Cowling separation, Boeing 747-240B, AP-BAT

Micro-summary: This Boeing 747-240B lost a large chunk of cowling on landing.

Event Date: 2002-06-13 at 0646 UTC

Investigative Body: Aircraft Accident Investigation Board (AAIB), Great Britain

Investigative Body's Web Site: http://www.aaib.dft.gov/uk/

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Boeing 747-240B, AP-BAT

AAIB Bulletin No: 3/2004	Ref: EW/C2002/06/03	Category: 1.1
INCIDENT		
Aircraft Type and Registration:	Boeing 747-240B, AP-BAT	
No & Type of Engines:	4 General Electric CF6-50C2 turbofan engines	
Year of Manufacture:	1980	
Date & Time (UTC):	13 June 2002 at 0646 hrs	
Location:	Manchester International Airport, Manchester	
Type of Flight:	Public Transport	
Persons on Board:	Crew - 16	Passengers - 303
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Outboard half of the No 3 engine thrust reverser translating sleeve separated from aircraft	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	56 years	
Commander's Flying Experience:	12,945 hours (of which 3,071were on type)	
	Last 90 days - 132 hours	
	Last 28 days - 44 hours	
Information Source:	AAIB Field Investigation	

History of flight

The aircraft was operating a scheduled service between New York Kennedy Airport and Manchester International Airport. An uneventful approach and touchdown were carried out on Runway 24R following which reverse thrust was selected on all engines to approximately three-quarters power. At around 80 kt reverse thrust was cancelled, engine Nos 1, 2 and 4 reversers stowed normally but flight deck indications showed No 3 reverser remained unlocked and in transit.

After the landing of the B747, a Boeing 757 aircraft was cleared to cross Runway 24R, from the F2 holding point on the north side to the south side. While crossing behind the B747 the first officer on the B757 noticed a large piece of engine cowling falling from the aircraft during its landing roll. He notified Air Traffic Control (ATC) who took action to prevent other aircraft landing on the runway. ATC also offered the support of the emergency services to the commander of the B747 which was declined. The B747 continued taxiing to its allocated parking stand where, following engine shutdown, the passengers were disembarked.

Airport information

Manchester Airport has two staggered parallel operational runways 24R/06L and 24L/06R, separated by a distance of 380 metres. The terminal area is located to the north of the runways and so traffic utilising the southern runway 24L/06R is required to cross the northern runway 24R/06L. As part of the programme for the introduction of the second runway operation (R24L opened 5 February 2001) a Runway Incursion Monitoring (RIM) system was installed on Runway 24R/06L. This system works by utilising ground movement radar to detect conflicts within a defined zone. On detecting a conflict the system issues an audio alert and the affected target(s) are displayed in red on ground movement and approach radar screens.

The RIM system was not necessary on this occasion because action was taken as a result of the pilot report. However, the recorded data was reviewed after the incident to determine whether it would have been effective in detecting the debris on the runway. The large section of thrust reverser cowl could be clearly seen as it detached from the aircraft and it would have triggered an automatic system alert if an aircraft was on final approach to the runway and thereby in conflict.

Flight Recorders

The half-hour duration CVR had continued to run after the event and the recording from that period had been over-written.

The FDR showed that, following an uneventful touchdown at 133 kt, thrust reversers were deployed on all engines. Peak N1 values of 94%, 78%, 95% and 89% were recorded for engines 1 through 4 respectively. Thrust reverser unlocked and in-transit discrete parameters showed no anomaly during reverse thrust selection.

Reverse was cancelled at 90 kt on engines 2 to 4 and at 68 kt on engine 1. Normal thrust reverser stowage on engines 1, 2 and 4 was evident from their discrete parameter recordings but the reverser in-transit and unlocked discretes for engine 3 remained active for the remainder of the FDR recording.

