AI2019-6

AIRCRAFT SERIOUS INCIDENT INVESTIGATION REPORT

KOREAN AIRLINES CO., LTD.
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September 26, 2019

Japan Transport Safety Board

The objective of the investigation conducted by the Japan Transport Safety Board in accordance with the Act for Establishment of the Japan Transport Safety Board (and with Annex 13 to the Convention on International Civil Aviation) is to prevent future accidents and incidents. It is not the purpose of the investigation to apportion blame or liability.

Nobuo Takeda
Chairman
Japan Transport Safety Board

Note:

This report is a translation of the Japanese original investigation report. The text in Japanese shall prevail in the interpretation of the report.

AIRCRAFT SERIOUS INCIDENT INVESTIGATION REPORT

AIRCRAFT DISABLED TO CONTINUE TAXIING DUE TO FRACTURED LANDING GEAR AXLE KOREAN AIRLINES CO., LTD. BOEING 777-300, HL7573 AT NARITA INTERNATIONAL AIRPORT, JAPAN AROUND 12:43 JST, JUNE 29, 2018

August 30, 2019

Adopted by the Japan Transport Safety Board

Chairman	Nobuo Takeda
Member	Toru Miyashita
Member	Yoshiko Kakishima
Member	Yuichi Marui
Member	Yoshikazu Miyazawa
Member	Miwa Nakanishi

1. PROCESS AND PROGRESS OF THE AIRCRAFT SERIOUS INCIDENT INVESTIGATION

1.1 Summary of the Serious Incident	On Friday, June 29, 2018, a Boeing 777-300, registered HL7573, operated by Korean Airlines Co., Ltd., had the right main landing gear aft axle fractured when landing at Narita international airport. Consequently, the aircraft was forced to halt and was unable to continue taxiing on the taxiway.
1.2 Outline of the Serious Incident Investigation	The occurrence covered by this report falls under the category of "landing gear is damaged and thus flight of the subject aircraft could not be continued" as stipulated in Article 166-4 (viii) of the Ordinance for Enforcement of the Civil Aeronautics Act of Japan (Ordinance of Ministry of Transport No. 56 of 1952), and is classified as a serious incident. The Japan Transport Safety Board designated an investigator-in-charge and three investigators on June 29, 2018 to investigate this serious incident. An accredited representative of the Republic of Korea, as the State of Registry and Operator of the aircraft involved in this serious incident, and an accredited representative and an advisor of the United States of America, as the State of Design and Manufacture of the aircraft, participated in the investigation. On July 24, 2018, factual information on the condition of the fracture of the right main landing gear aft axle obtained from the fact-finding investigation was submitted to the Civil Aviation Bureau. Comments were invited from parties relevant to the cause of this serious incident and the Relevant State.

2. FACTUAL INFORMATION

2.1 History of the Flight	According to the statements of the captain, the first officer, the ground controller at Narita Airport Traffic Control Tower (hereinafter referred to as "the Narita Ground") and staff of an aerodrome facility management company

and the records of FDR (Flight Data Recorder), the history of the flight is summarized as follows.

On June 29, 2018 at 10:38 in Japan Standard Time (JST: UTC+9 hours; unless otherwise stated, all times are indicated in JST in this report on a 24-hour clock), Boeing 777-300, registered HL7573, operated by Korean Airlines Co., Ltd. (hereinafter referred to as “the Operator”) as a scheduled flight 703, took off from Incheon airport in the Republic of Korea, with 335 persons on board consisting of the captain, 15 crew members and 319 passengers, and arrived at Narita international airport at 12:37.

According to the captain, the aircraft touched down, decelerated thereafter and taxied on taxiway without any trouble. Besides, there was no need to increase engine power during taxiing.

Around 12:41, other aircraft, which was taxiing after the aircraft on the right side, reported with radio communication to the Narita Ground that it sighted something, which was seemingly smoke, on the right main landing gear aft of the aircraft; and subsequently, the Narita Ground instructed the aircraft to halt at the position where it was.

Around 12:43, the captain halted the aircraft in accordance with the instruction from the Narita Ground. The position where the aircraft halted was between E6 and E7 on taxiway K.

