FULL SCALE FLIGHT BY FLIGHT WING SPAR FATIGUE TEST

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The airframe fatigue life prediction of production aircraft must be verified by fatigue test. All available loading programmes were unusable for testing purposes in our case. Therefore, an original loading programme TALOS has been developed.
The fatigue test of four main wing spars was based on service loading simulation. The fatigue test was stopped at the critical crack length and the residual strenght of the cracked spar was investigated. It has been reached about 50% longer fatigue life under flight by flight test, compared with constant amplitude test results.

INTRODUCTION

During the certification, new jet trainer modification has been inevitable to proove an effect of structure changes using flight by flight simulation. It was necessary to realize a research programme with a full scale evaluation; its goal was, as follows :

1. To develop a new software for flight by flight simulation, based on Markov peak/through occurrences matrix.
2. To realize a test programme on specimens to determine the influence of some omitted service load spectra.
3. To carry out a fatigue test of the most fatigue sensitive part of the wing, i.e. the main wing spar with a part of torsion box and parts of ribs.
4. To apply fractographic analysis for studying fracture propagation processes.

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Fatigue test realization

The tests were controlled by the load factor of peak/through occurrences. The flight recording 679 service hours has been used as a data source. The records were divided into six types of flights to involve all probable missions of the trainer investigated. All available loading programmes including FALSTAFF were found unsuitable for this trainer testing purposes. That is why a special programme for generation of randomized loading data has been developed (1). This programme named TALOS (Training Aircraft Loading Spectrum) is presented in its flow chart form in Fig.1.

There were a lot of insignificant cycle amplitudes in flight recorded spectra. Theoretical assumptions of their negligible fatigue damage effect were verified by specimens tests. Fifty specimens with load transfer were tested under both flight by flight load sequence and constant amplitude loading. The results proved the possibility of omitting 90% of cycles without any influence on the initiation or propagation of cracks. All tests were carried out on 2124 aluminium alloy class.

Flight by flight loading spectra were applied to four specimens of wing spars by 16 channel MTS Model 872 Structural Fatigue TSC System. The standard TSC 872 application software was tailored and integrated with TALOS. The test ran under constant frequence of 0.7 Hz. The load sequence of 62,500 cycles corresponded to 4,000 service hours. Landing gear loading was not applied.

Results of the tests

The wing spar is able to reveal important fatigue properties of the whole wing structure (2). Close attention was paid to crack growth during the tests. All cracks were initiated at rivets or bolt joints. First cracks appeared in the skin between 48-60% of the total life. Cracks in the spar boom spare were visually detected between 90-95% of the total life. Cracked skin was an effective crack signalizator for booms. Critical length of cracks was calculated. Fatigue test was stopped at critical crack lengths and residual strength tested. The scatter of the fatigue tests results was very small. The standard deviation of the log life was about 0.018 in case of the wing spar test and 0.10 in case of the specimen test.

Total fatigue life, achieved under flight by flight simulation test has been compared with results of the constant amplitude tests. Calculations were carried out using Miner hypotesis and S-N curves by Payne (P 51 Mustang wings) (3), R.A.E. and our own results from specimen tests.

TABLE 1 - Comparison of flight by flight simulation results with those from constant amplitude test

Calculation and test results		Total fatigue life (flight hours)	Rate to this test (%)
S-N curve	ref.(1)	94.668	67.5
by :	R.A.E.	79.910	56.8
	specimens	106.175	75.5
	flight by flight	140.668	100.0

Flight by flight test has brought about 50% longer fatigue life, compared with constant amplitude tests.

Fracture analysis was applied to cracked areas. Due to an expressive peak load pattern in the spectrum, it was possible to follow crack growth path up to crack lenght less than 1.0 mm. According to the analysis, more then 80% of the total life was crack free life.

All these tests were carried out as a support programme for certification of a new jet trainer variant.

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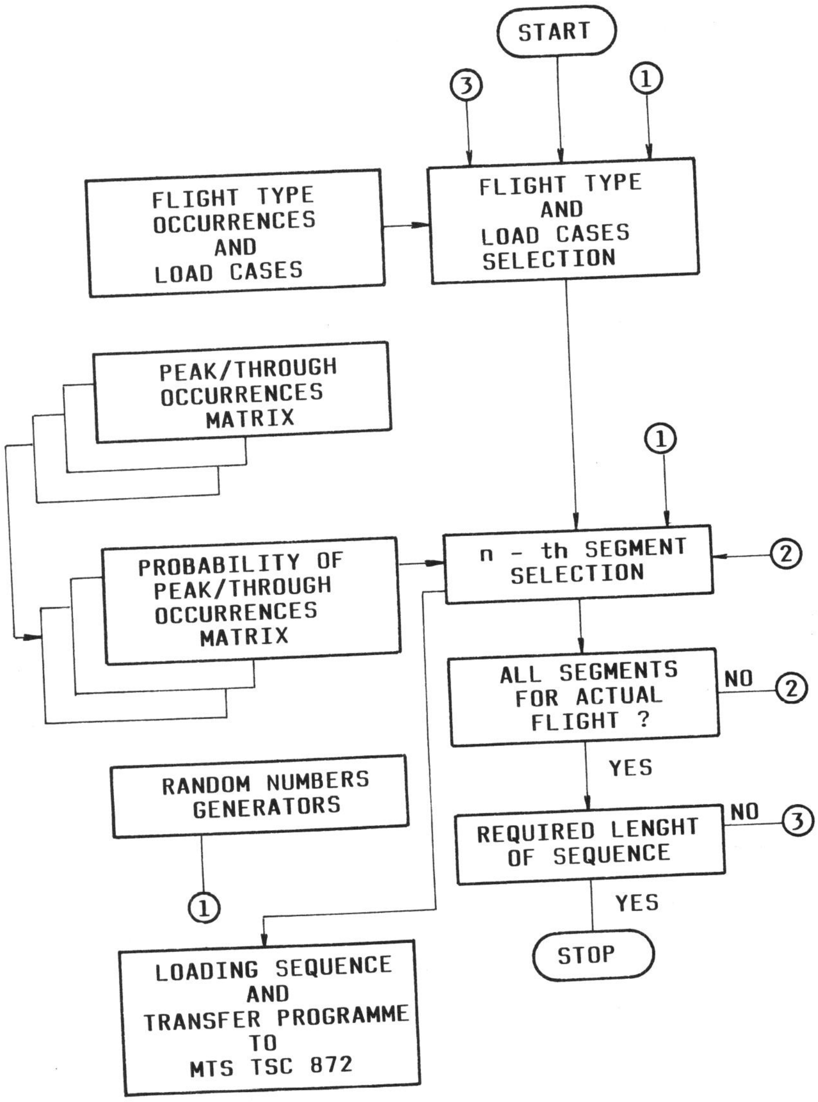

Figure 1 : Flow chart of TALOS programme