الهيئة العامة للطيران المدني
GENERAL CIVIL AVIATION AUTHORITY

United Arab Emirates

Air Accident Investigation Sector

Incident

- Summary Report -

AAIS Case Nº AIFN/0011/2021

In-flight Engine Shutdown

Operator:	Etihad Airways
Make and Model:	Boeing 777-300ER
Nationality and Registration:	United Arab Emirates, A6-ETP
Place of Occurrence:	Oman Airspace
State of Occurrence:	Sultanate of Oman
Date of Occurrence:	12 September 2021

This Investigation was conducted by the Air Accident Investigation Sector of the United Arab Emirates pursuant to Civil Aviation Law No. 20 of 1991, in compliance with Air Accident and Incident Investigation Regulation, and in conformance with the provisions of Annex 13 to the Convention on International Civil Aviation.

This Investigation was conducted independently and without prejudice. The sole objective of the investigation is to prevent future aircraft accidents and incidents. It is not the purpose of this activity to apportion blame or liability.

The Air Accident Investigation Sector issued this Summary Report in accordance with national and international standards and best practices. Consultation with applicable stakeholders, and consideration of their comments, took place prior to the publication of this Report.

The Summary Report is publicly available at:
http://www.gcaa.gov.ae/en/epublication/pages/investigationReport.aspx

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Investigation Process

The occurrence involving a Boeing 777-300 Extended Range (ER) aircraft, registration marks A6-ETP, was notified to the Air Accident Investigation Sector (AAIS) of the United Arab Emirates Duty Investigator (DI) by phone call to the Hotline Number (+971 50 641 4667) on 19 September 2021.

AAIS forwarded a notification to the Directorate General of Civil Aviation and Meteorology, being the investigation authority of Sultanate of Oman (the State of Occurrence) According to Standard 4.1 of Annex 13. The AAIS did not receive a response and therefore decided to conduct the investigation.

After the initial investigation phase, the occurrence was classified as an 'Incident'.

The scope of this investigation is limited to the events leading up to the occurrence; no in-depth analysis of non-contributing factors was undertaken.

Notes:

1. Whenever the following words are mentioned in this Report with first capital letter, they shall mean the following:
   - (Aircraft) – The aircraft involved in this incident
   - (Commander) – The commander of the incident flight
   - (Copilot) – the copilot of the incident flight
   - (Incident) – This investigated incident
   - (Investigation) - The investigation into this incident
   - (Operator) - Etihad Airways
   - (Report) – This incident investigation Summary Report
2. Unless otherwise mentioned, all times in this Report are given in 24-hour clock Coordinated Universal Time (UTC), (UAE local time minus 4).
3. The structure of this Summary Report is adapted from the Annex 13 Final Report format.

Factual Information

History of the Flight

At 0556, Etihad Airways Boeing B777, registration marks A6-ETP, departed from Abu Dhabi International Airport (OMAA[1]), the United Arab Emirates, to Hazrat Shahjalal International Airport (VGHS), Bangladesh, for operating a turnaround flight number EY245.

At 0712, after 1 hour 16 minutes into the flight over Mumbai flight information region (FIR), the Aircraft's Engine Indicating and Crew Alerting System (EICAS) displayed a High-Pressure Turbine Active Clearance Control (HPTACC) status message, which did not require flight crew action. As recorded on the *operational flight plan (OFP)*, the Operator's maintenance control center (MCC) was notified and the flight crew continued to VGHS normally.

At 1029, the Aircraft landed in VGHS.

At 1037, the Aircraft parked at the designated parking stand. After inspection, the maintenance engineer advised the flight crew that an engine dry run would be required to clear the status message from the previous sector.

After the dry engine run procedure had been completed and the status message cleared, the maintenance engineer signed the technical log and the Commander accepted the Aircraft for the return flight to OMAA.

Shortly thereafter, the MCC called the crew requesting a second dry run in order to ensure that the status message would not re-appear during pushback. The requested run was carried out and no HPTACC status message appeared.

