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GOVERNMENT OF INDIA

FINAL INVESTIGATION REPORT OF IN-FLIGHT ENGINE SHUTDOWN INCIDENT TO M/s SPICEJET LTD. BOEING B737-8, AIRCRAFT VT-MXA ON 03.05.2022 AT CHENNAI.

O/o DIRECTOR AIR SAFETY, SOUTHERN REGION, INTERNATIONAL CARGO COMPLEX, MEENAMBAKKAM, CHENNAI-600016

FOREWORD

In accordance with Annex 13 to the International Civil Aviation Organization Convention and the Aircraft (Investigation of Accidents and Incidents) Rules 2017, the sole objective of this investigation is to prevent aviation incidents and accidents in the future. It is not the purpose of the investigation to apportion blame or liability.

This report has been prepared based upon the evidences collected during the investigation and opinions obtained from the experts. Consequently, the use of this report for any purpose other than for the prevention of future incidents /accidents, could lead to erroneous interpretations.

ABBREVIATIONS

Aircraft	Incident Aircraft
AMM	Aircraft Maintenance Manual
AOC	Air Operator Certificate
ATC	Air Traffic Control
ATPL	Airline Transport Pilot License
CAS	Calibrated Air Speed
CG	Center of Gravity
CPL	Commercial Pilot Licence
CSN	Cycles Since New
CVR	Cockpit Voice Recorder
DFDR	Digital Flight Data Recorder
ELPL	English Language Proficiency Level
FAA	Federal Aviation Administration
FCOM	Flight Crew Operating Manual
FCTM	Flight Crew Training Manual
FDR	Flight Data Recorder
FDTL	Flight and Duty Time Limitations
FL	Flight Level
FO	Co-Pilot/ First Officer
FRTOL	Flight Radio Telephone Operator’s Licence
IATA	International Air Traffic Association
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
IR	Instrument Rating
IST	Indian Standard Time
LH	Left Hand
MEL	Minimum Equipment List
Operator	AOP Holder of The Incident Aircraft
PF	Pilot Flying

PIC	Pilot in Command
PM	Pilot Monitoring
PPC	Pilot Proficiency Check
RA	Radio Altitude
RWY	Runway
SSCVR	Solid State Cockpit Voice Recorder
SSFDR	Solid State Flight Data Recorder
TSN	Time Since New
UTC	Coordinated Universal Time
VFR	Visual Flight Rules

INDEX

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1	Aircraft	Type	Boeing B737-8 MAX
		Nationality	India
		Registration	VT-MXA
2	Name of the Owner		M/s Sky High LXXX Leasing Company Ltd.
3	Name of the Operator or Hirer		M/s SpiceJet Ltd.
4	Pilot – in –Command		Valid ATPL holder
	Extent of injuries		Nil
5	First Officer		Valid CPL holder
	Extent of injuries		Nil
6	Date and Time of Incident		03rd May 2022, 1430 UTC (03rd May 2022, 1930 IST)
7	Place of Incident		VOMM (Chennai Airport, Chennai, India)
8	Last point of Departure		VOMM (Chennai Airport, Chennai, India)
9	Intended place of landing		VEDG (Kazi Nazrul Islam Airport, Durgapur, India)
10	Crew on Board		07 (02+05)
11	No. of Passengers on board		179
12	Type of Operation		Schedule, Passenger
13	Phase of Operation		During Climb
14	Type of Incident		SCF-PP (System/Component Failure – Power plant)

(All timings in the report are in UTC)

SYNOPSIS

On 03rd May 2022, M/s SpiceJet Boeing B737-8 aircraft registration VT-MXA while operating a scheduled flight from Chennai to Durgapur was involved in an air turn back incident due Eng#2 in-flight shutdown during climb at 1430UTC. There were 186 persons including seven crew members on board the aircraft.

The aircraft took off from Chennai at 1412 UTC. While climbing, passing FL80, "Oil Filter Bypass Light" (OFB Light) illuminated for Engine#2 at 1417 UTC. Crew started doing checklist and the light was extinguished after levelled out at FL90, and at about FL93, the OFB light for Engine#2 came once again and remained. Crew carried out the checklist and it directed to shut down the engine. Crew carried out the In-Flight Shut Down (IFSD) of the ENG#2 and declared PAN PAN.

Further, crew requested to ATC for priority landing and made a safe single engine landing at Chennai (1448 UTC) and taxied to the parking bay. There was no fire and injury to any of the occupants on board the aircraft.

The incident was reported to DGCA, subsequently the investigation was ordered by DGCA under Rule 13(1) of the Aircraft (Investigation of Accidents and Incidents) Rules, 2017, by appointing the Investigator-in-charge vide order no DGCA-15018(07)/8/2022-DAS dated 11.05.2022.

The investigation reveals that, the incident occurred due to the ENG#2 Radial Drive Shaft Ball Bearing cage rivet fatigue failure.

1. Factual Information:

1.1 History of the flight:

On 03/05/2022, M/s SpiceJet, Boeing B737-8 MAX aircraft registration VT-MXA was operating a scheduled flight (SG331) sector Chennai to Durgapur. Flight SG-331 was the fifth flight of the day by VT-MXA aircraft. There were 179 passengers and 07 crew members on board the aircraft. There was no abnormality reported on the aircraft during any of the previous flights on said date and previous day.

The flight was under the command of PIC holder of ATPL license with Co-Pilot holder of CPL license and both duly qualified on aircraft type B737-8. The first sector for the crew on the incident day was Chennai to Durgapur and they had been provided adequate rest before the flight. Pilot in Command (PIC) was Pilot Flying (PF) and First Officer (FO) was Pilot Monitoring (PM).

The flight SG331 took off from Chennai at around 1412 UTC. The take-off was uneventful, weather reported at 1400 UTC was visibility 5000m, mist and winds calm. While climbing, passing FL80, "Oil Filter Bypass Light" (OFB Light) illuminated for Engine#2 at 1417 UTC. Crew levelled out at FL90, started non-normal checklist and the light was extinguished before completion of it. At about FL93, the OFB light for Engine#2 came once again. Crew carried out the QRH and it directed to shut down the engine. Crew carried out the In-Flight Shut Down (IFSD) of the ENG#2 and declared PAN PAN.

Further, crew requested to ATC for priority landing and made a safe single engine landing at Chennai (1448 UTC) and taxied to the parking bay. All persons on board were safe and there was no fire reported.

1.2 Injuries to persons:

Injuries	Crew	Passengers	Others
Fatal	NIL	NIL	NIL
Serious	NIL	NIL	NIL
Minor/None	NIL/07	NIL/179	

Total personnel on board: 186

1.3 Damage to Aircraft:

There was no damage to the aircraft. However, ENG#2 was shut down due internal failure.

1.4 Other Damage: NIL

1.5 Personnel information:

Details	Commander	First Officer
Age/Gender	43Years/Male	33 years/Male
Licence type	ATPL	CPL
Date of issue	12-10-10	26-05-14
Licence Valid up to	29-10-26	22-04-24
Licence Category	Aeroplane	Aeroplane
Endorsement as PIC	C-152, C-172, PA-34, ATR42/72, B737 300-900	DA-42, C-172
Date of Class I/II Medical	01-10-21	16-07-21
Medical Exam valid up to	08-10-22	23-07-22
Date of issue of FRTO License	22-10-2000	26-05-14
FRTO Licence Valid up to	12-11-22	22-04-24
Instrument rating done on	10-02-22	12-11-21
Last PPC done on	10-02-22	12-11-21
Total Flying Experience	9322.31	618.54
Experience on Type	6163 Hours 28 mins	401 Hours 44 mins
Experience as PIC on Type	6110 Hours 20 mins	NA
Last flown on Type	02-05-22	02-05-22
Total Flying Experience in last 1 year	317:33	280:32
Total Flying Experience in last 6 months	172:33	191:51
Total Flying Experience in last 30 days	34:25	52:56
Total flying experience in last 7 days	00:00	19:06
Total flying experience in last 24 Hrs.	00:00	03:46
Duty time last 24 Hrs.	0215 Hrs.	0725 Hrs.
Rest before the flight	2159 Hrs.	1700 Hrs.

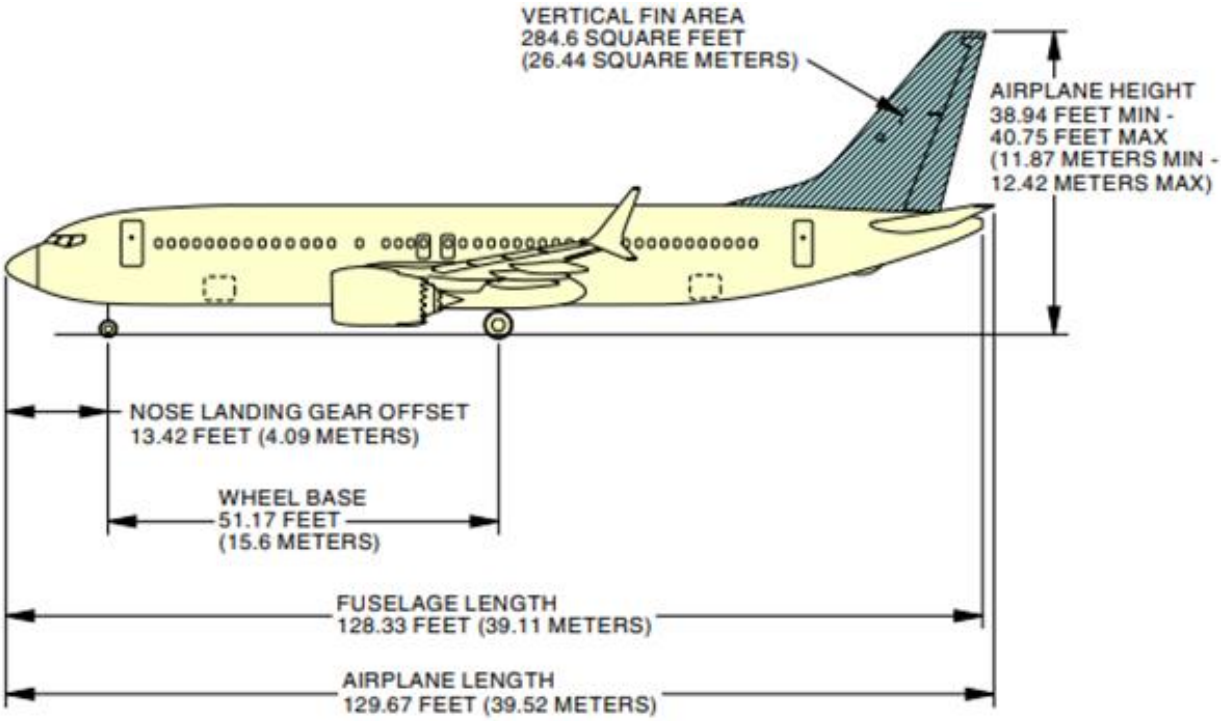
English Language Proficiency Level (ELP)	L-5	L-4
ELP Valid till	17-12-25	16-08-23

