DE GRUYTER OPEN

Fatigue of Aircraft Structures
Vol. 1 (2014) 107-112
10.1515/fas-2014-0011

STRESS ANALYSIS OF THE PZL M28'S AIRFRAME SUBJECTED TO REPAIRS DURING FATIGUE TESTS

Józef Brzęczek
Henryk Gruszecki
Leszek Pieróg
Franciszek Deszcz
Janusz Pietruszka

Polskie Zakłady Lotnicze Sp. z o.o., ul. Wojska Polskiego 3, 39-300 Mielec

j_brzeczek@pzlmielec.com.pl, h_gruszecki@pzlmielec.com.pl, l_pierog@pzlmielec.com.pl, f_deszcz@pzlmielec.com.pl, j_pietruszka@pzlmielec.com.pl

Abstract

The PZL M28's service life is determined based on the fatigue tests of the wing and wing loads-carry-through structure. During the fatigue test, the first occurrence of significance was the appearance of a in the area of the wing where loads are applied from the strut. It was demonstrated during further activities that repairs of the wing and other basic assemblies enabled, when performed at an appropriate time, the airplane's service life to be significantly increase.

In the case of each design change implemented in the airframe subject to the fatigue testing, a stress analysis of the airframe was required in order to check if local changes, i.e. local repairs, did not affect the stress level in other tested areas. This helped to avoid significant stress redistribution in the airframe after the repair, so the fatigue test was still valid for all areas of interest.

Keywords: *metallic airframe structure, full scale fatigue tests*

THE RATIONALE BEHIND THE REPAIRS OF THE PZL M28'S AIRFRAME SUBJECTED TO FATIGUE TESTING

The service life of the PZL M28 is computed based on the fatigue tests of the wing and wing loads-carry-through structure [1]. The wing, fuselage and the empennage are metallic, thin walled, riveted structures, with bolts applied at the most heavily loaded junctions. Safe life philosophy is applied to determine the airframe's service life. This philosophy is concerned with the main structural elements, essential for the load carrying paths. In other areas, nonessential from the point of view of load carrying, cracks are admissible on the condition that it is possible to detect them during periodic service activities, described in airplane's maintenance manual. This philosophy complies with the requirements of 14 CFR, Part 23, section 23.574 with Amendment 23-48.

During fatigue testing, the airframe was visually inspected in order to find any cracks. This procedure was supported by the strain gauges indications analysis. Strain gauges were located in the areas of the significant stress level, primarily exposed to fatigue damage according to the fatigue analysis. All cracks detected in the test were analyzed and categorized as any of the following:

- damage of main structural members, threatening with catastrophic failure of the airplane (critical damage);
- damage of secondary structural members, not affecting safety of flight in the time interval up to their detection (not critical damage);
- damage at dummy areas, which are not of interest.