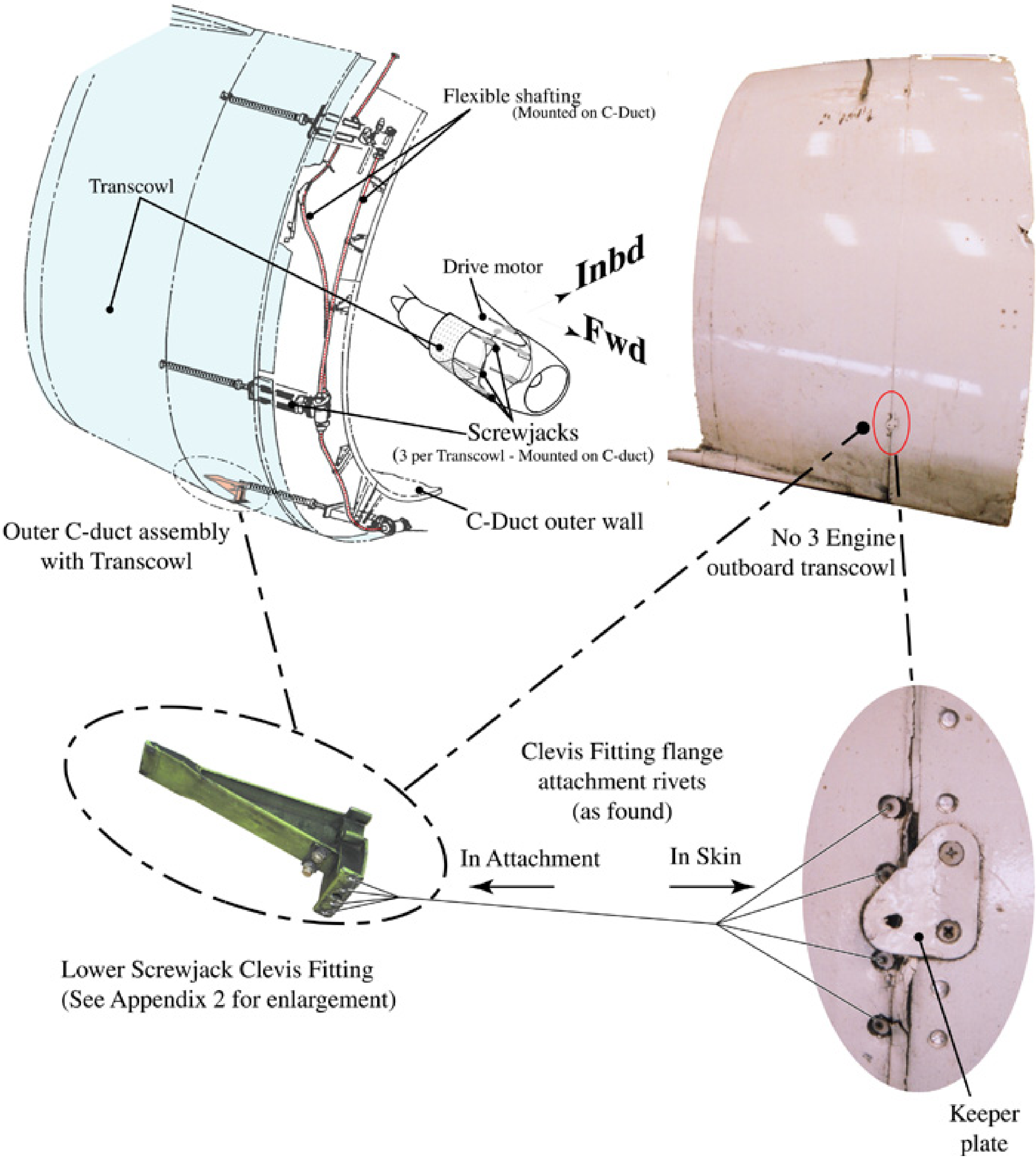
Engineering examination

The separated part of the reverser was identified as the outboard half of the No 3 engine thrust reverser translating sleeve (normally called the transcowl). This, together with several small pieces of debris, amongst which was the lower screwjack clevis fitting, were removed from the runway and stored for investigation.

General description of the thrust reverser system (See Appendix 1)

Appendix 1

Location of Transcowl drive system components and lower clevis fitting on No.3 Engine outboard C-duct and transcowl



The thrust reverser assembly constitutes the rear section of the engine's fan-stream duct and is constructed in two halves, one either side of the pylon centreline. Each half consists of two major sub-assemblies which are the C-duct, which is supported at the top by hinges on the pylon and latched to the other C-duct at the bottom and the transcowl, which is attached to and slides on the C-duct structure.

The C-duct constitutes the core engine cowling and the inner wall of the fan-stream throughout its length. At its forward end the C-duct structure also constitutes the outer wall of the fan-stream, on the aft end of which it carries the reversing cascades. The transcowl drive system consists of three synchronised and evenly spaced screwjacks, also mounted on the C-duct, which control its fore-and-aft position and maintain its orientation at right angles to the engine axis. The screwjacks are driven, via a flexible shafting (flexshaft) system, by an air motor mounted in the pylon. The top and bottom edges of the transcowl, which moves rearwards when reverse thrust is selected, run in slider tracks on the C-duct structure.

When the reverser transcowl is in the stowed position (forward), it comprises the outer wall of the fan-stream and the nacelle outer skin and encloses the reverser cascades between the two skins. When reverse thrust is selected, the transcowl moves aft and, as the reversing cascades become exposed, blocker doors close off the rearwards flow of the fan-stream and divert it through the cascades. The blocker doors are hinge mounted on the transcowl and their angle is controlled by levers pivoted on the C-duct, below the inner wall skin.