Both the operating crew were current in all training and was not involved in any serious incident/accident in the past. The licenses of both the cockpit crew and all the ratings were valid. Both the crew had adequate rest prior to roster for the incident flight. Both the cockpit crew had undergone pre-flight medical examination prior to flight and same was negative.

1.6 Aircraft information:

The Boeing B737-8 is a subsonic civil transport aircraft. The aircraft has two high bypass turbofan LEAP-1B (Leading Edge Aviation Propulsion) engines manufactured by M/s CFM International. It is for short to medium range flights with a capacity of up to 210 passengers. The aircraft is certified in Normal (Passenger) category, for day and night operation under VFR & IFR. The airplane has a design range of 3,550 nautical miles and maximum operating altitude is 41,000 feet (12496.8m).

The aircraft length is 39.52m, wingspan is 35.91m and height of this aircraft is 12.42m. The distance between main wheel center is 5.72m and has an engine clearance of 0.54 meters.



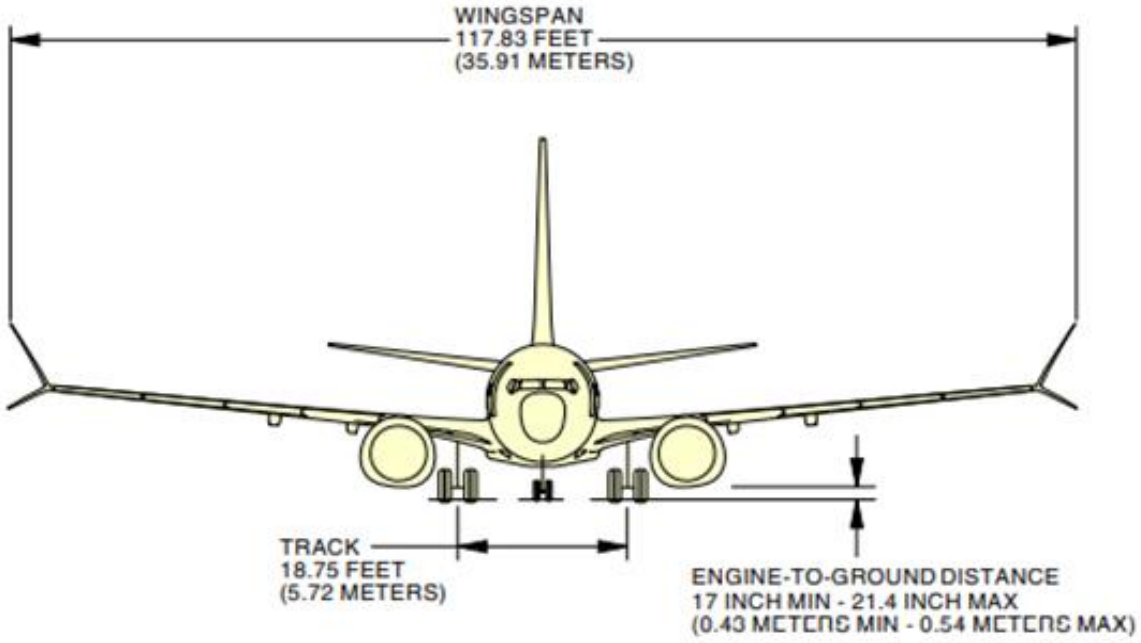


Figure 1: B737-8 External dimensions as shown

1.6.1 Brief Technical Description of CFM turbofan LEAP-1B Engine

The LEAP-1B (Leading Edge Aviation Propulsion) is a high bypass ratio, dual rotor turbofan engine.

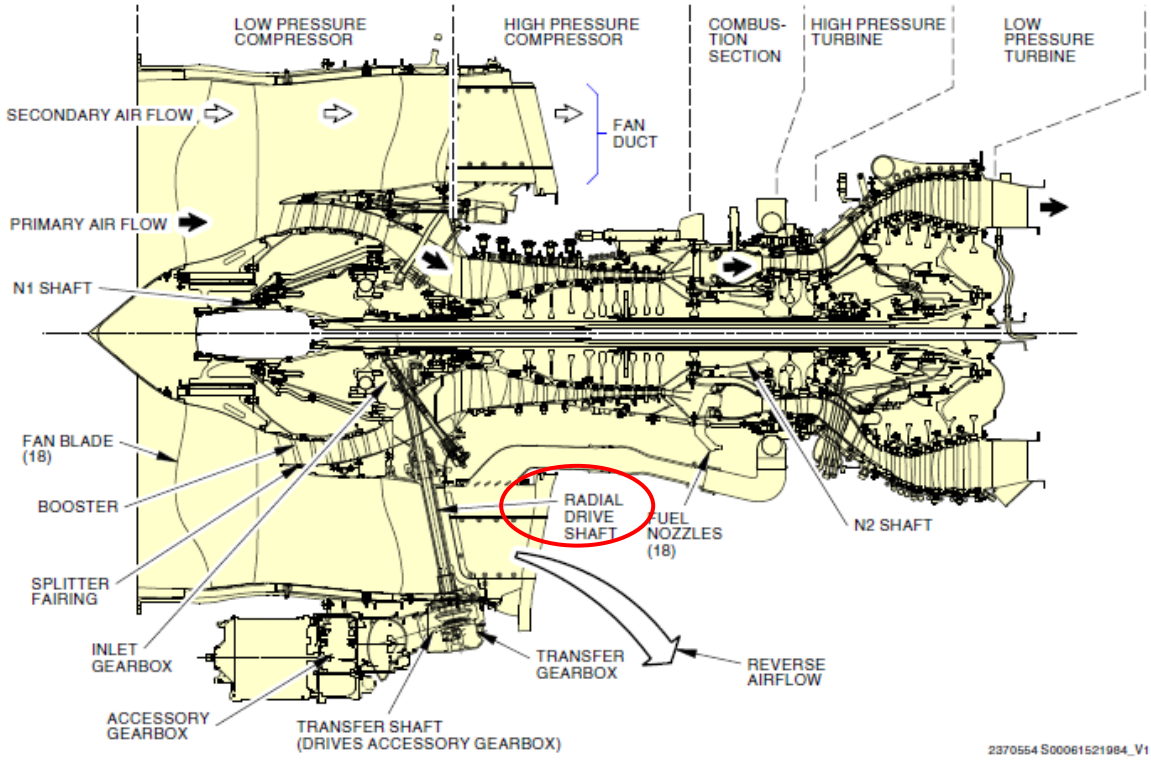


Figure 2: Engine General Description

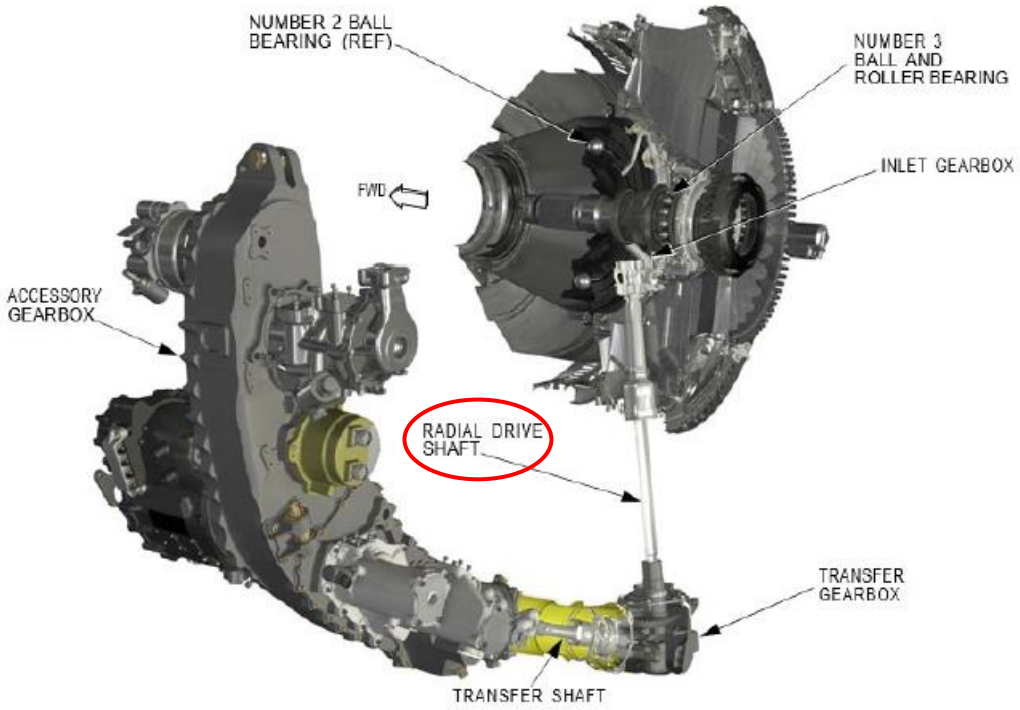


Figure 3: Engine Accessory Drive

ENGINE - ACCESSORY DRIVE

General

The accessory drive transmits mechanical energy from the N2 shaft to the accessory gearbox. The inlet gearbox (IGB) turns the radial drive shaft (RDS). The RDS turns the transfer gearbox (TGB). The TGB turns the transfer shaft (TS). The TS turns the accessory gearbox (AGB). The transfer of mechanical energy reverses when the starter operates.

