State of Israel
Ministry of Transport and Road Safety
Aviation Incidents and Accidents Investigation

Safety Investigation Report
(Final Report)

Ground Accident No. 7-12

Severe structural failure in main landing gear in preparation for flight

Date	**31.1.2012**
Aircraft	**B-747-400 (Cargo)**
Registration mark	**4X-ELF**
Place of incident	**Ben Gurion Airport**

For safety purposes only

The Investigations conducted by the Israeli Investigation Office (IAIAI) are in accordance with Annex 13 to the ICAO Convention on International Civil Aviation, and the Israeli Aviation Law 2011, chapter 7, and its respective Aviation regulations.

The sole objective of the investigation of an accident or incident under these Regulations is the prevention of future accidents and incidents. It is not the purpose of such an investigation to apportion blame or liability.

Accordingly, it is not appropriate that AIAI reports should be used to assign fault or blame or determine liability, since neither the investigation nor the reporting process has been undertaken for that purpose.

This report has been translated to the English language for other parties' convenience, and should adhere to the Original report in the Hebrew language - In any case of abstruseness or miss-understanding, the original report in the Hebrew language is taking over.

Summary

On 31st January 2012, during pre-flight technical checks on a Boeing 747-400, cargo aircraft, an alert "EL AL" technician spotted a wide crack in the aircraft's right main body landing gear outer cylinder. The accident was reported immediately to the Chief Investigator who opened an investigation into the incident.

Since the accident occurred, according to the definitions given in the Aviation Law, during "maintenance time", the Chief Investigator is under a statutory duty to open an investigation. During the preparatory stages of the investigation, it became clear that a trunnion lug passes through the bushing at the top of the cylinder, the external side of which, the side facing the wings, is held in place by a tightening nut. In order to release the trunnion lug and dismantle the landing gear - the nut had to be sawn. The crack was located on the left side of the landing gear, in an area facing the aircraft's longitudinal axis. The aircraft was grounded immediately pending replacement of the cracked landing gear and to inspect it for collateral damage. Four days after the crack had been discovered, the aircraft was released back to EL AL in order to be put back into service.

The aircraft which was involved in the accident
(the arrow points to the failed landing gear)

1. Factual information

1.1 The investigation

The aircraft was manufactured in 1994, and was originally operated by Singapore Airlines Cargo until May 2010, when it was leased to EL AL. Between 2001 and 2002, the landing gear in which the crack had been found had been inspected and restored in a Singaporean repair center before being refitted to the aircraft being investigated in January 2003. Prior to its restoration, the landing gear had been used in 5,799 landings, and thereafter, in 2,682 landings.

The findings of the investigation show that the fault in question was rare and similar to one which had occurred in 2006 in the same landing gear in a 747 passenger aircraft belonging to another Singaporean airline.

In light of the potential implications of the investigation's findings and their impact on airlines throughout the world, the Chief Investigator decided to include external organizations in the investigation team, such as the U.S. National Transportation Safety Board (NTSB), the Singaporean Air Accident Investigation Bureau (AAIB), the Boeing Corporation, EL AL Ltd and the Singaporean repair center, some of which sent representatives to Israel during the course of the investigation.

The investigation involved, inter alia, an examination of the possible causes of the fault, including: the design of the landing gear, the processes by which it is manufactured, reconditioned and affixed to the aircraft and possible reasons for the wearing out of or fault in the materials from which it is made as a result of operating the aircraft.

After dismantling the landing gear and analyzing the cracked part, initial evidence indicated that the crack in question was long (around 60 centimeters) and that the first section of it had developed through gradual fatigue rather than as a result of a one-time overload. Another section of the fracture was examined by the Ruppin College "Institute of Failure Analysis" while another segment of the cracked part was sent to the Boeing Corporation for further metallurgical tests to be carried out. The Boeing Corporation long ago forwarded its findings, although it has yet to issue them as a final report.

