Hawk Mk 51/51A/66 Tailplane Full-Scale Fatigue Tests

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As there was no certainty about the Hawk Mk 51/51A/66 tailplane fatigue life in FINAF flight conditions, the FINAF initiated full-scale fatigue tests to be performed on Hawk Mk51/51A/66 tailplane. The FINAF's main objective was to have conclusive results to determine if the FINAF is required to procure more tailplanes to keep its fleet operational for all its intended life cycle. The secondary objective was to have data about the crack growth time, which could be used to increase the related structural inspection interval time. This was mainly achieved by means of the periodic NDT inspections during the tests.

The tests were performed by Patria Aviation Ltd. (prime contractor) and VTT Ltd. & VTT Expert Services Ltd. (main subcontractors) during 2017. The design work and manufacturing, as well as load spectrum basics, were mainly done in 2016. The tests were conducted with two tailplane units, which both had flown approx. 4000 FH, up to maximum of 10000 EFH to achieve additional 2000 FHs with SF = 5. The first unit had undergone structural repairs during its normal operational cycle; the latter had repairs done just before the test. The tailplane's fatigue life is determined by its critical primary structural components: the upper and lower centre buttstrap plates, and centre spar.

The tests were installed under a portal loading frame, and the tailplanes were attached to the custom made test bench bolted on the test hall floor (Figure 1). The aerodynamic resultant load location was analyzed with Hawk CFD and FE models in four different flight conditions. Aerodynamic loads were transferred to the FE model, and the FSFT loading method was also modelled. The location of the resultant load was selected by the criteria of obtaining similar stress distribution in both models, which corresponded well to the OEM's tailplane aerodynamic centre. Test loads were applied with two symmetrically mounted 50 kN servo hydraulic actuators. The test spectrum was based on i) the strain gage signal at the top skin of the tailplane centre box (S15) of two FINAF OLM Hawks: HW-368 (Mk 66) and HW-319 (Mk 51A), and ii) on today's real, flight hour and syllabus based usage spectrum of the FINAF flights. However, the developed spectrum was not a general Basic Operational Spectrum (BOS), because it was further edited and verified with stress life analysis to match correctly the needs of the FSFT's command system feeding both buffet and manoeuvring components to the test symmetrically at the same time.

Figure 1. Hawk Mk 51/51A/66 tailplane full-scale fatigue test set-up.

The instrumentation was based on the FINAF's Hawk OLM programmes, but was smaller. Three strain gages (S15, S01, and S02) were similar, and three additional verification and backup strain gages were fitted to support the primary gage S15. All actuator forces and displacements, as well as the upper connecting rod forces, were measured. The predetermined critical area NDT inspections were done after every 200–340 EFH in a limited extent, and a full inspection were done after approx.every 1000 EFH. The tests were conducted full-time 24/7 with normal monitoring resource allocations, and proceeded unmanned when out of the working hours. The operation stopped automatically and controlled way, when the next EFH target was reached, or when exceeding the limits of force or displacement. The first fatigue test with the first tailplane commenced in May, and ended in July; the second commenced in August, and ended in October, all in 2017.

As the test progressed several injuries, such as damaged rivets and cracks in the spars and angles, were created. The broken rivets were replaced, cracked items strengthened and cracks end-drilled (Figure 2).

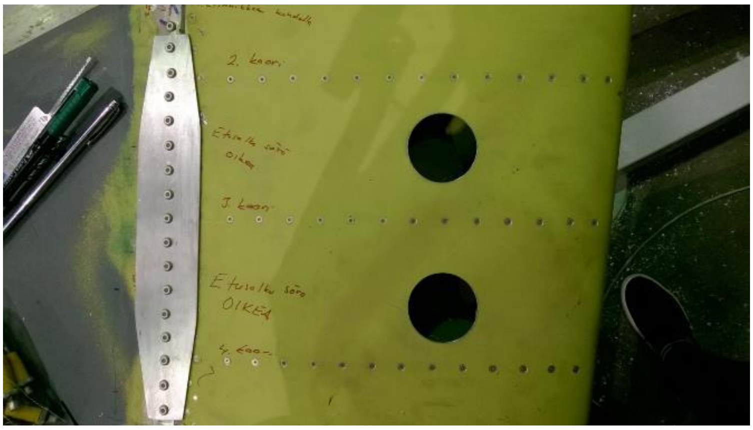

Figure 2. Replaced front spar rivets and a reinforcement strap attached on tailplane skin. Holes on skin were made for end-drilling the cracks in front spar web.

The first crack indications from the central joint were acquired in the NDT examination at 5236 EFH for the first test tailplane and at 6052 EFH for the second test tailplane. At this point cracks could not be seen visually. The effect of the crack growth and the structure loosening on the loads and accumulated fatigue were checked after each 340 EFH period, and if necessary, load adjustments were made to ensure that the load level of the central joint remained adequate. As the test progressed, the largest cracks developed visible, and their growth rate could be monitored. All in all, 22 crack indications in two tailpane centre joints were received in the final stages of the tests.

Following 10000 EFH fatigue testing the tailplanes were subjected to a residual strength test with the load corresponding the ultimate design load of the tailplane defined by the manufacturer. The both tailplanes passed the test without noticeable additional damage.

The tailplane center section was teared down for more detailed inspections. The NDT methods were the eddy current, ultrasonic and penetration liquid tests. Some new fault indicators were obtained from the centre buttstraps. However, all buttstrap defects could be confirmed very small, less than 0.5 mm, which could have been the scratch during assembly or tear down, not a real crack. On the other hand, seven cracks were found on the skins, the longest 20 mm.

The most important result of the fatigue test was that the tailplane centre joint lasted throughout the planned fatigue test period. The second important result was that the tailplane residual strength was sufficient with a 20 mm crack at the rivet hole which was estimated to be the most loaded in advance. Third, from the fatigue test it was possible to determine the crack propagation rate to verify the structural inspection period to be used for FINAF Hawk fleet. The test gives a strong basis for increasing tailplane’s acceptable usage life by 1000 FH. This is based on (1) two test specimens where crack was initiated after 5000 EFH, (2) the used load spectrum was based on measured operational (current & future) usage, (3) test load levels were valid until 5000 EFH, (4) usage of conservative scatter factor of 5 and (5) the damages did not extend during the residual strength test i.e. the worst case scenario (ultimate loading) would not cause an immediate danger to the flight safety.

The significance of the research is considerable cost savings that will be achieved, when the inspection can be optimized for the FINAF Hawk fleet. In addition, now it is known that the current number of tailplanes is sufficient for the remaining fuselage flight hours and no additional tailplane procurement is required.

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