[1] OMAA is the ICAO four letter airport code for Abu Dhabi International Airport

At 1145, the flight crew received a message via the Aircraft Communications, Addressing and Reporting System (ACARS), informing them about an 'oil consumption' message that needed action. After inspection, the maintenance engineer informed the Commander that extra time was needed to inspect the engine and he anticipated that this might take few hours.

Based on the Commander's statement, the MCC told the engineer that there is a list of checks that need to be done on the engine. This was to eliminate any defects that might affect the engine and to ensure that the engine is in a good condition. The engineer advised the Commander that it would take around 45 minutes to one hour for clearing the associated message.

At 1253, the flight crew sent a message to NOC stating that they have agreed to extend their FDP and asking for the latest estimated time of departure (ETD) with discretion.

At 1308, the NOC sent a message advising the crew that the latest ETD with discretion is 1500. At 1325, the NOC sent the flight crew a new *OFP* with the new ETD from VGHS.

The Commander stated that at about 1410, the maintenance engineer requested the electronic aircraft technical log (eATL) from the flight crew for filling the inspection and maintenance information.

At 1422, the NOC sent another load sheet with a change in take-off fuel, and it was annotated as final.

At 1454, the flight crew advised NOC that they are still waiting for maintenance paper work.

At about 1500, the maintenance engineer completed the eATL. As per the Commander's statement, there was no residual *MEL, configuration deviation list (CDL),* or any operational comment that prohibited the Aircraft dispatch, and therefore he accepted the flight.

As per the ACARS message record, the Commander notified the NOC about reaching the maximum allowed FDP, and the NOC replied that the flight crew are allowed to extend their duty for 15 minutes.

At 1520, the Aircraft was pushed back from the parking stand. At 1543, the Aircraft took off with the Commander as the pilot flying (PF).

At about 1633, the flight crew observed an EICAS status message of HPTACC Left Valve and Engine Overspeed Left Governor which did not require flight crew action. The flight crew communicated the message to the NOC. The Aircraft was over Kolkata FIR by that time.

At 1844, the Aircraft entered Muscat FIR at flight level 380, and the flight crew requested the weather information for OMAA in preparation for the descent and approach.

The Commander stated that at 1928 he heard two bangs from the engine with moderate airframe vibration. The Commander stated, "I thought after the initial bang that it was due to turbulence." He added that after the second or third bang, there was an EICAS message of Engine Thrust Left with N1 reducing to 40% and displaying in amber. The Commander later requested for the engine severe damage checklist due to having abnormal engine indications and airframe vibration. The flight crew then initiated the engine out drift down procedure.

The crew made an assessment of the most suitable airport for landing based on the *Operations Manual – Part C* (*OM-C*). The Commander chose OMAA as the destination based on the time required for Aircraft preparation for landing.

At 1959, the Aircraft landed at OMAA, runway 31 left.

At 2026, the chocks were positioned when the Aircraft parked at the designated stand.

Damage to Aircraft and Property

The Aircraft was intact.

Personnel Information

The Commander held a valid air transport pilot license (ATPL) issued by the General Civil Aviation Authority of the United Arab Emirates (GCAA), with B777 and B787 rating endorsement. In addition, the Commander held a valid class 1 medical certificate.

The Copilot held a valid ATPL with Airbus A320, A330, B777 and B787 rating endorsement. In addition, the Copilot held a valid class 1 medical certificate.

The Commander had a total of 12,993 flying hours, whereas the Copilot had a total of 3,955 flying hours.

The flight was a training flight for the Copilot, who was completing a difference course from the B787 to the B777.

Aircraft Information

The Boeing B777 is a long range, high capacity, wide-body airliner in service since 1995 and Boeing's first fly-by-wire airliner with an electronic flight instrument system, flight deck and flight envelope protection.

The review of the Aircraft's technical log (including *MEL* of *CDL* items) did not reveal any technical anomaly prior to the flight.