Inlet Gearbox (IGB)

The IGB transmits mechanical energy from the high-pressure compressor front shaft to the RDS. It also holds the front of the HPC rotor.
The IGB contains these parts:

- Horizontal bevel gear with coupling/locking nut
- Pinion bevel gear
- Number 3 bearing (roller and ball)
- Number 3 bearing rotating seal.

Radial Drive Shaft (RDS)

The RDS transmits mechanical energy from the IGB to the Transfer Gearbox. The assembly is located at the 6:00 position (aft looking forward). The RDS has an inner Radial Drive Shaft and housing, a shaft mid- length ball bearing, and an outer Radial Drive Shaft and housing. The shaft mid-length bearing gives correct centering of the RDS in its housing.

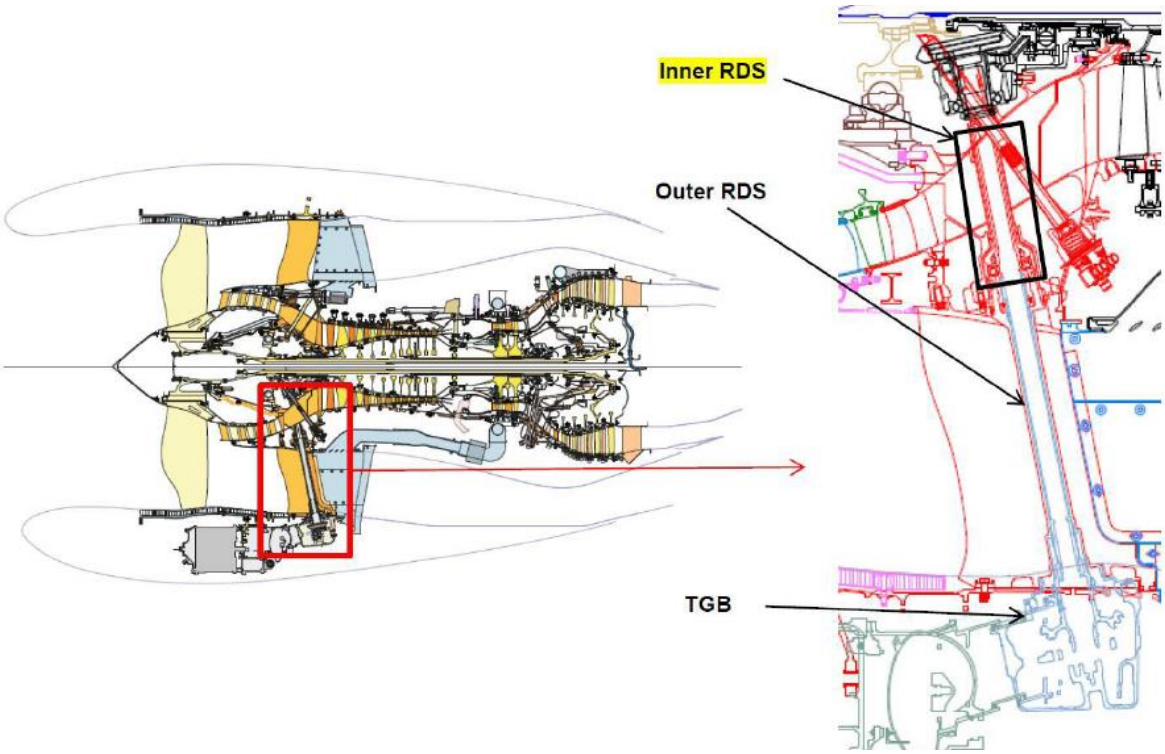


Figure 4: Inner RDS Location

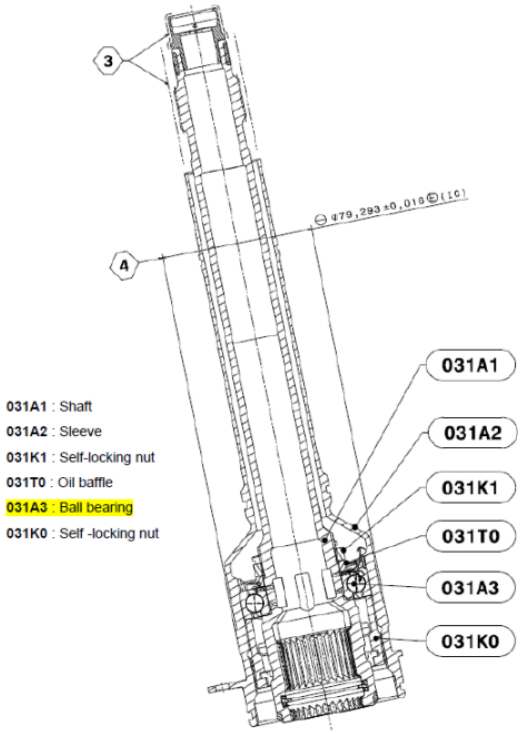


Figure 5: Inner RDS

Transfer Gearbox (TGB)

The TGB transmits mechanical energy from the RDS to the Transfer Drive Shaft. The TGB is on the fan frame module at the 6:00 position and has:

- Transfer gearbox housing
- Input bevel gear
- Horizontal bevel gear and transfer shaft assembly

Transfer Shaft (TS) and Transfer Tube

The TS has a spline at each end and transmits mechanical energy from the TGB to the Accessory Gear Box (AGB). The transfer shaft is inside the transfer tube.
The TGB transfer tube is made of an aluminium alloy. The TGB transfer tube ensures oil containment between the TGB housing and the AGB housing. It also houses the TGB horizontal bevel gear assembly. It provides a bearing support for two TGB roller bearings and one TGB ball bearing for the TGB horizontal bevel gear assembly. The transfer tube attaches to the TGB housing with bolts, and makes the connection with the AGB.

ENGINE OIL - INDICATING - OIL FILTER BYPASS WARNING SYSTEM

General

The oil filter bypass warning system shows a message when the oil filter is near a bypass condition. The message shows on the engine indication display. The oil filter bypass indicating system uses a single, dual element differential pressure sensor. The signal from the sensor is sent to the EECs which in turn sends the signal to the Display Processing Computers (DPCs) just before the oil filter bypass valve opens. The oil filter differential sensor connects with the EEC through a single connector. The sensor is installed on the lubrication unit.

Functional Description

The oil filter differential pressure sensor monitors the oil pressure difference between the inlet and the outlet of the oil filter. The oil filter differential pressure sensor is a dual, strain gauge type pressure sensor. Each element in the sensor sends an output to the related EEC channel. The EECs change this signal to an ARINC 429 signal and send it to the DPCs.

Oil Filter Bypass Message

Just before the oil filter bypass valve opens, the EEC sends a signal to the DPCs. This causes the engine indication display to show the amber OIL FILTER BYPASS message. There is one OIL FILTER BYPASS message for each engine.
The amber OIL FILTER BYPASS message flashes initially for 10 seconds, and then shows continuously. The DPCs do not allow the flash mode during takeoffs and landings.

ENGINE OIL -- DISTRIBUTION - ODMS UNIT

The oil debris monitoring system (ODMS) unit filters and conditions the signal from the ODMS sensor, and provides a signal to EEC channel B when it detects ferrous particles in the scavenge oil. The ODMS unit is under the oil tank, in the 04:00 o'clock position, aft looking forward.

Functional Description

The ODMS unit receives a pulse from the ODMS sensor when it captures a ferromagnetic particle. The ODMS unit amplifies and filters the particle pulse, and compares the pulse magnitude to a threshold. If the signal is larger than the threshold, the signal is conditioned and sent to EEC channel B. The EECs store the number of chips that are counted in NVM memory. If the number of pulses reaches a threshold, the EECs send a maintenance message to the Onboard Maintenance Function (OMF). At another threshold, the EECs send a signal to the display processing computers (DPCs), which then show a status message and turn on the maintenance light. There is an OMF special function to erase the chip count in the EECs.