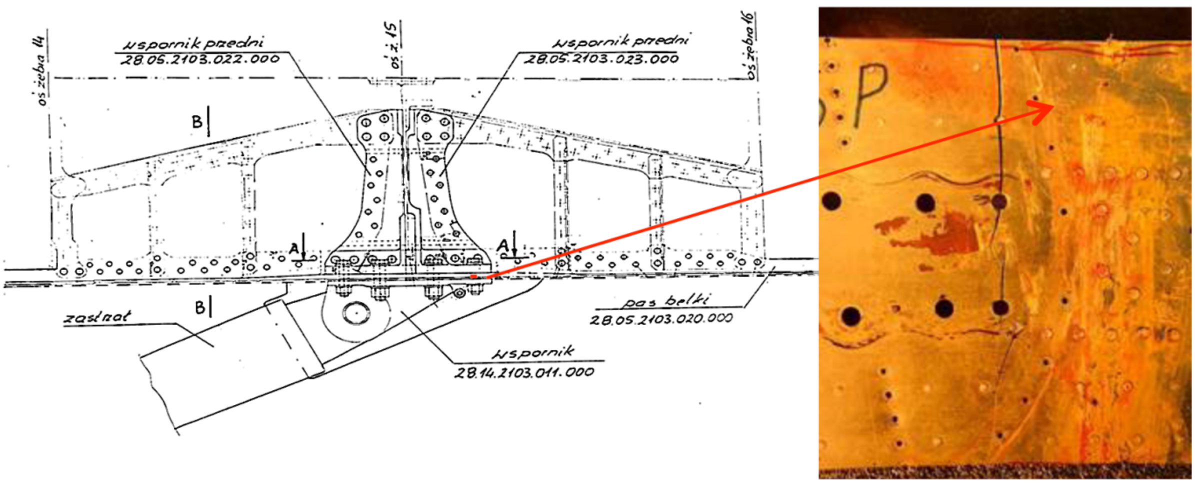
Detection of a crack in the main structural member (critical damage) determines the limit of its operation. A damaged element may be replaced by a new one and the test may be continued, counting time for a new element from 0. This procedure makes the continuation of the test possible on the condition that such a replacement can be performed during the airplane's operation. If this is not feasible, the damaged area may be repaired in order to continue the test with repaired area treated as a dummy. A detailed stress analysis is required in this case as the repair may redistribute stresses in tested elements. In case of the stress level change in the tested area, the fatigue life must be recalculated.

After a not critical damage of the tested airframe was detected, a detailed stress analysis was performed in order to establish the repair procedure that can be performed during airplane's operation in the case of crack detection, and to check the effect of the repair on the stress distribution in the tested element, e.g. the wing structure. In case of the stress level change in the tested area, the fatigue life must be recalculated.

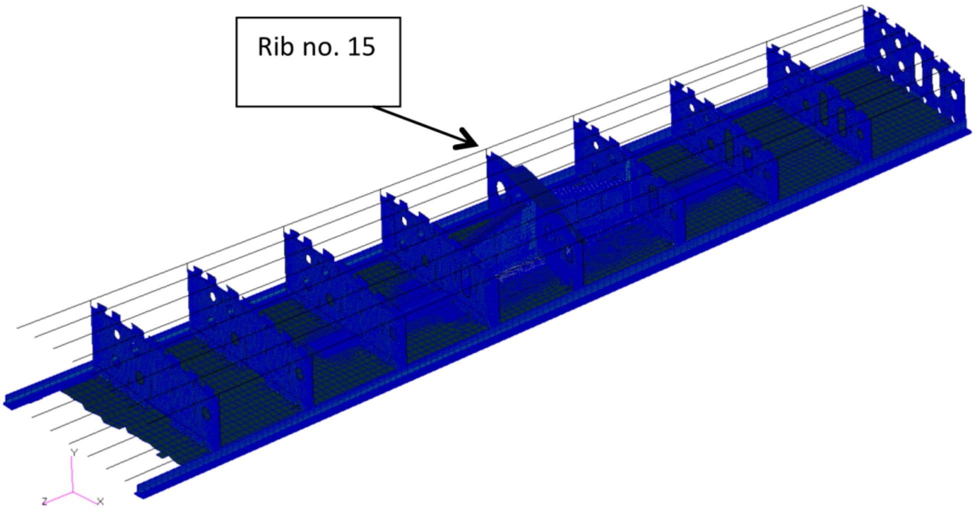
Below two cracks in wing structure are presented in detail.

