Nose gear cylinder failure while taxiing, Boeing 747-367, AP-BFV

Micro-summary: **While taxiing, this Boeing 747-367 experienced a nose gear cylinder fracture.**

Event Date: **2002-12-07 at 2040 UTC**

Investigative Body: **Aircraft Accident Investigation Board (AAIB), United Kingdom**

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

Note: **Reprinted by kind permission of the AAIB.**

Cautions:

1. Accident reports can be and sometimes are revised. Be sure to consult the investigative agency for the latest version before basing anything significant on content (e.g., thesis, research, etc).

2. Readers are advised that each report is a glimpse of events at specific points in time. While broad themes permeate the causal events leading up to crashes, and we can learn from those, the specific regulatory and technological environments can and do change. ***Your company's flight operations manual is the final authority as to the safe operation of your aircraft!***

3. Reports may or may not represent reality. Many many non-scientific factors go into an investigation, including the magnitude of the event, the experience of the investigator, the political climate, relationship with the regulatory authority, technological and recovery capabilities, etc. It is recommended that the reader review all reports analytically. Even a "bad" report can be a very useful launching point for learning.

4. Contact us before reproducing or redistributing a report from this anthology. Individual countries have very differing views on copyright! We can advise you on the steps to follow.

Aircraft Accident Reports on DVD, Copyright © 2006 by Flight Simulation Systems, LLC
All rights reserved.
www.fss.aero

Boeing 747-367, AP-BFV

AAIB Bulletin No: 11/2004	Ref: EW/C2002/12/01	Category: 1.1
Aircraft Type and Registration:	Boeing 747-367, AP-BFV	
No & Type of Engines:	4 RB211-524C2 turbofan engines	
Year of Manufacture:	1986	
Date & Time (UTC):	7 December 2002 at 2040 hrs	
Location:	London Heathrow Airport, Middlesex	
Type of Flight:	Public Transport	
Persons on Board:	Crew -15	Passengers - 457
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Failure of the nose landing gear oleo outer cylinder	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	Not relevant	
Commander's Flying Experience:	Not relevant	
Information Source:	AAIB Field Investigation	

Synopsis

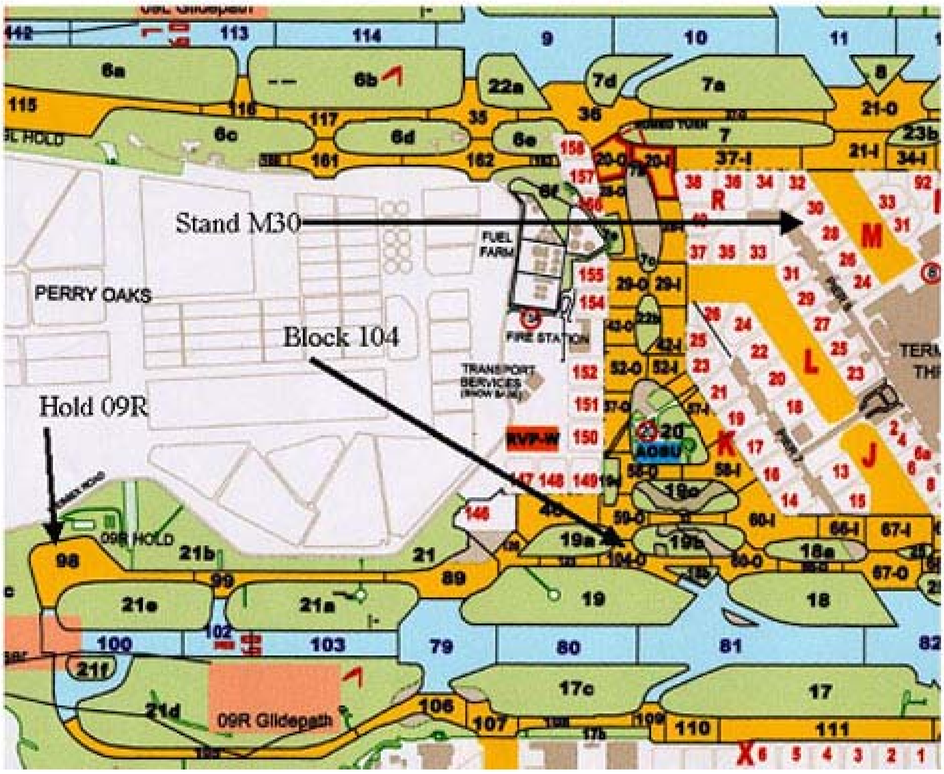
The aircraft was taxiing for departure when the crew heard a bang, the aircraft nose pitched down significantly and moments later the 'STAB TRIM' caption on the master warning panel illuminated. The commander cancelled the departure and taxied the aircraft back to a stand without further incident. A subsequent engineering examination revealed that the nose landing gear outer cylinder had suffered a circumferential fracture and a large section of the cylinder material had been ejected onto the taxiway. A metallurgical examination concluded that the fracture had occurred as the result of fatigue initiating at the base of a groove at the upper edge of the internal diameter (ID) seal band. The fracture had propagated through approximately half of the cylinder wall thickness prior to the final failure. The groove, square shaped in cross section and of an appearance that it had been made by a rotating cutting wheel, was machined into 70% of the internal circumference. The outer cylinder had been overhauled once since original manufacture during which rework in the area of the ID Seal had been carried out.