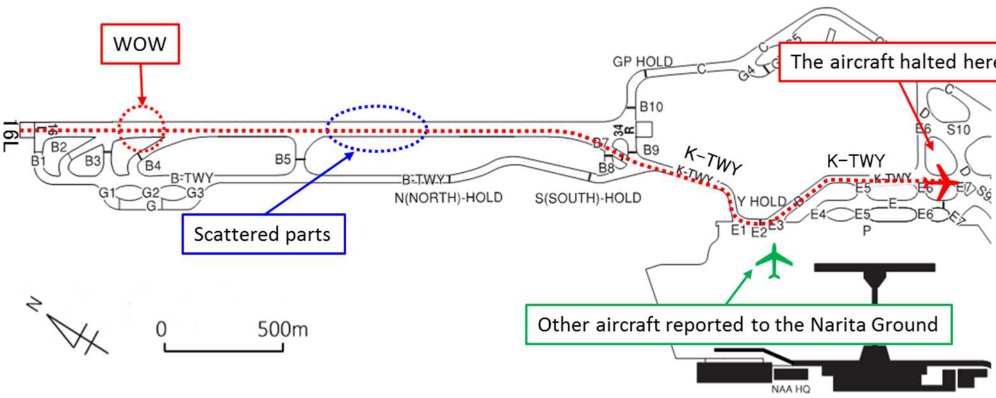


Figure 1 Serious Incident Site

The captain and the first officer checked the condition of the aircraft with EICAS[*1] after halted the aircraft. There were no warning and caution messages appeared on EICAS; however, they confirmed that the temperature of the No. 12 brake was disappeared (see Figure 6), the hydraulic quantity on the right system was gradually decreasing, and status messages of “MAIN GEAR STEERING” and “BRAKE TEMP SYS” were appeared.

At 12:58, the captain shut down both engines and switched off hydraulic pumps to prevent leakage of hydraulic fluid.

The Narita Ground confirmed with binoculars that tires of the right main landing gear were pointed to an unusual direction. There was no

*1 EICAS is an abbreviation of Engine Indication and Crew Alert System, and is a system that indicates operational status of engine and various systems equipped with a function to let a pilot aware of anomalous conditions in a visual and auditory way in the case of system malfunction.

	outbreak of smoke confirmed. At 13:00, staff of the aerodrome facility management company, who arrived near the aircraft, reported to the Narita Ground that the tires of the right main landing gear were pointed to the unusual direction and the hydraulic fluid was leaking. Around 13:10, the captain decided, from the information of the Narita Ground and, in addition, the detailed explanations on the condition of the aircraft from the engineers of the Operator, who arrived at the aircraft site, that the tires pointed to the unusual direction caused by the fractured axle and the hydraulic fluid was leaking, that the aircraft could not continue taxiing.  Figure 2 Condition of Aircraft Around 14:20, all passengers and crew members disembarked from the aircraft halted on the taxiway and then were transferred to the terminal by buses. Due to the serious incident, runway 16L where the aircraft landed was closed from 12:43 until 13:03, during which time it was checked and scattered parts were recovered. The Taxiway K where the aircraft was kept halting was closed from 13:16 of the day of the serious incident until 7:00 the following day. There was no outbreak of fire. This serious incident occurred on June 29, 2018 around 12:43 on taxiway K at Narita international airport (35° 46' 29" N, 140° 23' 50" E).
2.2 Injuries to Persons	None
2.3 Damage to Aircraft	Slightly damaged ・The R-MLG AFT Axle was fractured. ・The R-MLG Truck beam was damaged. ・The R-MLG Steering system was damaged. ・Hydraulic hoses of Brake and the Steering system were cut. ・Hydraulic system fluid leaked. ・Brake components were damaged. ・Electric cables and junction box of the R-MLG were damaged.

	 Figure 3 R-MLG (Rear View)  Figure 4 R-MLG (Right View)  Figure 5 R-MLG AFT axle (Rear View)
2.4 Personnel Information	Captain Male, Age 50 Airline transport pilot certificate (Airplane) May 17, 2002 Type rating for Boeing 777 September 23, 1998 Class 1 aviation medical certificate Validity June 30, 2019 Total flight time 14,208 hours 05 minutes Total flight time on the type of aircraft 11,675 hours 54 minutes Total flight time on the type of aircraft in the last 30 days 70 hours 35 minutes
2.5 Aircraft Information	Type: Boeing 777-300 Serial number: 27952, Date of manufacture: May 30, 2000 Certificate of airworthiness No. AS05069 Category of airworthiness the Aircraft Transport T Total flight time 69,674 hours 16 minutes Total flight cycles 20,673 cycles Flight time since the last periodic check (a 500-hour periodic check conducted on June 12, 2018) 192 hours 31minutes When the serious incident occurred, the weight and balance of the aircraft were within the allowable ranges.
2.6 Meteorological Information	Aeronautical weather observations at Narita international airport around the time of the serious incident were as follows: 12:30 Wind direction 210° ; Wind velocity 14 kt; Maximum instantaneous wind velocity 24 kt; Wind direction variable between 180° and 250° ; Prevailing Visibility 10km or more

Cloud: Amount 1/8 – 2/8;
Temperature 31℃; Due point 22℃ ;
Altimeter setting (QNH): 1011 hPa

2.7 Additional Information

(1) Main Landing Gear Steering System

The aircraft adopts a main landing gear steering system, which has a mechanism to make a main landing gear aft axle operate by hydraulic pressure in response to the movement of a nose landing gear steering.