The eye ends of the screwjack shafts are attached to the transcowl by pins which are inserted, through holes in the nacelle outer skin, into clevis fittings which are built into the transcowl structure. The pins are retained at their outer ends by small cover plates attached to the transcowl outer skin and at their inner ends by blocks on the clevis fittings. There is an anti-rotational fitting on each of the screwjack eye-ends.

Owing to the cross-sectional shape of the nacelle, the lower clevis fitting is larger and has a different attachment to the transcowl structure than the simpler upper and centre clevis fittings. The upper and centre fittings are relatively narrow and their inner and outer flanges are attached directly to the transcowl skin structure using solid rivets. By contrast, the lower clevis is stood off from the transcowl outer skin (see Appendix 2, Figures 2a & 2b) and has a more complex rivetted and bolted attachment.

Appendix 2

Sections showing attachment of lower clevis fitting to transcowl

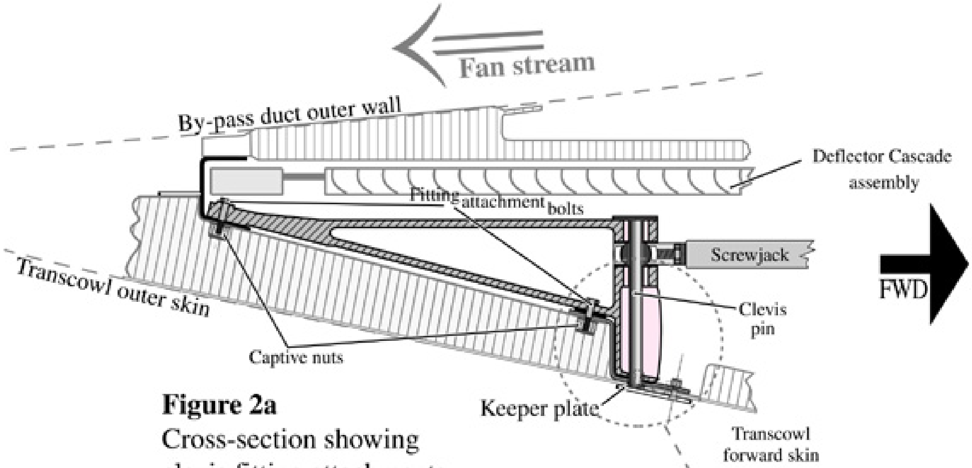


Figure 2a
Cross-section showing clevis fitting attachments

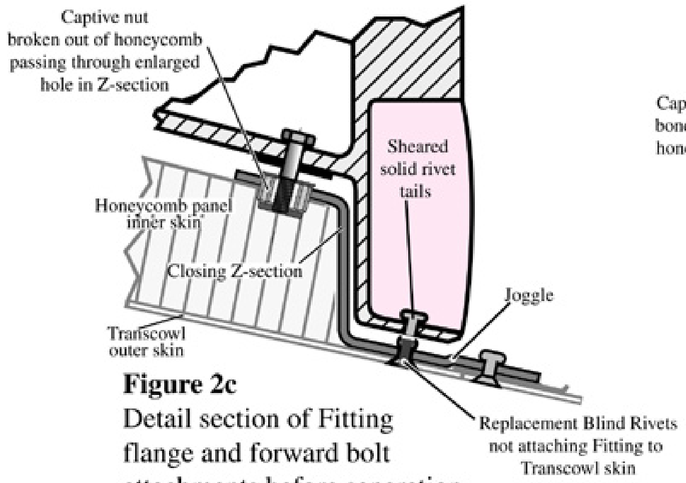


Figure 2c
Detail section of Fitting flange and forward bolt attachments before separation.

