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FINAL REPORT ON ACCIDENT INVOLVING BEECHCRAFT KING AIR C90A AIRCRAFT VT-JIL OPERATED BY M/s JET SERVE AVIATION PVT LTD AT MUMBAI ON 06TH MAY 2021

Government of India
Ministry of Civil Aviation
Aircraft Accident Investigation Bureau

FOREWORD

In accordance with Annex 13 to the Convention on International Civil Aviation Organization (ICAO) and Rule 3 of Aircraft (Investigation of Accidents and Incidents), Rules 2017, the sole objective of the investigation of an accident shall be the prevention of accidents and incidents and not to apportion blame or liability. The investigation conducted in accordance with the provisions of the above said rules shall be separate from any judicial or administrative proceedings to apportion blame or liability.

This report is prepared based on the evidence collected during the investigation, opinions obtained from the experts, and laboratory examination of various components. Consequently, the use of this report for any purpose other than for the prevention of future accidents or incidents could lead to erroneous interpretations.

ABBREVIATIONS	
AAIB	Aircraft Accident Investigation Bureau
AFM	Airplane Flight Manual
AGL	Above Ground level
AME	Aircraft Maintenance Engineer
AMM	Aircraft Maintenance Manual
AMP	Aircraft Maintenance Program
AMSL	Above Mean Sea Level
ARC	Airworthiness Review Certificate
ARFF	Aircraft Rescue and Fire Fighting
ASDA	Accelerate Stop Distance Available
A-SMGCS	Advanced Surface Movement Guidance and Control System
ASR	Airport Surveillance Radar
ATC	Air Traffic Control
ATIS	Automatic Terminal Information Service
ATPL	Airline Transport Pilot License
BECMG	Becoming
CAMO	Continuing Airworthiness Management Organization
CAR	Civil Aviation Requirements
CCTV	Closed-circuit television
CFT	Crash Fire Tender
Cm	Centimeters
CMM	Component Maintenance Manual
CoFS	Chief of Flight Safety
CPL	Commercial Pilot License
CRM	Crew Resource Management
CRS	Certificate of Release to Service
CSIA	Chhatrapati Shivaji Maharaj International Airport
CSIR-NAL	Council of Scientific & Industrial Research- National Aerospace Laboratories
CVR	Cockpit Voice Recorder
DCP	Dry Chemical Powder
DGCA	Directorate General of Civil Aviation, India
DFDR	Digital Flight Data Recorder
DME	Distance Measuring Equipment
DOC	ICAO Document
DVOR	Doppler Very High Frequency Omni Range
e-AIP	Electronic Aeronautical Information Publication
ENG	Engine
FAA	Federal Aviation Administration, United States of America
FDP	Flight Duty Period
FDTL	Flight Duty Time Limitation
FOQA	Flight Operation Quality Assurance

FPI	Florescent Penetrant Inspection
Hrs	Hours
HZ	Haze
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
IGI	Indira Gandhi International Airport, New Delhi
ILS	Instrument Landing System
IMD	India Meteorological Department
IPC	Illustrated Parts Catalogue
IR	Instrument Rating
JSAPL	M/s Jet Serve Aviation Pvt. Ltd.
Kg	Kilograms
LDA	Landing Distance Available
L/G	Landing Gear
LH	Left Hand
m	Meter
METAR	Meteorological Terminal Air Report
MHz	Megahertz
MIAL	Mumbai International Airport Limited
MLG	Main Landing Gear
MOE	Maintenance Organization Exposition
MSN	Manufacturer's Serial Number
NDB	Non-Directional Beacon
NOSIG	No Significant
NOTAM	Notice to Air Missions
OEM	Original Equipment Manufacturer
PAPI	Precision Approach Path Indicator
PIC	Pilot -in-Command
POH	Pilot Operating Handbook
PPC	Pilot Proficiency Check
P/N	Part Number
RA	Radio Altitude
RESA	Runway End Safety Area
RFF	Rescue and Fire Fighting
RH	Right Hand
RPM	Rotation Per Minute
RWY	Runway
SCT	Scattered
TODA	Take-off Distance Available
TORA	Take-off Run Available
TWY	Taxiway
VFR	Visual Flight Rules
VHF	Very High Frequency

VOR	VHF Omni Directional Range
UTC	Coordinated Universal Time

FINAL INVESTIGATION REPORT ON ACCIDENT OF M/s JET SERVE AVIATION PVT. LTD. BEECHCRAFT KING AIR C90A AIRCRAFT VT-JIL AT MUMBAI ON 06TH MAY 2021

