Air Accident Investigation Unit Ireland

SYNOPTIC REPORT

SERIOUS INCIDENT
Boeing 737-800, EI-GXG
Frankfurt-Hahn Airport

29 January 2019

An Roinn Iompair
Turasóireachta agus Spóirt
Department of Transport,
Tourism and Sport

Foreword

This safety investigation is exclusively of a technical nature and the Final Report reflects the determination of the AAIU regarding the circumstances of this occurrence and its probable and contributory causes.

In accordance with the provisions of Annex 13[1] to the Convention on International Civil Aviation, Regulation (EU) No 996/2010[2] and Statutory Instrument No. 460 of 2009[3], safety investigations are in no case concerned with apportioning blame or liability. They are independent of, separate from and without prejudice to any judicial or administrative proceedings to apportion blame or liability. The sole objective of this safety investigation and Final Report is the prevention of accidents and incidents.

Accordingly, it is inappropriate that AAIU Reports should be used to assign fault or blame or determine liability, since neither the safety investigation nor the reporting process has been undertaken for that purpose.

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[1] **Annex 13**: International Civil Aviation Organization (ICAO), Annex 13, Aircraft Accident and Incident Investigation.
[2] **Regulation (EU) No 996/2010** of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation.
[3] **Statutory Instrument (SI) No. 460 of 2009**: Air Navigation (Notification and Investigation of Accidents, Serious Incidents and Incidents) Regulations 2009.

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In accordance with Annex 13 to the Convention on International Civil Aviation, Regulation (EU) No 996/2010 and the provisions of SI No. 460 of 2009, the Chief Inspector of Air Accidents, on 14 March 2019, appointed Kate Fitzgerald as the Investigator-in-Charge to carry out an Investigation into this Serious Incident and prepare a Report.

Aircraft Type and Registration:	Boeing 737-800, EI-GXG	
No. and Type of Engines:	2 x CFM56-7B26E	
Aircraft Serial Number:	44853	
Year of Manufacture:	2018	
Date and Time (UTC)[4]:	29 January 2019 @ 16.54 hrs	
Location:	Frankfurt-Hahn Airport (EDFH)	
Type of Operation:	Commercial Air Transport, Scheduled Passenger	
Persons on Board:	Crew – 6	Passengers – 128
Injuries:	Crew – Nil	Passengers – Nil
Nature of Damage:	Substantial	
Commander's Licence:	Airline Transport Pilot Licence (ATPL) Aeroplane (A), issued by the Irish Aviation Authority (IAA)	
Commander's Age:	38 years	
Commander's Flying Experience:	6,710 hours, of which 6,536 hours were on type	
Notification Source:	Aircraft Operator	
Information Source:	Air Safety Report submitted by the Commander, Initial Field Investigation Report supplied by the Bundesstelle für Flugunfalluntersuchung - German Federal Bureau of Air Accident Investigation (BFU)	

[4] **UTC**: Co-ordinated Universal Time. All timings in this report are quoted in UTC, which was local time -1 hour on the date of the occurrence.

SYNOPSIS

After a take-off from Frankfurt-Hahn Airport, the aircraft Commander called for *'gear-up'*. During gear retraction, the Flight Crew heard an unusual noise. This was followed by the aircraft rolling to the left, and the illumination of the left-hand landing gear red and green indication lights. The Flight Crew completed the '*GEAR DISAGREE*' checklist and elected to return to Frankfurt-Hahn. The aircraft landed normally, but as a precautionary measure the Airport Rescue and Firefighting Service attended the aircraft. The aircraft taxied to a parking stand where they were informed by Air Traffic Control (ATC) that a small, metallic piece from the aircraft had been found on the runway. Damage to the upper surface of the left wing was observed by the Crew and passengers. No injuries were reported to the Investigation. There was no fire.

NOTIFICATION

The Operator notified the BFU, as the Safety Investigation Authority in the state of occurrence, and the AAIU of this Serious Incident. On the 6 March 2019, the BFU, in accordance with ICAO Annex 13, Section 5.1.2, delegated the Investigation of this Serious Incident to the AAIU, as the Safety Investigation Authority (SIA) of the State of Registration and of the Operator. The BFU appointed an accredited representative (ACCREP) to the Investigation.