History of flight

The aircraft, scheduled to depart London Heathrow Airport for Lahore, Pakistan, pushed back from Stand M30 at 2019 hrs and was subsequently cleared to "TAXI ON THE GREENS" to the holding point for Runway 09R. The visibility was 4,500 metres in light drizzle, with a 12 kt wind and a temperature of 4°C as they departed the stand.

On reaching Block 104 (see Figure 1) the aircraft was transferred from Ground Movement Control to the Tower Control frequency. As the aircraft started to turn right at Block 104 the flight crew heard a bang beneath them and felt the aircraft pitch down. Shortly after this a 'STAB TRIM' caption came up on the master warning panel.

Figure 1 London Heathrow Airport Western Area



London Heathrow Airport Western Area
Figure 1

The commander continued the turn, with the steering apparently operating normally and it was reported to ATC that the aircraft had a technical problem and would need to return to stand. ATC instructed the crew to manoeuvre the aircraft and hold in Block 98 adjacent to the threshold of Runway 09R. Meanwhile one of the flight crew contacted their company operations requesting an engineer to inspect the aircraft as the commander suspected that the nose landing gear had sustained damage. A minute later ATC cleared the aircraft to return to stand but the crew, awaiting their engineer, requested to hold their position.

Company staff were still waiting to be transported to the aircraft when the tower controller asked the crew how long they expected to be. The controller advised them that they could not hold in their present position for long because other large aircraft could not taxi past them. The crew replied that if that were the case they would have to return to stand for a landing gear inspection. The tower controller then received information, originally passed by another aircraft on the ground frequency, that debris had been found on the taxiway. He advised the crew of this and suggested once again that they should hold their position while he arranged for somebody to attend the aircraft. Two vehicles were dispatched to the holding area, one an airfield operations vehicle and the second a vehicle used for bird scaring operations. The debris was recovered from the taxiway and airfield operations were then advised that the taxiways were clear.

The largest piece of debris, measuring about 40 cm by 30 cm and weighing approximately 2 kg, was from the nose landing gear outer cylinder casing. Information about the size and nature of the debris however, was not relayed to either ATC or the aircraft commander. When informed that the taxiway was clear ATC passed instructions to the crew to taxi, initially along the runway and then via the taxiways, to park on Stand 34. The aircraft taxied to Stand 34 where the passengers were disembarked without further incident.

Recorded information

All ATC transmissions and some of the airside vehicle communications were recorded. The Cockpit Voice Recorder had been overwritten and information on the Flight Data Recorder, although recovered, was not able to assist the investigation.

Wreckage examination

The nose landing gear outer cylinder had suffered a complete circumferential fracture resulting in a large section of the cylinder material being ejected onto the taxiway (see Figures 2, 3 and 4). The nose landing gear was removed from the aircraft and the upper section of the outer cylinder was dispatched to the aircraft manufacturer for a detailed metallurgical examination.

Figure 2 Nose landing gear showing the area of the failure

Nose landing gear showing the area of failure

Figure 2

Figure 3 Nose landing gear outer cylinder showing the area from which the ejected section of cylinder material originated

Nose landing gear outer cylinder showing the area from which the ejected section of cylinder material originated

Figure 3

Figure 4 Nose landing gear outer cylinder showing the circumferential failure

Nose landing gear outer culinder showing the circumferential failure

Figure 4

Metallurgical examination

The metallurgical examination concluded that the fracture of the landing gear outer cylinder had occurred as the result of fatigue that had initiated at the base of a groove at the upper edge of the internal diameter (ID) seal band (see Figure 5 and Figure 6) and propagated through approximately half of the cylinder wall thickness prior to the final failure. The groove, square shaped in cross section and of an appearance that it had been made by a rotating cutting wheel, was machined into 70% of the internal circumference. The depth of the groove varied around the circumference. The deepest section was in the middle of the affected area where significant thinning of the outer cylinder wall thickness had introduced a critical stress concentration area. The groove was not part of the design, manufacturing or overhaul specifications.