Pivot bore of the main landing gear aft axle has a press-fitted bushings (bearing of pivot pin). Bushings have a hole to apply grease in, and the surface of the pivot pin OD and the bushings ID are lubricated by the grease (see Figure 13).

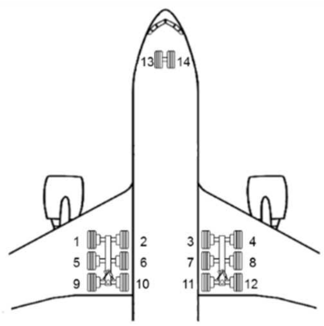


Figure 6 Number Assigned for Each Tire

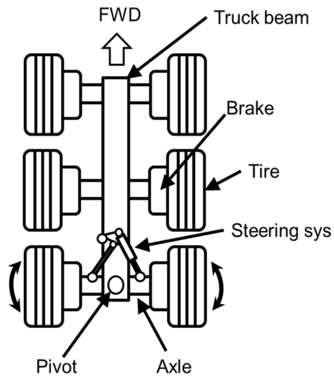


Figure 7 Image of MLG Steering System

(2) Maintenance Standard and Maintenance History of the Landing Gears

According to the maintenance manual of the Operator, which had been established in accordance with a manual of the manufacturer of the aircraft, and the maintenance records of the Operator, maintenance work of the landing gears was performed as follows.

Overhaul was entrusted to other company. Grease up work was performed even after water-washing aircraft apart from the regular maintenance work. Visual inspection was conducted from the ground level to see the condition of the landing gear, and detailed visual inspection was conducted as closely to aircraft as possible with the use of a ladder or the like and even under cleaned condition if necessary. Because both visual inspection and detailed visual inspection were performed without disassembly of the landing gears, the front side of pivot was not subject to the inspection due to the nature of its hidden portion.

Maintenance	Interval of Periodic Maintenance	Date of Maintenance	Reference
Overhaul	10 years or 16,000 cycles whichever comes first.	2009/7/15	CMM
Grease Up	150 days or 800 cycles whichever comes first.	2018/3/18	AMM
Visual Inspection	150 days or 800 cycles whichever comes first.	2018/3/18	AMM
Detailed Visual Inspection	750 days or 4,000 cycles whichever comes first.	2018/4/16	AMM

Table 1 Periodic Maintenance Work

(3) Parts Recovered from Runway

All parts recovered from runway and stated below turned out to be identical to the damaged portions of right main landing gear of the aircraft as a result of comparing (see Figure 8).

- Clamp of HYD hose
- Guide of HYD hose
- Thrust washer debris
- Axle debris

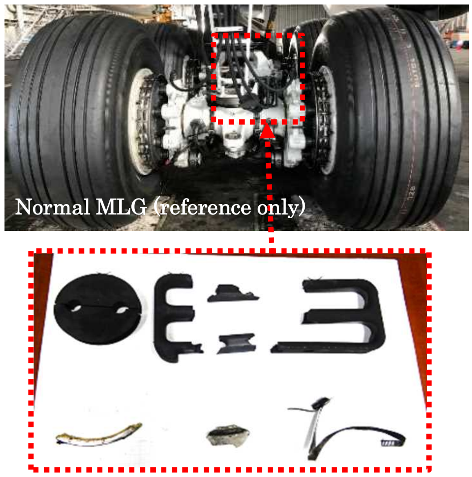


Figure 8 Recovered Parts from RWY

(4) Data of FDR

The aircraft landed on runway 16L of the airport at 12:37. The condition of the aircraft at the time of touchdown was as follows.

- Aircraft speed: about 144 kt
- Aircraft weight: about 467,000 lb
- Vertical acceleration: 1.41 G

(5) Impact of Hard Landing

According to the maintenance manual of the aircraft, it is classified as hard landing if the vertical acceleration at touchdown is 1.9 G or more, which requires inspections of the airframe to be performed. The inspection records of the aircraft performed after hard landing in the past showed that no damage had been caused to it.

(6) Total Flight Cycles and Flight Time

According to the maintenance records of the aircraft, the number of flight cycles was 11,083 and flight time was 33,752 hours since the overhaul conducted on July 15, 2009 until the day of the serious incident.

(7) Similar Case

The designer and manufacturer of the aircraft has provided operators with information related to the case where axle was cracked. Such information is summarized as follows.