1. FACTUAL INFORMATION

1.1 History of the Flight

At approximately 18.00 hrs on the 29 January 2019, the aircraft departed Frankfurt-Hahn Airport (EDFH). When established in the climb, the Commander called for *'gear-up'*. During gear retraction, the Flight Crew heard an unusual noise. This was followed by the aircraft rolling to the left, and the illumination of the left-hand landing gear red and green indication lights. The Flight Crew trimmed the aircraft to reduce the roll and attempted unsuccessfully to engage Autopilot Channel A. The Flight Crew then actioned and completed the *'GEAR DISAGREE'* checklist in the aircraft Quick Reference Handbook (QRH). ATC directed the Flight Crew to continue to Flight Level (FL) 100 and turn right at their discretion. The Flight Crew made a further, successful attempt to engage the Autopilot Channel A. After reviewing the situation, the Flight Crew elected to return to EDFH, briefed the Cabin Crew and following ATC clearance, took up a holding pattern.

Whilst in the hold, the Flight Crew discussed the situation with ATC and requested that the Airport Rescue and Firefighting service be in attendance for their arrival, but they did not declare an emergency. On final approach, at seven nautical miles (nm) from EDFH, the landing gear was selected to down. All indications were normal, so the approach and landing proceeded as planned. No abnormal indications were observed during roll-out and taxi. When the aircraft arrived at its assigned gate, the tower controller informed the Flight Crew that a small piece of metal from the aircraft had been found on the runway. Damage to the upper surface of the left wing of the aircraft was observed by the passengers and Crew.

The passengers and Crew disembarked the aircraft normally. The part found on the runway was subsequently confirmed to be part of the skin from the upper surface of the left wing.

1.2 Injuries to Persons

No injuries were reported to the Investigation

1.3 Personnel Information

1.3.1 Commander

Age:	38 years
Licence:	ATPL(A) issued by the IAA on 15 April 2014
Total all Types:	6,710 hours
Total on Type:	6,536 hours
Medical:	Class 1 issued by the CAA, Netherlands, valid until 8 March 2019

1.3.2 First Officer

Age:	28 years
Licence:	CPL(A) issued by the IAA on 7 November 2018
Total all Types:	898 hours
Total on Type:	605 hours
Medical:	Class 1 issued by the CAA, Austria, valid until 21 March 2020

1.4 Aircraft Information

The aircraft was a Boeing 737-800, powered by two CFM56-7B26E turbofan engines and manufactured in 2018. It was operated on a Certificate of Airworthiness which was issued by the IAA on the 29 September 2018 and its associated Airworthiness Review Certificate had an expiry date of 28 September 2019.

1.4.1 Main Landing Gear

The general arrangement of the Main Landing Gear (MLG) on the subject aircraft type is shown in **Figure No. 1**. The area of interest in this occurrence is highlighted by the red oval marking. **Note: Figure No. 1** and **Photo No. 2** depict the right-hand gear which is the mirror image of the subject left-hand gear.

