

**MINISTRY OF COMMUNICATION
AND TRANSPORT**

ACCIDENT INVESTIGATION BRANCH

CIVIL AIRCRAFT ACCIDENT No. CAV/ACC/5/99

**REPORT ON THE ACCIDENT TO BOEING 737 - 200 AIRCRAFT
REGISTRATION 5H-MRK WHICH OCCURRED IN FLIGHT
(DAR ES SALAAM - MWANZA) ON 26 MAY 1999**

TANZANIA ACCIDENT INVESTIGATION BRANCH

Civil Aircraft Accident No.: CAV/ACC/5/99
Aircraft type: Boeing 737-200
Nationality & Reg. Marks: 5H-MRK
Operator: Air Tanzania Corporation
P.O. Box 543, Dar es Salaam
Crew: Pilots - 2 uninjured
Flight Engineer - 1 uninjured
Cabin Crew - 4 uninjured
Passengers: 63 uninjured
Place of accident: The accident occurred at position S 05° 40',
E 037° 00' at 31,000 feet amsl during a Dar es
Salaam - Mwanza flight
Date: 26 May 1999
Time: 0531 hours

ALL TIMES IN THIS REPORT ARE UTC

SYNOPSIS

The accident was notified to the Tanzania Accident Investigation Branch by the Air Tanzania safety Manager shortly after it occurred. The investigations began on the following day.

The aircraft took off from Dar es Salaam International Airport at 0452 hours for a scheduled flight to Mwanza. It was carrying 63 passengers and a crew of seven. The initial phase of the flight was normal and the aircraft levelled at 31,000 feet. At 0531 hours a loud bang was heard from the left engine followed by the loss of oil pressure and power. The commander subsequently shut down the engine and diverted to Kilimanjaro where he landed safely at 0546 hours.

Whilst taxiing on the apron at Kilimanjaro fuel was observed spewing out of the left engine. The occupants were disembarked quickly without further incident.

Examination of the left engine showed that a bevel gear wheel in the gearbox assembly had fractured and punctured the front gearbox housing. The released debris had damaged the fuel control unit causing fuel spillage. The fuel pump and the engine nacelle were also damaged.

It is concluded that the accident was caused by the in-flight fracture of the No. 1 engine accessory drive bevel gear wheel in the main gearbox. The gear fracture was caused by a high cycle fatigue crack arising from improper alignment of gear teeth during the previous engine overhaul.

1. FACTUAL INFORMATION

1.1 History of the Flight

The aircraft was operating Air Tanzania flight TC 530 from Dar es Salaam to Mwanza. Take-off from Dar es Salaam was initiated at 0320 hours. The Commander said that when the aircraft was accelerating through 60 knots the No.2 engine (the RIGHT engine) EPR indication short up to 2.5. He immediately aborted the take off roll and taxied the aircraft back to the ramp.

Air Tanzania engineers established that the No.2 engine PT2 probe was blocked. When this probe was blown with pressurized air, pieces of fresh grass came out and normal indications were restored.

5H-MRK took off again for Mwanza at 0452 hours. The take off and the climb out was normal and the aircraft cruised at FL310. Shortly after transiting the reporting point LUGAP and setting course for Mwanza the commander briefed the passengers that the flight would be landing (at Mwanza) in the next 50 minutes. At this time a hissing sound was heard from the left engine. However there was no abnormal indication in the engine parameters. Moments later a loud bang was heard from the same engine followed by the loss of oil pressure. The engine subsequently failed to respond to further throttle inputs. The commander then initiated engine failure and shutdown checks.

However, during the shutdown process the fuel starter lever could not be brought to idle detent. It was consistently stuck close to idle detent but could not reach it.

The commander then diverted to Kilimanjaro International Airport (KIA). During descent to KIA the crew noticed that the No.1 fuel tank was depleting faster than is normally the case although it was not being used. The commander also reported to have experienced same problem in balancing the aircraft.

