MLG failure, Boeing 737-500 EI-CDE, September 8, 2003

Micro-summary: **On landing this Boeing 737-500, the left main landing gear trunnion pin had sheared.**

Event Date: **2003-09-08 at 1804 UTC**

Investigative Body: **Air Accident Investigation Unit (AAIU), Ireland**

Investigative Body's Web Site: **http://www.aaiu.ie/**

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FINAL REPORT

AAIU Synoptic Report No:2005-006
AAIU File No: 2003/0056
Published: 29/04/05

In accordance with the provisions of SI 205 of 1997, the Chief Inspector of Accidents, on 8 September 2003 appointed John Hughes as the Investigator-in-Charge to carry out a Field Investigation into this occurrence and prepare a Synoptic Report.

Aircraft Type and Registration:	Boeing 737-500, EI-CDE
No. and Type of Engines:	2 x CFM56-3-B1
Aircraft Serial Number:	25115
Year of Manufacture:	1991
Date and Time (UTC):	8 Sept 2003 @ 18.04 hrs
Persons on Board	Crew - 6 Passengers - 19
Injuries:	Crew - Nil Passengers - Nil
Location:	On landing at Cork Airport
Type of Flight:	Scheduled Public Transport
Nature of Damage:	LH main landing gear trunnion pin sheared
Commander's Licence:	Not applicable
Commander's Details:	Not applicable
Commander's Flying Experience:	Not applicable
Information Source:	Aer Lingus Safety Office AAIU Investigation

SYNOPSIS

As the undercarriage was selected down on approach to Runway (RWY) 17 at Cork Airport, the flight crew heard a loud bang from the landing gear. On arrival at the stand, an inspection was initiated, during which it was discovered that the LH main landing gear trunnion pin had sheared.

1. FACTUAL INFORMATION

1.1 History of the Flight

The aircraft departed from Dublin Airport (EIDW) at 17.40 hrs with 19 passengers on board. As the undercarriage was selected down on the approach to RWY 17 at Cork, a loud bang was heard from the landing gear.

Following a normal landing the Captain asked for the aircraft to be towed to the stand. On inspection of the LH Main Landing Gear (MLG), the trunnion pin was found to be sheared at its head, which is attached to the actuator. No other defects or damage was found and there were no injuries as a result of this incident.

The subject pin and associated links and nuts, trunnion bearing and fuse bolt were replaced at Cork. Other components associated with the MLG were also replaced. The aircraft was ferried (flight crew only) back to Dublin with the gear down and the safety pins installed.

At Dublin, the RH MLG trunnion pin was inspected and found corroded. This pin was also replaced and following successful retractions of the aircraft MLG the aircraft was returned to service.

1.2 Aircraft Information

1.2.1 Trunnion Pin Overhaul

The LH MLG trunnion pin Part No. 65-46113-20, Serial No. AT067 failed at the outboard end at the MLG actuator attachment point **(APPENDIX A**).

The aircraft, EI-CDE was delivered on the 21 May 1991. The LH MLG, which had been removed from EI-CDC, another aircraft of the fleet, was overhauled in April 1998 by the Operator's overhaul contractor, when it had accumulated 14,116 flight cycles on EI-CDC. Overhaul of the pin is due at 16,000 flight cycles.

The trunnion pin, S/N AT067, had been removed for shop servicing from the RH MLG assembly Part No. 65- 73761-128, Serial No. 3874, also previously installed on aircraft EI-CDC. That shop servicing included:

- Removal of Existing Corrosion (per fig.406,OHM 32-16-01)
- Magnetic Particle Inspections (per OPM 20-20-01)
- Removing of Existing Plate (per OPM 20-30-02)
- Shot Peening of all Reworked Areas (per OPM 20-10-03)
- Nitol Etch Inspection (per OPM 20-10-02)
- Pre Plate Bake (per OPM 20-10-02)
- Hard Chrome Plate (per OPM 20-42-03)
- Post Plate Bake (per OPM 20-42-03)
- LHE Cadmium Plate (as per OPM 20-42-01)
- Post Plate Bake (per OPM 20-42-01)
- Application of BMS 10-11 primer and BMS 10-60 Grey top coat

When shop servicing was completed, the pin was then fitted to the LH MLG Assembly Part No. 65-73761-127, S/N 3873 and installed on EI-CDE. Prior to this incident the pin had accumulated a further 9,806 cycles on EI-CDE, making a total of 23,922 cycles since new.