1.2 Information about the defective part

- ☒ Name of the part: RIGHT MAIN BODY GEAR OUTER CYLINDER.
- ☒ Catalogue number of the unit: 65 B05187-3-2.
- ☒ The metal from which it is manufactured: 4340M.
- ☒ Catalogue number of the defective part: 163W1500-62.
- ☒ Total hours of operation: 119,426.
- ☒ Hours of operation since the last overhaul: 38,851.
- ☒ Cycles since new (CSN): 19,226.
- ☒ Number of cycles since the last overhaul: 6,901.
- ☒ Last overhaul carried out abroad between the years 2001 and 2002.
- ☒ The item was affixed to the aircraft in January 2003.
- ☒ According to the manufacturer's literature, the time between renovations for this part is 10 years.

1.3 Findings of the metallurgical tests undertaken in Israel

1.3.1 The main tests which were performed

- ☒ Fractography of the fractured surface.
- ☒ Chemical analysis.
- ☒ Metallurgic examination perpendicular to the crack.
- ☒ Analysis of mechanical properties.

1.3.2 Results and diagnoses

The results of the laboratory tests which were carried out using a scanning electron microscope, suggest that the crack in the cylinder was the result of **an initial fracture in a brittle mechanism which deteriorated.**

- ☒ The center of the fracture was in a bushing spring retention groove (hereinafter: **"the recess"**).
- ☒ Around the groove, on the internal wall, **evidence was found of relative vibration** between the bushing and the cylinder to the point of disintegration of the inner surface of the cylinder.

- ☒ The initial cracked surface in the cylinder was found to be covered by rust which could not be completely removed and which contained traces of cadmium and oxygen. These traces attested to an advanced oxidation process.
- ☒ It became clear that the fracture had progressed in the form of an unstable ductile fracture until it reached its final size.
- ☒ At the source of the fracture, no metallurgical irregularity was found within the recess (other than differences in silicon and molybdenum alloy contents) which may have contributed to the development of the fracture.
- ☒ No traces were found there to indicate the presence of coating and it seems that this was eroded during the unit's operation.
- ☒ Inter-nuclear phased cracking was found **adjacent to the fracture**, which characterized the surface of the fracture.
- ☒ Upon examination, the surface of the defective part did not show signs of hardening.
- ☒ Far from the cracked area, within the defective part, evidence was found to indicate the presence of a disintegrated layer of cadmium coating. In part of and above the coating, two layers of paint were identified.

1.3.3 Summary of the laboratory tests conducted in Israel

- ☒ The cracking of the landing gear cylinder had been caused by the progression of an initial fracture within the security spring recess of one of the bushings in the damaged cylinder. The fracture deteriorated up to 60 millimeters wide, relative to its . initial origin, in a brittle inter-nuclear fissuring mechanism.
- ☒ No irregularities were detected in the micro-structure of the surface material or the mechanical properties (hardness), apart from the absence of the layer of cadmium coating around the area of the crack. Traces of the cadmium were found, however, within the crack itself, although not on the surface of the fracture. This may indicate that a layer of cadmium had originally existed.

- On the internal wall of the cylinder, around the cracked area, there was evidence of surface disintegration attributable to an abrasion-erosion process which caused localized removal of the coating (its presence at some distance from the crack was verified) and damage to the surface of the material to such an extent that micro fractures were created. It appears that one of the fractures had developed and progressed during a time-dependent "stress corrosion" like process until it reached its final size. A further finding, which supports the notion that the cracking had developed over a long period of time, is the presence of cadmium within the crack, a feature which characterizes a process of dissolving the coating and its dispersion within the crack. Moreover, signs of internal paint peeling within the cylinder bore, under the cracked area, also support the suspected existence of mutual vibration between the cylinder's horizontal axle and bushing.
- Peeling in the paint coating was observed on the surface of the cylinder, parallel to the cracked area.
- The possibility was considered that a similar phenomenon also existed in the area under the copper bushing, potentially exposing the metal surface to vibration against the bushing. Another possibility is that progression of the crack and the relative enlargement of the cylinder's diameter enabled grease penetration from the internal surfaces of the bushing to the space between the bushing and the cylinder.