1.6.2 Aircraft details:

Air Operator Certificate (AOC)	Scheduled Operator's Permit No S-16 which was valid up to 16th May 2023.
Aircraft Registration	VT-MXA
Type of Aircraft	Boeing 737-8
Manufacture Serial No.	64505
State of Manufacturing	USA
Manufacturing year	2018
Certificate of Registration	4977
Certificate of Airworthiness number and issue date	Number 7080, issued on 05.11.2018
Category	Normal
Airworthiness Review Certificate number and Validity	DDG/NR/ARC/2021/179, valid till 10.12.2022
Aircraft TSN / CSN	2976:45 Hrs. / 1593
Minimum crew necessary	2 / 4
Type of fuel	ATF Jet-A1
Aero mobile Licence	31.12.2023
Next schedule maintenance due at	C-01 check of aircraft expected on Oct 29, 2022.
Weight Schedule Valid up to	28.10.2023
Maxi. Aircraft Take-off Weight	72302 Kg
Maxi. Aircraft Landing Weight	69308 Kg
For incident sector (Chennai-Durgapur)	
Aircraft Take-off Weight	68377 Kg
Aircraft Landing Weight	67200 Kg

Fuel On-board before Flight	21 ton	
Engine Details		
Engine -	**LH**	**RH**
Engine Manufacturer	CFM	CFM
Engine Model	Leap-1B	Leap-1B
Engine S.no	602673	602691
Date of Manufacture	30.09.2018	30.09.2018
Total Engine Hours/Cycles	2976:45 / 1593	2976:45 / 1593
Engine Time since Last Shop Visit	First run Engine	First run Engine
Last major check carried out	First run Engine	First run Engine
Last minor check carried out	PS-3 check carried out on Apr 23, 2022. Borescope inspection of SN 602691 on Apr 27, 2022.	PS-3 check carried out on Apr 23, 2022. Borescope inspection of SN 602673 on Apr 26, 2022.
Failed Part/ Component in flight	Engine Serial number **602691 (RH Engine)**	

The aircraft was last weighed on 29th Oct 2018 at Seattle, USA and the Weight Schedule was prepared and duly approved by the office of the Director of Airworthiness, DGCA New Delhi. Prior to the incident flight the weight and balance of the aircraft was well within the operating limits.

The aircraft VT-MXA was inducted into M/s SpiceJet on 02.11.2018 and operated until DGCA issued a Public Notice on 13.03.2019 i.e. "Operation of B-737 MAX aircraft will not take place from/to Indian airports and transit or enter into Indian airspace effective from 1030 UTC 13 March 2019 till further notice" due the Boeing 737 MAX aircraft was grounded globally after two fatal crashes on the aircraft type. At the time of grounding TSN-1547:03Hrs, CSN-793. As per DGCA order: DGCA - 25011(02)/2/21 dated August 26, 2021 and after completions of approved Return to service work package for B737-8(MAX) Aircraft vide DGCA letter: DEL-11011(13)29/2019-DAWNR/1436 dated November 18, 2021, the Boeing 737 MAX aircraft returned to service on 09.12.2021.

During grounded period aircraft was preserved under service and protection on 30-day active storage procedure. Post release to service dated 09.12.2021; aircraft completed 2976:45 Hrs. (TSN) / 1593 (CSN) before the subject incident on 03.05.2022.

The defect record of the aircraft was scrutinized on the date of occurrence of the incident and observed that LH Ignition system for ENG#1 declared inoperative, MEL 74-00-01-01B under CAT'C' invoked on 01.05.2022 and valid up to 11.05.2022.

1.6.3 Post incident details:

On arrival of aircraft to the bay, during initial inspection of failed Engine#2, the following observations were made by the arrival AME:

1. On board maintenance function interrogated and found Flight Deck Effect-(FDE) -: ENG #2 OIL FILTER BYPASS IND with Maintenance Message: 79-42895 CLIMB - OIL FILTER IMPENDING BYPASS ENG#2 ON.
2. Oil quantity Indication and physical level found satisfactory (ENG#1=20, ENG#2=21).
3. No evidence of oil leaks observed upon visual inspection.
4. Engine Air inlet area is clean.
5. Oil Debris Monitoring System (ODMS) sensor inspection carried out and found more metal particles on the magnetic tip. (Refer: Figure 2)
6. Scavenge screens plug inspection carried out & observed that
   a. Sump A, B, and C - NIL particles observed.
   b. Accessory Gear Box (AGB) –Sump - found with less metal particles (Refer: Figure 1)
   c. Transfer Gear Box (TGB) - TGB 1 & TGB 2 sumps– were found with more metal particles (Refer: Figure 3)

Subsequently the aircraft was grounded for detailed inspection.

Figure 6: AGB Sump

Figure 7: ODMS Sensor

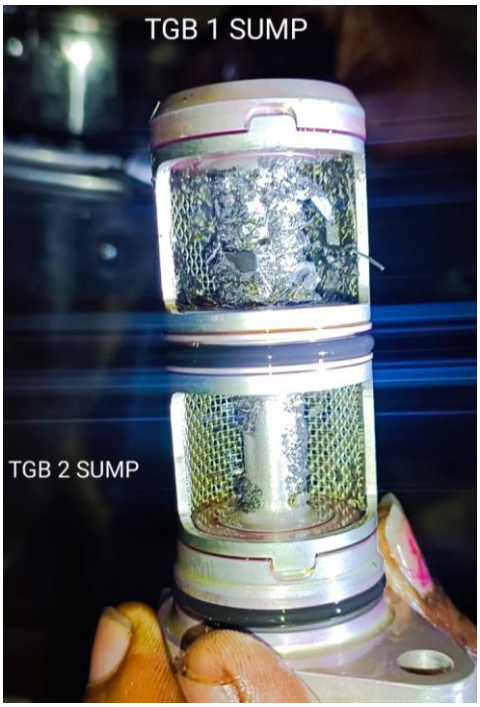


Figure 8: TGB Sump 1 & 2

1.6.4 Airworthiness Directives and Service Bulletins

The Federal Aviation Administration (FAA) learned of five commanded IFSD events that occurred on certain CFM LEAP-1B model turbofan engines beginning in August 2018. The affected CFM LEAP-1B model turbofan engines experienced multiple RDS bearing cage failures resulting in five IFSDs. M/s CFM's investigations identified debris on the TGB scavenge screen, A-sump screen, and other screens. Subsequently, CFM determined that these IFSD events were the result of inadequate oil flow to the RDS bearing, which caused the RDS bearing cage to fail.

The FAA has issued the **AD 2019-12-01 dt. 18th June 2019** (for certain CFM International S.A. (CFM) LEAP-1B21, -1B23, **-1B25**, -1B27, -1B28, -1B28B1, -1B28B2, -1B28B3, -1B28B2C, -1B28BBJ1, and -1B28BBJ2 model turbofan engines with certain RDS bearings installed) to address the unsafe condition on these products. The FAA reviewed M/s CFM Service Bulletin (SB) LEAP-1B-72-00-0222-01A-930A-D, Issue 007, dated May 17, 2019, which describes procedures for inspections of TGB scavenge screens and borescope inspection (BSI) of the RDS bearing. For affected engines with ESN 602500 and higher (**the failed engine s.no 602691**):

(A) After the **RDS** accumulates 50 **FH**s since new but before accumulating 100 FHs since new, or within 50 **FH**s after the effective date of this AD, whichever occurs later, perform an initial inspection of the **TGB1** and **TGB2** scavenge screens.

(B) Thereafter, perform repetitive inspections of the **TGB1** and **TGB2** scavenge screens at intervals not exceeding 100 **FH**s since the last inspection.

And along with the above mandatory instructions, the optional Borescope Inspection (BSI) may be carried out i.e., once the RDS bearing has accumulated 1,000 FHs since new, operator may perform a BSI of the RDS bearing in accordance with the Accomplishment Instructions of CFM SB LEAP-1B-72-00-0222-01A-930A-D dated May 17, 2019. If the results of this BSI are "satisfactory" then operators are not required to perform the repetitive inspections of the AD until the RDS bearing accumulates 4,250 FHs since new.

Further, M/s CFM issued SB LEAP-1B-72-00-0317-01A-930A-D, Issue 001, dated January 9, 2020 for repetitive inspection of the **Transfer Gearbox (TGB)** Scavenge Screens and repetitive borescope inspection of **RDS** bearing cage. As per the SB, the repetitive **TGB** screen inspection as follows-

(a) The first **TGB** screen inspection at 75 **FH** since new, within a window of ± 25 flight hours.
(b) Repeat **TGB** screen inspection with an interval not exceeding 100 **FH** until engine reaches 1,500 **FH** since new.
(c) For engines above 1,500 **FH** since new, **TGB** screen repetitive inspection is no longer required.

And the repetitive **RDS** bearing inspections as follows-

(a) **RDS** bearing inspection at 1,500 **FH** since new, within a window of ± 100 flight hours.
(b) Another **RDS** bearing inspection at 6,000 **FH** since new, within a window of ±250 flight hours.

Later, the FAA has issued a new airworthiness directive **AD 2020-06-01 dt. 12.03.2020** and it superseded the AD 2019-12-01 dt. 18th June 2019. This AD requires revising the Airworthiness Limitations Section (ALS) of the applicable CFM LEAP-1B Engine Shop Manual and the operator's approved continuous airworthiness maintenance program. This AD provide credit for inspections of the TGB performed in accordance with CFM SB LEAP-1B-72-00-0222-01A-930A-D, Issue 007, dated May 17, 2019 ("SB 72-0222") and CFM SB LEAP-1B-72-00-0317-01A-930A-D, Issue 001, dated January 9, 2020 ("SB 72-0317"). Although the service bulletins refer to different maintenance manual tasks, both Service Bulletins, require inspections meeting the same criteria. This AD requires revising the ALS to include paragraph 6.B. (2) of ESM 05-29, which requires inspections of the RDS bearing as specified in SB 72-0317. SB 72-0317 provides the conditions for taking credit for inspections accomplished before the issuance of SB 72-0317, including inspections accomplished using SB 72-0222. Operators who meet the conditions specified in SB 72-0317 may take credit for previous inspections as part of their maintenance program.

Once an operator revises the ALS as required by this AD, the operator has fully complied with this AD. Compliance with the inspections remains mandatory as part of the ALS.