Figure 5 Drawing of the nose landing gear outer cylinder

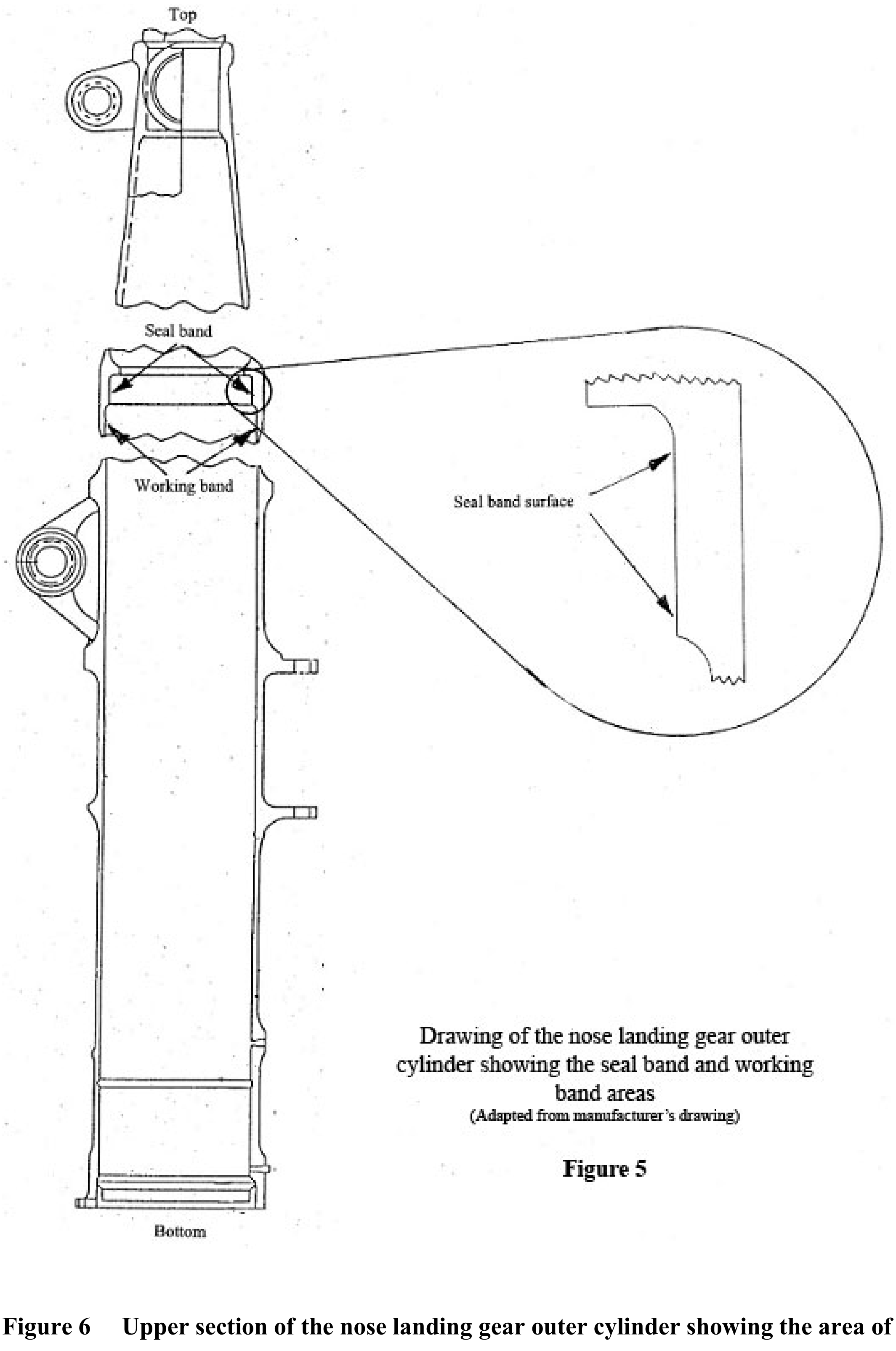
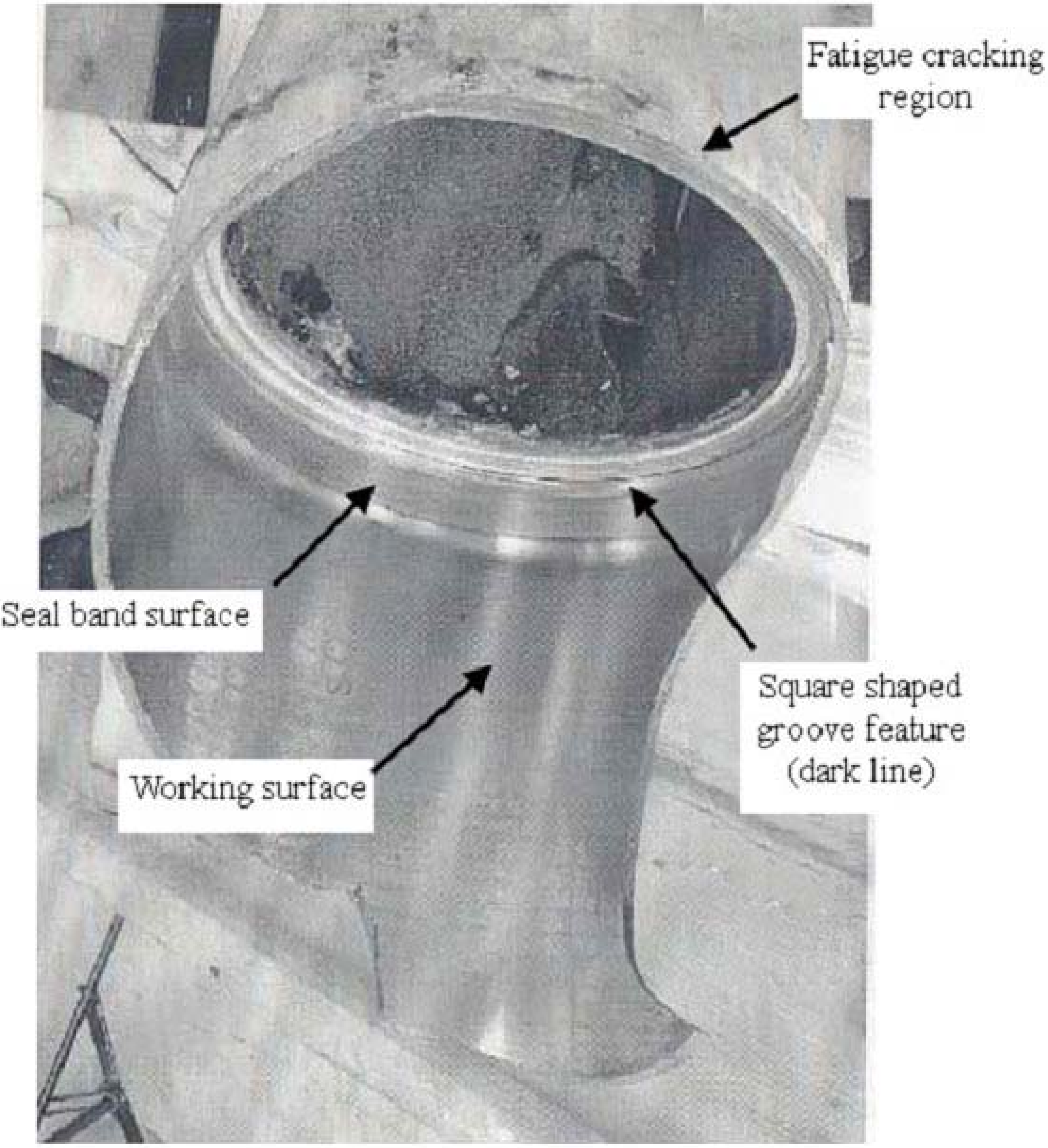


