for the wings-fuselage fitting [8]. The work principle of such a joint consists in the introduction of a concentrated force into a composite multi-layer glass-epoxy (GFRP) shell by means of special metal sleeves and pins. The joints are located in the main fuselage frame and in the wing spars shear webs. The main feature revealed by those joints is the lack of adhesive connections between the metal parts of joints and composite shells, respectively, (i.e. the joint with a labyrinth fastener, patented under: PL 146658). These joints (Fig. 1a) have been tested in a low-cycle fatigue mode. The program of investigations comprises the following phases (Fig. 1b) a/ static tests of fresh - not-fatigued specimens (specimens No: K02, K04), b/ constant-amplitude cycle fatigue tests (specimens K03, K05, K06), c/ increasing amplitude cycle tests (specimens K08, K09), d/ residual strength tests (after 10 000 cycles). In the aforementioned cases the load lower limit was the force corresponding to **n = 1**, where **n** is a load factor (a multiplier of $g = 9.81\ m/sec^{-2}$). The maximum load expected in glider service was exactly the same as in the case of specimen K03.

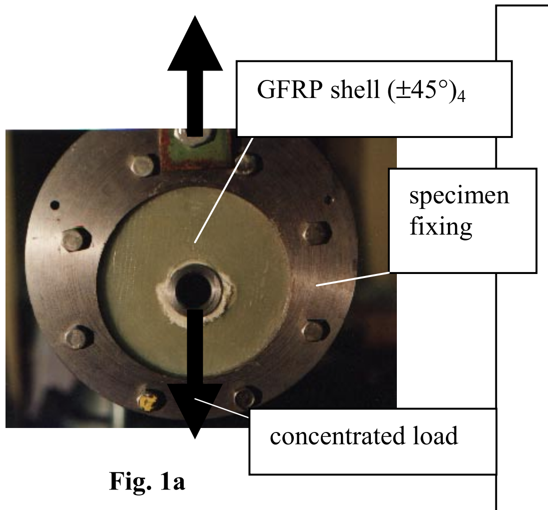

Fig. 1a

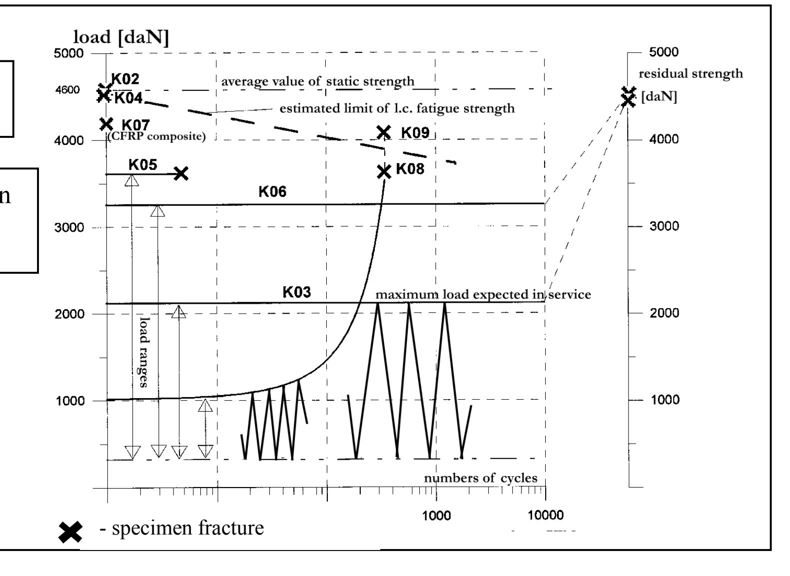

Fig. 1b

The rheological behaviour of specimens has been observed in the course of test procedures. A special attention was focused on the stagnation process of load-deformation hysteresis loops (Fig. 2a - the measured load deformation hysteresis loops). Taking a general approach this process can be represented by a three-parameters phenomenological model [8, 9]. The bond-graphs and the results of numerical simulation of the specimen behaviour are shown in Fig.2b.

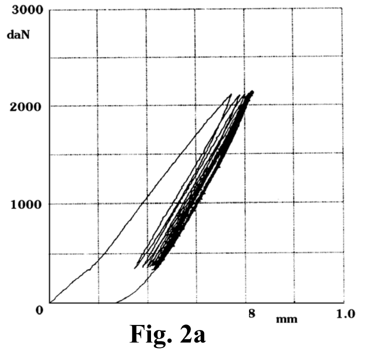

Fig. 2a

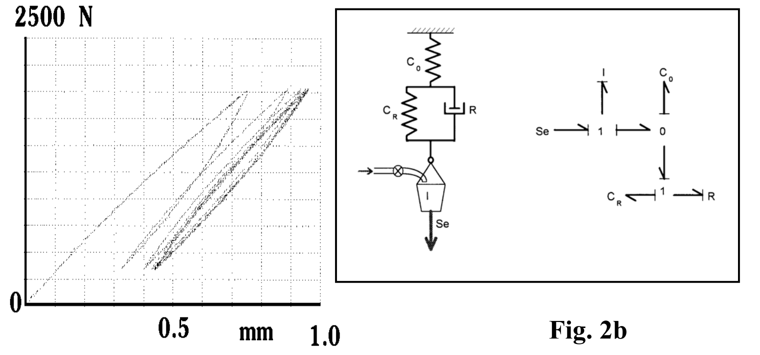

Fig. 2b

The fatigue and residual strength tests of the main wings-fuselage joints have proved that the fatigue loads not exceeding 70% of the fracture load exert only an insignificant influence on the residual strength.
This load level corresponds to the safety factor of 1.6 relative to the glider load limit. The number of 10 000 constant amplitude cycles at the design stress level was proposed as the proof covering fatigue of the glider FRP structure [10] .
The aforementioned type of joints was initially tested for the CFRP specimen (cf. K07 in the Fig. 1b).

Fatigue tests of the wing spar and the wings-fuselage system

The load spectrum as a basis for the fatigue tests – consisted of a number of constant amplitude load blocks [11]. Each load block is represented by an average value and amplitude of the load, and the number of cycles. For the PW-5 glider a cumulated sum of load cycles was about 900 000 per 1000 hours of the glider operation. Only a few percent of cycles reached the minimum and maximum limit load levels, and low amplitude oscillations around n = 1 dominated. In both the cases of fatigue test (wing-spar root and wings-fuselage system tests) the method for producing of the load was based on bending oscillation of specimens, excited a new, designed electrodynamic activator (patent PL 176320 B1). The system used for fatigue test is shown in Fig. 3. During the tests there were simulated fatigue loads corresponding to 27 000 hours of flight for the wing spar, and 12 000 hours of flight for the wings-fuselage system. Basing on the results the aviation authorities have approved the service life of the glider.

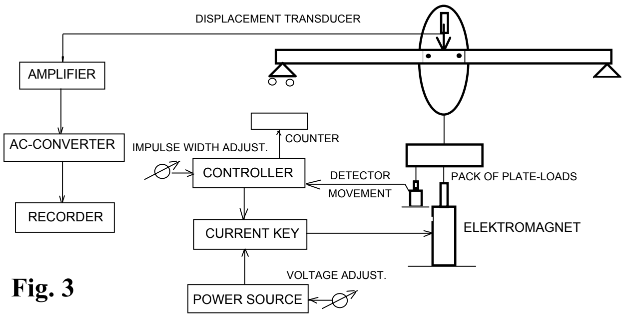

Fig. 3

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