Fleet Team Digest (777-FTD-32-12008) issued on December 19, 2012

There were two cases occurred in the process of overhaul of main landing gear where cracks were found in pivot bore, which connects main landing gear truck beam with axle. The number of flight cycles and flight time of the first case were about 7,500 cycles and about 50,000 hours and the same of the second case were 9,110 cycles and 45,800 hours, respectively. The cause of the cracks of both cases was stress corrosion cracking[*2] (hereinafter referred to as "SCC"), which was attributed to being subject to stress generated in corroded pivot. The designer and manufacturer revised CMM (Component Maintenance Manual) to incorporate coating of corrosion inhibitor BMS-3-38 to bushings of

[*2] Stress corrosion cracking denotes a phenomenon that material exposed in a corrosive environment generated and grow cracking more rapidly, when added by a tensile stress inclusive of a residual stress, than not exposed in a corrosive environment.

pivot in the process of assembling bushings as a preventive action in July 2012. The locations where the cracks occurred in the two cases were the lower front of pivot bore ID chamfer and the lubrication passage of the rear side of pivot bore ID.

(8) Corrosion Inhibitor Coating Situations

Main landing gear of the aircraft was overhauled in July 2009; however, the corrosion inhibitor was not coated because the CMM at that time required grease either ASG 7 or ASG 33 (MIL-PRF-23827) to be applied when assembling bushings.

(9) Detailed Investigation on Fractured Axle

Detailed investigation on the fractured axle and the pivot pin was conducted at the facility of the designer and manufacturer of the aircraft involved in the presence of the accredited representatives of the State of Design and Manufacture and the State of the Registry and Operator. The pivot pin was sent to the entrusted company of the main landing gear overhaul to remove it because it could not be removed from track beam. The visual investigation of the fractured axle revealed that the entire fractured surface of the front side of the pivot discolored black due to the corrosion. On the other hand, it was confirmed that a partially black-discolored portion due to corrosion and a grey

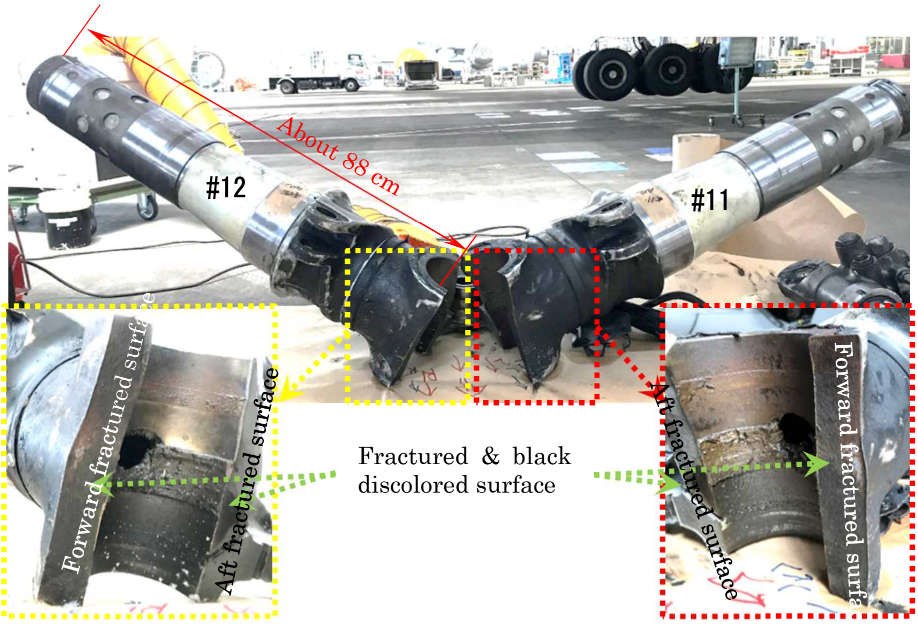


Figure 9 Fractured Axle of R-MLG (Front View)

new metal surface were confirmed on the fractured surface of the aft side of the pivot.

After having conducted the detailed investigation, the accredited representatives of the State of Design and Manufacturer expressed following views.

i) The axle was fractured at the point of the pivot, and the bushing suffered damage as well. It was observed that the pivot, to which the bushings were attached, had corrosion and wearing.

ii) Material analysis and hardness test were conducted on the heat-treated axle, which indicate that metallic composition and hardness met the design specifications; and thus, there was no indication of any anomaly associated with the materials and the heat treatment.

iii) Part of the axle was cut and cleaned for observation using Scanning Electron Microscope (SEM).

iv) The front fractured surface had a corrosion initiating region on the lower side of the pivot bore (see red arrows in Figure 10), which was further developed to SCC (see white dotted line in Figure 10).

v) The aft fractured surface had a corrosion initiating region on the lubrication passage on the lower side of the pivot bore, which was further developed to SCC. It was observed that the cracking that further progressed afterward (see red dotted lines in Figure 11).