Figure 6 Upper section of the nose landing gear outer cylinder showing the area of the failure



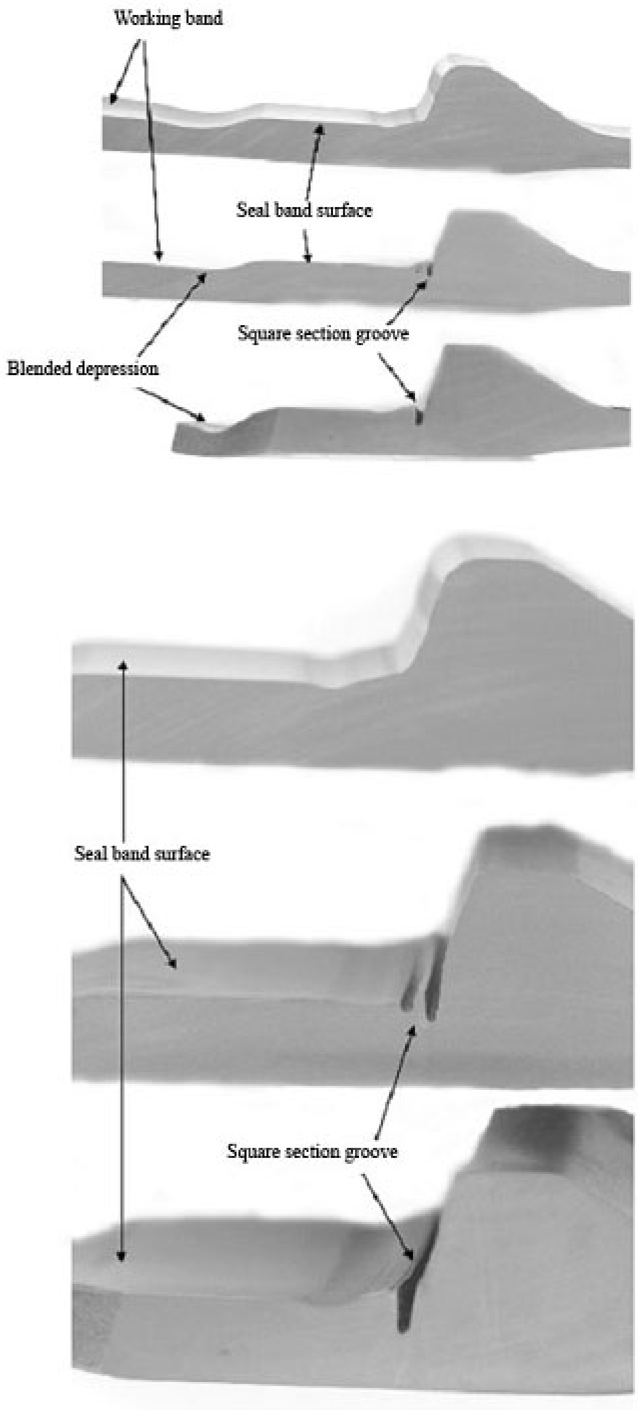
Upper section of the nose landing gear outer cylinder showing the area of the failure
(Photograph courtesy of Boeing Materials Technology)

Figure 6

The examination revealed a number of other deviations from the design, manufacturing and overhaul specifications in the area of the fatigue initiation. A blended depression was present at the transition between the seal band ID and the working surface ID that had resulted in localised outer cylinder wall thinning to a dimension below the minimum requirement. Some of the ID surfaces in the area of the fracture had been blended after nickel plating of the seal band surface. These areas showed no evidence of having been subsequently shot peened as required. Shot peening creates residual compressive stresses in the surface material which inhibits the development of fatigue cracks. A lack of shot peening left the material more prone to fatigue crack development.

The manufacturer subsequently cut three vertical sections (see Figure 7) from the seal band area of the outer cylinder showing the internal profile and the square shaped groove in the area immediately above the seal band.

Figure 7 Two sets of photographs of the 3 vertical sections cut from the seal band area of the nose landing gear outer cylinder



Two sets of photographs of the 3 vertical sections cut from the seal band area of the nose landing gear outer cylinder
(Photographs courtesy of Boeing Materials Technology)

Figure 7

History of the nose landing gear

In 1998 the nose landing gear was removed from the aircraft to which it was fitted and sent to a Federal Aviation Administration (FAA) approved Repair Station for overhaul (required every

10 years or 50,000 cycles). This particular Repair Station, which did not have the facility to overhaul/rework the outer cylinder, obtained an exchange unit from another suitably equipped FAA approved Repair Station. The primary Repair Station rebuilt the nose landing gear using the exchange outer cylinder and returned it to the operator. This operator was different to that operating the aircraft at the time of the accident.

The exchange outer cylinder had completed 12,323 cycles when it had been first overhauled/reworked in 1998. At the time of the accident the outer cylinder had completed a further 3,655 cycles.

Outer cylinder overhaul procedures

Chapter 20 of the aircraft manufacturer's Standard Overhaul Practices Manual (SOPM), gives guidance on processes and procedures for the repair and refinishing of high strength steel parts. The SOPM gives general guidance for 'surface grinding', 'breaking edges and blending' and 'electro-deposited nickel plating'. Chapter 32 of the aircraft manufacturer's Component Maintenance Manual (CMM), gives guidance on repair and overhaul procedures, information necessary to perform maintenance functions from simple checks and replacements to complete shop-type repair with overhaul dimensions and specifications. The approved Repair Stations develop and produce procedures and 'workpacks' that reflect the guidance and specifications given in the SOPM and CMM. The Authority granting the Repair Station's approval, oversees their procedures and work practices to ensure the continued airworthiness of those components processed by that Repair Station.