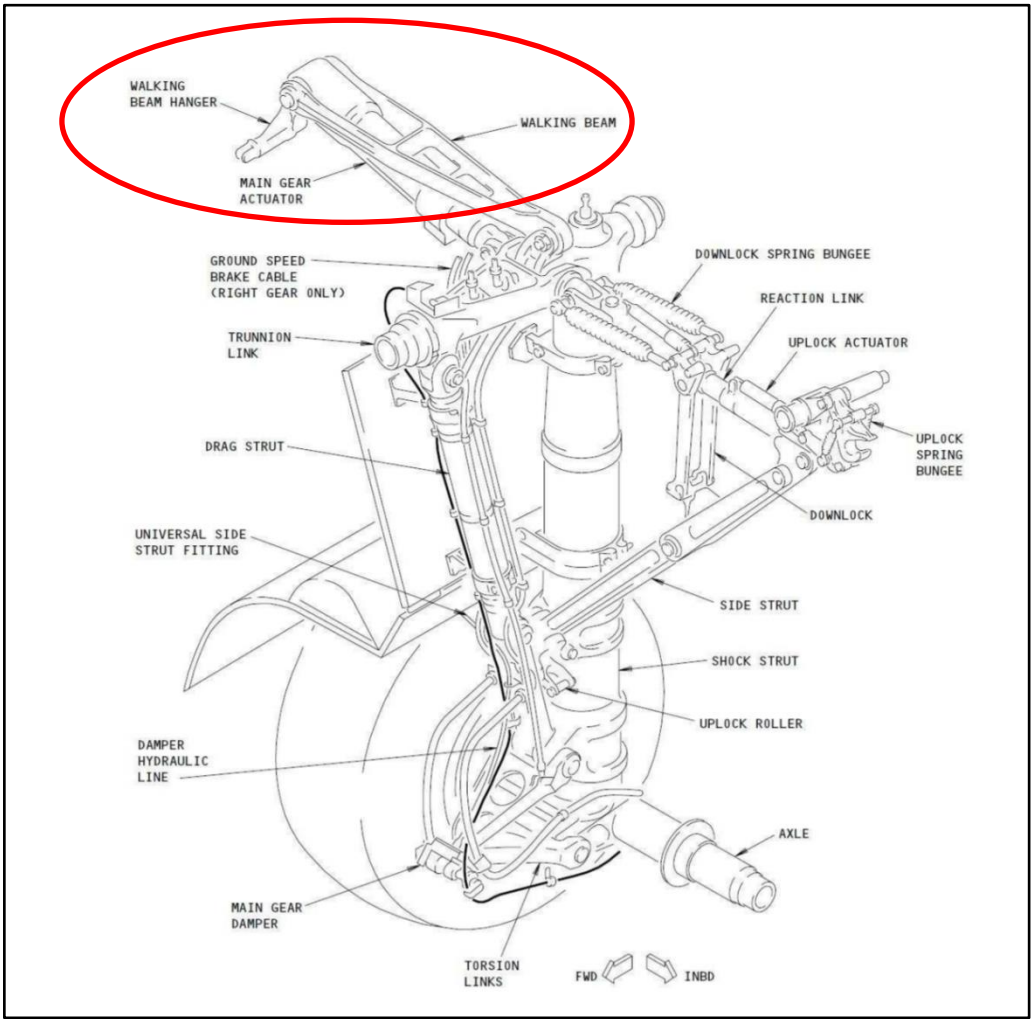

Figure No. 1: Main landing gear assembly with walking beam and walking beam hanger highlighted (Aircraft Manufacturer)

The MLG is extended and retracted by a hydraulic main gear actuator. A walking beam, attached to the actuator at one end, and to the upper part of the MLG at the other end, reacts against the force of the actuator when it is pressurised and extending, causing the MLG to retract into the main wheel well. The walking beam is connected to the aircraft structure by a walking beam hanger (**Photo No. 1**). Maintenance records did not indicate that any maintenance had been carried out on the walking beam attachment mechanism since delivery of the aircraft.