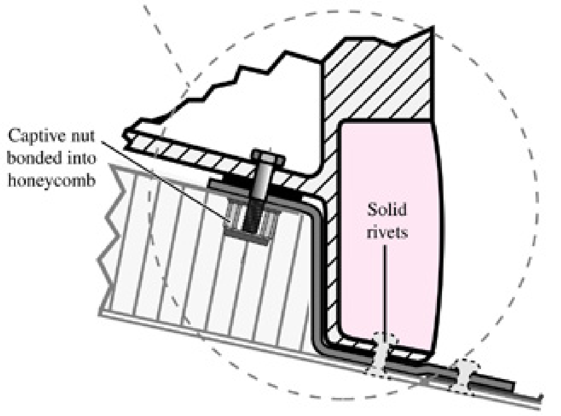


Figure 2b
Detail of correct attachment of forward end of clevis fitting

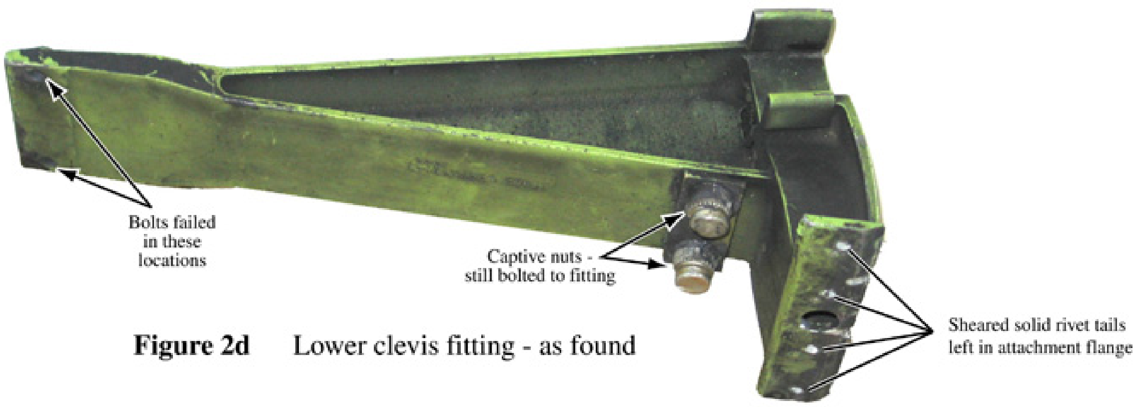


Figure 2d Lower clevis fitting - as found

Historical problems with the reverser system

This reverser system has, over the 30 years, been in service on CF6-6 engine installations, on DC10-10 aircraft & CF6-50 engine installations, on DC10-30, A300B4 and Boeing 747 aircraft. The current active fleet consists of about 400 aircraft world-wide. Whilst having been generally robust and reliable in its current design configuration, it has, over its whole service life, suffered a considerable number of transcowl detachment events, of which the majority typically occurred during stowage after the application of reverse thrust. The underlying cause of most of these events has been attributed to either misrigging or incorrect maintenance/lubrication of the system leading to abnormally high loads developing in the system during translation.

The maintenance of correct rigging of the translation mechanism is considered critical, as any tendency for the transcowl to become skewed on its slides can lead to jamming of its movement. If jamming occurs, the pneumatic motor is sufficiently powerful to break other parts of the mechanism, leaving the transcowl only partially restrained and liable to separate from the C-duct. This problem has not been experienced on the thrust reversers fitted to CF6-80 engines because that design used a less powerful pneumatic drive motor.

In the late 1980s, the engine manufacturers assessed that the rate of transcowl liberation events was unsatisfactory and they instituted a campaign to reduce this rate. This campaign consisted of a maintenance education programme conducted directly with the operators and the issue of Commercial Engine Service Memorandums for both the CF6-6 (CESM 75) and the CF6-50 (CESM 76). These provided a consolidated listing of Inspections and Servicing Tasks recommended by the engine manufacturer and were to assist maintenance planning only. Procedures, limits and specific requests are defined in the referenced publications such as the Aircraft Maintenance Manuals, Engine Maintenance Manuals, Service Bulletins, and Component Maintenance Manuals. The CESMs did not supersede operators approved maintenance programmes, but provided a single publication which defined all the recommended scheduled installed inspection and servicing intervals. During this period a number of hardware and maintenance procedure changes were also introduced. These measures have resulted in a marked decrease in the number of transcowl liberation events.

The most common parts of the drive system to fail have been the flexible driveshafts and the screwjacks. The only previous instance attributed to a clevis fitting attachment failure occurred in 1987; it involved a lower clevis fitting and was associated with a failure of the lower flexshaft. The two most recent transcowl separation events, (in December 1993 and in December 1996) preceding this one, have been attributed to the failure of the bond between the honeycomb panel closing Z-section and its skins. In these events, however, transcowls had been subjected to bonding repair procedures and the lower clevis fitting itself was fractured at transcowl separation.

Initial examination of aircraft and separated parts

As found, the transcowl had separated from the C-duct, carrying with it four of the blocker doors. All three clevis fittings had also separated from the transcowl, the upper one remaining attached to the screwjack. The lower and centre clevis attachment pins had fallen out, releasing the clevis fittings. The upper slider fitting on the transcowl had been bent upwards and slightly outboard in a manner consistent with the transcowl having separated from the C-duct by pivoting aft and upwards about the mid point of the upper slider.

All three screwjacks were complete and still attached to the C-duct; the upper and lower jacks were almost fully retracted. The centre jack was in a position consistent with being about half way retracted and with its shaft was moderately bent; this had resulted in the seizure of the nut tube on the screw. There were wear marks on the cascades that indicated that the centre jack had been rotated whilst unattached to the clevis fitting and after it had become bent.