Overhaul of the outer cylinder

The outer cylinder is approximately 8 feet long with the working length of the inner surface approximately 4.7 feet from the bottom of the cylinder. The inner diameter (ID) seal band is at the top of the working length of the cylinder. The bottom of the cylinder is 10.25 inches in diameter reducing to 9.625 inches in the area of the ID seal band. The only way to access the ID seal band area for inspection and rework is from the bottom of the cylinder.

During initial receipt inspection of the failed outer cylinder, both wear and corrosion were observed in the area of the ID seal band. As part of the repair process, nickel plating was applied using the 'nickel bath' method. An inherent part of that process is the production of nickel 'trees'; small 'christmas tree' shaped protrusions that develop at the edges of the nickel plating. These nickel 'trees', which can be up to 25 mm long and 7 mm in diameter, have to be removed. The Repair Station found that when attempting to remove these nickel 'trees' using hand held revolving abrasive cross pads there was a tendency for the nickel 'trees' to snag and rip the pads. The out-of-balance forces caused by the snagging and ripping of the revolving pads occasionally caused the operator to loose control of the hand held tool. To resolve this problem the Repair Station used a hand held cutting wheel to cut a notch at the base of the nickel 'trees' allowing them to be easily removed with the revolving pads. It was suggested by the Repair Station that misuse of the cutting wheel had introduced the groove that had been observed during the metallurgical examination of the failure.

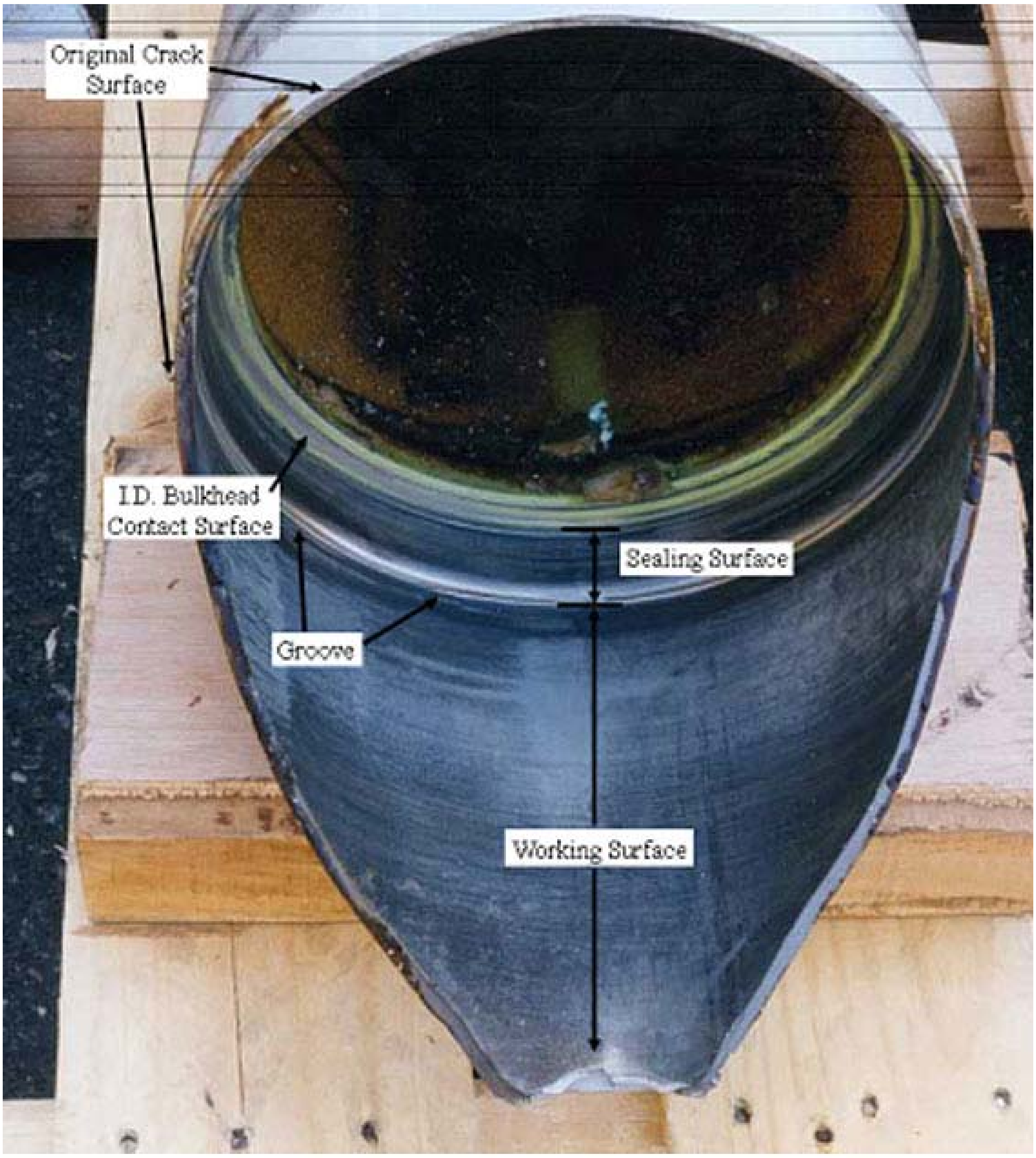
The method of inspection of the ID seal band following rework of the failed cylinder in 1998 was by the use of a mirror mounted on an extended handle. There were no ID seal band profile or ultra-sonic cylinder wall thickness measurements made at the time of the overhaul of the outer cylinder involved in this accident.