1.4 Findings of the metallurgical tests conducted by Boeing Corporation

1.4.1 The need for the tests and their coordination

After the tests had been carried out by "Institute of Failure Analysis" and their results had been received, investigators from Boeing and the NTSB were invited by the Chief Investigator to visit Israel and to review the investigation's findings. The investigators inspected the landing gear cylinder (and the opposite part of the sawed area) and found signs of suspected rotation between the bushing and the cylinder. Since it became clear that Boeing had experience in this matter, the Chief Investigator sent the second half of the sawed part to the Boeing Corporation in the U.S. in order for the metallurgical examinations to be completed by its Research and Technology Division (Boeing Research & Technology, BR&T).

The findings of the metallurgy examinations

A section of the inboard trunnion lug bore excluding the fracture surface was examined:

- ☒ Large wear marks were visible on the inner diameter (ID) where the bushing was located. The enamel and primer were worn away in several locations and corrosion product was prevalent. A small amount of wear was visible on the outer diameter (OD) where enamel was removed and primer was exposed.
- ☒ Grease and debris were found in the retention groove and appeared to be very dry. FTIR analysis was conducted on a sample of the grease and confirmed it was AeroShell 33 (per BMS3-33) that had lost some of its base oil. Debris particles were found in the grease sample and were consistent with 4340M, Aluminum Nickel Bronze, and cadmium corrosion product. After samples of grease were collected, the groove was cleaned with Acetone to remove all remaining grease and debris. All finishes were worn away and corrosion pitting was visible in the groove.

- ☒ A cross section of the cylinder where finishes were undisturbed was mounted and polished to examine the organic and inorganic finishes on the ID and OD. Cadmium plating was found on the base metal with a layer of primer and then enamel. These finishes are acceptable per CMM 32-13-40. However, corrosion pitting was found on the surface of the base metal, under the intact protective finishes, at the cadmium plating interface. The cadmium plate was intermittently found in two distinct layers on the ID.
- ☒ A two inch wide segment of the cylinder where finishes were undisturbed was sectioned. Enamel and primer were removed with Turko 6950 to expose the cadmium plated surface on the ID and OD. Photographs and SEM images capture the abnormalities of the two surfaces. The ID had several valleys that were shaped like corrosion pits. This indicates that corrosion pits were present on the surface of the base metal before the finishes were applied. The OD is nonuniform as raised cadmium spots are present. The ID and OD are not consistent with a typical cadmium plate appearance. Cadmium plating was electrochemically stripped to expose the base metal substrate. Photographs and SEM images capture the surface texture of the ID and OD. Small pits are visible on the ID, but since this section of the cylinder appeared undisturbed, the pits were likely not removed during overhaul and were covered with cadmium. The OD has scratches visible in multiple directions, consistent with a sanded surface. A typical base metal substrate under cadmium plating is expected to have a uniform grit blasted appearance. Neither ID nor OD has a typical appearance. Fluorescent penetrant inspection (FPI) was performed on both ID and OD. The FPI photos display the variations of appearance and neither is consistent with the appearance of a typical base metal substrate.
- ☒ The hardness and chemistry of the 4340M base metal are compliant with engineering requirements. X-Ray Diffraction (XRD) was conducted on the base metal. Compressive stress data shows the part was shot peened.