The aircraft landed at Kilimanjaro at 0546 hours with fuel spewing out of the left engine. When 5H-MRK was taxiing to parking position on the apron another aircraft which was also on the apron informed the commander that he had a fuel leak on the left engine. By this time the airport fire engine was also on the apron.

The commander subsequently ordered the occupants to disembark fast, which was done without further incident. During this time a company engineer based at Kilimanjaro climbed into the cockpit and shut off the fuel by operating the fire handle.

1.2 Injuries to persons

INJURIES	CREW	PASSENGERS	OTHERS
Fatal	-	-	-
Serious	-	-	-
None	7	63	N/A

1.3 Damage to Aircraft

The damage was confined to the left engine.

1.4 Other damage

There was no third party damage.

1.5 Personnel information

1.5.1 Commander : Male, aged 45 years
 Licence : ATPL
 Aircraft rating : Group 1 - Cessna 172, DHC-6, F27, Boeing 737
 Group 2 - Cessna 310
 Instrument Rating : Renewed 18 Nov. 1998
 Medical Certificate : Class One issued 19.05.1999
 Flying experience : Total all types 10,080 hours
 Total on type 3,307 hours
 Total last 28 days 45.5 hours
 Total last 24 hours 2.00 hours
 Last base check : 2 May, 1999
 Last line check : 30 December 1999
 Last emergencies check: 2 May 1999

1.5.2 First Officer : Male aged 43
 Licence : ATPL
 Aircraft ratings : Group 1 - BE 200, DHC 6 and PA 31
 Group 2 - F 27, B737

Instrument Rating	:	Renewed 13 May 1999
Medical Certificate	:	Class 1 issued 11 March 1999
Flying experience	:	Total all types 5,837.95 hours
		Total on type 2,357.95 hours
		Total last 28 days 41.00 hours
Last base check	:	14 May, 1999
Last line check	:	18 February 1999
Last emergencies check:		14 May 1999

1.6 Aircraft information

1.6.1 General Data

Aircraft type	:	Boeing 737-200 RC (2R8C)
Date of Manufacture	:	1979
Constructor's Number	:	21711
Certificate of Registration	:	C of R No. 236 issued
Certificate of Airworthiness	:	C of A No. 188, Public Transport category valid until 17 June 1999.

1.6.2 Engine data

Engine	:	Pratt & Whitney JT8D-17
Serial Number	:	P88466
Total Time	:	25,512 hours
Time since overhaul	:	8,519 hours

1.6.3 Part information

The part mentioned here is the Bevel Drive Gear wheel, which failed in flight.

Part Name	:	Main Gearbox Accessory Drive Bevel Gear
Part Number	:	46170
Serial Number	:	GH 0694
Quantity	:	1
Total time (hours)	:	25,512
Total cycles	:	23,891
Time since overhaul (hours):		8,718
Cycles since overhaul :		8,252

1.6.4 Maintenance history (Engine/gearbox)

The Operator does not do engine overhaul. He subcontracts this business to third parties. Company records show that the engine was last overhauled in 1994 at 16,794 hours. It was inspected again during a shop visit in March 1997. By the time of the accident the engine had logged 3,578 hours and 3,541 cycles since the last inspection. The engine had 1,482 hours remaining before its next scheduled overhaul.

1.7 Meteorological information

It was a bright, sunny and clear day. The weather had no bearing on the accident.

1.8 Aids to navigation

Not applicable

1.9 Communications

Not applicable

1.10 Aerodrome and ground facilities

Not relevant to this accident

1.11 Flight recorder

The investigation did not warrant the use of the flight data recorder information.

1.12 Wreckage information

Examination of the left engine showed that a bevel gear wheel in the main gearbox assembly had fractured and a piece of it separated and punctured the gearbox housing. It also damaged a number of engine parts including the fuel pump, the fuel control unit, the fuel lines, the linkages and the nacelle. However all the debris was contained in the nacelle. It was evident from the examination that the fuel starter lever could not reach the détente position because its linkage had jammed against other linkages in the accident sequence. Fuel started spewing out when the fuel lines were damaged.