Previous nose landing gear failure

In June 1998 the nose landing gear outer cylinder fitted to a Boeing 747-300 failed while the aircraft was being towed. The outer cylinder had been overhauled/reworked in 1996 and at the time of the accident had completed 689 cycles since the overhaul. The type and location of the failure was very similar to that which is the subject of this investigation (see Figure 7) and the overhaul/rework had been carried out at the same Repair Station.

A metallurgical examination carried out by the aircraft manufacturer concluded that the fracture of the landing gear outer cylinder had occurred as the result of fatigue. The fatigue had been initiated at multiple sites at the base of an irregular circumferential groove just below the lower edge of the ID seal band (see Figures 5, 8 and 9). This had propagated through approximately 40% of the cylinder wall thickness prior to the final failure. The grove had resulted in a significant thinning of the outer cylinder wall thickness. During the examination it was also noted that there was an intermittent 'V- shaped' circumferential groove just above the seal band and that the bulkhead contact surface had been reworked to an angle of 109° instead of 90° as specified in the CMM.

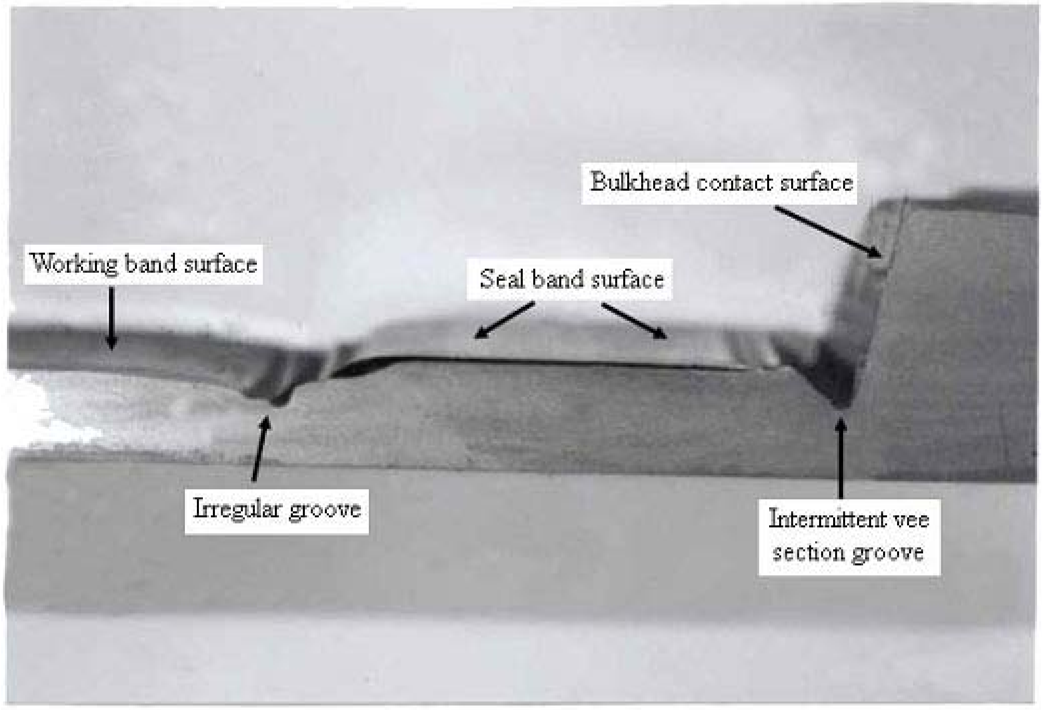
Figure 8 Nose landing gear outer cylinder that was involved in the 1998 incident showing the area of failure