There were light wear marks at the position of the upper screwjack where the clevis fitting had been drawn across the cascades after the clevis had been separated from the transcowl but the jack had continued to retract. There were also wear marks on the cascades, at the position of the lower screwjack, and on the inner surfaces of its clevis fitting, which were consistent with the clevis fitting rubbing against them persistently over a considerable number of reverser deployments.

Examination of the lower clevis fitting showed that the tails of the four solid flange to skin attachment rivets were still retained in their holes in the flange. (See Appendix 2, Figures 2c & 2d.) All four had failed in shear in a direction consistent with the fitting being pulled forwards relative to the transcowl. The two bolts immediately aft of the riveted flange were still attached to the clevis fitting and their captive nuts, which had been bonded into the transcowl honeycomb skin structure, were still attached to the bolts. Of the two bolts which should have attached the tail of the fitting to the skin structure, one was completely missing and only the threaded portion of the other remained in the captive nut.

Measurement of the transcowl and C-duct, together with the determination of the operating positions of the transcowl drive limit switches, showed that these switches had been set to operate within the correct limits. The 'reverser unlocked' indication microswitch was set towards the forward limit of its range which would have rendered the 'reverser unlocked' indication more sensitive in the event of the transcowl not being held fully forwards when the reverser was stowed.

The C-duct was dismounted from the aircraft and taken with the transcowl and small components to the AAIB facility for further examination.

Detailed examination of No 3 outboard C-duct, transcowl and mode of transcowl separation.

Examination of the C-duct showed that the flexible driveshafts were all intact and it was possible to turn all the shafting and gearboxes to the screwjacks easily. Opening the jack drive units showed that, whilst the upper and lower jacks had returned to a position close to their fully retracted states, the centre jack had been prevented from retracting because it had been bent.

An examination of the C-duct inner surface showed that the wall had been crushed inwards close to the positions where the blocker doors close against it, particularly in the lower sector. There were also several scrape marks on the inner wall aft of this point. This indicated that the transcowl had travelled further aft than would have been allowed by the screwjacks at full extension, resulting in the blocker doors becoming wedged against the inner wall as the positioning links drew them inwards. The implication was that the clevis attachment of the lower screwjack had separated, allowing some transcowl distortion, before the blocker door wedging could occur.

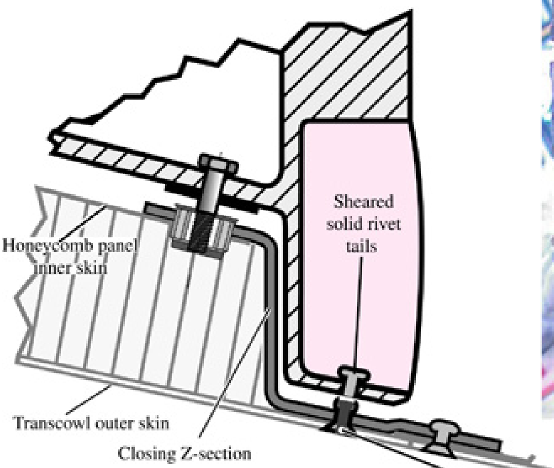
The separations of the three clevis fittings from the transcowl had all been different. The upper clevis fitting had been torn forward from the transcowl structure. All its attachment rivets had been sheared but the clevis pin keeper plate fastening screws, which attach to the fitting, had remained intact. As a result a fragment of skin and the keeper plate had remained attached to the clevis fitting and, consequently, the clevis pin had been retained, keeping the fitting attached to the jack end.

The centre fitting had also separated by being pulled directly forward relative to the transcowl, shearing all the attaching rivets. The keeper plate fastening screws had distorted the skin before failing in tension and this had released the keeper plate, leaving the clevis pin unrestrained. The pin had fallen out and the clevis fitting was amongst the debris recovered from the runway.

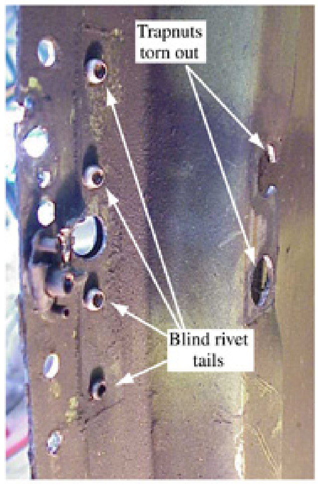
The lower clevis fitting had separated, complete and undistorted, from the transcowl and there was little evidence of overload distortion on the outside of the transcowl, in the area of its attachment. The heads of the four rivets which should have attached the forward flange of the fitting to the transcowl outer skin were all apparently in place and appeared to be 'blind' type, (see Appendix 1) unlike all the other rivets in the area which were countersunk alloy 'solids'. The replacement rivets were all deeply set into the countersinks and the metal between the holes and the forward edge of the transcowl skin section had been torn out (Appendix 3, Figure 3b). The clevis pin keeper plate was still in position.

