Failure Analysis Engine/Pylon Separation EL AL B-747

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Summary
In this paper the possible scenarios, which resulted in the separation of the engine/pylon #3 of the El Al Boeing B-747 which crashed near Amsterdam on 4 October 1992, are discussed. The text of this paper is derived from the official accident investigation report. For additional information on related subjects like maintenance, fusepin and pylon redesign, and the recommendations made by the Netherlands Aviation Safety Board, reference is made to the Aircraft Accident Report 92-11.

Engine/pylon separation

At the time of the accident the airplane had a valid Certificate of Airworthiness. The maintenance transit check was properly carried out at Schiphol Airport. No defects were recorded which could have played a role in the accident.

External and internal examination of the engines showed that all damage was either a result of gyroscopic effects during pylon separation or the impact of engine no. 3 with engine no. 4 and/or the impact of the engines with the water. No physical evidence was found inside the engines indicating that a surge could have occurred. Also examination of the El Al maintenance records and DFDR data from before the accident flight revealed no signs of surges.

The possibility of sabotage was examined by several police and security agencies familiar with sabotage techniques and terrorist activity. No evidence of sabotage was found.

It is therefore concluded that the separation of the engine pylon was caused by a failure of connecting components that attach the pylon to the wing of the airplane (see Fig. 1).
To determine the initial failure origin a total of 9 different scenarios were identified each of which could lead to the separation of the engine pylon from the wing.

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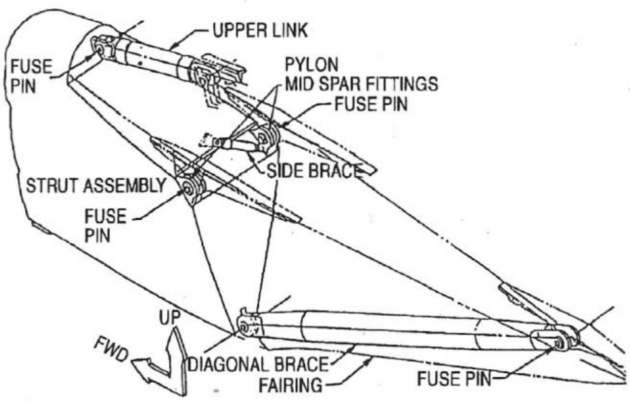


Fig. 1 Pylon to wing attachments RH wing

Separation scenarios:
1. Upper link/pin fractured or disconnected first;
2. Inboard midspar fitting/pin fractured or disconnected first;
3. Outboard midspar fitting/pin fractured or disconnected first;
4. Simultaneous fracture or disconnection of both the inboard and outboard midspar fitting/pins;
5. Diagonal brace/pin fractured or disconnected first;
6. Massive static overload occurred;
7. Bird impact occurred;
8. Engine seizure occurred;
9. Side brace fractured or disconnected first.

Scenarios 4 through 9 were eliminated as viable options. The reasons are summarized below:

Scenario 4: only a large overload in lateral direction could have caused this type of failure. There was no evidence on the DFDR that any unusual load occurred.

Scenario 5: examination of the diagonal brace and its attachments indicate that the disconnection was due to overload at engine separation.

Scenario 6: there was no indication of any unusual loading on the DFDR.

Scenario 7: no evidence of foreign object damage, e.g. bird impact, to the engine prior to the separation was found.

Scenario 8: examination of the engine indicated that the fan was rotating at the time of separation, therefore no engine seizure could have occurred.

Scenario 9: examination of the side brace and its attachment indicated that the disconnection was due to an overload at engine separation.

As the upper part of the upper link and corresponding fitting was not recovered the question arose whether or not this link was properly attached at the time of the separation. By means of a stress analysis it was shown that the fracture of the upper link in the noted bending/torsion mode could only have occurred if the wing-end pin was in place and intact. Scenario 1 could therefore be eliminated.

The elimination process resulted thus in two possible remaining scenarios. The approach taken for the further evaluation of these scenarios was mainly one of deduction, augmented with stress and load analysis.