The findings of the chemical analysis

- ☒ The material submitted for analysis is a mixture consistent with grease, cadmium and steel reaction products, aluminum-nickel bronze, BMS10-11 primer, BMS10-60 topcoat, elastomeric material (possibly polysulfide sealant), and an oxide of low alloy steel.
- ☒ The fine-grained brown solids suggest the presence of cadmium and steel reaction products along with a copper-based material. It was not possible to determine if the copper based material is a corrosion product or very fine wear debris.
  - ✓ The bronze-colored metallic particles are consistent with aluminum-nickel-bronze
  - ✓ The green flakes contain elements suggestive of BMS10-11 primer
  - ✓ The white flakes contain elements suggestive of BMS10-60 polyurethane topcoat
  - ✓ The brown elastomeric-looking particles contain elements suggestive of a polysulfide sealant, although no manganese was detected (which is typically present in polysulfide sealants).
  - ✓ The shiny black platelets are consistent with an oxide of a low alloy steel
- ☒ No contamination was detected that would have contributed to the corrosion seen on the hardware.
- ☒ While chromium, silicon, and aluminum were detected, the elements could not be specifically attributed to JC5A corrosion inhibitor. Additionally, due to the complexity of the mixture it could not be determined if any corrosion inhibiting compounds were present.

1.4.2 Summary of the test results

- ☒ Signs of erosion extending as far as the metal layer were discovered in the trunnion lug (not in the cylinder).
- ☒ Dry grease was found in the retention groove protection spring which had lost part of its natural oiliness.
- ☒ "Corrosion scars" were seen within and around the retention groove which had been created due to erosion of the protective coating.

- ☒ An incision made in a part of the cylinder which was not disturbed by the operation of the landing gear revealed "corrosion scars" in the basic metal layer, beneath a layer of paint covering the internal and external parts. This finding proves **that the rust spots had not been removed as required during the reconditioning work which had been carried out on the landing gear.**
- ☒ The layer of cadmium coating on the interior of the cylinder was alternately characterized as two separate layers, which is a typical result of partial removing the old cadmium before recoating the cylinder with a new layer of cadmium.
- ☒ The "basic metal" layer of the cylinder's exterior, beneath the finishes, was characterized as a rusty surface which had undergone a shot peening process.
- ☒ The cadmium coated interior and exterior surfaces were both found to be uneven. "Corrosion scars" were seen in the interior and according to the results of various tests conducted on the exterior the rust appeared to have "spread".
- ☒ The results of tensile stress and chemical tests showed that the basic material M 4340 complied with the engineering requirements for manufacturing the damaged part.
- ☒ The rotation of the bushing within the cylinder showed a certain freedom between the two parts, that manifested, inter alia, by the gap between them. Over time, such a gap becomes a conduit for moisture penetration and the creation ofan initial corrosion mechanism, a process which would be accelerated if the initial rust spots were located in the gap.
- ☒ The chemical analysis of the compound containing grease and various sediments which was extracted from the area of the bushing, managed to identify all its components but found no evidence of any contamination which could cause or contribute to the onset of corrosion.

1.4.3 The responses of the landing gear maintenance facility The reports containing the results of the metallurgical tests which had been carried out in Israel by the "Institute of Failure Analysis", and of the tests carried out by the Boeing Corporation, were forwarded by the Chief Investigator to the Singaporean investigating authority and landing gear maintenance facility for their comments. The maintenance facility's response was as follows:

☒ **Movement of the bushing**

The movement of the bushing could also be attributable to its incorrect geometric measurements or maintenance.

☒ **Dimensions of the trunnion bore and bushing**

As a result of the findings, the maintenance center reviewed all the paperwork relating to the overhaul of the defective landing gear, while putting emphasis on the dimensions of the external diameter of the bushing and the diameter of the trunnion bore. According to its records, the bore diameter was 8.753" within a possible range of 8.750"-8.753" and the external diameter of the bushing 8.759". The recorded tolerance of 0.0060", between the external diameter of the bushing and the diameter of the trunnion bore was also within the manufacturer's permitted range of 0.0025"- 0.0068".

The maintenance facility attached a document relating tothe overhaul which listed, inter alia, the aforementioned dimensions.