Appendix 3

Damage to transcowl structure around attachment of lower clevis fitting



Detail section of Fitting attachments before separation.



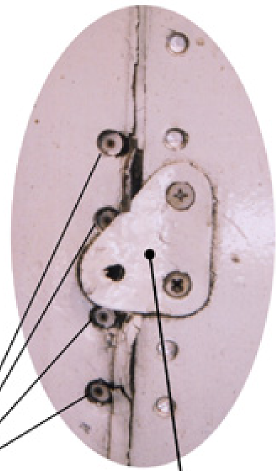


Figure 3a
Replacement Blind Rivets not attaching Fitting to Transcowl skin

Keeper plate

Torn rivet holes in outer skin and sunken rivet heads

Figure 3b
View on outer skin and Z section forward flange (forward skin removed)

Torn and enlarged holes in Z-section

and

Damage caused by Clevis pin in joggled flange and fatigue crack along joggle

Figure 3c
View on inside of Z-section

When the keeper plate had been removed it could be clearly seen that the skin forward of all four of the rivet holes had been broken out but there was no shear distortion of any of the rivets. This indicated that the rivets had been installed with the holes already in this condition. The forward skin of the transcowl was removed for better access to examine the failed clevis fitting attachment points. This confirmed that, on the lower fitting, the flange attachment had not been effective since the installation of the existing rivets.

Examination of the lower clevis fitting attachment zone revealed evidence that the original solid rivets attaching the fitting to the transcowl had failed in shear overload. (Appendix 2, Figure 2d.) One of the two aft attachment bolts had failed in shear but there was no trace of the second. The bond between the closing section and the honeycomb panel inner skin had failed, allowing the honeycomb panel closing Z-section to flex forwards, tearing out the bolt holes in the inner skin to its forward free edge and destroying the bond between the honeycomb and the Z-section web. The captive nuts at this location had also separated from the inner skin, allowing the bolts to enlarge the holes in the Z-section. (Appendix 3, Figure 3c.)

There were marks on the attachment flange of the clevis fitting made by the tails of the blind rivets which appear to have been installed to fill the holes left in the outer skin and Z-section flange. These marks indicated that the fitting was generally held against the rivet tails, at a slight angle to its proper orientation and slightly forward of its proper position. (Appendix 2, Figure 2c.) There were other marks on the fitting flange which, together with a set distortion of the Z-section web and damage to its forward flange, indicated that the fitting had been drawn forward, repeatedly and progressively further, relative to the transcowl structure. This movement had resulted in the clevis pin end riding up out of its insertion hole through the Z-section and striking the joggle in the forward flange of the section. (Appendix 3, Figure 3c.)

This action had resulted in a fatigue failure initiating and running circumferentially round the joggle line in both directions from the point at which the clevis pin had contacted the joggled edge. This contact had torn an indentation into the raised element of the joggled flange and progressively rolled its lip forward. The presence of this fatigue indicated that the damage had resulted from repeated operation of the thrust reverser with the lower clevis fitting inadequately attached to the transcowl. The fatigue had characteristics consistent with relatively rapid progression, indicating that the shear failure of the clevis fitting attachment rivets had been relatively recent.

Maintenance History

At the request of the AAIB, the operator conducted a review of all the recent recorded maintenance related to the No 3 engine outboard thrust reverser half. This had completed 2,961 landings at the time of this incident; the life of a reverser half being restricted to 5,500 landings. The record for the transcowl showed that it had been installed on the aircraft during November 1997. There was no record of any repair to the lower screw jack clevis fitting during the last three years, the period for which both company policy and the Airworthiness Authority required such records to be saved.

The most recent recorded work on this thrust reverser half was as follows:-

a All three flexible drive shafts were replaced by new ones on 19 September 2001.

b The most recent Check-C was done between 16 December 2001 and 2 January 2002. All Check-C interval inspections and repairs were undertaken in accordance with the approved maintenance schedule; no repairs were done on the No 3 outboard lower clevis fitting. All thrust reverser flexible drive shafts were lubricated in December 2001 whilst the aircraft was on C check. Since this time the aircraft had flown about 1,800 hours and 300 flight cycles.

c During March 2002, a defect was reported on the No 3 engine thrust reverser; no significant work, except adjusting the rigging, was carried out to correct this defect.

d On 20 April 2002, No 3 engine thrust reverser rigging was adjusted again following the replacement of the Directional Pilot Valve.