THE CRACK AT THE WING RIB 15

The first significant event in the test was a crack in the wing, in the area where wing strut loads are introduced at the rib 15. The crack was caused by the fatigue damage of the wing in the area of the local stress concentration (holes for bolts in the wing strut fitting mounting). The test was terminated before the damage of the tested wing could spread – see Fig. 1. The subsequent analysis showed that it was possible to repair the critical wing area on the airplane in operation, and in this way significantly extend the airplane's service life. A careful stress analysis was performed for the PZL M28's outer wing, in which the most interesting area was the rib 15, where the wing strut loads were introduced. A detailed FEM model covers the wing area from rib 10 (the root rib of the outer wing, with four fittings of the junction with the centerwing) to the rib 19 – see Fig. 1(c) and Fig. 2.



a) *b)*

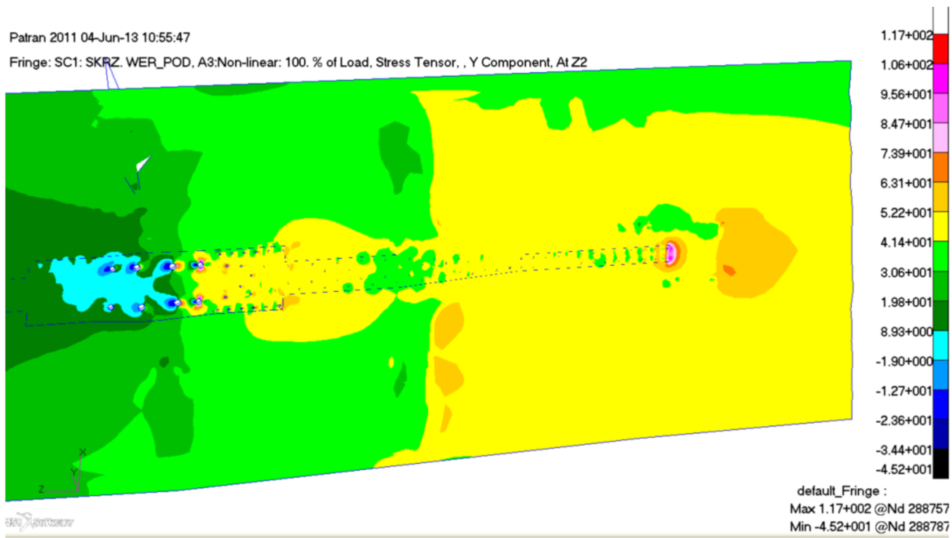


c)

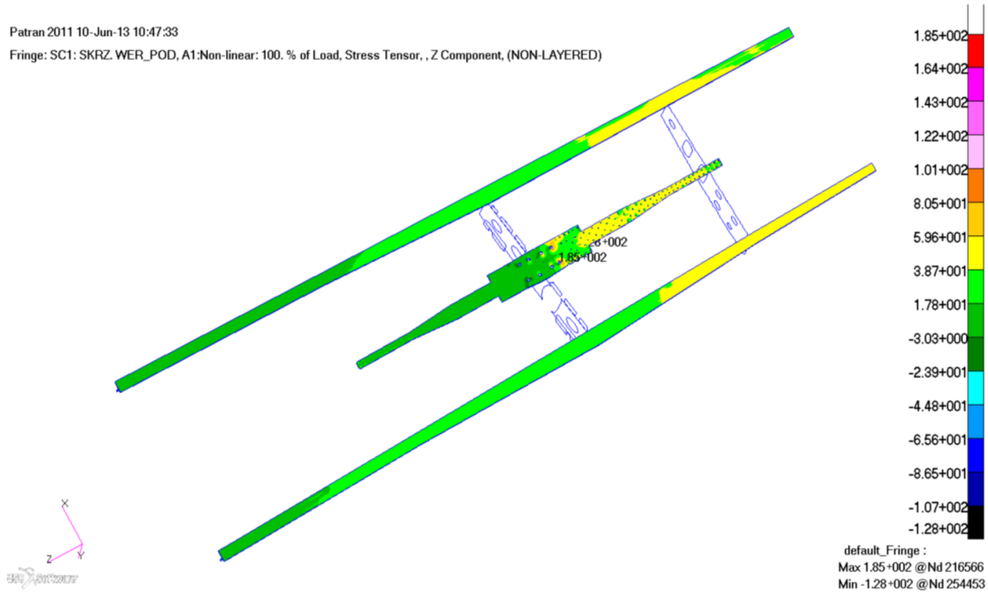
Fig. 1. PZL M28 wing area of rib 15:
(a) Sketch of the area of rib 15 with a crack indicated
(b) Cracked wing skin after removal of a wing strut fitting
(c) The FEM model of the wing, general view

The wing area aft of the rib 19 was modeled as a beam. Design changes implemented in the structural beam lying between the front and rear wingspans considerably increased the service life of the wing. These changes can be introduced to the wing taken from the airplane in operation during the repair process.