The analysis largely relies on an understanding of the response of a linear structural system to steady state and transient loads. When an element of the support structure fractures, the surviving supports are subjected to shock inputs as the new equilibrium state is established. The shock input to any support was taken to be the difference in steady state loads between successive equilibrium conditions. The maximum load imposed on the adjacent structure is then the combination of the steady state load and the increment of the load due to the redistribution after the initial element fracture. The load increment is caused by dynamic magnification factor effects. The derived maximum loads are compared with the allowable loads for the adjacent structure to determine, whether the fracture sequence will result in pylon separation.

Using this approach it could be proven that a separation initiated by a failure in the outboard midspar fitting was highly improbable.

The inboard midspar fitting was recovered. The outboard lug of the fitting had fractured with a 150 degrees segment of the lug missing. The lug fracture was determined to be ductile (i.e. no fatigue) and appeared to have resulted primarily from tension and to a lesser extent from lateral bending (see Fig. 2). The ductile failure can only be explained if it was excentrically loaded. For this to occur the inboard shear face of the fuse pin must have sheared first in order to subject the lug to an excentric load.

As there is no in service evidence that the El Al airplane experienced a static overload preceding the accident it is assumed that the inboard shear face of the fuse pin was initially fatigued and then failed under normal flight conditions.

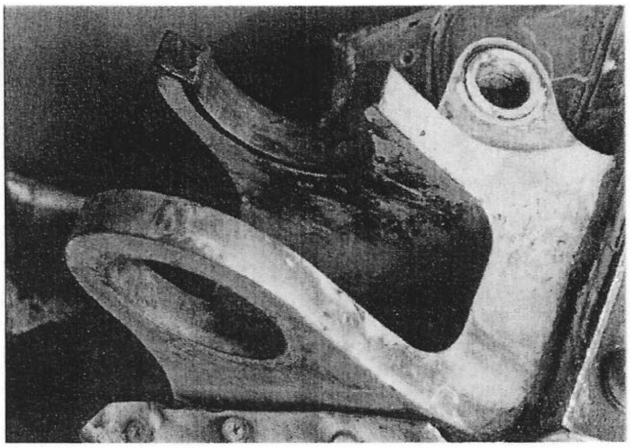


Fig. 2 Inboard midspar fitting

Based on this assumption separation scenario 2 was further developed with regard to the question whether the failure did occur before the fatal flight or during this flight.

By applying the methodology as explained above, it can be proven that a fracture of the inboard fuse pin before the start of the flight out of Schiphol Airport is highly improbable.
The load capability of the remaining structural elements, taking into account dynamic effects, is sufficient to carry the redistributed loads.