Since that date, no significant maintenance work had been recorded as having been carried out on the thrust reverser.

Discussion and analysis

a Mechanism leading to separation of the transcowl

The historical evidence supplied by the manufacturer has shown that the most common reasons for the separation of reverser transcowls in this type of installation have been the mis-rigging of the reverser drive mechanism and lack of lubrication of the drive system. Since, after the incident, all the flexible driveshafts were found to be intact and the drive train to turn easily, lack of lubrication of the drive was clearly not an issue. Similarly the screwjacks themselves were also found to operate easily, having made allowance for the distortion which had occurred to the centre jack during the separation of the transcowl. This suggested that the most probable cause of separation was either misrigging or a misalignment resulting from loss of transcowl positional control. The two recent records of rigging adjustment since a relatively recent C-check demonstrated that the operator was well aware of the importance of the correct rigging of this mechanism.

Comparing the failure modes of the three clevis fitting attachments to the transcowl, the upper two were clearly single event overload failures consistent with the transcowl separating rearwards from the jacks. By contrast, the local evidence of fatigue in the flange joggle and persistent movement of the clevis fitting relative to the transcowl structure showed that the lower clevis fitting separation had occurred over a considerable number of reverser deployments.

The marking found on the lower clevis fitting riveted attachment flange and on the forward flange of the honeycomb panel closing Z-section indicated that the effective rigidity of the attachment of the fitting to the transcowl had been low and had degraded progressively over a period before the separation of the transcowl from the nacelle.

It was clear that the flange attachment riveting had failed in shear at some time in the relatively recent past and that the rivet holes in the skin had been refilled without restoring the joint. Since the shearing of the original solid rivets implied a significant displacement of the clevis fitting relative to the skin to which it had been attached, it would also imply that additional load was thrown onto the four attaching bolts. As there was no evidence of distortion or movement of the skin structure around the aft trapnuts to match movement of the clevis attachment relative to the transcowl skin, it is probable that, either earlier or at the same time, the aft attachment bolt pair had also failed. The area of the closing Z-section around the trapnuts for the forward bolt pair, however, showed marked distortion in the forward direction with disbonding of the inner skin from the Z-section and the trapnuts from the inner skin.

Whilst the shearing of the rivets and one of the aft bolts was, most probably, associated with an earlier high load event, it was not possible to determine whether the overall attachment of the clevis fitting to the transcowl had already been compromised by the absence of one of the aft bolts, a loss of the bond between the Z-section and the transcowl inner skin, or a combination of both effects.

The attachment of the lower clevis fitting to the transcowl would, however, appear to have been degraded to a state where only the forward bolt pair was holding the clevis fitting in its correct radial and circumferential locations but it was able to move in the axial direction by exploiting the flexibility of the now poorly restrained Z-section. There appear to have been two significant secondary effects of this movement, the repeated driving of the clevis pin against the joggle of the Z-section and the gradual enlargement of the bolt holes in the Z-section and inner skin.

The enlargement of the bolt holes appears to have progressed to the point where the forward bolt trapnuts were able to pass through these holes and the clevis fitting then became wholly detached from the transcowl structure. In this condition, the necessary positive positional control of the transcowl was lost and the possibility arose for the transcowl to become misaligned and jammed, particularly during reverser stowage.

To summarise, therefore, the overall damage pattern in the area of the lower clevis fitting attachment is not inconsistent with there having been an initiating local failure of the bond between the aft flange of the honeycomb panel closing Z-section and the inner skin of the transcowl. Such a failure would have reduced the effectiveness of the forward bolt pair and, consequently, thrown additional loads onto the aft bolt pair and the rivets attaching the Z-section flange to the outer skin. The apparent absence of one of the aft bolts may have further increased the vulnerability of the attachment to a high load event.

It is difficult to assess the security of the clevis attachment fittings with the thrust reverser in the closed position, which it normally is when the aircraft is on the ground. To obtain access to these fittings the reverser needs to be put into the deployed position.

An inspection to ensure the security of the actuator clevis fittings (all three) is the subject of a specific instruction in the Aircraft Maintenance Manual [AMM 78-31-01, para. C.(5)(i)] and is scheduled to be done at 'C-Check' intervals (4,400 hours - no cycle limit). This aircraft had been subjected to a C-Check, completed on 2 January 2002, about 1,800 hours and 300 flight cycles before this incident. Since then, however, unscheduled rigging work had been done on the reverser drive mechanism in both March and April. The need for the work in April arose as a result of a component change, but that in March appears to have arisen as a result of a drift in rigging. There was no evidence to indicate whether increasing looseness of the lower clevis support fitting was or was not the cause of this drift.