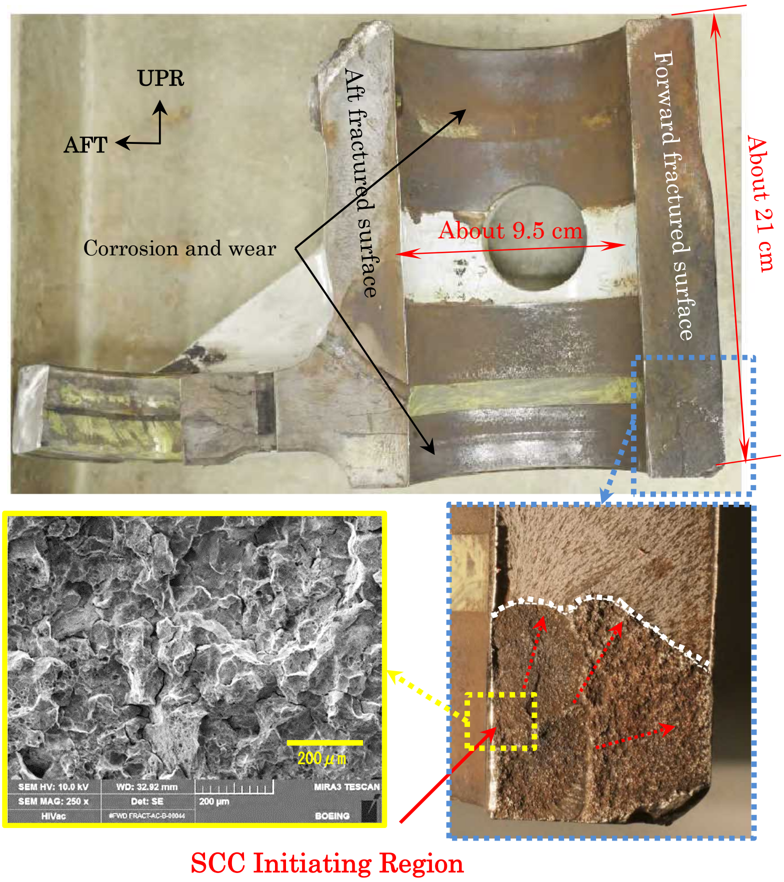


Figure 10 Forward Fractured Surface of Left Half of Fractured Axle (after Cleaning)

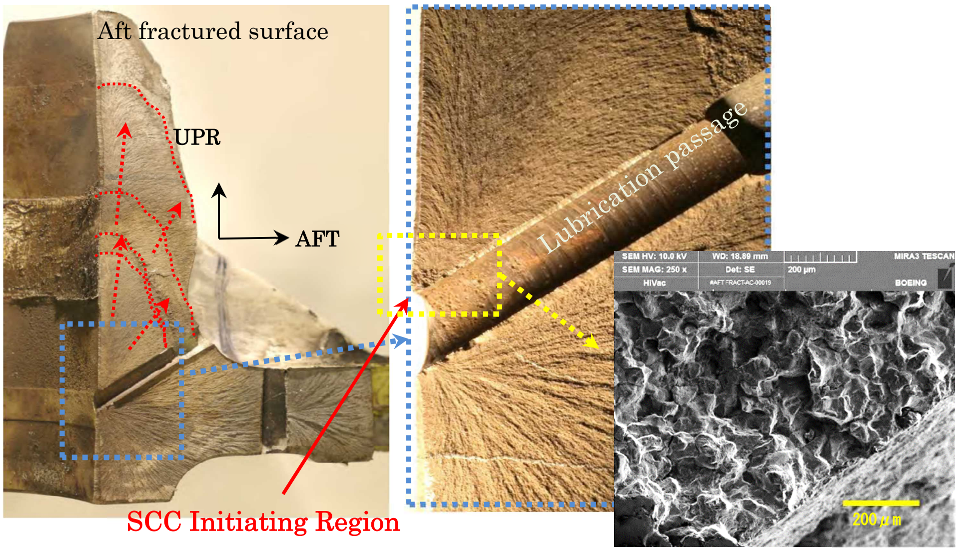


Figure 11 Aft Fractured Surface of the Right Half of the Fractured Axle (after Cleaning)

vi) Wear and corrosion were generated on the inner surface of the pivot. The bushings were press-fitted to the inner surface of the pivot and a fillet seal is applied on flange to prevent environmental ingress (see Figure 13). It is probable that the fillet seal was damaged due to the rotation of the bushings, which allowed water to penetrate between the pivot bore and the bushings; and thereafter, plating and primer applied on pivot bore were deteriorated, peeled off, developed to wearing and corrosion through a long period of time and finally resulted in the initiation of SCC. The observation indicates that the front side of the axle fractured first, followed by the fracture of the aft side.

vii) Sampling and analysis of the grease taken from the pivot of the axle detected Lithium grease and Clay-thickened grease. AMM (Aircraft Maintenance Manual) stipulates that Lithium grease of ASG 33 (BMS 3-33) shall be used for the pivot. ASG 7, ASG 16 and Mobil-28 are among Clay-thickened grease.