1.	Aircraft	Type	Beechcraft King Air C90A
		Nationality	Indian
		Registration	VT-JIL
2.	Owner & Operator		M/s Jet Serve Aviation Pvt. Ltd.
3.	Pilot		ATPL Holder
4.	Co-Pilot		CPL Holder
5.	No. of Person on board		05
6.	Date & Time of Accident		06th May 2021 at 1540 UTC
7.	Place of Accident		Mumbai Airport
8.	Co-ordinates of accident site		Lat: 19°05'18.7"N / Long: 72°52'13.8"E
9.	Last point of Departure		Nagpur Airport
10.	Intended landing place		Mumbai Airport
11.	Type of Operation		Non-Scheduled operation (Air ambulance)
12.	Phase of operation		Landing
13.	Type of Accident		Gear up landing [Abnormal Runway Contact / System/Component Failure or Malfunction (Non-Powerplant)]

All timings in the report are in UTC.

SYNOPSIS

On May 6th 2021, M/s Jet Serve Aviation Beechcraft King Air C90 A aircraft VT-JIL operated an air ambulance flight from Nagpur to Mumbai with two cockpit crew, a medical patient, one doctor and one medical attendant on board.

Aircraft took off from runway 32 of Nagpur airport at 11:35 UTC. Airport Security personnel deployed at watchtower no. 12 near the perimeter boundary wall observed that the wheel detached from the undercarriage as the aircraft got airborne. The airport security personnel informed the same to ATC. The flight crew did not observe any abnormality during the take-off and were unaware of the event till ATC Nagpur informed them subsequently. The crew reported operations normal.

Nagpur ATC later confirmed that the wheel belonged to VT-JIL. The crew requested ATC to confirm the wheel's identity from their company engineering team. Since the crew were midway to Mumbai when the confirmation was received, the crew continued the flight to Mumbai.

Aircraft was in contact with ATC Mumbai, who facilitated communication with their company Operations/ Engineering department to explore all the available possibilities for landing. The crew requested a low altitude flight over runway 27 in Mumbai with the landing gear extended to obtain a ground observation for the missing wheel and establish the full extent of the damage. The low pass operation was carried out by aircraft at 13:43 UTC at approximately 300ft AGL. Upon confirmation about the missing LH wheel, the crew decided to carry out a belly landing at Mumbai airport.

The crew decided to burn fuel by holding in order to make the aircraft lighter for a belly landing. The ATC instructed ARFF to foam the relevant portion of the runway. The foam carpeting was completed by 15:32 UTC. At approximately 15:34 UTC, runway 27 was made available to the aircraft for landing, and the aircraft was at 10NM on approach.

The aircraft did a gear up landing at 15:40 UTC with the rescue and firefighting services team available in full emergency preparedness at predetermined ready positions for runway 27. The aircraft remained within runway 27 and came to rest at approximately 564 meters from the displaced threshold opposite Taxiway N5. The aircraft halted 8 meters left of the runway centreline facing south. All passengers and crew evacuated the aircraft immediately. No injuries were reported after landing. The patient and the attending doctor were transferred to an ambulance and taken to the hospital. No fire was observed/ reported after landing. However, the aircraft sustained substantial damage to the underbelly and the propellers.

The probable cause of LHS main landing gear wheel separation was due to the catastrophic failure of the outer bearing on the LH main wheel assembly within the component's service life leading to a belly landing in the absence of prescriptive guidance to the pilots.

The draft report was shared with the Accredited Representative appointed by the National Transport Safety Board of the United States of America. The Accredited Representative had no comments on the report.

1 FACTUAL INFORMATION

1.1 HISTORY OF THE FLIGHT

On 06th May 2021, M/s Jet Serve Aviation Pvt. Ltd, Beechcraft King Air C90A met with an accident at Mumbai airport, India, during a non-scheduled ambulance flight to Mumbai.

The aircraft operated sectors Bagdogra- Durgapur- Nagpur- Mumbai. For all sectors, the aircraft was operated by the same flight crew and a medical team comprising of one doctor and one medical attendant. The patient boarded the aircraft in Durgapur. The first two sectors, Bagdogra- Durgapur- Nagpur, were uneventful.

The crew carried out the pre-flight inspection for all three sectors under company authorization. During take-off roll from Nagpur, the LH main wheel got separated just as the aircraft was airborne, which was observed by the airport security personnel on duty. The flight crew was unaware of the event, till such time, ATC Nagpur informed them that a wheel was found near the runway. The crew verified operations normal.

As confirmed by the Aerodrome Operation Jeep, who inspected the runway, ATC Nagpur subsequently informed the crew that the wheel found was a rear wheel. However, since they did not experience any abnormality during take-off, they requested ATC to reconfirm the wheel's identity from their company's engineering team. Meanwhile, the crew continued the flight as per the flight plan. At this point, the aircraft was approaching Mumbai area control, and Nagpur ATC handed over the aircraft to Mumbai ATC.