1.2.2. Background

The aircraft manufacturer stated that there had been five such fractures of this part reported to them since June 2002. These occurred at the shaft relief radius and were caused by stress corrosion cracking.

A common factor was that a corrosion inhibiting compound (CIC) JC5A had been detected on these parts. The design of the pin assembly was carried through from the 737-200 and 300 series to the 737-500 series. The 737-400 trunnion pin is exempt from the JC5A issue, as the pin is installed with grease and the joint is lubricated in service.

Fracture at the inboard end of the shank could result in gear collapse due to loss of the reaction link connection. However, the aircraft manufacturers say that no trunnion pin fracture has ever resulted in gear collapse. Fracture of the outboard end of the trunnion pin results in the retract actuator being disconnected from the gear. This impacts the flight crew's ability to retract the gear.

Recent discovery of JC5A related corrosion at the inboard end thread relief led to the initiation of a Service Related Problem (SRP). However, the last reported fracture at the thread relief was in 1987.

In May 2001, the manufacturer issued an Operator Message informing all operators of the discontinuance of JC5A as a corrosion inhibiting material in the landing gear assembly. JC5A, in the presence of moisture, would decompose and produce decomposition by-products. These in turn would attack the primer first, and then the cadmium plating underneath, resulting in the accelerated corrosion rates of the base metal substate. They have had many design improvements to try and improve the corrosion resistance of this part.

1.3. Technical Analysis

The pin was removed from the landing gear and sent to the aircraft manufacturer for investigation and laboratory report. The manufacturer said that the pin material was per specification and that no JC5A corrosion-inhibiting compound was detected in the transition radius. The results of their analysis include the following:

The pin was fractured at the transition radius between the shaft and retract flange **(APPENDIX A)**. *The surfaces of the pin at and near the fracture were heavily oxidized and corroded and much of the chrome plating in these areas was missing. Due to experience with similar trunnion pin fractures in the past where the corrosion inhibiting compound JC5A has been implicated in accelerating the corrosion process, a chemical analysis was performed on deposits taken from the transition radius as well as nearby locations. There was no indication that JC5A was present.*

The fracture surfaces on the separated retract flange section can be seen in **(APPENDIX B).** *The fracture surfaces were cleaned in the laboratory due to the heavy oxidation and corrosion products. The fracture surfaces exhibit three separate planes of fracture propagation, which indicates three separate initiation or origin sites. Each fracture plane exhibits a blocky, rough thumbnail shaped region on the fracture surface emanating from the outer surface of the pin.*

This surface morphology is consistent with stress corrosion cracking (SCC). All three fracture planes exhibit the flat grainy surface appearance with directional flow lines that are typical of final fracture in high strength steel beyond the SCC regions.

The primary fracture origin as well as the two other secondary fracture origins are located in or adjacent to the transition radius where much of the chrome plating was missing. The severity and number of through-thickness cracks in the plating **(APPENDIX C)** *indicates poor quality and adhesion characteristics. Additionally, the thickness of the plating is approximately 0.013 inches. Even though the design drawing specification allows for 0.003 inches minimum for the chrome plating, the 0.013 inch layer indicates that the pin might have been reworked or overhauled.*

The aircraft manufacturer stated that the chrome plate is called out on the drawing to be 0.003- 0.005 inch finished thickness after grinding. The manufacturer also stated that a chrome plate run-out of 0.02 - 0.07 inch at the extremities of the shank was specified in the overhaul manual. However, the specification will be revised to 0.05 - 0.07 inch and this will be reflected in the next revision of the Overhaul Manual scheduled for July 2005.

1.4 Overhaul Contractor Comment

The Contractor stated that following examination of the pin they concluded that the primary corrosion origin was located in the area between the flange and the pin shaft and is in an area beyond the chrome run-out area not designed to be covered by chrome plating. This area would normally have cadmium or cadmium-titanium (Ti-Cad) plating treatment only, followed by application of a protective primer. They state that, in their opinion, the degradation of the cadmium plate is due to the previous use of JC5A inhibiting compound. They also state that Overhaul Manual 32-16-01 allows for a maximum of 0.015 inch of chrome plate on the steel shank. This contractor had carried out the chrome and cadmium plating at overhaul and stated that chemical analysis records taken just prior to plating taking place showed the shop plating tank to be within specified limits.

Their experience was that there was a much better performance from the 737-400 arrangement, but that they have seen pins cracking and corrosion problems on the actuator attach lugs of these also. Mastinox or the new approved product, Corban, help greatly in this application but in themselves may not be a full solution to the problem. They have seen pins with corrosion which would originally have been installed with Mastinox.