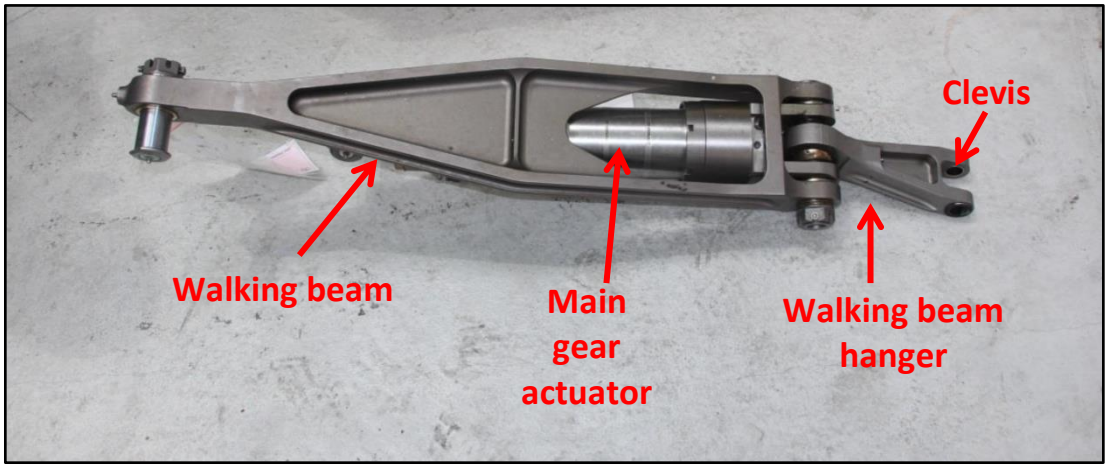

Photo No. 1: General layout of walking beam and walking beam hanger

A pivot pin located in the clevis of the walking beam hanger connects the hanger to the aircraft structure and is secured by a castellated nut and cotter pin (split pin) (**Photo No. 2**). The castellated nut has a slightly deformed thread which acts as a self-locking feature. The Aircraft Manufacturer informed the Investigation that the *'[Cotter] PIN, P/N BACP18BC04A14P, is considered to be a secondary means of preventing migration of PIN, P/N 161A7301-1, with NUT [self-locking], CASTELLATED, P/N BACN11N112CD, representing the primary means of retention.'*

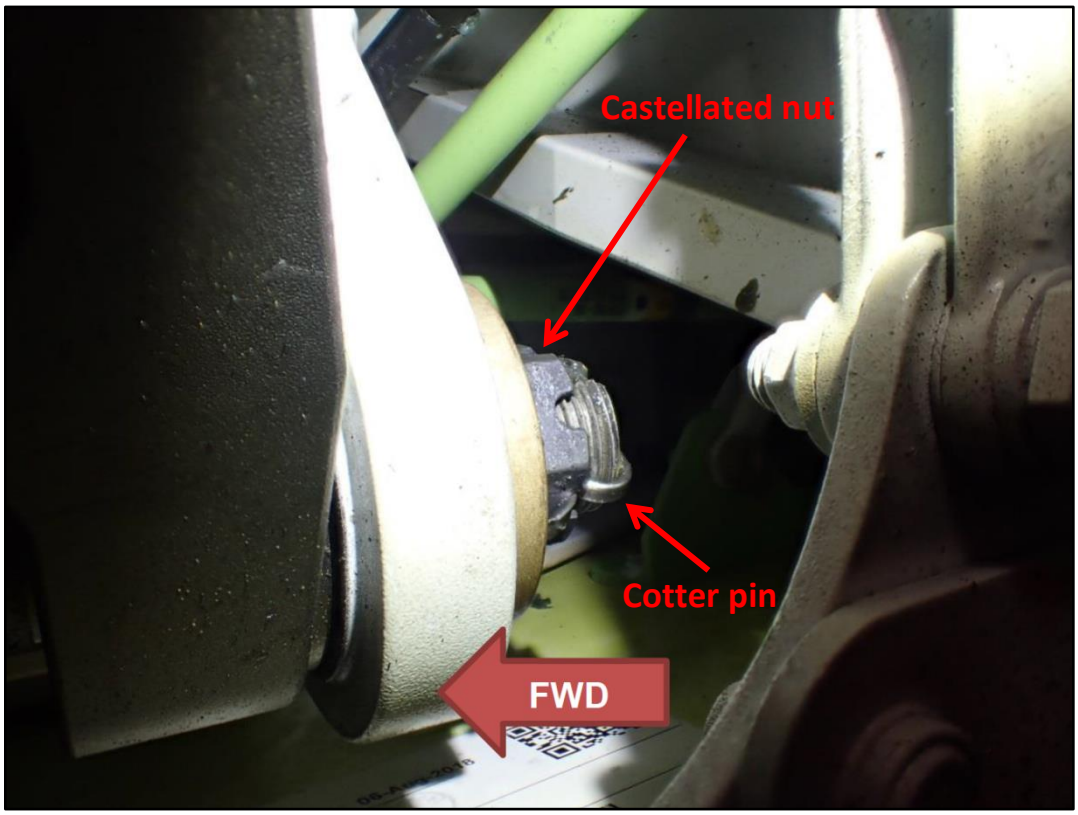

Photo No. 2: Castellated nut and cotter pin arrangement (in right wing of aircraft)

1.5 Damage to Aircraft

The left-hand main landing gear walking beam hanger was found detached and had punctured the upper surface of the wing in the area of the landing gear bay cover (**Photo No. 3**). The forward support position of the walking beam hanger clevis exhibited slight damage (**Photo No. 4**), which appeared to be an imprint of the threaded part of the pivot pin. The pivot pin and associated tang washer (**Photos No. 5** and **6**) were found separately in the landing gear wheel well. The thread of the pivot pin appeared to show some minor damage. The castellated nut and cotter pin were not found. In addition, one fractured hydraulic pipe was found and the rubber coating of two hydraulic hoses sustained damage.