The post-Incident, manufacturer technical review of the engine determined that there was a damage to the accessory gearbox (AGB) hydro-mechanical unit (HMU) ball bearing. Consequently, the HMU quill shaft sheared by accumulated hard particles contamination, handling damage, and assembly damage as the inner ring found migrated and misaligned.

Engine number 1

Engine number 1 (left engine) was General Electric, GE90-115BG03, serial number 907329. It was installed on the Aircraft on 25 August 2020, with 31,661:18 hours, 4,592 cycles since new, and 1,512 cycles since last inspection. Upon landing at OMAA, the engineers observed fuel mixed with oil stains on the lower left engine exhaust area. According to the Operator, the left engine oil quantity indicated 26 quarts while engine number 2 (right) indicated 20 quarts. Physical checks of the oil tanks confirmed a significantly higher oil level on the left engine compared to the right engine.

An oil sample was taken from the left engine for laboratory analysis. Approximately 91 percent of fuel were found present in the left engine oil tank. Due to the fuel viscosity being less when compared to that of the oil, the engine internal bearings were also found damaged. The engine magnetic chip detector (MCD) also exhibited evidence of metal debris.

Aerodrome Information

Abu Dhabi International Airport (OMAA), coordinates 24°25'59"N 54°39'04"E, located 16.5 kilometers east of Abu Dhabi city. The airport elevation is 83 feet. OMAA is equipped with two asphalt runways: 13R/31L; and 13L/31R. Runway 31L has a landing distance available of 4,106 meters. The distance between both runways' centerlines is 2,000 meters.

Dhaka Hazrat Shahjalal International (VGHS) coordinates 23°50′34″ N 090°24′02″E, located 17 kilometers from city center of Dhaka. The airport elevation is 27 feet. VGHS is equipped with one asphalt runway: 14/32, and it has a landing distance of 3,200 meters.

Tests and Research

Engine manufacturer test

On 19 September 2021, the left engine was sent to the engine manufacturer's facility for disassembly and examination. During 19 to 20 October, the engine manufacturer conducted multiple tests and examinations to determine the root cause of the failure. Following its removal from the engine, a table examination of the accessory gear box was performed by experts from the engine manufacturer. Representative of the United Kingdom Air Accidents Investigation Branch (AAIB) were present for AGB examination after it had been removed from engine and accessories had been removed from AGB.

The findings were as follows:

- Accessory gearbox (AGB) hydro-mechanical unit (HMU) ball bearing damage
- The HMU quill shaft had sheared and consequently the HMU guard, sleeve, seal, housing and O-ring were damaged causing fuel leak into oil from the shaft out of HMU line of the AGB
- Fuel leak was confirmed during the HMU test (0.33 to 1.33 gallons per minute was measured). This was consistent with what happened during the flight from VGHS to OMAA. (Figure.1)

The examination report referred the damage to:

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- "Hard particles contamination, which were found in silver plating of the bearing cage
- Signs of handling damage which was evident from the deformation of outer ring raceway
- Assembly damage as the inner ring found migrated and misaligned."

According to the engine manufacture's root cause report, the handling damage was related to the AGB HMU ball bearing installation.

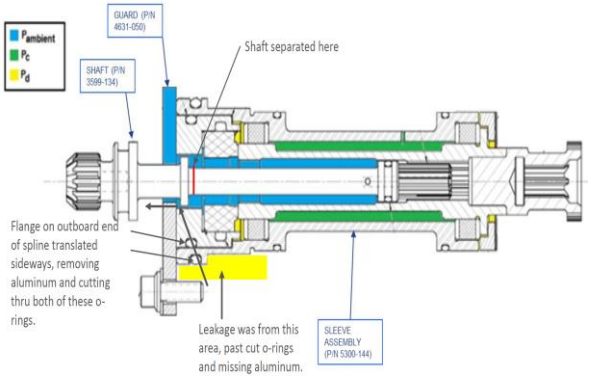

Figure 1. Description of the failure

Organizational and Management Information

The Aircraft manufacturer revised *fault isolation manual (FIM)*

The Aircraft manufacturer subsequently revised the *FIM* on 5 January 2022. This included the following changes after the revision:

HPTACC Position Error- Fault Isolation

1) Fuel Driven Actuator Test was replaced with an Engine Air Driven Actuator Test.