Nose landing gear outer cylinder that was involved in the 1998 incident showing the area of failure
(Photograph courtesy of Boeing Materials Technology)

Figure 8

Figure 9 A vertical section cut from the seal band area of the nose landing gear outer cylinder involved in the 1998 incident



A vertical section cut from the seal band area of the nose landing gear outer cylinder involved in the 1998 incident
(Photograph courtesy of Boeing Materials Technology)

Figure 9

Safety actions following the 1998 outer cylinder failure

Following the failure of the nose landing gear outer cylinder in 1998 the Repair Station instigated a number of significant changes to their overhaul/rework practices and procedures and an inspection of all suspect outer cylinders that had been overhauled/reworked in their facility. This inspection required a unique Non Destructive Testing (NDT) technique to be developed to allow inspection of outer cylinders fitted on aircraft without removal or disassembly of the nose landing gear. A total of 35 outer cylinders were inspected using this NDT technique resulting in the rejection of 22 units because of incorrect internal tolerances detected during the inspection.

Following removal and disassembly of the rejected nose landing gears, all the outer cylinders were subjected to a detailed internal examination. A number of these rejected outer cylinders were found to have rework anomalies in the area of the ID Seal. Following an examination of these anomalies the Repair Station introduced a number of major changes to their rework processes.

The outer cylinder that is the subject of this investigation was not identified by the Repair Station as one that required NDT inspection, due to record keeping irregularities.

Safety actions following the 2002 outer cylinder failure

Following the failure of the outer cylinder that is the subject of this investigation, the Repair Station conducted an intensive review of all their historical paper records to establish whether any other similar outer cylinders had also been omitted from the NDT inspection programme carried out following the failure in 1998. A total of 16 outer cylinders were identified as possibly requiring inspection. The NDT Inspection technique developed following the 1998 outer cylinder failure was reassessed, re-qualified and carried out on 8 of these 16 outer cylinders (the remaining 8 cylinders were not inspected as it was possible to establish that these units had been scrapped and were no longer in service). Two of the 8 cylinders tested were found to have rework anomalies in the area of the ID Seal. None of the 16 cylinders had been overhauled/reworked by the Repair Station since the overhaul process, procedures and quality assurance inspections had been changed following the 1998 outer cylinder failure.

Retention of records

Federal Aviation Regulation (FAR) 145.219 paragraph c states:

> *"A certified repair station must retain the records required by this section for at least 2 years from the date the article was approved for return to service."*

This implies that there is no requirement for a Repair Station to keep these records after this two year period and that they can therefore be destroyed.

Discussion

After hearing the initial bang the crew were at first uncertain as to what had happened to the aircraft although they thought the nose landing gear was the area affected. The aircraft was turning a corner at the time and the commander detected no apparent change in the way the aircraft was taxiing. The appearance of the 'STAB TRIM' message (associated with the air/ground sensing system) then confirmed the crew's suspicion that there was a problem with the nose landing gear. The commander decided that they should stop and get the aircraft inspected. Following the initial discussions with ATC the commander reported that he felt able to accept the request to continue taxiing because the aircraft had continued to respond normally to steering inputs.

Once the debris had been found ATC had suggested that the aircraft should await inspection. The debris was recovered but the nature and size of the main piece was not passed on to ATC or to the commander. Had either one been advised of the substantial size of the debris it is unlikely that taxiing would have continued without a safety inspection being carried out by a qualified person. It is not clear if the aircraft was inspected until after its arrival back on stand. If an inspection had been carried out the damage, clearly visible from a position in front of the aircraft nose leg, would have been noticed and all further aircraft movement stopped.

The Repair Station that carried out the overhaul/rework of the outer cylinders that failed did not destroy their records after the required two year period and were able to trace those outer cylinders that had undergone similar overhaul/rework at their facility. Without those records it would have been virtually impossible to identify, and therefore inspect, other outer cylinders for possible incorrect rework.

Safety Recommendations

Safety Recommendation 2004-69

It is recommended that the Federal Aviation Administration (FAA) should consider deleting or amending Federal Aviation Regulation (FAR) 145.219 paragraph 'c' to ensure that maintenance/overhaul records are retained for the life of the aircraft/component.

Safety Recommendation 2004-70

It is recommended that the Federal Aviation Administration (FAA) adopt a programme for performing targeted surveillance and increased oversight of overhaul practices at *'14 Code of Fedral Regulations Part 145'* Repair Stations that are conducting repair, overhaul and rework of aircraft landing gears, to ensure that the manufacturer's overhaul manuals and instructions are followed and that appropriate quality assurance procedures are in place for the continued airworthiness of these components.