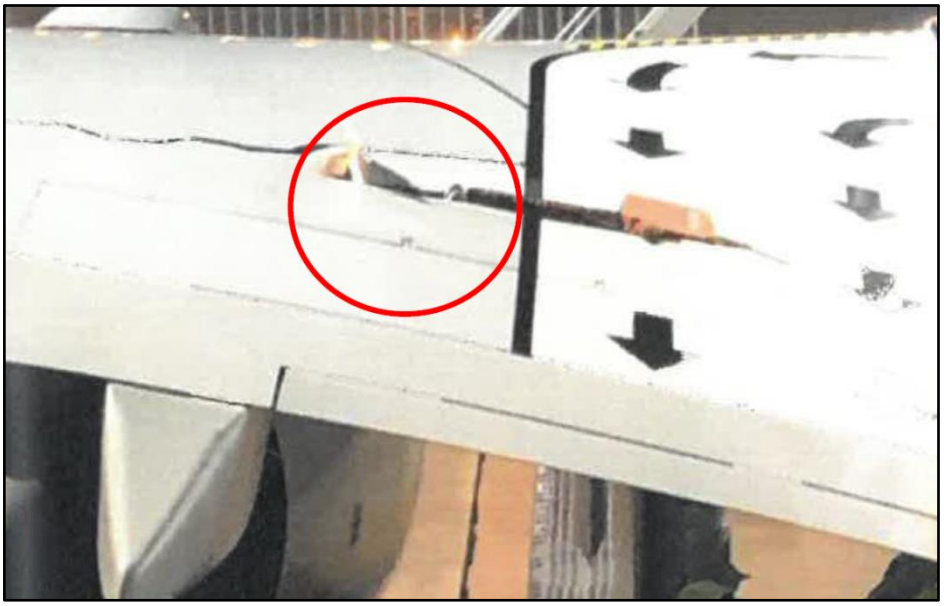

Photo No. 3: Damage to upper surface of the left wing

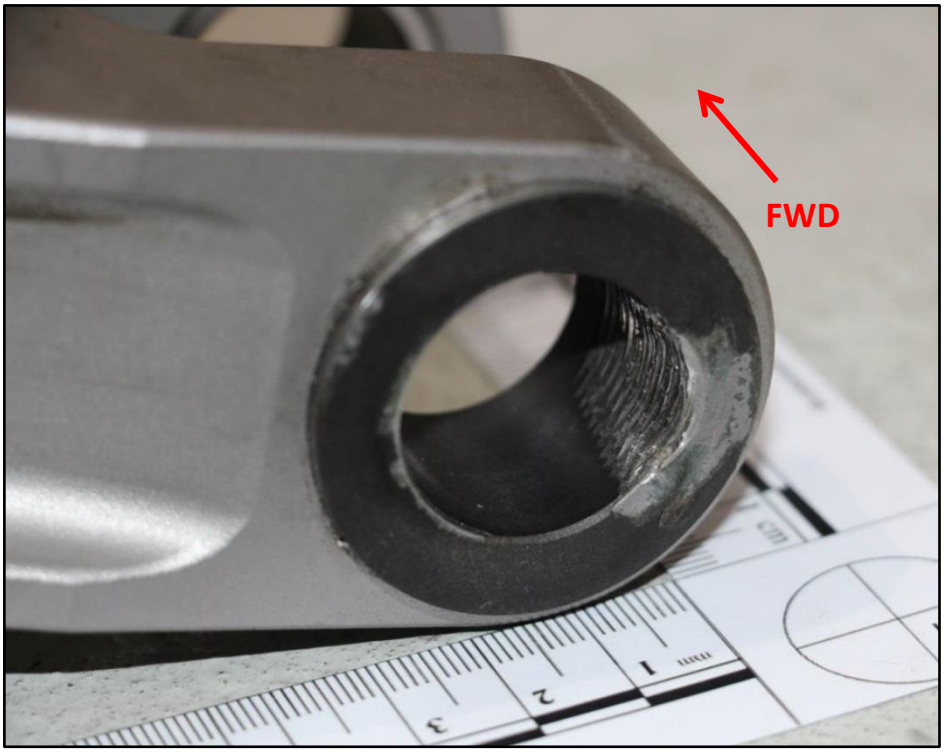

Photo No. 4: Damage to forward support position of walking beam hanger clevis

Photo No. 5: Pivot pin and tang washer with label attached

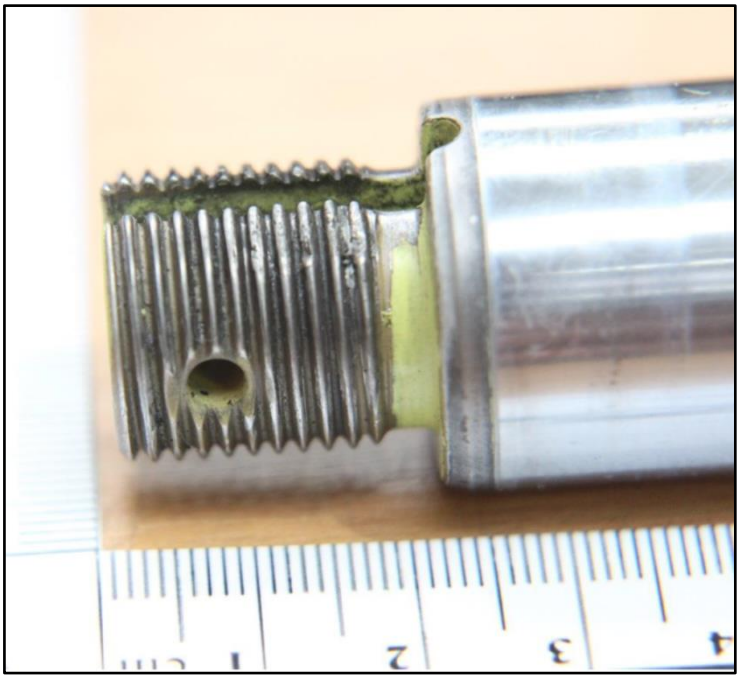

Photo No. 6: Threaded end of pivot pin showing machined hole for cotter pin and tang washer slot

1.6 Initial BFU Field Investigation

An investigator from the BFU (Germany) examined the occurrence aircraft and the parts that had become separated. The investigator concluded that the pivot pin and tang washer had been correctly positioned in the walking beam hanger as there were witness marks on the clevis of the walking beam hanger. The BFU investigator concluded that it was most likely that the castellated nut and cotter pin had been incorrectly installed, or not installed at all. The BFU investigator noted that the condition of the cotter pin hole on the screw thread supported this hypothesis.

The BFU investigator also noted that the location of the installed castellated nut and cotter pin was difficult to access and inspect.

1.7 Manufacturer's Investigation

The Aircraft Manufacturer undertook a number of investigative actions in order to determine if other aircraft were affected, to assist in root cause analysis, and to seek to prevent a recurrence. These actions are described below.

The Aircraft Manufacturer also wished to carry out a laboratory analysis of the walking beam hanger pivot pin and tang washer. However, this was not possible as the pivot pin and tang washer were lost by the Operator. The Aircraft Manufacturer's investigation therefore concluded that they could not establish a definitive root cause. However, the Aircraft Manufacturer believed that it was possible that the inspection of the castellated nut and cotter pin on the subject aircraft had not been carried out effectively on the production line, before the aircraft was released to service.

1.7.1 Fleet Inspection

On the 19 February 2019, in response to the subject occurrence, the Aircraft Manufacturer issued a Multi-Operator Message (MOM). This recommended that operators of affected Boeing 737 NG and Boeing 737 Max aircraft (serial numbers 7150 – 7420) carry out a visual check of the MLG actuator, linkage and actuator attaching hardware in accordance with the Aircraft Maintenance Manual (AMM) to ensure that all hardware was correctly installed. No findings were reported by operators. The Aircraft Manufacturer also carried out a check of the left-hand and right-hand MLG of all affected aircraft on their production line (approximately 30 aircraft) to verify the correct installation of the relevant MLG hardware. There were no findings as a result of this check.

A review of in-service investigations did not identify any previous in-service occurrences of this nature that had been reported to the Manufacturer.