☒ **Lubrication and greasing**

Both the reports which were forwarded to the maintenance facility for review pointed to the presence of dry grease which indicated inadequate lubrication of the trunnion bore area. The maintenance facility's records show that the dimensions of the bushing were within the permitted range, which led it to conclude that the reason for the bushing rotation was prolonged, ineffective greasing.

☒ **Identification of trunnion corrosion spots**

The size of the spots when the overhaul was carried out in 2001,may have been even less than 0.5 millimeters. Moreover, according to the relevant maintenance regulations, only a visual corrosion damage identification inspection was required when undertaking the reconditioning work; it was difficult to detect the tiny corrosion spots referred to in the lab report with the naked eye, and in order to do so it would have had to use high-powered

magnifying equipment, which went beyond the overhaul requirements. Had such a detailed examination been necessary, then the manufacturer should have updated its maintenance literature accordingly.

☒ **Corrosion smear on outer surface of the cylinder**

According to the maintenance facility's records, no repair work at all, let alone shot peening, had been carried out on the outer surface of the cylinder. The corrosion smear referred to may have existed before the current overhaul had been carried out, or shot peening may have been undertaken after the part was released from the overhaul.

☒ **The two layers of cadmium found on the inner surface**

In 2001, when the overhaul was carried out, use of aluminum-oxide was the proven and accepted method for removing old cadmium. From 2003 onwards a chemical method has been used. Moreover, indications had been found to suggest the existence of corrosion spots beneath the first cadmium layer (the old layer of cadmium), a fact which, according to the maintenance facility, showed that the corrosion spots may have existed even before the current overhaul had been carried out.

☒ **Summary and conclusions**

Based on the foregoing, the company which reconditioned the landing gear claims that it complied with all the requirements

stipulated in the maintenance literature and followed the approved

procedures that were in force at the time of the overhaul.

2. Analysis

2.1 General

As is the case with other parts of an aircraft, its landing gear has a defined, operation based lifespan, after which it has to be serviced/reconditioned in accordance with the manufacturer's instructions.

As a rule, after the part in question has been reconditioned, it will normally then be reattached to the aircraft with its operating hours reset to zero.

Many parts of the aircraft, and in particular those designed to bear heavy loads, are manufactured to conform to strict standards in terms of material chosen, metalwork and, most importantly, thermal treatment and coating, which are designed to ensure that these parts function properly in the conditions in which they operate until the time arrives for them to be removed from the aircraft and serviced/reconditioned and/or replaced, depending on the manufacturer's recommendations.

During their ordinary operating conditions, the exterior of the aircraft's load-bearing parts are exposed to hazards arising from air exposure or routine movement - the retraction and extension of landing gear - which requires that its various parts do not come into contact with each other, since any such contact creates a defect which constitutes a basis for prolonged failure. In order to ensure that the landing gear satisfies the strict strength standards, the manufacturer must produce parts which are durable enough to carry out their function without compromising their flexibility. Reaching the required strength is a result of a thermal metal treatment followed by covering with an anti-corrosion layer coated with paint or other protective material.

2.2 Reconditioning of the unit

Upon completing its lifespan as defined by the manufacturer, the part is removed from the aircraft and sent to a maintenance facility. The reconditioning process is based on the manufacturer's instructions and entails various tasks which are designed to make the part fit for use in its next life cycle as determined by the manufacturer.

For the sake of proper disclosure, it should be pointed out that the same maintenance institute had one year earlier been involved in the failure of the main landing gear on a Boeing 777 belonging to EL AL Ltd (Investigation No. 54-11, the report for which has not yet been published). Within the framework of the overhaul, the outer surface of the part underwent various treatments which were designed to remove the old coating and process the surface, while removing the corrosion (if any), and thereafter to protect and recoat it.

The manufacturer has specified the amount of material to be removed from the item during treatment of the metal in order to eliminate the corrosion.