The fatigue test was continued after the repair of the wing critical area, with separate design solutions implemented in the LH outer wing and the RH outer wing. This resulted in increasing the test scatter factor for the wing, according to the advisory literature recognized by the Authorities as FAA or EASA [2].



a)

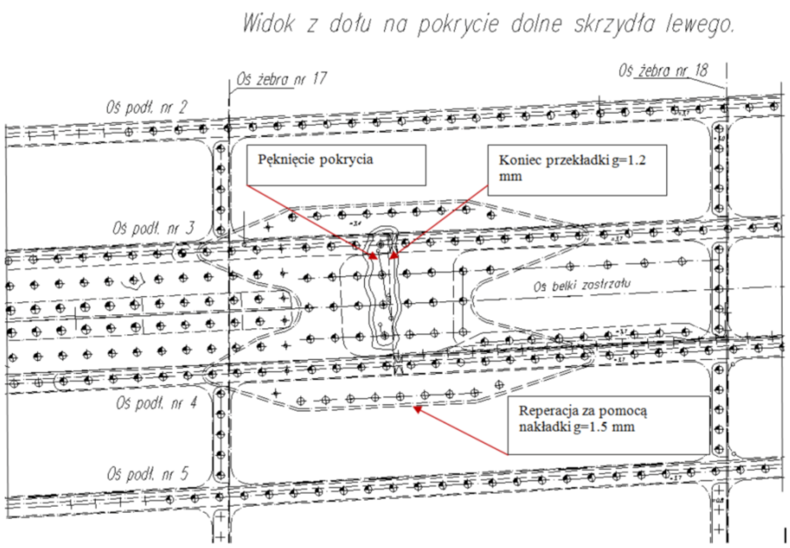


b)

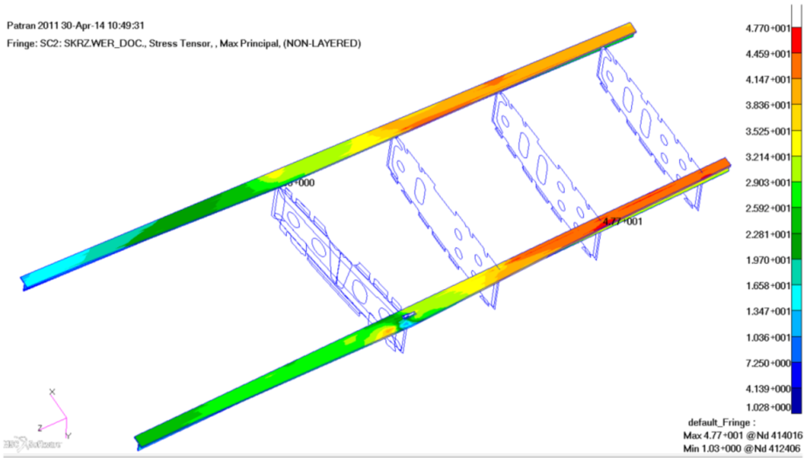
Fig. 2.Stress distribution in the PZL M28 critical wing area according to the FEM analysis at a maximum load level during the fatigue test:
(a) Stress in the lower skin critical area
(b) Stress in the wing spars' lower caps and the beam's lower cap