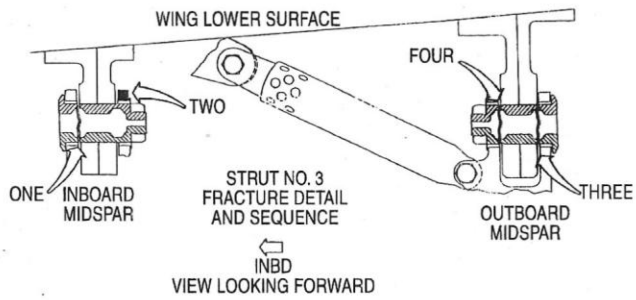
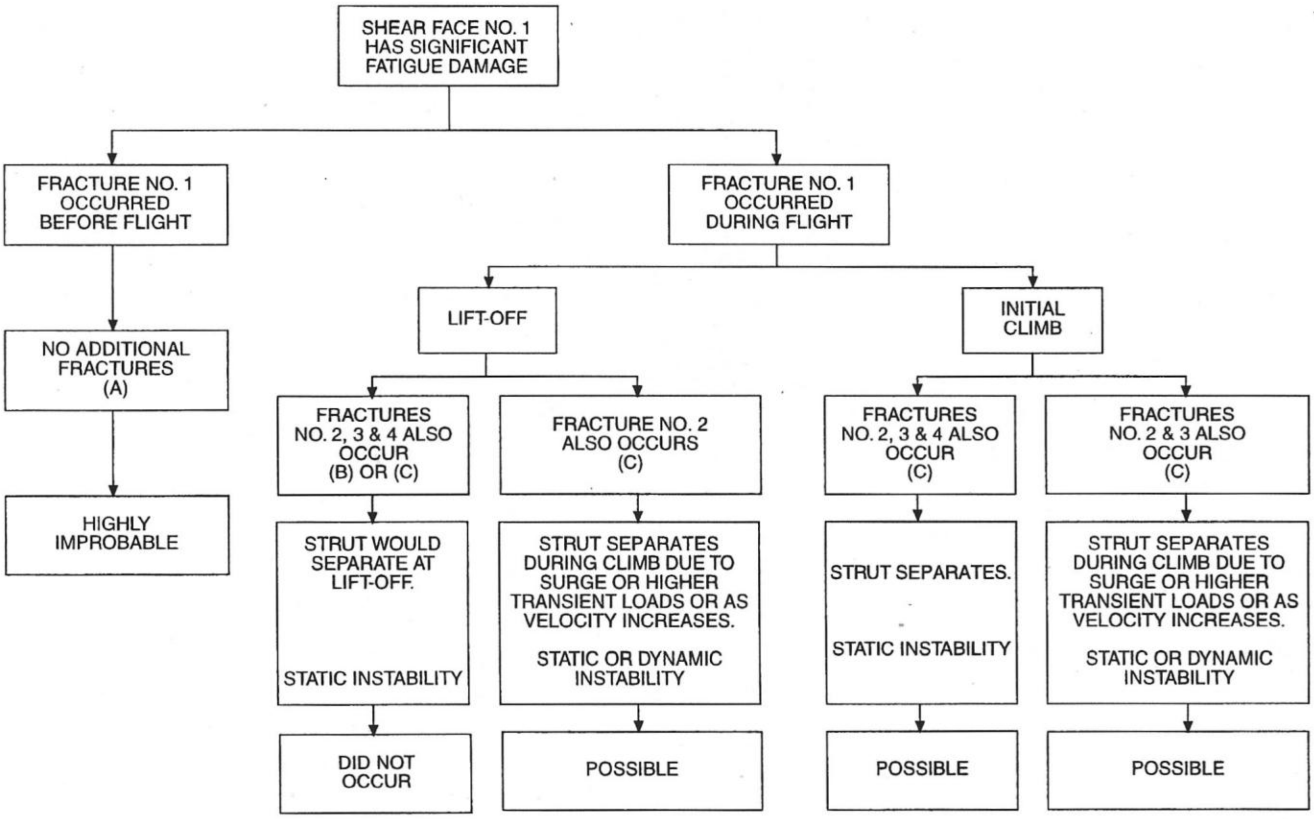


Fig. 3 Probable separation sequence

Therefore the scenario which is most likely, is (1) a fracture initiated by a fatigue crack of the shear face of the inboard midspar fuse pin. This was followed by (2) sequential failure of the outboard lug of the inboard midspar fitting. Then (3) the outboard shear face. Finally (4) the inboard shear face of the outboard midspar fuse pin (see Fig. 3 and 4). The subsequent engine/pylon separation occurred during the flight out of Schiphol Airport at 6500 feet altitude and at an IAS of 267 knots.



(A) OPERATING LOADS + 0.20G TRANSIENT LATERAL ACCELERATION LOADS ARE INSUFFICIENT TO CAUSE ADDITIONAL FRACTURES.

(B) OPERATING LOADS AND DYNAMIC REDISTRIBUTION OF LOADS RESULT IN SEQUENTIAL FRACTURES.

(C) OPERATING LOADS + 0.20G TRANSIENT LATERAL ACCELERATION LOADS AND DYNAMIC REDISTRIBUTION OF LOADS RESULT IN SEQUENTIAL FRACTURES.

Fig. 4 Separation scenario no. 2 (Refer to Fig. 3)