Mumbai ATC offered all assistance to the crew and asked if the crew would like to have the runway foamed for the landing. Since the crew remained uncertain about the landing gear condition, they requested ATC Mumbai for a low pass over Runway 27 with the landing gear extended in order for ground personnel to visually inspect and ascertain the missing wheel and establish the full extent of the damage. The aircraft was flown down to approximately 300 feet on the ILS and subsequently maintained level flight for the ground personnel to inspect the undercarriage visually. The low pass was carried out at 13:43 UTC. Although the sunset was at 13:33 UTC, the lighting was adequate for the ground personnel to make a visual observation. The ground personnel informed the ATC, who then informed the crew that the LH main landing gear wheel was missing. The crew discussed their options and sought inputs from a few operations and engineering personnel with the help of ATC to aid in their decision making. They evaluated their options between a landing with available wheels, ditching and a belly landing. Based on confirmatory input received from another type rated examiner, the crew decided to carry out a belly (gear up) landing.

The crew then entered a holding pattern near the airport to consume the additional fuel in order to reduce aircraft weight and the risk of fire prior to landing. The crew then requested ATC to foam the runway as proposed by ATC earlier, prior to commencing the approach. The ARFF carried out foaming of the runway portion between taxiways N4 & N5. The aircraft carried out a stabilized approach for ILS 27. The engines were shut down just prior to touchdown, and the gears up landing was carried out on runway 27 at 1540 UTC. Rescue and firefighting services available in full emergency preparedness at predetermined ready positions for runway 27. After landing, the aircraft remained within the runway. All passengers and crew evacuated the aircraft immediately. There were no injuries.

1.2 INJURIES TO PERSONS

Injuries	Crew	Passengers	Others
Fatal	NIL	NIL	NIL
Serious	NIL	NIL	NIL
None	02	03	NIL

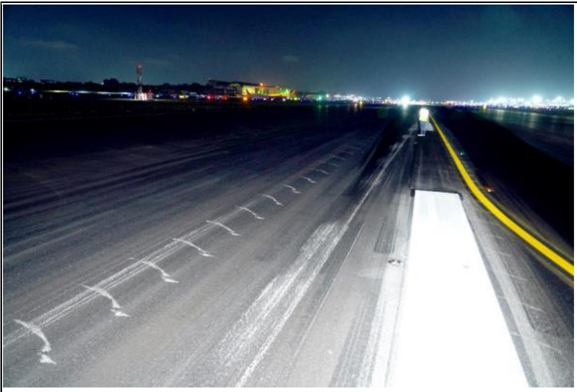
1.3 DAMAGE TO AIRCRAFT

The aircraft sustained substantial damage to the lower fuselage section and both the propellers. A detailed damage description is provided in section 1.12.

Based on damage assessment post the accident, the damage sustained to the aircraft was commensurate with the belly landing.

1.4 OTHER DAMAGES

Propeller and fuselage scratch marks were evident on the runway surface. Additionally, minor damage (surface peel-off) was observed on the surface of runway 27 at the aircraft's touchdown point due to the impact of propeller blades.

 Rotating Propeller Markings	 Propeller Markings
 Damaged portion of RWY	 Damage portion of RWY

Figure#1 Other damages

1.5 PERSONNEL INFORMATION

All information provided below are as on the date of the accident.
(excluding the accident flight)

1.5.1 PILOT – IN – COMMAND

Nationality	:	Indian
Age	:	52 years
Employed with M/s JSAPL w.e.f.	:	30.01.2021
License Type	:	Airline Transport Pilot License
Date of issue	:	28-03-2012
Valid Up to	:	27-03-2026
Category	:	Aeroplane
Endorsements as PIC	:	BE 200, C 172, C 152, BE 90/99/100/200, C206
Date of Medical Exam	:	04-07-2020
Medical Validity	:	06-07-2021
FRTOL Validity	:	21/12/2021
RTR Validity	:	30/09/2030
Total Flying Experience	:	10,541 Hrs
Hours Flown on Type	:	7165:10 Hrs
Experience as PIC on Type	:	6642:50 Hrs
Hours flown in last 365 days	:	204:25 Hrs
Hours flown in last 180 days	:	176:25 Hrs
Hours flown in last 30 days	:	70:10 Hrs
Hours flown in last 7 days	:	05:55 Hrs
Hours flown in last 24 Hrs	:	04:30 Hrs
Rest period before start of FDP	:	14 Hrs
Last IR/PPC	:	08.03.2021
Last Ground Refresher	:	February 2021
Trainer Qualification	:	Designated Examiner