M/s CFM issued SB LEAP-1B-72-00-0365-01A-930A-D Issue 002, dated February 22, 2022 ("SB 72-0365") as they have identified a sub-population of engines susceptible to **RDS** Bearing Cage rivet fatigue failure and Commanded **In-Flight Shutdown (IFSD)** due to **RDS** Bearing failures occurred beyond Service Bulletin LEAP-1B-72-00-0317-01A-930A-D inspection requirements. This Service Bulletin recommends extended repetitive **Transfer Gearbox (TGB)** Scavenge Screens inspections for engines equipped with Inner **RDS** Serial Numbers listed and it is observed that the incident involved Engine#2 s.no 602691 equipped with Inner **RDS** s.no EE856110 is listed in the SB. Further, CFM recommends to not install two (2) engines listed in the SB on the same aircraft and it is to be noted that, the ENG#1 s.no 602673 is not listed in the SB, which means its not an affected Engine.

The statistical analysis by CFM identified a RDS bearing subpopulation i.e., the RDS ball bearing cage belongs to batch M13685 (Inner RDS S.no EE856110), which is one of the batches where it includes 13 cage failure events occurred due to rivet rupture..

All the above & concerned Airworthiness Directives, mandatory Service Bulletins, mandatory Modifications on the aircraft and its engine had been complied by the operator. There were no abnormal observations noticed by airline engineering during the compliance of the ADs & SBs.

<u>As per M/s CFM, the RDS Bearing failures are caused due to</u>

- Insufficient oil film between cage pilot diameter and inner ring.
- Cage wear is due to
  - Inadequate bearing geometry that prevents proper oil film establishment.
  - Insufficient oil flow reaching cage journal bearing.
- The Rivets fatigue
  - Cage halves assembly not at design intent could contribute to rivets abnormal stress and early failure.

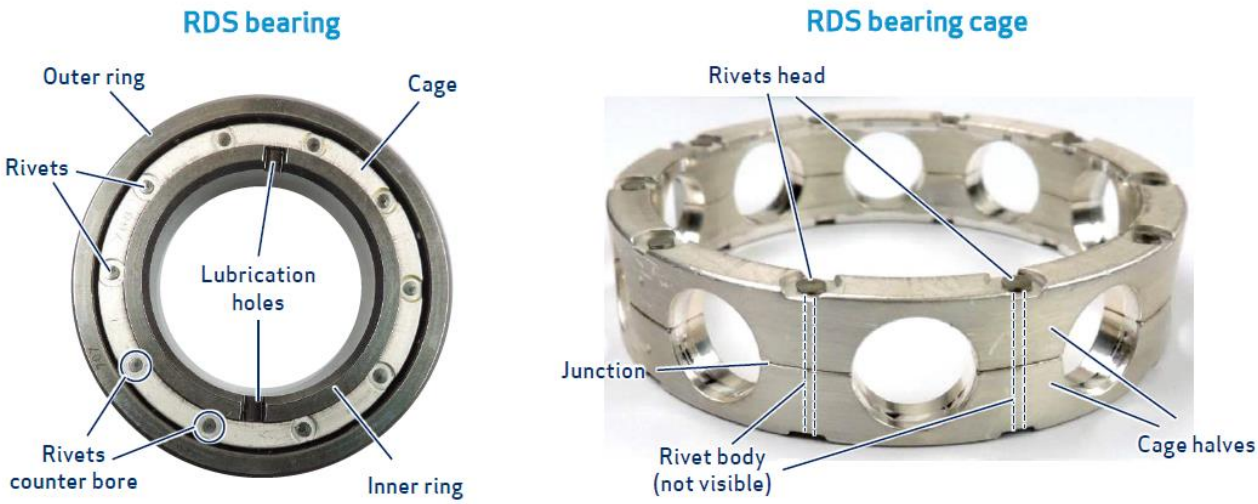


Figure 9: RDS bearing and cage (Source: M/s CFM)

Failure Modes:

1. **Cage inner diameter wear mode** –

Wear replicated in bearing rig test and the wear progression monitored on an endurance engine showed the cage wear progress was linear and then it slows down.

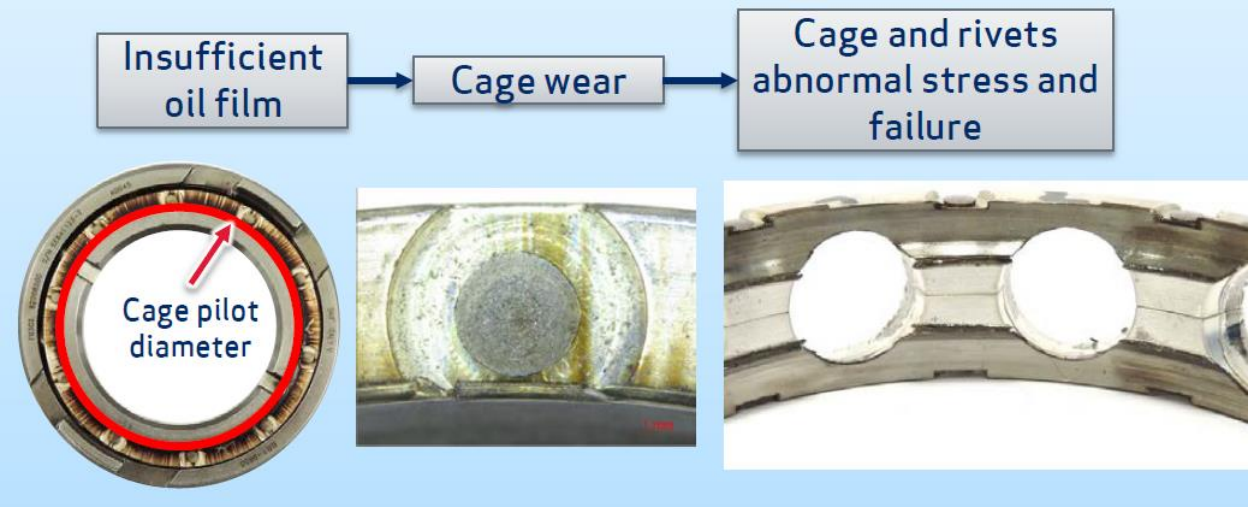


Figure 10: Cage wear (Source: M/s CFM)

2. **Rivets fatigue mode** –

Fleet engines investigations identified few cases of cage halves assembly not at design intent but the riveting process is human factor dependent. Riveting gaps contribute to rivet abnormal stress, which is a potential early life failure.

Figure 11: Rivet fatigue (Source: M/s CFM)

The above two failure modes were addressed by M/s CFM through Service Bulletins SB 72-0222 & 72-0317 – TGB screen inspections during early life.

As of 03.05.2022 (i.e., from Jun'2021) commanded/un-commanded In-flight engine shutdowns (IFSDs) worldwide due to OIL FILTER BYPASS (OFB) light were 09 and the total unscheduled removals worldwide due technical are 90.

1.7 Meteorological Information:

The following is the Met report of Chennai Airport on the date of incident 03rd May 2022 between 1400 Hrs. to 1500 Hrs.:

Time	Wind Direction/Speed	Visibility	Weather	Trend	Cloud
1400	19008KT	5000m	BR	NO SIG	FEW020
1430	20007KT	5000m	BR	NO SIG	FEW020
1500	19006KT	5000m	BR	NO SIG	FEW020

1.8 Aids to navigation:

All Navigational Aids available at Chennai airport were serviceable. The aircraft was equipped with standard navigational equipment.

1.9 Communications:

Aircraft is equipped with Very High Frequency transmitter and receiver set and High Frequency transmitter and receiver set. There was always two-way radio communications available between the ATC and aircraft.

1.10 Aerodrome information:

Chennai International Airport is in City of Chennai. It is operated & Managed by Airports Authority of India (AAI). The IATA Location Identifier Code is MAA and ICAO Location Indicator Code is VOMM. The airport has two runways with orientation 07/25 and 12/30. Runway 07/25 is the primary runway. The Airport Co-ordinates are: Lat: 12° 59 42, Long: 080° 10 32 and Elevation: 52 feet (16 meters).

1.11 Flight recorders:

The aircraft was fitted with SSCVR and SSFDR. After the incident at Chennai, both were replaced and downloaded. The data was retrieved and utilized in the investigation.

1.11.1 Flight Data Recorder (SSCVR):

CVR details:

Make: L3 Technologies Inc.
Model: FA2100CVR
Serial Number: ULB022036
Part number: 2100-1925-22.

The following observations are made from the data (in relative time):

1. At 01:18:25, while aircraft climbing, Engine#2 Oil filter bypass light illuminated. PIC advised FO to inform ATC due technical they would like to maintain FL90 and the same was conveyed by FO to ATC.
2. At 01:19:44, crew when started reading Engine Oil Filter Bypass alert non-normal checklist, the light extinguishes. On PIC advise, FO requested for vectors to climb.
3. At 01:21:40, once again Oil filter bypass light illuminated and then FO informed ATC that they would like to maintain FL100 due technical issue.
4. At 01:24:33, crew started the Engine Oil Filter Bypass light non-normal checklist.
5. At 01:30:29, PAN PAN PAN PAN PAN PAN SJ331. We are in single engine operation was made by P2.
6. The ATC vectored the aircraft for priority landing on RWY07.
7. Crew carried out the checklist and call outs as required.