If the Engine Air Driven Actuator Test shows ACTIVE for the maintenance message, the following inspection steps were added:

2) A check for fuel in the engine oil which includes a warning sign.
3) An inspection of the engine debris monitoring system.
4) An inspection of the lube and scavenge pump screens and magnetic plugs.
5) Removal of the HMU and inspection of the HMU driveshaft.

The Commander's authority to extend FDP

According to the *Operations Manual – Part A, (OM-A)*:

> "An aircraft commander may, at his discretion, and after taking note of the circumstances of the other members of the crew, extend an FDP beyond the permitted in *OM-A* part 7.11, provided that he is satisfied that the flight can be made safely."

In addition, it states:

> "…in a flying duty period involving 2 or more sectors, up to a maximum of 2 hours' discretion may be exercised prior to the first and subsequent sectors, but this may be up to 3 hours prior to the start of a single sector flight, or prior to the last sector on a multi-sector flight."

The discretion report from the Operator shows that the Commander and the Copilot had an extended FDP of 2 hours 25 minutes.

Minimum Equipment List (MEL)

According to the *MEL*, EICAS is the primary means of displaying aircraft system information to the flight crew. EICAS consolidates engine and subsystem indications and provides a centrally located crew alerting function. EICAS displays system alerts (warning, caution, and advisory), communication alerts, memo messages, and status messages.

A status message is defined according to the *MEL* as: "a system condition which affects airplane dispatch, displayed in white text on the Multi-function display (MFD) status page. Status messages are checked prior to engine start and the condition should be corrected or dispatched per the *MEL*. There are no inflight crew procedures associated with status messages."

After reviewing the *MEL's cross reference list* associated with HPTACC message on the EICAS, the Investigation found that the level of this message is categorized as a 'status message' that did not have a corresponding *MEL* item to be considered for dispatch relief which is annotated by 'none', which reflects 'no dispatch'.

As per the eATL entries, the status message was cleared at the stand in VGHS before departure.

The definition of adequate airport and suitable airport

According to the *OM-A*, an adequate airport is an airport that the operation considers to be satisfactory, considering the applicable performance requirements and runway characteristics. In addition, it should be anticipated that at the expected time of use, the airport will be available and equipped with necessary ancillary services such as air traffic services, sufficient lighting, communications, weather reporting,

navigation aids and emergency services (rescue and firefighting services). The available runway characteristics (width, length, and pavement classification number "PCN") must be sufficient to meet aircraft performance requirements including required take-off and landing distances.

According to the *OM-A*, an airport is suitable if it is adequate for operations and the meteorological conditions satisfy the planning minima for the expected landing, and meets the approach, runway and aircraft capabilities and crew qualifications.

OM-A **methods to establish escape route charts (depressurization/drift down)**

The *OM-A* states that:

> "Diversion procedures for critical phases have been established taking into account the topographical along the route and the requirements mentioned below (engine(s) failure, depressurization). Refer to *operations manual − part B* (*OM-B*) Flight Crew Training Manuals (FCOM) for drift down techniques and *OM-C* for drift down and descend maneuver."
>
> ……..
>
> "….an escape procedure in the *OM-C* provides instructions on the descent procedures and will describe an escape strategy ensuring that terrain will be cleared by a minimum of 2000 feet within 5 nautical miles corridor either side of the trach using topographical data. Grid *Minimum Off Route Altitude (MORA)*[2] depicted on the Jeppesen charts can also be used to devise instructions."