1.5.2 Co-Pilot

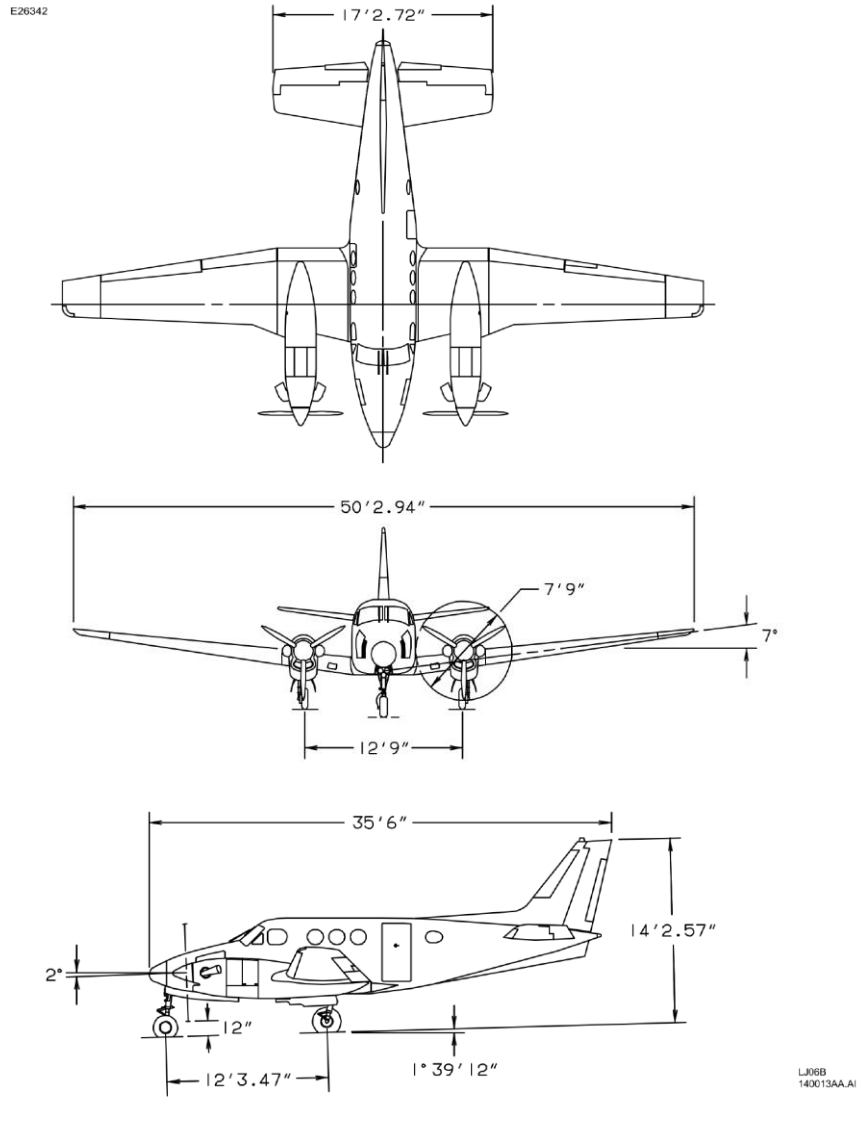
Nationality	:	Indian
Age	:	32 years
Employed with M/s JSAPL w.e.f.	:	01-10-2019
License Type	:	Commercial Pilot License
Date of issue	:	10-01-2011
Valid Up to	:	31-01-2026
Category	:	Aeroplane
Endorsements as PIC	:	C152, C172, BE 90/99/100/200/200GT, BE 90/99/100/200
Date of Medical Exam	:	03-10-2020
Medical Validity	:	04-10-2021
FRTOL Validity	:	20-01-2026
RTR Validity	:	12-04-2069
Total Flying Experience	:	634 Hrs
Hours Flown on Type	:	425 Hrs
Experience as PIC on Type	:	N/A
Hours flown in last 365 days	:	405 Hrs
Hours flown in last 180 days	:	151 Hrs
Hours flown in last 30 days	:	22:00 Hrs
Hours flown in last 7 days	:	05:20 Hrs
Hours flown in last 24 Hrs	:	04:30 Hrs
Rest period before start of FDP	:	14 Hrs
Last IR/PPC	:	13-02-2021
Last Ground Refresher	:	January 2021

1.6 AIRCRAFT INFORMATION

1.6.1 AIRCRAFT GENERAL

The King Air C-90A is an all-metal, low-wing, twin-engine turbo-propeller airplane with retractable landing gear. The airplane is equipped with conventional ailerons, elevators and rudder, for roll, pitch and yaw control. The airplane is equipped with dual controls for the pilot and co-pilot.