1.11.2 Flight Data Recorder (SSDFDR):

FDR details:

Model: FA2100FDR
Make: L3 Technologies Inc.
Serial Number: 001272136
Part number: 2100-4945-22

The observations made from the provided data are:

Time (UTC)	EVENT
14:12:25	The aircraft took-off from Chennai.
14:17:05	At altitude 7875feet, it is observed that the Oil Filter Bypass ENG#2 light is illuminated and it got extinguished at 14:17:59hrs at altitude 8989feet. The CAS was observed to be reduced from 310Kts to 304Kts. There was no other parameter found exceedance.
14:18:01	Just for one second again the Oil Filter Bypass ENG#2 light is illuminated and extinguished.
14:20:21	Once again, the Oil Filter Bypass ENG#2 light is illuminated at altitude 9460feet and remained till 14:30:30hrs. There was no other parameter found exceedance.
14:23:45	Aircraft at altitude 9805feet the Auto Throttle was disengaged & Thrust Lever of ENG#2 was closed, the Selected Fuel flow#2 found decreasing and ENG#2 was cutoff at 14:30:30hrs at 9792ft.
14:30:39	It is observed that #2 Low Oil Pressure caution alert came & has remained thereafter.
14:32:08	At altitude 9793feet, there was master caution and continued till 14:40:14hrs.
14:48:46	Aircraft landed with vertical acceleration of 1.072g.

1.12 Wreckage and Impact Information: NIL.

1.13 Medical and pathological Information: NIL.

1.14 Fire:

There was no fire.

1.15 Survival aspects:

The incident was survivable. There was no injury reported to the passengers, crew, or any other ground personnel.

1.16 Tests and research:

1.16.1 Investigation of Failed Engine at Manufacturer Facility:

The failed engine was returned to M/s CFM for disassembly and investigation. During disassembly, the major findings after investigations performed on the Radial Drive Shaft are:

Figure 12: Inner Radial Drive Shaft (Main Assembly)

Figure 13: Inner RDS

- Strong wear and spalling on outer ring raceway with a strain hardening on the surface of the raceway and shoulders over the circumference. The strain hardening covered 1/3 of the total thickness of the ring and shows a second quenching then an over tempering on hardness profiles. Raceway with wear (burrs observed on raceway edges) and spalling all over the circumference.

Figure 14: RDS Bearing outer ring Characterization (raceway & shoulders)

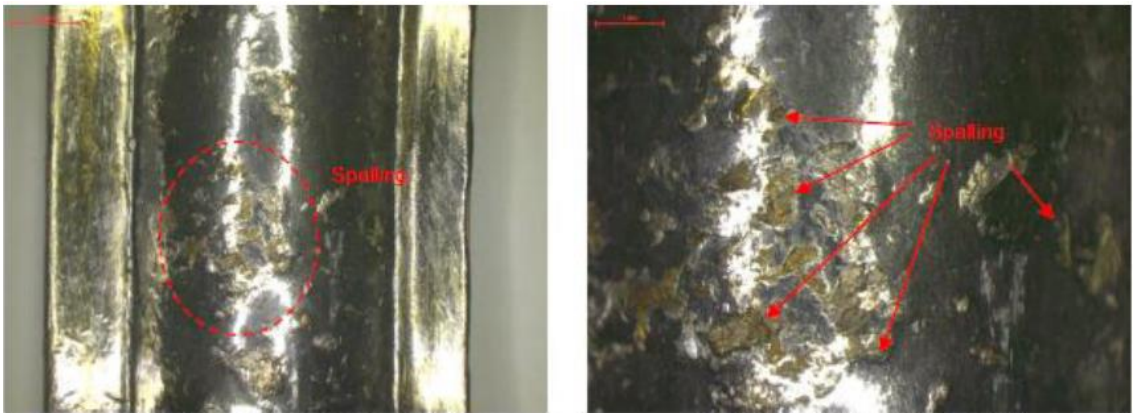


Figure 15: RDS Bearing Outer ring Characterization (raceway)

- Overheating signs are also visible on the outer diameter, in regard with the exhaust oil grooves. Rupture of outer ring slots. Blue and brownish strong oil discoloration on the external diameter and the lateral face corresponding to lubrication slot's location.

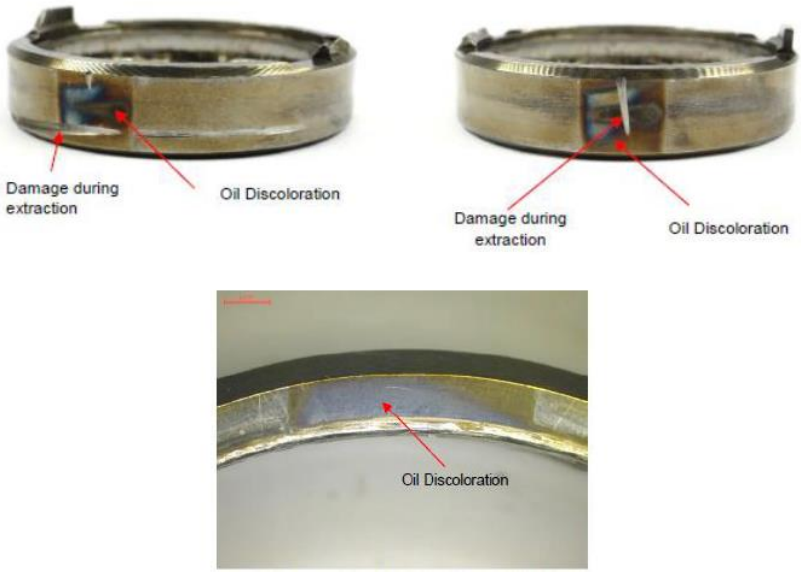


Figure 16: RDS Bearing Outer ring Characterization (Outer ring lateral face, TGB side)

Figure 17: Fracture of anti-rotation pins (Outer ring lateral face, IGB side)

- Global wear over the circumference of the inner ring raceway and presence of linear axial marks on the raceway on 270°, mostly with a spacing like distance between balls. Heavy wear of shoulders and washer.

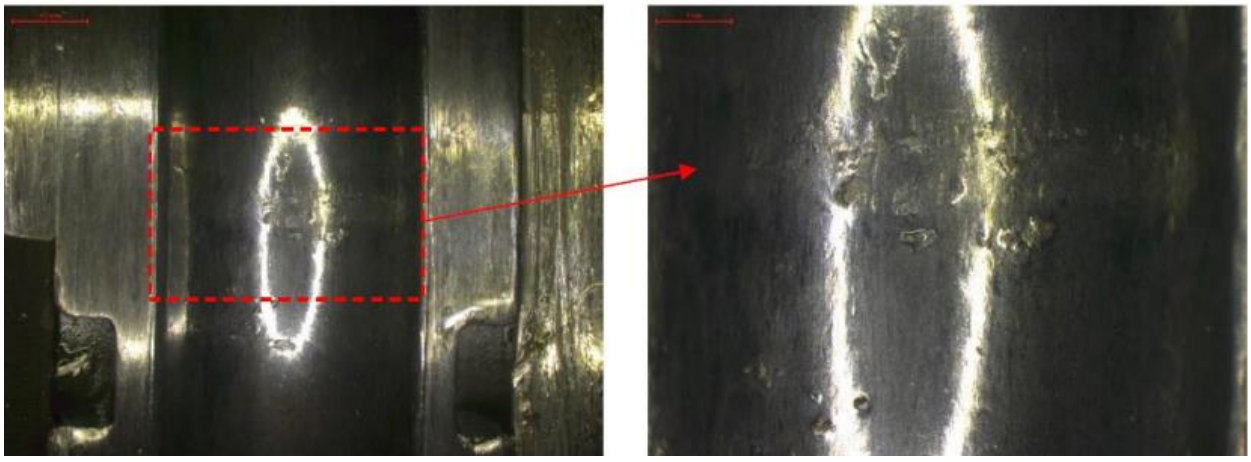


Figure 18: RDS Bearing Inner ring Characterization (raceway & shoulders)

- Some (8 or 9) axial marks on the raceway show smearing (adhesive wear probably due to sliding) or spalling next to them. Those axial marks show a strain hardening area on the surface. These deformations take an axial shape on the raceway and are distributed all over the circumference, probably at the ball space. Inner ring expanded by global overheating with loss of shrinking.

Figure 19: RDS Bearing Inner ring Characterization (raceway details)

- Cage totally fragmented. Heavy wear on each fragment, no fracture surface or pocket surface is still visible.

Figure 20: RDS Bearing Cage Characterization (cage fragmented)

- Balls are totally worn, 2 of them up to a cylinder shape. Others with scattered spalling on most of them. Most of the spalling are partially covered due to balls rotation or sliding on raceways.