In the case under investigation, it was proved that during the last overhaul carried out on the damaged item, **corrosion spots were not removed as required but remained on the surface of the part during its reconditioning**, coated over with a layer of cadmium, (to protect it from corrosion) and then an outer protective layer of vitreous enamel. The basis for this analysis was a metallurgical examination carried out by cutting into the cylinder to the depth of the basic metal to reveal "corrosion scars" - a clear indication of defective priming of the surface before the anti-corrosion layer was added.

2.3 Creation of the crack

The initial crack in the landing gear cylinder was created in a recess of the security spring of one of the bushings and was surrounded by what was observed to be an abrasion-erosion induced disintegration of the surface that had induced the "removal" and disappearance of the sectional coating thus creating numerous micro fractures, one of which developed into the initial crack. Movement of the bushing within the cylinder, as identified during the examinations showed that there had been "freedom" between the two parts which created a certain gap between them through which moisture entered. The "corrosion scars" observed during the metallurgical examination had widened over time, resulting in an enlargement of the corrosive area and eventually fissuring, causing the crack found in the cylinder.

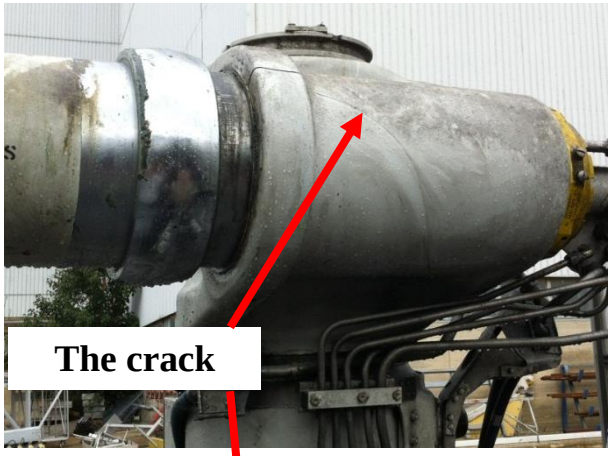
2.4 Results of the joint investigation

Since the investigation focused on a technical failure with possible ramifications for a large number of aircraft throughout the world, representatives of the NTSB, the aircraft's U.S. manufacturer and AAIB (the Singaporean Air Accident Investigation Bureau) joined the investigation. Apart from the fact that such cooperation is required under Annex 13 to the Chicago Convention, the intention was that these organizations should not only be extensively involved in the investigation and given the fullest information about the failure, but should also help by completing the picture and creating "the motivation" to correct the deficiencies which were identified.

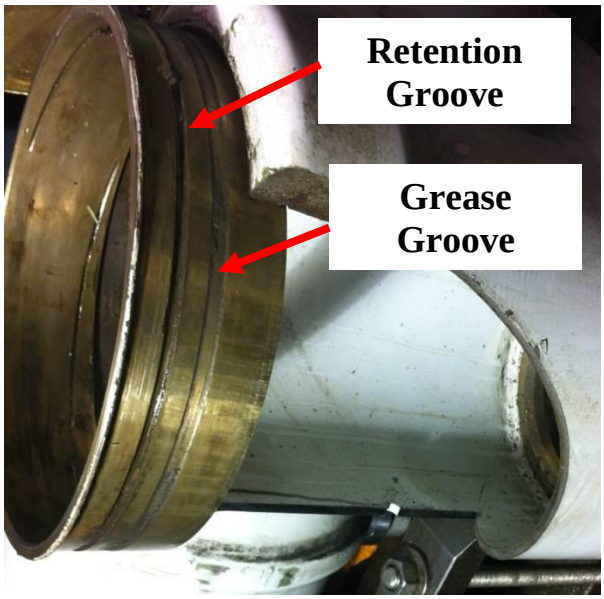
Beyond the manufacturer's subjective reaction to the failure, as expressed in this report, there was a consensus regarding the findings of the investigation. No information, or other findings, were received from any source that may lead to a different analysis other than the one presented by the investigation team, and which could shed light on the reasons for the failure. At the end of what had been a long and complex investigation, the investigating team reached a consensus regarding how the failure had come about. Nevertheless, as the previous landing gear investigation (AIAI Case 54-11) also showed, the maintenance facility which carried out the overhaul appeared to lack the detailed inspection and reconditioning programs required. Since a relatively long period of time elapsed without any significant information being received from the foreign representatives who participated in the investigation to supplement the report, the Chief Investigator decided not to wait for the final version of Boeing's report, but to make do in the meantime with the intermediate report which had been submitted (and which according to Boeing, fully reflects the final report to be submitted in due course), and the material which had been gathered and investigated, as presented in this report.