The King Air C 90A aircraft bearing serial number LJ 1573 was manufactured by Raytheon Aircraft Company, Wichita, Kansas, the USA, in the year 1999. The aircraft has been duly entered in the register of India with effect from 11.12.2001 and allotted with registration VT-JIL endorsed in the certificate of registration No. 3014. C of R of VT-JIL was issued in the name of M/s Jet Serve Aviation Pvt. Ltd. on 06.05.2019.



Figure# 2 Airplane Dimensions

1.6.2 AIRCRAFT VT-JIL DETAILS

Aircraft Model	:	King Air C90A
MSN	:	LJ-1573
Year of Manufacturer	:	1999
Name of Owner	:	M/s Jet Serve Aviation Private Limited
C of R	:	3014/13
C of A	:	2423/3 Issued on 10.05.2019
Category/Sub Category	:	Normal/Passenger/Mail/Goods
A R C issued on	:	01.07.2020
ARC valid up to	:	28.05.2021
Aircraft Empty Weight	:	3109.96 Kg
Maximum Take-off weight	:	4581 Kg
Maximum Landing weight		4354 Kg
Date of Aircraft weighment	:	01.09.2020
Operating Empty Weight	:	4,446.72 Kg
Max Usable Fuel	:	1453 Litres
Max Payload with full fuel	:	134.28 Kg
Empty Weight C.G	:	152.45 inch
Next Weighing due	:	01/09/2025
Total Aircraft Hours	:	4396:09 Hrs
Last major inspection	:	Phase III/600 Hrs & Phase IV / 800 Hrs on 25.02.2021 at 4337:05 Airframe hours
List of Repairs carried out after last major inspection till date of accident	:	NIL
Defect/ Snags	:	NIL for rectification
Engine Type	:	PT6A-21
Engine Sl. No. LH	:	PCE-25928
Date of Manufacture LH engine	:	23/04/1996
Last major inspection LH engine	:	Phase III/600 Hrs & Phase IV / 800 Hrs on 25.02.2021
List of Repairs carried out on LH engine after last major inspection till date of accident	:	NIL
Total Engine Hours LH	:	3570:28 Hrs
Engine Sl. No. RH	:	PCE-25925
Date of Manufacture RH engine	:	23/04/1996
Last major inspection RH engine	:	Phase III/600 Hrs & Phase IV / 800 Hrs on 25.02.2021

List of Repairs carried out on RH engine after last major inspection till date of accident	:	NIL
Total Engine Hours RH	:	3570:28 Hrs
Aero mobile License	:	Schedule 002/727 of License NO. A-155/002/RLO(NR) valid till 31.07.2023
Propellers Model	:	HC-E4N-3N
Propellers SL No. (LH & RH)	:	HH-167 & HH-702
Propeller hours since overhaul (LH & RH)		441:23 Hrs and 230:58 Hrs
Minimum crew necessary	:	One

All AD/SB/Modifications were complied with for Airframe, Engines and Propellers.

1.6.3 LANDING GEAR

The landing gear on King Air C90A Aircraft VT-JIL (MSN LJ-1573) are retracted and extended by an electrically operated hydraulic system. The electrically operated hydraulic power pack is located in the centre of the wing centre section forward of the main spar. As per the OEM maintenance manual, the landing gear of King Air C90A aircraft should be inspected at an interval of every 8000 cycles/ 6 years.