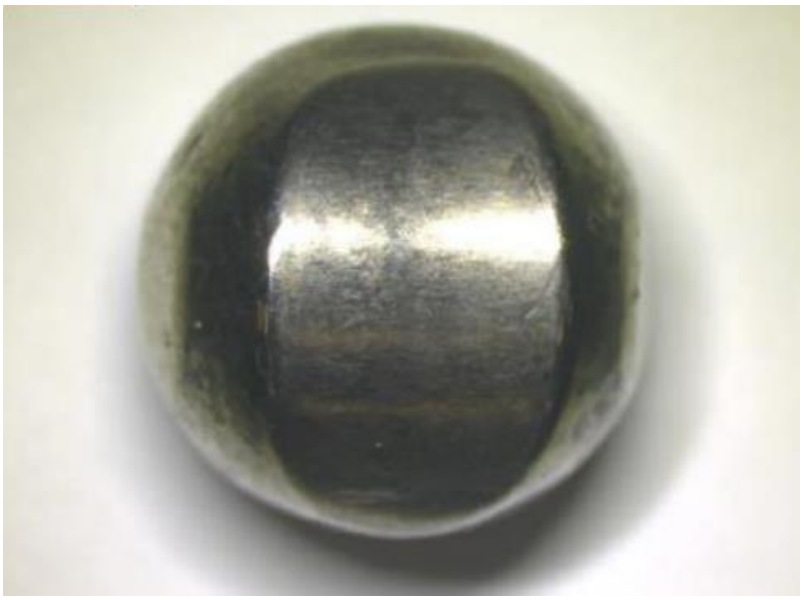


Figure 21: RDS Bearing Ball Characterization (cage fragmented)

As per M/s CFM, the new design is addressing both root causes through the SB 72-0258 (Cat 3) Issue no. 003 dated 04.11.2022, SB 72-0271 Issue no. 02 dated 11.08.2020. CFM advised the operators to comply with these Service Bulletins at next shop visit of engine or module. The following are the design modifications -

1. The Design modified to address the cage wear –
   - New RDS bearing [1], oil diverter [2} & IGB oil nozzle [3] Makes oil film back at design intent

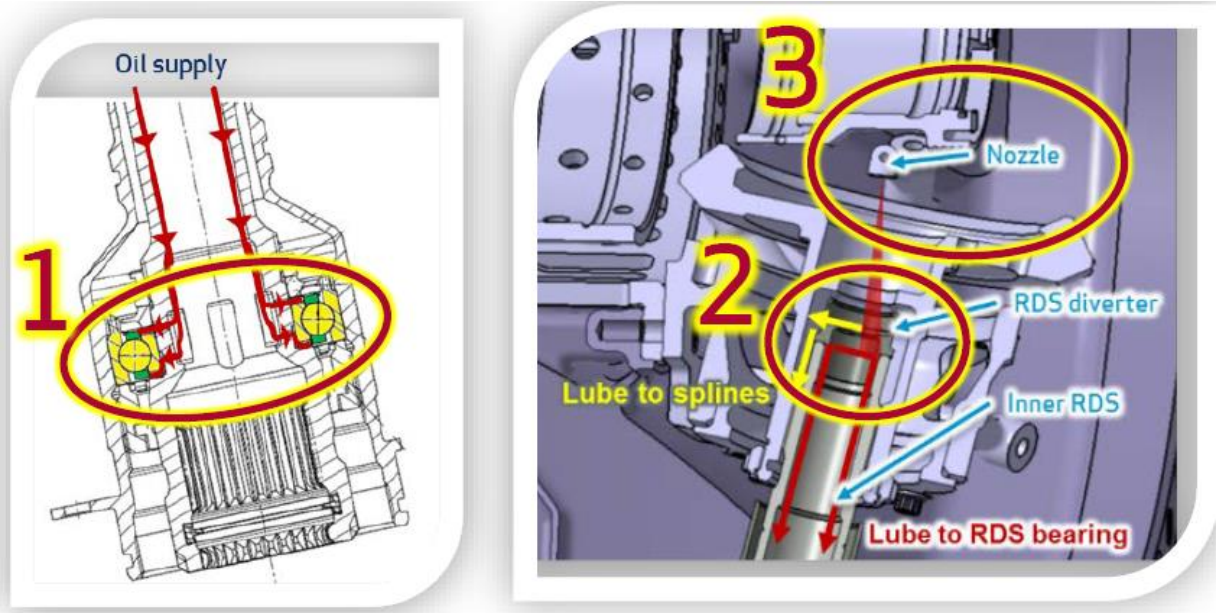


Figure 22: New design to address the cage wear (Source: M/s CFM)

2. And rivet fatigue is addressed by –
   - Improved riveting process to reduce susceptibility to human factor
     - Traceability and cage clearance control
     - Rivets positioning before applying the load in order to guarantee no circumferential gap
     - New tool to set cage preload during riveting
     - Removal of silver from rivet holes
   - Improved cage design
     - Higher cage stiffness has improved halves cages flatness
     - Lowered the rivet stress

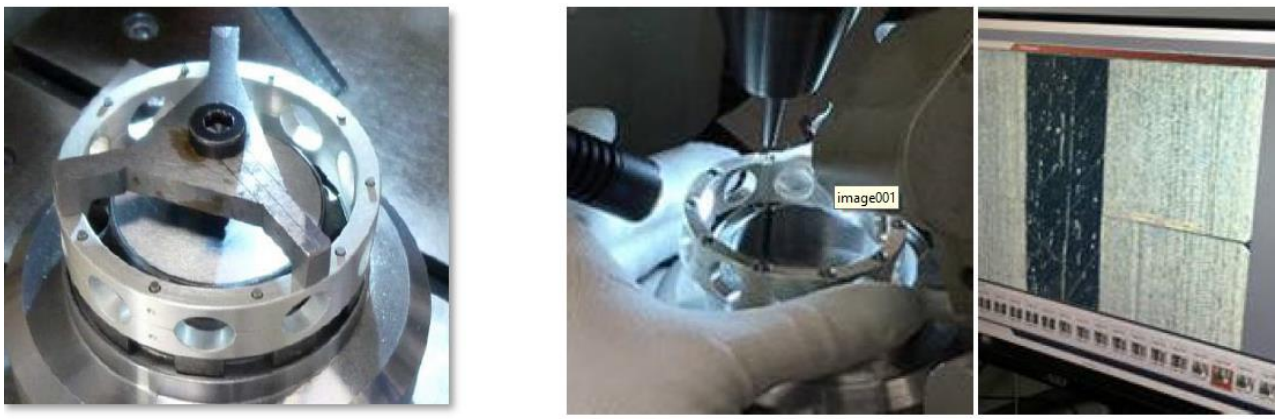


Figure 23: Improved riveting with preload (Source: M/s CFM)

1.17 Organizational and management information:

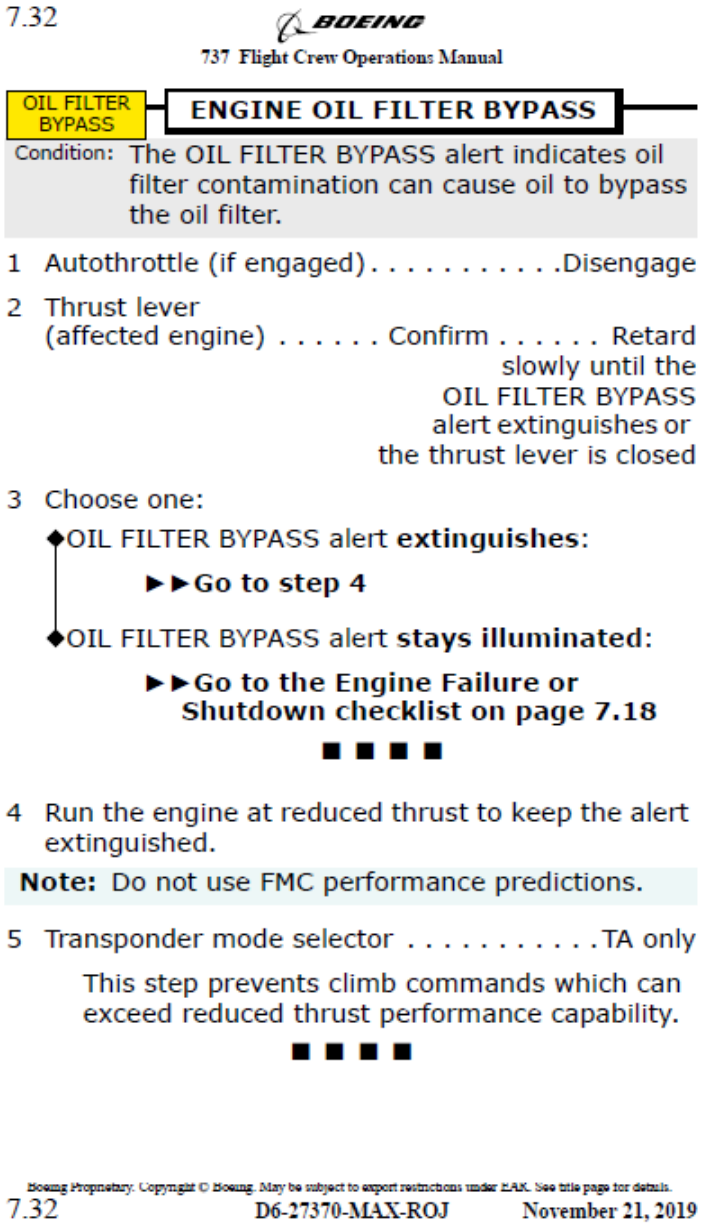
M/s SpiceJet Ltd.:

SpiceJet is scheduled airline based in Delhi, India and operates domestic and international destinations. The airline is holding a valid Air Operator Certificate

no. S-16 issued by DGCA valid up to 16.05.2023. The organization commenced its operations with the fleet of three Boeing 737-800 aircraft and is consistently expanding its fleet since start of the operations in May 2005. SpiceJet current fleet is a composition of 47 Boeing B737 (Passenger & Freighter), 32 DHC-8 Q400 and 13 Boeing B737-8 MAX aircraft. Total fleet of 92 as on date. The 13 Boeing B737 MAX aircraft were inducted into SpiceJet from September 2018 to March 2019.

1.18 Additional information:

1.18.1 FCOM PROCEDURE FOR ENGINE OIL FILTER BYPASS:



7.32

737 Flight Crew Operations Manual

OIL FILTER BYPASS

ENGINE OIL FILTER BYPASS

Condition: The OIL FILTER BYPASS alert indicates oil filter contamination can cause oil to bypass the oil filter.