Figure 12 Bushing B2

viii) Remnants of dried and hardened grease residues were found at multiple locations (G3, B2, B3 and Thrust washer) throughout the pivot joint assembly lubrication passage. These Clay-like products impeded the proper flow of grease to the pivot joint interfaces.

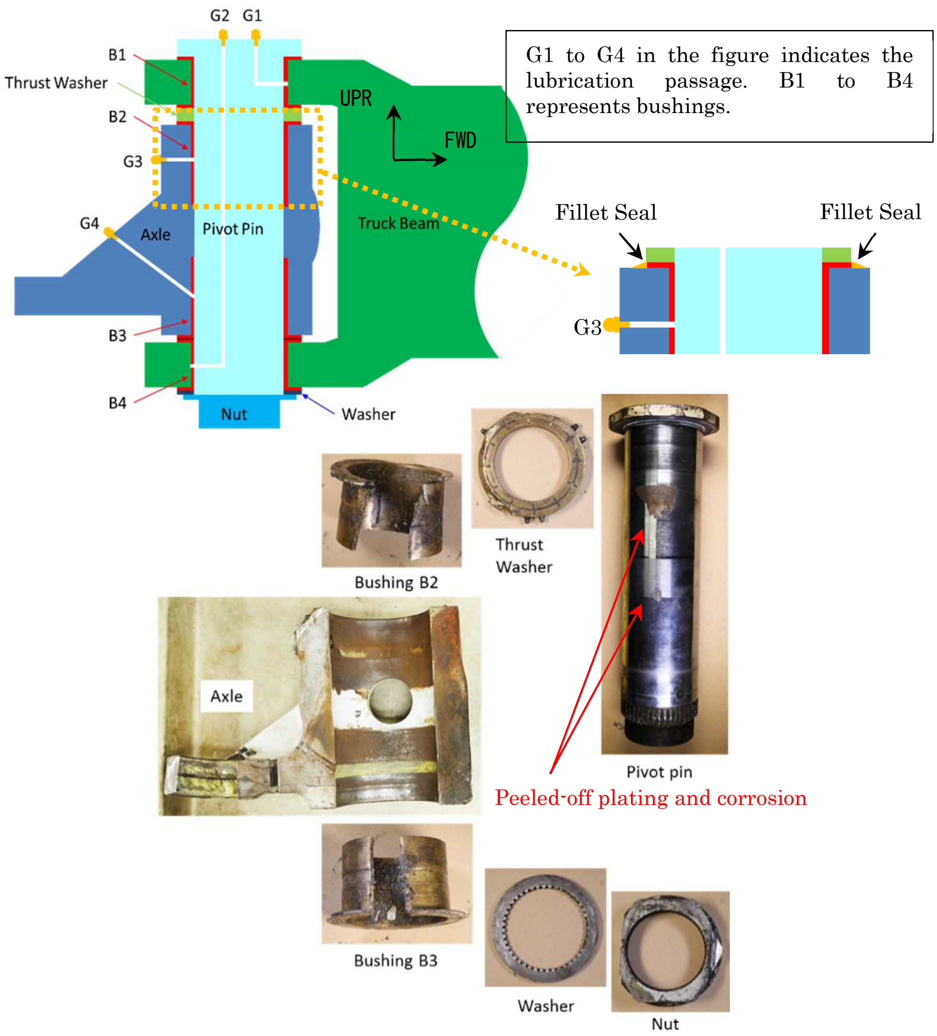


Figure 13 Cross Sections of Pivot and Disassembled Parts

ix) Analysis of the grease sampled from the grease passage G3 shown in Figure 13 contained portions which were visually brown (bushing side) or green (grease fitting side).(see Figure 14) Both the brown and green portion were overall consistent with ASG 33 (BMS 3-33) grease. The brown portion also contained corrosion products and cadmium plating.

x) It is probable that peeling-off of plating on the pivot pin was caused by the bushings and the pivot pin, which impeded the free rotation of the pin.