1.5 Follow-up Tests and Operator Action

Following the incident the Operator approved an Engineering Order Inspection (EOI) applicable to eight 737-500 series and three 737-400 series aircraft. In the case of the former, the trunnion pins were to be replaced with serviceable pins, and to be installed with corrosion inhibiting material Corban 27. All the work was completed by December 2003. The 400 series trunnion pin was exempt from the JC5A issue as the trunnion pin is installed with grease and the joint is relubricated in service.

There is a grease nipple on the trunnion link and beam arm on the 400 series, which is not on the 200, 300 or 500 series. However, the three 400 series aircraft were also inspected at this time. All removed pins were routed to the landing gear shop for non-destructive testing (NDT), repair and/or overhaul. Of the 22 pins removed, only 3 were found to have chrome damage. Approximately 70% of the pins were found to be corroded in other areas, and deemed beyond economical repair.

Four pins did not pass the "magnetic particle" crack detection examination and were rejected. The Operator has now placed emphasis on the elimination of pressure washing in the wheel wells and the re-application of grease after any washing taking place.

1.6 Manufacturer Action

The Manufacturer received 12 reports of JC5A related corrosion on components of the MLG including trunnion pins and released a Service Bulletin (SB) in August of 2004, which divided the 737 fleet into aircraft delivered with JC5A and not yet overhauled, and those aircraft that have been overhauled by repair facilities that have used JC5A. Compliance for both groups of airplanes will be an inspection 6 months after SB release or 48 months from delivery/overhaul, whichever is later.

The SB states that, "*JC5A has been found to decompose in the presence of moisture. This decomposition can make chemical by-products, which cause damage to the primer. The primer gives protection to the titanium-cadmium (TI-Cad) plating which is the primary protection against corrosion of the base metal.*"

"If corrosion of the part is found (on inspection) *then replace the damaged part. Damaged parts can be overhauled and repaired."*

2. ANALYSIS

The fracture was adjacent to the transition radius where the cadmium plating/primer, applied at overhaul, was absent, leaving the base metal to corrode in that area. Although not related to the primary cause of the pin failure, the severity and number of through-thickness cracks found in the chrome plating during laboratory examination, indicates that there may have been some problem with the plating process at overhaul. However, the thickness of the plating was within manufacturers specification. The pin had completed more than 60% of its overhaul cycle period and it is difficult to estimate the extent of the in-service deterioration in that time.

There was no evidence of JC5A on the pin during the manufacturers examination. On removing and installing the pin following overhaul in 1998, JC5A was almost certainly applied, as this was the manufacturer's approved substitute for Mastinox and was in use in the shop. The corrosion could have commenced in the JC5A environment and continued later after the JC5A had been washed away through landing gear pressure washing. Following the EOI, the Operator replaced approximately 70% of the trunnion pins in the fleet, including pins of the 737-400 aircraft.

The removed pins were deemed to be beyond economical repair due to corrosion found in other areas of the pin. From the contractor's experience, it is not altogether clear that JC5A is the sole contributor to corrosion found on trunnion pins.

The 400 series has a facility to grease the pin in service but with the absence of this facility on the 500 series it is likely that corrosion of the pin will not be eliminated, despite the use of Mastinox or Corban corrosion inhibitor. In view of this, perhaps the Service Bulletin should have stated that, depending on their condition, the pins may be repaired.

3. CONCLUSIONS

(a) Findings

3.1 The pin fracture was due to stress corrosion cracking.

3.2 Fracture initiation occurred in and adjacent to the shaft-to-flange radius.

3.3 The Manufacturers examination indicated that the quality of the chrome plating on the shaft, conducted during overhaul in 1998, appears not to have been of the appropriate standard. After 9,806 cycles in service there were numerous areas on the shaft where the chrome plating was absent.

3.4 At the time of the lab examination, no JC5A corrosion-inhibiting compound was detected in the transition radius of the pin.

3.5 There was a lack of primer or cadmium plating at the fracture origin.

(b) Causes

3.6 The primary fracture, due to Stress Corrosion Cracking (SCC), may have been caused by the previous use of corrosion inhibiter JC5A.