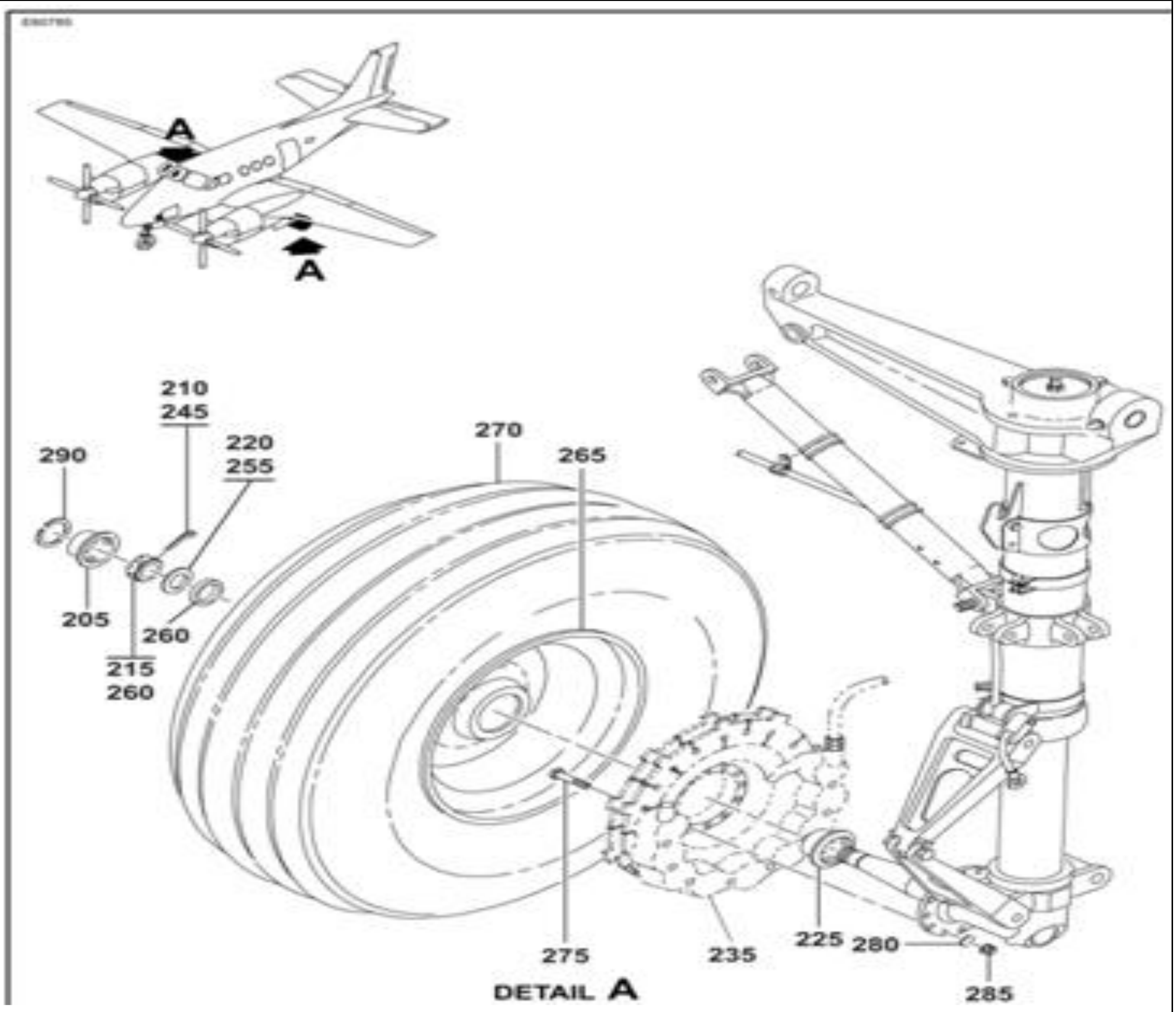
a) The LH Main Landing Gear of VT-JIL was last inspected for 6years/ 8000 Cycles inspection on 10.06.2015, 2742 Cycles at CAR 145 approved facility. The next Inspection was due on 09.06.2021 or 10742 cycles.

b) The RH Main Landing Gear of VT-JIL was last inspected for 6years/ 8000 Cycles inspection on 27.02.2018, 3225 Cycles at CAR 145 approved facility. The next Inspection is due on 26.02.2024 or 11225 cycles.

1.6.4 WHEEL ASSEMBLY

The King Air C90A Aircraft main wheel 3-1208-1 is a split-type assembly made of cast magnesium. The wheel assembly uses an 8.50 X 10 tubeless tire.