xi) Diameter, roundness and

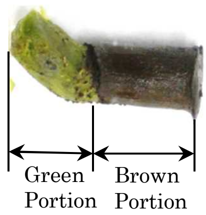


Figure14 Grease sampled from G3

Table 2 Measurements of Pivot Pin

Distance from flange (inch)	Diameter (inch) 0 - 180°	Diameter (inch) 90 - 270°
12.76	3.7461	3.7472
11.45	3.7460	3.7456
10.43	3.7456	3.7454
9.43	3.7475	3.7472
8.43	3.7465	3.7464
7.43	3.7495	3.7492
6.43	3.7495	3.7492
4.50	3.7502	3.7500
2.75	3.7496	3.7493
1.75	3.7495	3.7494
0.75	3.7500	3.7501

straightness of the pivot pin were measured. All diameters measured deviated from the specified values of 3.7480 to 3.7490 inches as shown in Table 2. Roundness and straightness were within the specified values.

(10) Grease passage (groove)

The bushing is to have a grease passage (groove) on bushing ID surface in a circumferential direction formed by machining when it is manufactured at the time of overhaul. To the contrary, the fractured bushing did not have the circumferential groove (see Figure 15).

Figure 15 Circumferential grease groove on Bushing ID

(11) Overhaul Maintenance Records

Maintenance records of overhaul of the main landing gear performed in 2009 revealed that the diameter of the pivot pin, when it was assembled, was 3.749 inches and was stated as “OK”. Distance from flange was not included in the record items.

(12) Grease Up Work

Grease up work of the main landing gear including steering mechanism requires grease to be applied into the designated 80 spots or more per side of the main landing gear using several kinds of grease guns. The grease up work of the Operator was performed using job card. Generally, the force required for pumping a grease gun becomes heavier when there is “clogging” in the grease passage and lighter when there is “leaking”.

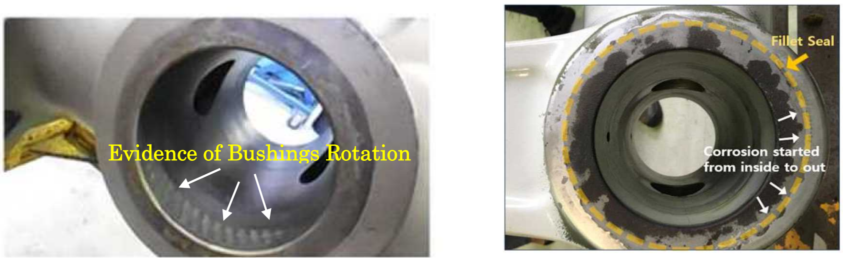
The grease up work in AMM contains following descriptions.

- Dispense grease into the grease fitting until the used grease is visually removed and only new grease comes out in one or more locations at this joint interface.
- Use Grease ASG 33 (recommended) or ASG 7 (alternative).
- Limit grease to no more than 10 - 15 pumps from a medium sized grease gun.

(13) Records of Use of Grease at the Operator

Investigation of the records of use of the grease at the Operator shows that it never used Mobile-28 and ASG 16. The Operator stated that it had used ASG 33 and ASG 7 in the past; however, it had never used ASG 7 for the grease up of the main landing gear.

(13) Pivot of the Same Type of the Aircraft of the Operator

	It was confirmed that the axle of the pivot of the same type of the aircraft of the Operator, which had been overhauled before CMM was revised, had evidence of rotation of the bushings and corrosion in the pivot bore. Pivot pin and grease of axle pivot were maintained in good condition.  Figure 16 Axle Pivot of the Same Type of the Aircraft (after removing bushing)

3. ANALYSIS

3.1 Involvement of Weather	None
3.2 Involvement of Pilot	None
3.3 Involvement of Aircraft	Yes
3.4 Analysis of Findings	(1) It is highly probable from the statements of the captain and the first officer and FDR records that there did not occur hard landing when the aircraft landed at Narita international airport. (2) From the fact that all parts scattered on runway were identified as ones of the right main landing gear of the aircraft, it is certain that the aircraft was forced to halt on taxiway due to the axle fractured at landing and could not continue taxiing further. (3) It is highly probable that leakage of hydraulic fluid was attributed to the hydraulic hoses of the brake and the hydraulic hoses of the steering system, which were cut by the fractured axle. (4) It is highly probable that the temperature display of brake No. 12 of EICAS, which was not displayed, and status messages of the “MAIN GEAR STEERING” and the “BRAKE TEMP SYS”, which appeared, were caused by the damaged right main landing gear steering system (see Figure 7) and the damaged temperature sensor associated with the fractured axle. (5) It is highly probable that sighted smoke or something, which seemed like it, was a hydraulic fluid that squirted in misty condition from the cut hydraulic fluid hoses, and then became smoky after being sprayed on the brake, the temperature of which had become high due to braking action. (6) It is highly probable from the maintenance records of the aircraft that the Scheduled maintenance task was performed in accordance with the maintenance requirements of the Operator, which had been established originating from the manual of the manufacturer of the aircraft. (7) It is highly probable that the forward fractured surface had an initiating region of corrosion on the lower side of the pivot bore, then was generating SCC

and finally was fractured due to repetitively imposed loads. Besides, it is highly probable that a long period of time had passed since the fracture occurred from the entire fractured surface, which was discolored black by dusts and corrosion. However, it could not be determined when the fracture had occurred due to the nature of corrosive condition of the fractured surface, which varies depending on the operating environment of aircraft.