Quick reference handbook (QRH) **− Procedures for engine abnormal indications and airframe vibration**

As per the *QRH*, in case of abnormal engine indications with airframe vibrations, the crew is instructed to use the checklist of engine severe damage. The checklist procedures are outlined as follows:

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1. Autothrottle arm switch (affected side): Confirm- OFF
2. Thrust lever (affected side): Confirm-idle
3. Fuel Control Switch (affected side): Confirm-Cut off
4. Engine Fire Switch (affected side): Confirm-Pull
5. If high airframe vibration occurs and continues after engine shutdown: without delay, reduce airspeed and descend to a safe altitude which results in an acceptable vibration level. If high vibration returns and further airspeed reduction and descent are not practical, increasing the airspeed may reduce the vibration.
6. APU selector (if APU available): START, then ON
7. Transponder mode selector: TA (Traffic Advisory) ONLY
8. Plan to land at the nearest suitable airport.
9. Do not accomplish the following checklists: AUTOTHROTTLE, ENG FAIL."

Emergency escape route **procedures in case of engine failure over Muscat FIR**

As per the Operator's *emergency escape route manual* procedures, which is a part of *OM-C*, in case of engine failure and/or depressurization within Muscat FIR, descend initially to flight level (FL) 140.

The diversion options as per the manual are: Abu Dhabi (OMAA), Dubai International Airport (OMDB), Al Ain International Airport (OMAL), Al Bateen Executive Airport (OMAD), Sharjah International Airport (OMSJ), Ras Al Khaimah International Airport (OMRK), and Fujairah International Airport (OMFJ).

OM-A − Handling of in-Flight Abnormalities/ Emergencies

[2] MORA: This is the minimum altitude which ensures safe obstacle clearance at any point on the entire route of flight [Source:skybrary.com]

According to the *OM-A*, during emergencies the following criteria must be considered for selecting the nearest suitable airport:

- Technical condition of the aircraft affecting performance and handling
- Actual gross weight
- Remaining fuel onboard
- Terrain clearance requirements
- Enroute and terminal weather
- Route and airfield facilities.

If two or more possible airfields exist, the nearest airfield in terms of flight time should normally be selected unless weather or Notice to Airmen (NOTAM) critically become more limiting.

Suitable airport in this context is an airfield where a safe approach and landing maybe conducted and does not consider:

- Repair facilities
- Commercial passenger handling facilities
- Rescue and Fire Fighting service (RFF) category.

This section continues with the statement that in the event of a depressurization or drift down scenario in an area where published Escape Routes have been established, these Escape Routes will ensure adequate terrain clearance at all times to the specified enroute alternate. However, it is the operating crew's responsibility to assess the suitability of the instructions based on the circumstances at the time of the emergency.

Analysis

Root Cause of the Engine Failure

The analysis of the engine at the manufacturer premises indicated that both the stall/in-flight shutdown and fuel-in-oil root causes are traced to the ball bearing failure in the HMU line of the AGB. The engine manufacturer analysis of the engine revealed that the root cause of the engine failure is related to:

- Hard particles contamination, which were found in silver plating of the bearing cage
- Signs of handling damage which was evident from the deformation of outer ring raceway
- Assembly damage as the inner ring found migrated and misaligned.

The engine manufacturer had issued a safety action as described in the Factual Information part of this Report.

This is due to the design of the HMU which includes a speed related restriction on the use of the HPTACC. Servo valve which controls the position of the HPTACC valve. Below N2 speed of 45%, control of HPTACC servo valve is not possible. Control of the HPTACC servo valve is only possible at N2 speeds greater than 45%.

The previously *FIM* defined Fuel Driven Actuator test is preformed while monitoring the engine using the starter. A typical starter monitoring speed is 30% N2. This speed will not allow HPTACC servo valve to function. The Fuel Driven Actuator test will indicate PASS no matter what the condition of the HMU drive shaft is.