The thrust reverser is a very hostile structural environment and the severe buffeting and vibration to which it is continually subjected will degrade imperfectly secure attachments more rapidly than in other aircraft zones. Even with rigorous maintenance, with age the durability of the structural joints will become less secure. Although, historically, the clevis attachments have not been troublesome within the CF6 powered fleet this incident may indicate that their deterioration manifests itself as a loss of correct rigging.

It is considered, therefore, that the manufacturer of the reverser system should consider requiring an inspection procedure, to ensure the security of the fasteners attaching the clevis fittings to the transcowl and the soundness of the bond between the aft flange of the honeycomb panel closing Z-section and the inner skin of the transcowl in the region of the lower clevis fitting attachment to be performed whenever reverser re-rigging becomes necessary.

b Incorrect maintenance of the lower clevis attachment

The operator's search of their maintenance records and technical log revealed no indication of any restorative work having been done on the transcowl lower clevis fitting attachment during the last three years. It was, however, evident that at some time in the recent past the lower clevis fitting riveted flange attachment had failed. This had probably resulted in the rivet heads, visible from the outside, becoming loose or dropping out and it would appear that an attempt to replace the missing rivets had been made.

The attempted repair was not in accordance with any instructions in the Manual and it was apparent that the, incorrect, blind rivets had been installed with no understanding of their full purpose. It is also probable that the holes into which they were installed were already damaged, although it is possible that the tearing to the panel edge was the result of loading induced by the clevis pin battering against the Z-section joggle, subsequent to the rivets being installed. Although the position of these rivets is on the underside of the cowling and damage to them could readily escape notice during normal daily inspections, it is highly improbable that it would have been missed during the recent C-Check.

Examination of the recorded recent maintenance work on this thrust reverser suggested that the partial failure of the fitting attachment (ie at least the flange riveting) may have given rise to the reported fault which led to the rigging being adjusted during March 2002. However, it is improbable that, had any repair action been made at that time, it also would have gone unrecorded in the maintenance documentation.

It would appear, therefore, that the rivets attaching the lower clevis fitting flange failed in shear and were replaced without any reference to a Manual or understanding of their purpose. It also seems that the installer of the new and incorrect rivets considered them so unimportant that their installation was not recorded or mentioned to anyone who might record it. The subsequent non-detection of the erroneous and ineffective rivets led eventually to the separation of the reverser transcowl half.

Potential hazard created

In this case, the presence of the transcowl on the active runway was detected very quickly, and there was no hazard caused to other aircraft. Had a similar transcowl separation occurred in less favourable circumstances, an aircraft taking off on the same runway, shortly afterwards, could have been at risk of colliding with the debris on the runway at a critical time.

Conclusion and Safety action

This transcowl separation event was associated with an unnoticed degradation of the lower clevis fitting attachment. The failed attachment rivets, which would have been visible during external inspection, had been replaced using an incorrect type, which failed to serve the design purpose. This appears to have been done without appreciation of the significance of distressed fasteners for indicating local structural overload. The failure to record the replacement of the rivets defeated the operator's quality assurance system and resulted in them not becoming aware of the degradation of the attachment. The replacement of the rivets made its subsequent detection more difficult.

The cause of the degradation of the attachment of the fitting could not be determined but may have been associated with whatever gave rise to the need to adjust the transcowl drive system rigging in the recent past. These occasions were after the last C-Check, at which time the checking of the security of the Clevis fittings is a specific task and these fittings were not scheduled for inspection until the next C-Check which, on average utilisation would have been about 10 months and 500 flight cycles later.

The thrust reversers are normally closed whilst the aircraft is on the ground and subject to general inspection. In this position, the condition and security of the attachments of the clevis fittings cannot be determined and the relative importance of indications given by the externally visible elements is not readily apparent.

Most transcowl separations have been attributed to misrigging or lack of maintenance. In this case, the possibility that the recent need to re-rig the reverser arose as a result of the degradation of the lower clevis fitting attachment cannot be eliminated. Although inspection of the security of the transcowl support attachments before re-rigging would be deemed normal good engineering practice, the absence of a specific instruction to inspect these results in uncertainty as to whether degradation of these attachments could be the cause of rigging drift.

Since very similar installations of this type of thrust reverser occur on a number of aircraft types, the following safety recommendation is, therefore, made.

Safety Recommendation 2004-09

The Federal Aviation Administration and the European Aviation Safety Agency, in conjunction with the manufacturers of the thrust reverser system and the affected aircraft types, should consider requiring an inspection procedure, to be performed whenever reverser re-rigging becomes necessary, to ensure the soundness of the bonding and mechanical fastenings attaching the clevis fittings to the transcowl of the thrust reversers of CF6-6 and CF6-50 engine installations.