1.7.2 Installation of subject Castellated Nut and Cotter Pin

The Aircraft Manufacturer reviewed all of the records for the subject aircraft relating to the installation of the castellated nut and cotter pin on the production line. The Aircraft Manufacturer informed the Investigation that:

- On 4 September 2018 a '*CRITICAL REQUIREMENT*' inspection of the cotter pin installation was stamped complete with no exceptions.

- The recorded applied (nut) torque was 271 in-lbs which was within the range 250-300 in-lbs specified by the Aircraft Manufacturer's relevant Product Sheet Data List.

- The torque wrench used for installation was properly calibrated with no calibration failures recorded for each of the tool's historical inspection intervals.

- On 10 September 2018 a '*shakedown*' inspection of the left-hand Main Landing Gear and left-hand wing interior was performed, with no related exceptions noted.

- On 18 September 2018 an airworthiness inspection of the left-hand wheel well, landing gear, and wing (inboard) interior was performed, with no related exceptions noted.

Photographs of the tang washer (**Photos No. 7** and **8**) provided to the Aircraft Manufacturer by the Operator appear to show that the surface treatment on one side of the tang washer had been removed due to contact with the adjacent bushing. However, the opposite side of the tang washer (i.e. the nut side), which should show similar wear to the surface treatment due to contact with the castellated nut does not appear to show any wear. The Aircraft Manufacturer believes that this may indicate that the castellated nut was not fully seated against the tang washer, and that the torque wrench may have registered the correct applied torque without the components being correctly seated.

The Aircraft Manufacturer informed the Investigation that, '*It's possible that the 'deformed' part of the thread* [in the nut] *may have been slightly out of tolerance and caused excessive run on torque to be applied or that there may have been some sort of anomaly with the pin threads that caused the nut to require excessive torque to seat. Without the hardware to examine,* [Aircraft Manufacturer] *can only speculate as to the cause.'*

Photo No. 7: Tang Washer showing evidence of surface in contact with adjacent bushing

Photo No. 8: Tang Washer, no evidence of surface contact with adjacent castellated nut

1.7.3 Engineering and Production Line Checks

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The Aircraft Manufacturer reviewed all production line records and found three related reports:

1. One record in 2013 of an incorrectly bent cotter pin (insufficient bend)
2. One record in 2016 of a missing pin which was not installed due to a planning sequencing/precedence error
3. One record in 2017 of a migrating pivot pin due to a missing nut/cotter pin

A review of the relevant engineering drawings, associated functional tests, and installation plans[5] was also carried out and no anomalies were identified. The Aircraft Manufacturer noted that the MLG functional test would not detect a mechanical problem with the pin installation unless the pin had partially or fully migrated out of its position prior to, or during functional testing.

The Aircraft Manufacturer interviewed Shop and Quality Assurance supervisors and mechanics on the production lines. They stated that the installation of the parts in question was straightforward and did not present any particular challenges. However, they also stated that, due to access issues, they applied the torque to the head of the pin and held the nut in place with an open-ended wrench.

[5] **Installation Plans:** There are specific planning operations to install the pivot pin, apply torque, and install and inspect the cotter pin installation in the castellated nut.

When torque was applied to the head of the pin, a torque wrench adapter, which is a standard tool that fits the two machined flats on the head of the pin, was used. This method was also observed during an audit of the walking beam installation process and was found to be different to the Aircraft Maintenance Manual process which stated *'[…] Tighten the nut [6] to 250 in-lb (28.25 N.m) – 300 in-lb (33.9 N.m)'.*

The investigation relating to this process non-conformance concluded that '*It is acceptable to Engineering to apply torque to the head of the pin in lieu of the nut, provided the following condition applies; The 161A7301-1 PIN, BACN11N112CD NUT, 161A7304-3 TANG WASHER, and BACP18BC04A14P (cotter) PIN are present, and properly installed.'*

The Aircraft Manufacturer informed the Investigation that the walking beam installation plan requirements contain approval for electronic torque measurement. This means that the applied torque is recorded and transferred electronically by a data collection unit.

In addition, the Aircraft Manufacturer reviewed the kits used on the production line and confirmed that they contained the correct standard of hardware. Nuts from these kits were randomly selected and checked. All of the checked nuts showed the required self-locking characteristics.

2. ANALYSIS

The failure of a main landing gear component on a commercial aircraft is significant, and as such, this occurrence was classified as a Serious Incident by the AAIU. In this instance, more significant damage or injury was avoided because the aircraft was still controllable during the landing, roll-out and taxi phases, and the Flight Crew were able to park the aircraft and disembark the passengers normally.