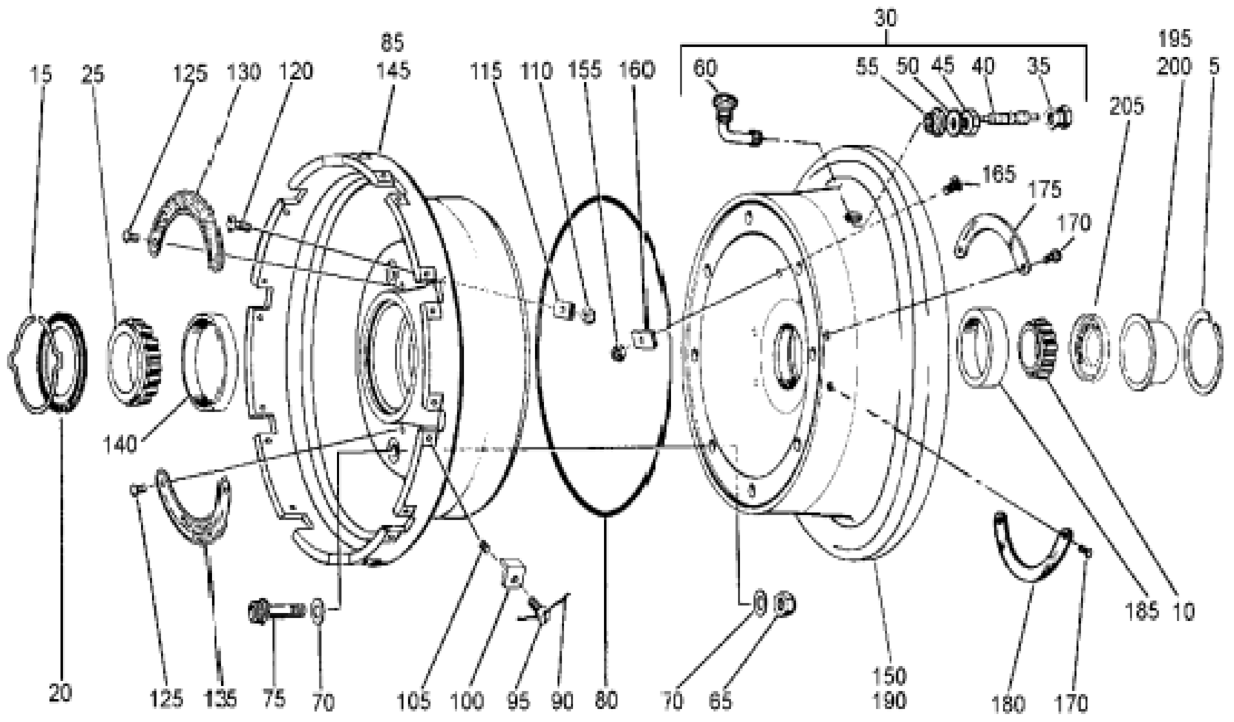
The LH main wheel assembly of VT-JIL is fitted with P/N 50-300010-133 (Wheel Assy-Main, Rim Inflation Half) and P/N 50-300010-87 (Wheel Assy-Brake Half) as per IPC.



Figure# 3 Main Gear Wheel

Table# 1: Component nomenclature of Main Gear Wheel

Number indicated in the above figure	Component nomenclature
215/260	NUT
210/245	PIN- COTTER
220/255	WASHER
260	SPACER



Figure# 4 Exploded view of Main Landing Gear Wheel Assembly

Table# 2: Component nomenclature of Main Landing Gear Wheel Assembly

Number indicated in the above figure	Component nomenclature
5	Ring, Lock
10	Cone, Bearing, Outer
15	Retainer, Inner
20	Seal Assembly, Inner
25	Cone, Bearing, Inner
65	Nut, Self-locking
70	Washer, Countersunk
75	Bolt
85	Wheel Half Assembly, Inner
130	Identification Plate
135	Instruction Plate
140	Cup, Bearing, Inner
145	Wheel Half, Inner
150	Wheel Half Assembly, Outer
185	Cup, Bearing, Outer
190	Wheel Half, Outer
200	Cap, Hub (No Axle Hole)

As per OEM and DGCA's approved Aircraft Maintenance Program (AMP), there is no recommended independent inspection interval for bearings of MLG wheel assembly. However, bearings are required to be visually inspected as a part of other inspections related to wheel assembly, such as wheel assembly tyre change, wheel assembly overhaul inspection and phase inspections.

As per OEM Component Maintenance Manual, the wheel assembly is required to be inspected either as per the number of tyre changes or in a number of years:

a) <u>Wheel assembly Inspection based on number of tyre changes:</u>

Tire Change Number	Penetrant or Eddy Current Inspection	Mandatory Penetrant Inspection of the full Wheel Halves
5	X	
8, 11, 14, 17	X	
21 and Thereafter (Every Tire Change)	X	
20 and Thereafter (Every Third Tire Change)		X

Table# 3: Wheel assembly Inspection based on number of tyre changes

If the wheel assemblies are in use for more than two years between tire changes, it is recommended to inspect the wheel in increments of years as an alternative to the number of tire changes.

b) <u>Wheel Assembly Inspection based on number of years:</u>

Inspection Schedule in Years	Penetrant or Eddy Current Inspection	Mandatory Penetrant Examination of the full Wheel Halves
AT 2, 4, 6, 8	X	
AT 11 and Thereafter (Every Two Years 13, 15, 17)	X	
At 10 and Thereafter (Every Two Years 12, 14, 16)		X

Table# 4: Wheel Assembly Inspection based on number of years

As per M/s JSAPL's, DGCA approved AMP, aircraft has 4 phase inspections. The inspections are as per the table given below:

Type of Inspection	Inspection Interval ~~Hours~~	Remarks
Inspection Phase 1	To be performed at 200 Hrs and every 800 Hrs thereafter.	Comibned together as suggested in Alternate Phase Inspection and Carried out on 25.02.2020 at 4283:46 airframe hours.
Inspection Phase 2	To be performed at 400 Hrs and every 800 Hrs thereafter.	
Inspection Phase 3	To be performed at 600 Hrs and every 800 Hrs thereafter.	Combined together as suggested in Alternate Phase Inspection and performed on 25.02.2021 at 4337:05 airframe hours.
Inspection Phase 4	To be performed at 800 Hrs and every 800 Hrs thereafter.	