Photographs of the relevant parts

The landing gear in which the failure was detected



The crack



Retention Groove

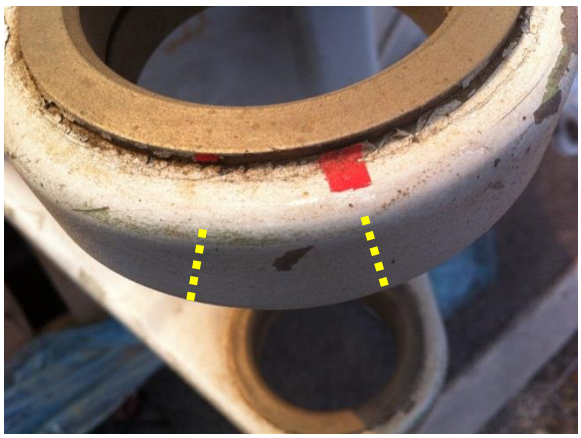
Grease Groove

Blocked Grease Groove

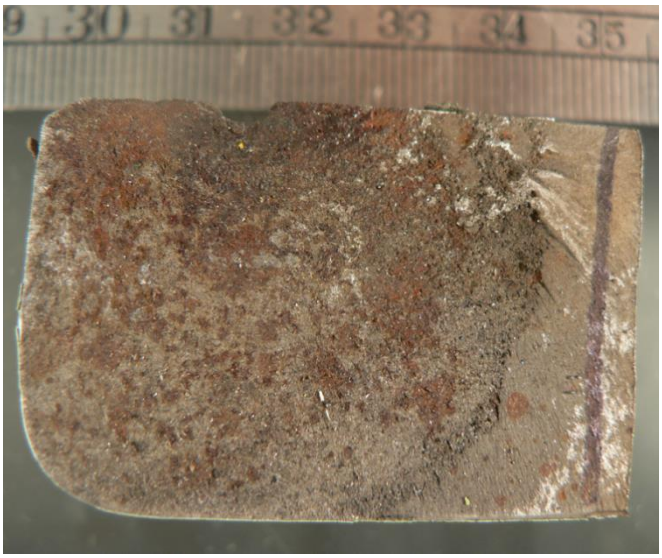
Bushing of Retention Groove

Bushing Spring

Confirmation of Bushing Movement



Example of Bushing Movement



Surface of the crack

3. Conclusions

3.1 The accident is attributable to a failure in the landing gear resulting from defective reconditioning by a foreign maintenance facility. An initial crack within a gap in the security spring of one of the landing gear cylinder bushings developed over time due to the non- removal of all corrosion spots from the surface of the part before it was coated, in a cracking mechanism between two brittle cores, until the final failure occurred.

Notes:

- ☒ According to the findings of the metallurgical lab, the corrosion spots were less than half a millimeter in size, which meant that it would have been difficult to see them with the naked eye, which is all that the manufacturer's inspection instructions at the time of the overhaul required.
- ☒ The facility which reconditioned the defective landing gear in this case, was the same one which on May 22, 2011, had reconditioned the landing gear of an EL AL Boeing 777, registration mark 4X-ECD, which was also subsequently found to be fractured, (AIAI Case 54-11, the report for which has not yet been published).