4. SAFETY RECOMMENDATIONS

4.1 The Manufacturer should amend Service Bulletin 737-32A1367 Page 6, "Action" paragraph, to read, "*depending on the damage found on inspection, the parts may be overhauled and repaired. Any damage or repairs done that exceed the current dimensional limits specified in the Overhaul Manual requires the operator to contact the Aircraft Manufacturer for proper disposition.*" **(SR 02 of 2005)**

4.2 Due to the initiation of corrosion not associated with the previous use of JC5A, but initiated by other possible causes of corrosion, the Manufacturer should review the requirement for a more frequent inspection of this pin. **(SR 03 of 2005)**

APPENDIX A

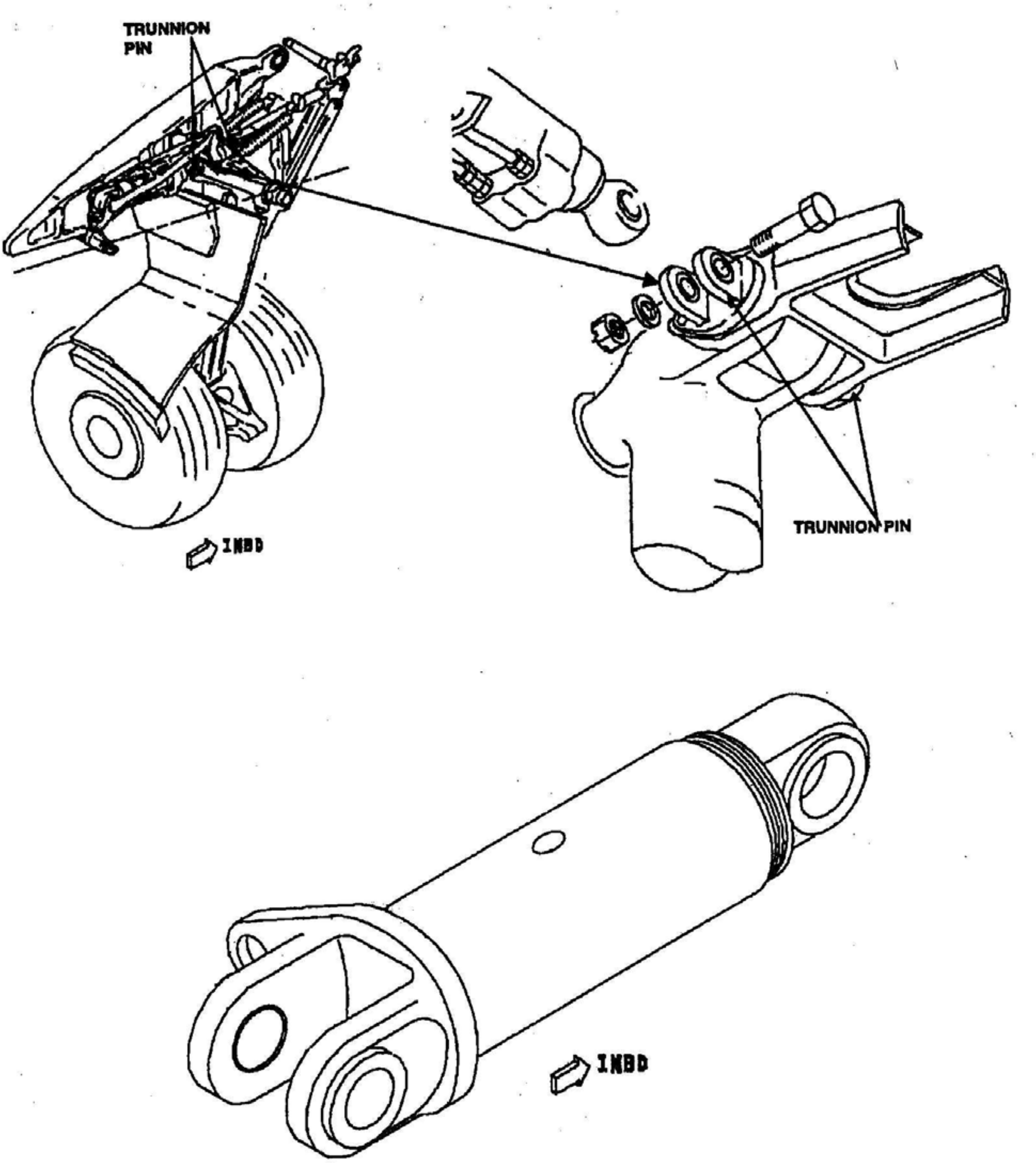

Figure 1. Illustration Showing a Trunnion Pin in the 737 Left Main Landing Gear (Right Main Landing Gear Opposite)