THE CRACK AT WING RIB 17

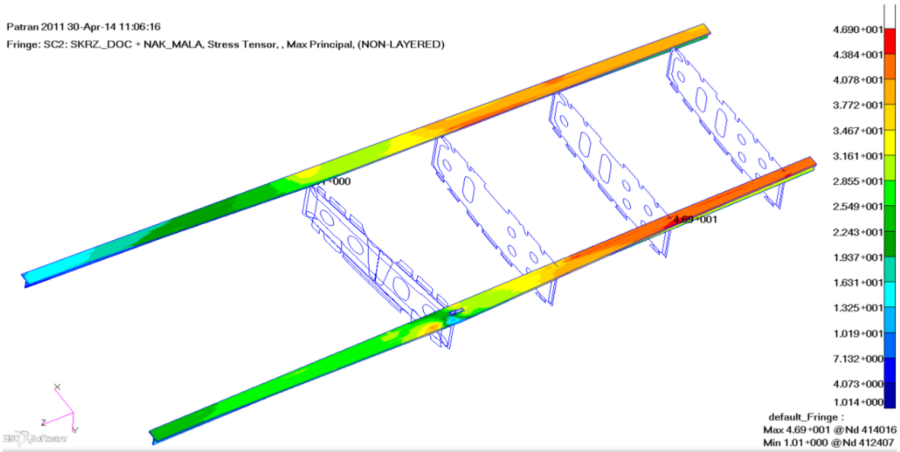
Another crack in the wing was observed at rib 17. The crack was in the wing skin only, so it was assessed as not critical. As it is the area of the integral fuel tank, a crack occurrence is signalized by a fuel leakage. Repair of the airplane in operation is possible, so such repair was made in the tested wing. The FEM stress analysis was performed in order to check the effect of the repair on the stress level in the wing spars – see Fig. 3.



a)



b)



c)

Fig. 3. The FEM analysis of a crack in the PZL M28 wing area of rib 17 during fatigue testing:
(a) Sketch of the cracked area of the skin between rib 17 and rib 18 with a strap
(b) Stress in the wing spars' lower caps for level flight (n_z = 1 g) load before the repair
(c) Stress in the wing spars' lower caps for level flight (n_z = 1 g) load after the repair

THE FATIGUE LIFE CALCULATION

When calculating the tested element's service life increase during the test period with repairs/changes implemented to it, which won't exist in airplane operation, care should be taken in order to avoid omitting of design changes on fatigue damage:

$$L_R = L_I * \frac{D_{C\,I}}{D_{C\,R}} + L_{II} * \frac{D_{C\,II}}{D_{C\,R}} + L_{III} * \frac{D_{C\,III}}{D_{C\,R}} + L_{IV} * \frac{D_{C\,IV}}{D_{C\,R}} .... = \sum_i L_i * \frac{D_{C\,i}}{D_{C\,R}}$$

where:

L_R – total fatigue life increase (for basic design),

D_{CR} – fatigue damage per flight hour for basic design,

L_i – number of flight hours tested at i-th stage of test,

D_{Ci} – fatigue damage per flight hour for airframe repaired at i-th stage of test.

According to the above, a detailed stress analysis was performed at each stage of the test in order to check whether these repairs/changes had any effect on other tested elements. In case of the airframe fatigue test, in total 7 wing structure FEM models were created: corresponding to the basic design and to each repair/change implemented during the test.

FINAL REMARKS

By carefully performing fatigue testing of the PZL M28 05's wing and wing load carry-through structure it was possible to avoid severe damage of the airframe and to test those repairs which can be made during airplane's operation, e.g. at break devoted to periodic service activities. The method described is a convenient way of increasing an airplane's service life above the initially established limit.

REFERENCES

1. J. Pietruszka "Full-Scale Fatigue Tests of PZL M28 05 SKYTRUCK Aircraft". *Transactions of Institute of Aviation*, 1/2009 (196). Warsaw, 2009.
2. "Fatigue, Fail-Safe, and Damage Tolerance Evaluation of Metallic Structure for Normal, Utility, Acrobatic, and Commuter Category Airplanes". AC 23-13A. FAA. September 29, 2005.