1.5 On the interior walls of the cylinder, surrounding the area of the crack, **investigators saw evidence of abrasion-erosion generated surface disintegration**, which had caused such surface damage to the material that micro fractures were created, one of which developed into the crack that was found in the cylinder. Within this process a certain small degree of freedom between the bushing and the cylinder covering it was created.

1.6 Apart from a gap in the layer of cadmium coating around the area of the crack, **no other irregular findings were identified on the surface in the micro-structure of the material or in its mechanical properties (strength).** Traces of cadmium were found within the crack, but not on the cylinder wall.

1.7 The degree of freedom between the bushing and the cylinder caused rotation displacement between the two parts which manifested itself, inter

alia, in an enlargement of the gap between them. Over time, this gap became a conduit for moisture penetration and created an initial corrosion process, a process which progressed rapidly since initial rust spots were already present in the gap.

1.8 The appearance of internal paint peeling, which was identified in the cylinder bore under the area of the fracture, **strengthens the finding of mutual vibration**, between the trunnion lug and the cylinder and the cylinder bushing.

1.9 The manufacturer's instructions concerning inspection of landing gear components prior to reconditioning and the manner in which such reconditioning should be carried out **are not sufficiently detailed, require updating and do not describe optimum reconditioning methods** at the level required for these critical components.

1.10 The technician who discovered the crack in the cylinder, while readying the aircraft for takeoff, **showed remarkable alertness.**

2. Recommendations

2.1 To revise and provide more detailed inspection and work instructions for Boeing aircraft landing gear maintenance facilities, while specifying the means and methods to be utilized when undertaking reconditioning work. It is also suggested that the method for identifying corrosion spots on surfaces designated for coating should be altered to incorporate the use of a device and/or processes which are customarily used in non-destructive examinations, such as optical magnification equipment, instead of relying on an unaided visual inspection only as specified in the manufacturer's current reconditioning instructions, in a way which shall guarantee the complete and absolute removal of corrosion spots, before the coating is applied.

Responsibility: Boeing (through the NTSB)

Recommended implementation date: As soon as possible

2.2 To ensure that when conducting standard or proactive inspections of B 747 landing gear in Israel, the correct bushings have been installed in accordance with the latest Standard.

Note: It became clear during the investigation, that as far back as 1980 certain changes had already been made in the bushing design in order to improve the lubrication of its internal section and the spring groove. Notwithstanding the foregoing, during the landing gear's reconditioning between the years 2001 and 2002 the bushing which was installed in it accorded with the old Standard.

Responsibility: Director of the Civil Aviation Authority

Recommended implementation date: 1st March 2014

2.3 To instruct the relevant repair stations to conspicuously mark those items and components the relative displacement between which is prohibited, in order for such displacement to be discovered while it may still be rectified and to undertake the maintenance work required in such a situation in accordance with the manufacturer's instructions.

Note: As illustrated in the above photographs, other parts of the landing gear have already been marked in this way, as have numerous other parts and accessories in the aircraft. The Boeing Corporation has recently indicated that it intends to consider issuing guidelines in this matter.

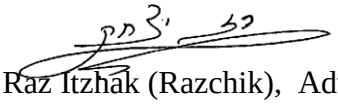
Responsibility: Director of the Civil Aviation Authority

Recommended implementation date: 1st March 2014

The investigation was protracted due to the involvement of foreign investigation agencies and observers, as a result of the international processes required to comply with ICAO Annex 13.

As mentioned in this report, both the manufacturer and the NTSB took part in the current investigation. For this reason, should these bodies, in the future, have any proposals concerning the reconditioning process or the maintenance facility, then they shall make such specific recommendations as they shall see fit.

Kind regards,



Raz Itzhak (Razchik), Adv.
Chief Investigator

Date: 4.12.2013 Ref: 27012714