Courtesy of The Boeing Company

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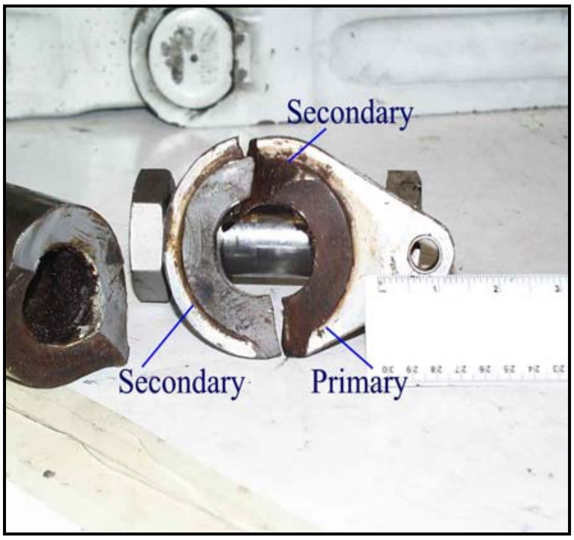
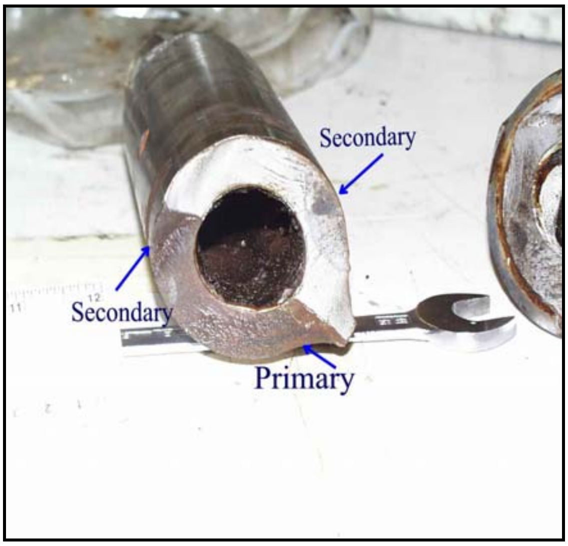
APPENDIX B

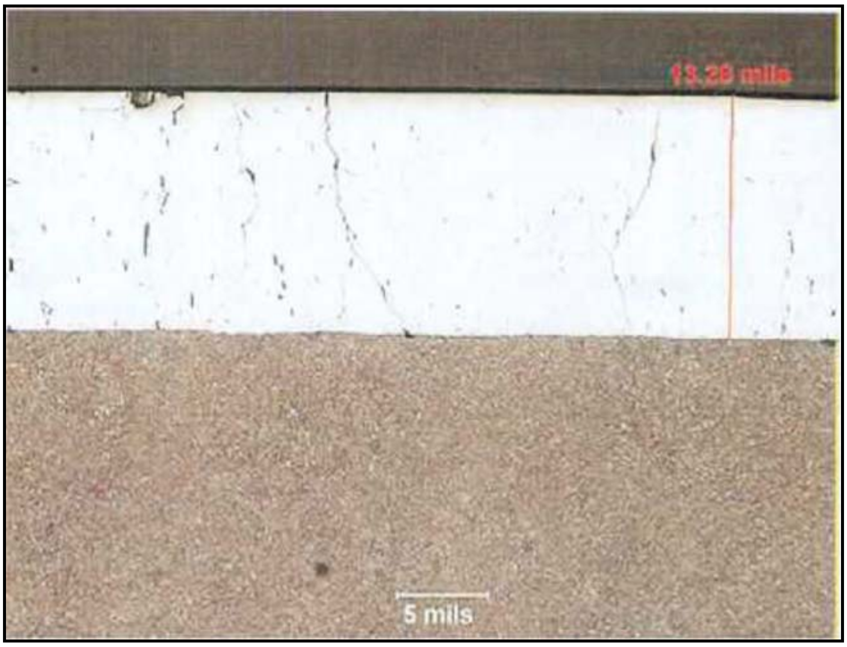
The above photos show the fractured pin shaft on the left with a detail view of the detached plating on the right.





The photo on the left shows the fracture surfaces on the retract flange sections of the pin. There were three Stress Corrosion Crack (SCC) origins and fields of propagation, which are denoted by the arrows. The photo on the right shows the corresponding fracture surface of the shaft section of the pin.

APPENDIX C



Cross section through the chrome plating showing the through-thickness cracks.
(Courtesy of The Boeing Company)