The revised *FIM* defined Air Driven Actuator test is performed while the engine is operating at idle. A typical idle speed is 67% N2. This speed will allow the HPTACC servo valve to function. The Air Driven Actuator test will PASS our FAIL based on how the HPTACC system operates.

The Commander's Decision to Accept the Flight

The Investigation reviewed all the circumstances surrounding the return flight from VGHS to OMAA in the pre-flight stage.

The Commander stated during the interview that challenges were experienced with in the quality of information exchange with the local engineering staff and MCC regarding the maintenance work undertaken on the Aircraft. This information was considered relevant by the Commander in order to execute a more informed decision about accepting the Aircraft and conducting the return flight.

Despite holding some residual reservations about the Aircraft status and detail on the maintenance actions undertaken at VGHS, the Commander accepted the flight based on the standard practice of reviewing the eATL entries, which declared the Aircraft serviceable.

The maintenance action undertaken at VGHS was in accordance with *FIM*, and is not considered the root cause of the failure encountered subsequently in flight.

The Commander's Decision to Continue to OMAA

The Investigation found that the Commander elected to land at OMAA based on the time required for preparation for landing and was consistent with the direction provided in *OM-A – Handling of In-flight Abnormalities/Emergencies*, and operations in areas in which escape routes and associated diversion airports have been established.

Conclusions

Findings

(a) The flight crew were appropriately licensed according to the existing *Civil Aviation Regulations* of the United Arab Emirates.

(b) The flight crew were medically fit.

(c) The flight crew were well-rested before the flight.

(d) There was no *MEL, CDL,* or technical log entries for the Aircraft prior to departing from OMAA.

(e) The flight had a HPTACC status message on the OMAA-VGHS sector without any action required from the flight crew to be executed.

(f) The Aircraft had undergone two engine dry runs when it was parked to clear the HPTACC status message.

(g) The engine manufacturer advised the Operator about an "oil consumption" message for the related engine.

(h) The maintenance engineers conducted maintenance work on the engine after being notified by the Operator's MCC about the "oil consumption" message.

(i) The Aircraft was delayed for the departure at VGHS for the return flight to OMAA.

(j) The FDP for both flight crewmembers were extended for 2 hours 25 minutes and the Commander operated the flight on his discretion which was inside the maximum permitted for the flight.

(k) The Commander accepted the flight based on the eATL entries made.

(l) The Aircraft encountered an HPTACC status message, followed by an engine thrust loss alert message and associated airframe vibrations during the flight between VGHS and OMAA.

(m) The Commander was in an escape route segment over Muscat FIR at the time of the engine thrust loss.

(n) The Commander applied the drift down procedure.

(o) The Commander elected to land at OMAA.

(p) The Commander declared a PAN PAN to ensure urgency and possible priority for the approach.

(q) On inspection of the engine, fuel and oil were found leaking onto the engine exhaust nozzle, there was damage to the HMU, and oil samples tested were found to contain 91% to 93% fuel.

(r) There was hard particles contamination, which were found in the silver plating of the AGB HMU ball bearing cage.

(s) Assembly damage as the inner ring found migrated and misaligned.

Causes

The Air Accident Investigation Sector determines that the cause of the in-flight engine shutdown was the damage of the accessory gearbox (AGB) hydro-mechanical unit (HMU) ball bearing. Consequently, the HMU quill shaft sheared by accumulated hard particles contamination, handling damage, and assembly damage as the inner ring found migrated and misaligned.

Safety Actions

The engine manufacturer subsequently revised the *FIM* to call up the correct maintenance task, to more reliably detect the imminent failure and prevent dispatch in cases where similar failures occur.

Safety Recommendations

The Air Accident Investigation Sector recommends that:

Etihad Airways

SR03/2023

Whilst the investigation did not determine any findings relating to the operator actions, and in the interests of continuous improvement, it is recommended to conduct a review of the communication protocols between crew members, line engineers, and MCC relating to reported aircraft defects, in support of aircraft dispatch decision-making efficacy.

This Report is issued by:

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