Initial field enquiries carried out by the BFU, concluded that the probable cause of the failure was that the castellated nut and cotter pin used to secure the walking beam hanger to the aircraft structure had either been improperly installed or not installed at all (these parts were not found at the scene of the occurrence). This conclusion was supported by the evidence gathered by the Aircraft Manufacturer, who carried out a full review of the relevant production line processes, engineering drawings and associated data.

The fact that following the occurrence the pivot pin and tang washer were lost, meant that a full laboratory analysis of these components was not possible, and this may have provided further evidence. However, the Investigation is satisfied that the most probable cause has been identified: that during the manufacturing of the aircraft, the castellated nut and cotter pin were either not installed, or installed incorrectly, and that this was not identified on the production line. Production line records indicate two previous instances (in 2016 and 2017) where the installation of the castellated nut and cotter pin were missed. However, in these instances, subsequent production line inspections identified the error before the aircraft was released to service.

Following the occurrence, the Aircraft Manufacturer inspected the castellated nut and cotter pin installations on all of the aircraft of this type in their custody, i.e. aircraft that had not yet been delivered to customers. All of the castellated nuts and cotter pins were found to be installed correctly. In addition, no further issues were reported by affected Boeing 737 NG and Boeing 737 Max operators following an MOM which recommended that they carry out a visual check of the MLG actuator, linkage and actuator attaching hardware. Furthermore, no previous in-service occurrences had been reported.

The Investigation notes that the Aircraft Manufacturer's own Investigation identified that although mechanics on the production line reported no issues with the installation of the castellated nut and cotter pin, they were not using the approved process, and due to access issues were applying torque to the head of the pivot pin, using a standard torque wrench adapter, rather than applying the torque to the castellated nut. The Aircraft Manufacturer's engineering team subsequently reviewed and approved the method that was being used by the mechanics.

In summary, although this appears to be an uncommon occurrence, it does serve to remind aircraft manufacturers and maintenance organisations of the importance of inspection tasks during assembly and maintenance, and the damage that can be caused if these tasks are missed, or incorrectly executed.

3. CONCLUSIONS

13 **3.1 Findings**

1. The airworthiness certification for the aircraft was valid.

2. The Flight Crew licences and medical certificates were valid and current.

3. Post-occurrence inspections of the aircraft and recovered components indicated that the pivot pin intended to attach the left-hand walking beam hanger to the aircraft had separated from the walking beam hanger and was found in the aircraft left-hand wheel well.

4. The castellated nut and cotter pin intended to secure the pivot pin were not found.

5. Photographic evidence of the tang washer found with the pivot pin showed some evidence of damage to the surface of one side of the washer which may have been caused by contact with the adjacent bushing. The other side of the tang washer (which should have been in contact with the castellated nut) did not appear to show any damage

6. The Aircraft Manufacturer confirmed that a critical requirement of the installation of the castellated nut and cotter pin on the production line was stamped as complete with no exceptions.

7. The Aircraft Manufacturer's records indicate that the torque wrench used to carry out the installation was correctly calibrated, and the torque applied was within the range specified on the Aircraft Manufacturer's relevant Product Sheet Data List.

3.2 Probable Cause

Migration of the pivot pin from the walking beam hanger in the left main landing gear assembly.

3.3 Contributory Cause(s)

1. The pivot pin was not held securely in the correct position.
2. Production line inspections did not identify that the castellated nut and cotter pin intended to hold the pivot pin securely in position, were either not installed or installed incorrectly.

4. SAFETY RECOMMENDATIONS

This Investigation does not sustain any Safety Recommendations.

- END -

In accordance with Annex 13 to the Convention on International Civil Aviation, Regulation (EU) No. 996/2010, and Statutory Instrument No. 460 of 2009, Air Navigation (Notification and Investigation of Accidents, Serious Incidents and Incidents) Regulation, 2009, the sole purpose of this investigation is to prevent aviation accidents and serious incidents. It is not the purpose of any such investigation and the associated investigation report to apportion blame or liability.

A safety recommendation shall in no case create a presumption of blame or liability for an occurrence.

Produced by the Air Accident Investigation Unit

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