1 Autothrottle (if engaged) . . . . . .Disengage

2 Thrust lever (affected engine) . . . . . Confirm . . . . . Retard slowly until the OIL FILTER BYPASS alert extinguishes or the thrust lever is closed

3 Choose one:

◆OIL FILTER BYPASS alert **extinguishes**:

►►**Go to step 4**

◆OIL FILTER BYPASS alert **stays illuminated**:

►►**Go to the Engine Failure or Shutdown checklist on page 7.18**

■ ■ ■ ■

4 Run the engine at reduced thrust to keep the alert extinguished.

Note: Do not use FMC performance predictions.

5 Transponder mode selector . . . . . .TA only

This step prevents climb commands which can exceed reduced thrust performance capability.

■ ■ ■ ■

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7.32 D6-27370-MAX-ROJ November 21, 2019

1.19 Useful or effective investigation techniques: NIL.

2. ANALYSIS

2.1 Operational aspect of aircraft:

Both the crew members were medically fit, had valid license, provided adequate rest, and found to be within FDTL limits before they operated flight SG 331(Chennai-Durgapur) on 03.05.2022. Flight SG-331 was the fifth flight of the day by VT-MXA aircraft and for both the flight crew it was first flight of the day. The Pilot in Command performed the duties of the Pilot Flying (PF) and First Officer performed the duties of Pilot Monitoring (PM).

The aircraft took-off at time 14:12:25UTC & it was uneventful. As per DFDR, during climb at altitude 7875feet (14:17:05UTC), the Oil Filter Bypass (OFB) ENG#2 light illuminated. By noticing the OFB light, PF advised PM to inform ATC due technical we would like to maintain FL90 and the same was conveyed by PM to ATC. Crew started Engine Oil Filter Bypass Light non-normal checklist as per FCOM and before completion of the checklist the OFB light got extinguished at 14:17:59UTC (8989feet). At 14:18:01UTC, just for one second again the Oil Filter Bypass ENG#2 light was illuminated and extinguished. FO requested for vectors to climb to ATC.

Further once again, the Oil Filter Bypass ENG#2 light was illuminated at 14:20:21UTC at 9460feet and remained till 14:30:30UTC. Then PF advised PM to inform ATC that they would like to maintain FL100 due technical issue and same was conveyed by PM. Crew carried out the checklist as per FCOM procedure of aircraft at 14:23:45UTC at 9805feet, disengaged the Auto throttle & closed the Thrust Lever of ENG#2, the Selected Fuel flow#2 found decreasing. Further as per the non-normal checklist, crew carried out inflight shut down of ENG#2 at 14:30:30UTC at 9792ft. As advised by PF, PM declared PAN PAN and said they are in single engine operation to the ATC. The ATC vectored the aircraft for priority landing on RWY07. Later, the crew carried out the checklist and all call outs as required and carried out safe single engine landing at Chennai at 14:48:46UTC, with vertical acceleration of 1.072g, which is not a hard landing.

From the above it is inferred that the crew actions were in line with the standard operating procedures as per FCOM.

2.2 Weather:

Prior to take off from Chennai, the weather was fine. The aircraft took off from Chennai at around 1412 UTC and weather reported for Chennai was within the crew operating minima. The weather reported was fine with visibility reported 5000 meters with mist and winds calm.

From the above, it is inferred that the weather is not a factor to the incident.

2.3 Engineering aspect of the aircraft:

M/s SpiceJet Boeing B737-8 MAX aircraft MSN 64505, Indian Registration VT-MXA with CFM LEAP 1B Engines, was registered with DGCA under the ownership of M/s Sky High LXXX Leasing Company Ltd. on 02nd November 2018. The aircraft is registered under Category 'A' and the Certificate of Registration No is 4977. As on 3rd May 2022, the aircraft had logged 2976:45 Airframe Hours and 1593 Cycles. The Aircraft was operated under Scheduled Operator's Permit No S-16 which was valid as on date.

Boeing B737-8 MAX aircraft and its engines are being maintained as per the maintenance program approved by the Regional Airworthiness Office, O/o DGCA, New Delhi. The aircraft weight and Center of Gravity (CG) were within limits.

Transit inspections are carried out as per approved Transit Inspection schedules and all the higher inspection schedules include checks/ inspection as per the manufacturer's guidelines as specified in the Maintenance Program and are approved by the Continuing Airworthiness Manager (CAMO) — post holder for Continuous Airworthiness.

The statistical analysis by CFM identified a RDS bearing subpopulation i.e., the RDS ball bearing cage belongs to batch M13685, which is one of the batches where it includes 13 cage failure events occurred due to rivet rupture. As per the SB 72-0365 issued dated 22.02.2023, the incident involved Engine#2 s.no 602691 equipped with Inner RDS s.no EE856110 is listed in the SB.

All the concerned Airworthiness Directive, Mandatory Service Bulletins, DGCA Mandatory Modifications on this aircraft and its engines has been complied with as on day of the event. There were no abnormal observations noticed by airline engineering during the compliance of the ADs & SBs.

The defect record of the aircraft was scrutinized on the date of occurrence of the incident and observed that LH Ignition system for ENG#1 declared inoperative, MEL 74-00-01-01B under CAT'C' invoked on 01.05.2022 and valid up to 11.05.2022. There were no other defects recorded.

Post incident, the engineering interrogated and found Flight Deck Effect-(FDE) -: ENG #2 OIL FILTER BYPASS IND with Maintenance Message: 79-42895 CLIMB - OIL FILTER IMPENDING BYPASS ENG#2 ON. The failed ENG#2 did not have any previous ODMS maintenance alerts.

On examination of Engine#2 ODMS sensor found metallic debris on the magnetic tip and further on scavenge screen inspection found metallic particles in Accessory Gear Box (AGB) Sump, Transfer Gear Box sumps i.e., TGB1 & TGB2. The involved ENG#2 S.no 602691 was sent to manufacturer facility for investigation.

During detailed examination, it was identified that the RDS ball bearing has failed and the most probable scenario of the RDS ball bearing failure was attributed to the following observations –

1. The progressive rupture of the rivets and pockets of the cage and blocking the balls in position.
2. There were inner ring axial marks and sliding all over the outer ring raceway circumference and observed total cage rupture.
3. There was overheating & ball sliding on inner and outer rings.
4. And, secondary spalling on outer ring raceway and balls was observed.

M/s CFM has identified the root cause of all the RDS ball bearing failures, is due to the insufficient oil film between cage pilot diameter & inner ring of the ball bearing and the riveting gaps which contribute to abnormal stress.

M/s CFM has addressed the root cause of the RDS ball bearing failures through the Service Bulletins SB 72-0258 (Cat 3) Issue no. 003 dated 04.11.2022, SB 72-0271 Issue no. 02 dated 11.08.2020 and advised the operators to comply the SB at next visit of engine or module.

From the above it is inferred that the ENG#2 Radial Drive Shaft ball bearing cage rivet failure was cause for the IFSD incident.

3. CONCLUSIONS

3.1 Findings:

1. The Certificate of Airworthiness and the Certificate of Registration of the aircraft was valid on the date of incident.
2. The certificate of flight release was valid on the day of incident.
3. All the concerned Airworthiness Directive, mandatory Service Bulletins, mandatory modifications on this aircraft and its engine have been complied with as and when due.
4. The aircraft was cleared by engineering at Chennai and from the defect record of the aircraft it was observed that LH Ignition system for ENG#1 declared inoperative, MEL 74-00-01-01B under CAT'C' invoked on 01.05.2022 and valid up to 11.05.2022.
5. The aircraft weight and CG were within limits.
6. Both crew members were appropriately qualified to operate the flight. The PIC was PF (Pilot Flying) and FO was PM (Pilot Monitoring).
7. At 14:20:21UTC, aircraft at 9460feet, the Oil Filter Bypass ENG#2 light was illuminated and remained. Crew carried out the checklist as per FCOM procedure and shut down the engine and declared PAN PAN to ATC.

8. The aircraft made a safe single engine landing at Chennai and taxied on its own power to the parking bay. There was no injury to any of the occupants onboard the aircraft and there was no fire.
9. No external damage to the aircraft.
10. The recorded landing g-value was 1.072g, which is within the AMM limits and it is not a hard landing.
11. Crew actions were satisfactory and in compliance of the FCOM procedure/checklists.
12. Both the cockpit crew had undergone pre-flight medical examination prior to flight and same was negative.
13. Weather was not a factor to the incident.
14. M/s CFM has identified two batches of RDS ball bearing cages, where all the RDS bearing failure events occurred. The involved RDS bearing cage belongs to one of the batches i.e., M13685.
15. M/s CFM has identified the root cause of all the RDS ball bearing failures, is due to insufficient oil film between cage pilot diameter & inner ring of the ball bearing and the riveting gaps which contribute to abnormal stress.
16. Post incident, the examination of Engine#2 found metallic debris on the magnetic tip of ODMS sensor, AGB sump and TGB sumps i.e. TGB1 & TGB2.
17. The engine strip inspection was carried out at manufacture facility and the shop report reveals that RDS ball bearing cage rivet was failed.
18. M/s CFM has addressed the root cause of the RDS ball bearing failures through the Service Bulletin SB 72-0258 (Cat 3) Issue no. 003 dated 04.11.2022, SB 72-0271 Issue no. 02 dated 11.08.2020 and advised the operators to comply the SB at next visit of engine or module.

3.2 **Probable Cause:**

The cause of the incident is due to the ENG#2 Radial Drive Shaft Ball Bearing cage rivet fatigue failure.

4. **Safety Recommendations:**

1. The compliance of Service Bulletin may be monitored by DGCA.

(Preetham Reddy N)
Assistant Director of Air Safety
Investigator-in-Charge

Place: Chennai
Dated: 26.04.2023.

------END OF THE REPORT------