1.13 Medical and pathological information

Not applicable

1.14 Fire

There was no fire

1.15 Survival aspects

The Kilimanjaro International airport fire services were put on standby alert when the pilot reported the incident and his subsequent diversion to the airport. A fire engine was also already positioned on the apron when the aircraft arrived for parking. The passengers and crew were uninjured and left the aircraft using the normal exits.

1.16 Tests and Research

Following the accident to 5H-ATC the Tanzania Accident Investigation Branch requested the engine manufacturer to conduct laboratory examination of the failed parts. The complete main gearbox assembly was shipped to Pratt & Whitney Headquarters in East Hartford, Connecticut, U.S.A.

1.16.1 Investigative Findings:

Inspection of the engine hardware, which included the recovered gear segment and the disassembled gearbox, led to the following findings:

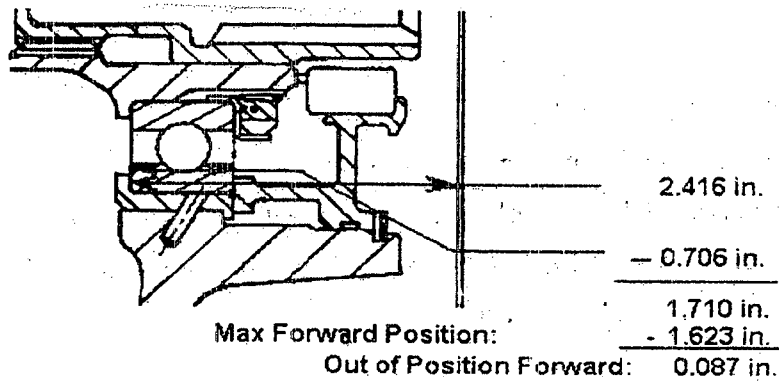
1. The damaged main fuel control/main fuel pump provided the path for the fuel leak.
2. The accessory drive gear fractured radially through the gear rim, peeled through the gear web, and liberated an approximately 180-degree section of the gear rim.
3. All the teeth on both the liberated section and the intact portion of the accessory drive bevel gear exhibited a heavy wear pattern on the "run" side, high on the tooth flanks.
4. Laboratory inspection revealed indications of high cycle fatigue across the origin of the primary fracture, which progressed from the surface at the inside diameter chamfer in the root between two teeth. Three additional cracks were found in similar locations between other teeth. Fatigue indications present in the three additional cracks progressed from origins associated with machining lines at the inside diameter chamfer in the root between two teeth. The inside diameter chamfer measurements were within Blue Print requirements.
5. The ball bearing liner, for the gear-shaft to which the accessory drive bevel gear was attached, was found to be out-of-position, in the engine-forward direction by 0.087 inches.

6. There were indications of gearbox housing step fretting under the shoulder of the ball bearing liner.
7. The bore diameter in the rear housing for the ball bearing liner was measured to be 3.788 inches, which was 0.004 larger than specified on the part drawing.
8. The three bearing liner retention-pin holes for the retention pins in the gearbox housing were drilled to a measured depth of 0.167 inches, instead of the drawing specified minimum depth of 0.390 inches.
9. Friction related discoloration was observed on the bearing outer race in the location of the liner pin.