It is probable that the aft fractured surface was caused by SCC initiated by the corrosion generated on the lubrication passage, which then led to progressing cracking due to repetitively imposed loads. Besides, part of the aft fractured surface was discolored black by dusts and corrosion. In view of what is stated above, it is highly probable that the forward side of the pivot bore had fractured first; and, even thereafter, the aircraft kept operations with the aft side of the pivot bore partially cracked. Consequently, it is highly probable that the axle was finally fractured at the time of landing in the serious incident.

(8) It is probable that the measured diameter of the pivot pin noted in table 2 exceeded the one specified in CMM and could possibly have contributed to interference between the pivot pin and bushing, which impeded the free rotation of the pin and contributed to the rotation of bushings.

(9) It is also probable that "dried and hardened grease" sampled from the pivot could possibly contributed to the pivot pin and the bushings, which impeded the free rotation of the pin. It is possible, from the fact that the Operator did not have records of using Clay-thickened grease in the grease up work of the pivot joint, that the grease in question was Clay-thickened grease (ASG 7), which had been applied during the overhaul in 2009 and had remained in the lubrication passage until the serious incident. Dispense grease into the grease fitting until the used grease is visually removed and only new grease comes out in one or more locations at this joint interface; however, it is probable that AGS 7 grease applied during the overhaul had not completely been replaced with new grease ASG 33, and then, it dried up and became solid due to the absence of circumferential grease groove on bushing ID surface and the limited grease to no more than 10 - 15 pumps from a grease gun according to AMM.

(10) Majority of the ingredients of the grease sample from the G3 passage were overall consistent with ASG33 grease. The brown portion contained corrosion products and cadmium plating. It is probable that this was the grease pushed back from the axle bore into grease G3 passage by rotation of the bushing.

(11) Investigation of the condition of the axle pivots of the same type of the aircraft conducted by the Operator revealed that some of axles had corrosion. It is highly probable, from the fact that those axles had been overhauled before CMM was revised, that the corrosion inhibitor, which had not been coated on bushings assembly portions, contributed to the corrosion. Besides, it is observed that even the axle pivot, which kept the pivot pins and grease in good condition, had evidence of bushings rotation. This implies that the bushings could possibly rotate even if the pivot pin did not impede the free rotation of

	the pin to the bushings. (12) From the aforementioned, it is highly probable that the fillet seal of bushing wore out by rotation of the bushing during the operation of the aircraft, which then led to water penetration and corrosion generated in the pivot bore. It is highly probable that generation of corrosion was attributed to the landing gear, which had been overhauled before CMM was revised, and because of that, corrosion inhibitor had not been applied to it. It is highly probable that corrosion led to SCC generated on the pivot bore, and ongoing operations of the aircraft thereafter with the axel cracked finally resulted in the fracture of the axle. (13) In view of possible detection of the cracked axle from the feeling and situation of pumping during grease up work, it is required that the Operator confirm that there exists no clog up or leakage of the grease during the grease up work and stipulate in the job card the ways to cope with if such has occurred.

4. PROBABLE CAUSES

It is certain that the aircraft had the right main landing gear aft axle fractured when landing in the serious incident, and subsequently, it was forced to halt on taxiway and could not continue taxiing.

It is highly probable that the fractured axle was attributed to the SCC originated from the corrosion generating on the pivot bore and ongoing operations of the aircraft thereafter with cracking occurred.

It is highly probable that the corrosion generated on the pivot bore was contributed by water penetration caused by the torn fillet seal due to rotation of the bushings and corrosion inhibitor that was not applied.

5. SAFETY ACTIONS

The Operator conducted visual inspection on seven aircraft, which had been overhauled before CMM was revised, to see if they had any damage. Thereafter, the Operator replaced all of aft axles of the main landing gear of those seven aircraft (14 axles in total).

The Operator implemented measures, which ensures that adequate grease up work is conducted, by adding in the job card appropriate ways to take in the event that plugging up has occurred during the grease up work, and eventually, has prevented new grease from spreading thoroughly in the surfaces.