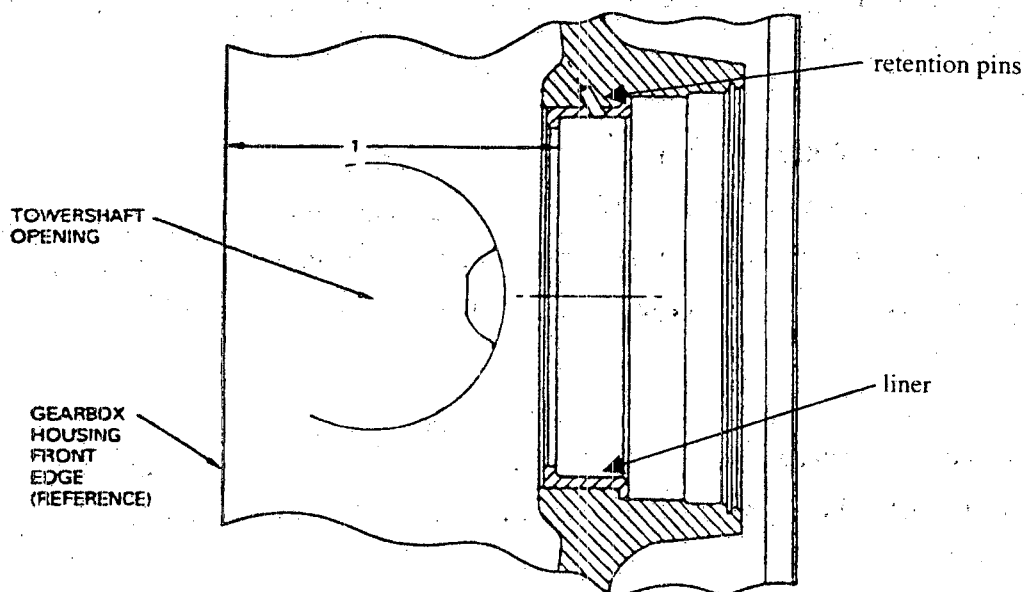
The damaged main fuel control/main fuel pump led to the fuel leak. Although the fuel shutoff lever for the fuel control unit (FCU) was in the off position, fuel was still being delivered to the fuel pump by the aircraft fuel tank boost pumps. The only manner in which to stop the flow was to pull the fire handle, which then closed the spar valve. The fire handle was pulled after the aircraft was landed and the fuel spillage was noted.

The accessory drive gear was found to have fractured radially and circumferentially through the gear rim, peeled through the gear web, and liberated an approximately 180-degree section of the gear rim that exited through the gearbox front housing. The gear tooth wear pattern, high on the tooth flanks, indicated that the bevel gear had been operating partially disengaged.

The ball bearing liner for the gear-shaft was found to be out-of-position, in the engine-forward direction by 0.087 inches, which would have allowed the bevel gears to operate partially disengaged.



The outside diameter, specified on the part drawing, of the ball bearing liner (P3 class) is 3.794 - 3.795 inches. This diameter would have required a 0.0065 inch to 0.0090 inch interference fit. Since the liner was sectioned for removal, the actual diameter could not be determined. If the liner were at the maximum outside diameter of 3.795 inches, there would have been a near minimal interference fit of 0.0070 inches. If the liner were at the minimum outside diameter, 3.794 inches, there would not have been an adequate interference fit.



Since the holes for the retention-pins were only drilled to a depth of 0.167 inches rather than a minimum of 0.390 inches, the three bearing liner retention-pins did not prevent the ball bearing liner from moving. This movement would have promoted the observed wear to develop in the pin holes, causing fretting of the gearbox housing shoulder step, in the gearbox housing.

2. ANALYSIS

2.1 The aborted take-off at Dar es Salaam

It was established that the first incident involving an aborted take-off at Dar es Salaam had no relation whatsoever with the gearbox failure incident which occurred two hours later. The first incident involved the right engine while the second one involved the left engine. These engines work independent of each other.

Company engineers working on the right engine established that the high EPR indication which forced the crew to abort the take-off from Dar es Salaam was due to a blocked PT 2 probe. When this was blown with pressurized air fresh pieces of grass came out.

Grass was being cut in the airport area but was not being removed. It was suspected that the right engine may have ingested the loose grass from taxiway P of Dar es Salaam International Airport shortly before take-off. This was the second time such an incident was happening. Earlier private people from the town were allowed to collect loose grass from the airport for cattle fodder. This was abolished following concern over security in the airport premises.

2.2 The gear box failure accident.

The No. 1 engine main gear box failure occurred during cruise at FL 310. This happened 39 minutes after take-off from Dar es Salaam. All the debris was contained in the engine nacelle and no other damage occurred. There were also no injuries to the aircraft occupants.

The potentially dangerous aspect of the accident was that fuel continued to spill out of the No. 1 engine fuel pipelines till when the aircraft had landed and taxied to the apron at Kilimanjaro.

There were two possible sources of danger. First the spewing fuel could catch fire in flight or on landing. Sparks from tire friction on touch down could easily ignite the fuel.

A cross wind during taxiing could feed the spilling fuel into the No. 2 engine/exhaust with a possible risk of ignition.

Secondly, fuel imbalance could have caused loss of control in flight. During the 15 minutes that the aircraft was airborne after the gearbox failure, the commander reported to have experienced control problems towards the final phase of the flight.

The Boeing 737-200 has three fuel tanks. One in each wing, 4590lb and a centre section tank whose capacity is 7416lb of fuel.

The maximum allowable fuel imbalance between main wing tanks is 1300lb for landing and 1500lb for taxi.

The quantity of fuel lost through spillage from the left wing tank was estimated at two tons. This would indicate that this tank was near the point of exhaustion when the aircraft came to a halt at Kilimanjaro.

If the incident had occurred in the middle of a route where there was no diversion airport in the vicinity, the control problem could have been more serious.

Given a situation in which fuel was draining off the No. 1 tank but was not being used, the crew should have realized that this fuel was spewing out of the aircraft. In the circumstances, they should have ordered evacuation on the runway immediately when the aircraft stopped.

2.3 The Main Gearbox Accessory Drive Bevel Gear failure.

Laboratory tests established that the main gearbox Accessory Drive Bevel Gear fractured due to high cycle fatigue that originated in the gear tooth root area.

The high cycle fatigue fractures were most likely caused by the gear-shaft running out of position, with respect to the tower-shaft bevel gear, in the engine-forward direction.

A ball bearing liner of P3 class was installed during the last shop repair. However, the liner outside diameter did not provide a sufficient press fit in the gearbox housing bore,

and looseness between the housing and the liner resulted during engine operation. Friction discoloration on the bearing outer race against the liner retention-pins suggests that there was loose contact and the outer bearing race was moving relative to the bearing housing.

Since the holes for the retention-pins were drilled improperly, the three bearing liner retention-pins did not prevent the ball bearing liner from moving. This movement would have promoted the observed wear to develop in the pin holes, causing fretting of the gearbox housing shoulder step, in the gearbox housing.

3. CONCLUSIONS

(a) Findings

- (i) The pilots were properly licenced to conduct the flight.
- (ii) The documentation of the aircraft was in order.
- (iii) The aircraft had a current Certificate of Airworthiness and a current Certificate of Maintenance.
- (iv) The No. 1 engine failed in flight. This failure was initiated by the fracture of an Accessory Drive Bevel Gear in the main gearbox.
- (v) The gear fracture was caused by high cycle fatigue which was induced by improper loading of gear teeth.
- (vi) The improper loading of gear teeth has been attributed to the gear-shaft running out of position due to improper maintenance operations.

(b) Cause

The accident was caused by the fracture of the No. 1 engine Accessory Drive Bevel Gear in the main gearbox during flight. The gear fracture was caused by a high cycle fatigue crack arising from improper alignment of gear teeth during the previous maintenance operation.

4. SAFETY RECOMMENDATIONS

It is recommended that:

- 4.1 For all grass cutting operations in the airport area all loose grass should be collected and burned or disposed.
- 4.2 The operator should do more work on crew emergency training.
- 4.3 Engineers undertaking engine overhaul should strictly follow Engine Manual (PN 481672) 72-61-01 repair section. Select the correct size (fit) for the liner, liner bore diameter for the liner selected and correct pin/holes depth according to drawing dimensions required.
- 4.4 Inspection check should be conducted to monitor the location requirements of the CSD gear-shaft liner dimension and location according the Engine Manual (PN 481 672) 72-61-01 Insp-01/Maintenance Manual (481 671) 72-60 Page 610D.



J. Nyamwihura

INSPECTOR OF ACCIDENTS