Table# 5: Phase inspections as per M/s JSAPL's, DGCA approved AMP

Alternate phase inspection: If an aircraft is not flown at least 400hours in 24 months, the owner /operator may perform schedule phase inspections 1 and 2 together within 12 months after the last aircraft inspection 3 and 4 together within 12 months after completing the phase 1 and 2 inspections.

The operator had carried out the above phase inspection as per OEM suggested Alternate phase inspection.

1.6.4.1 History of the accident involved LH and RH wheel assemblies installed on the aircraft VT-JIL

The details of LH and RH main wheel assembly installed on VT-JIL are as follows:

Nomenclature	**LH wheel**		**RH wheel**	
	Brake half	**Rim inflation half**	**Brake half**	**Rim inflation half**
	Beech Aircraft Corporation	**BF Goodrich Corporation**	**BF Goodrich Corporation**	**BF Goodrich Corporation**
PN	50-300010-87	50-300010-133	50-300010-133	50-300010-133
S.N.	A1651	A2141P	A6348	A6348
CHG	M	U	Y	U
Date MFD	3-88	04-00	10-08	10-08

Table# 6: LH and RH main wheel assembly details

The wheel assembly brake half (A1651) was removed from aircraft VT-EMJ operated by another operator on 15.02.2008, and the Wheel assembly half- Rim inflation (A2141P) was removed from aircraft VT-EMJ on 31.07.2010.

M/s JSAPL had purchased more than 100 spare components of King Air C 90 aircraft through a bidding process from another Indian operator on 21.09.2019. As per the bid, a few components were serviceable, and a few were due for overhaul. The accident involved wheel assemblies were received through the bid. The wheel assembly did not have records of maintenance history at the time of receipt/purchase and was due for overhaul at the time of receipt as per the bid. Then the purchased Wheel Assemblies were sent to M/s JSAPL's approved CAR 145 wheel shop, having one-time approval to carryout wheel assembly overhaul.

At the time of overhaul at M/s JSAPL wheel shop, all the required inspections as per applicable OEM maintenance data were carried out, including tyre change inspection, wheel half inspection, bearing inspection, Cleaning and seal assembly inspection. During the overhaul, wheel hubs were sent to DGCA CAR 145 approved shop for penetrant inspection. Subsequently, after satisfactorily passing Penetrant Inspection, LH and RH wheel assemblies were built up in the M/s JSAPL shop as per applicable OEM maintenance data.

After overhaul, the accident involved wheel assemblies were installed on the aircraft VT-JIL on 07.09.2020 at 4318:30 airframe hours as the previously installed wheel assemblies of aircraft VT-JIL were due for penetrant inspection.

On 25.02.2021, LH and RH wheel assemblies were subjected to Phase III and Phase IV inspection. During the said inspection, both LH and RH wheel assemblies were removed and inspected as per OEM maintenance requirements, including visual inspection of bearings. Both LH and RH wheel assemblies passed the inspection satisfactorily. Same were re-installed on the aircraft VT-JIL.

A total of 27 landings subsequent to release of aircraft from phase inspection were conducted prior to the accident.

Table# 7: History of LH main wheel assembly installed on VT-JIL	
Date	Remarks
15.02.2008	Wheel assembly brake half (A1651) removed from A/c VT-EMJ
31.07.2010	Wheel assembly half- Rim inflation (A2141P) removed from A/c VT-EMJ
No records for LH main wheel assembly were available between 2010 to 2019.	
21.09.2019	Wheel Assembly was sold to M/s JSAPL. Wheel assembly was due for overhaul when it was purchased by M/s JSAPL.
07.09.2020	Wheel Assembly (A1651& A2141P) overhauled at M/s JSAPL Wheel assembly Shop and installed on the LH MLG of aircraft VT-JIL
25.02.2021	Wheel assembly was inspected by M/s JSAPL under Phase III and Phase IV inspection
06.05.2021	Aircraft met with an accident at Mumbai

1.6.4.2 MAIN LANDING GEAR WHEEL ASSEMBLY BEARING INSPECTION AS SUGGESTED BY THE OEM

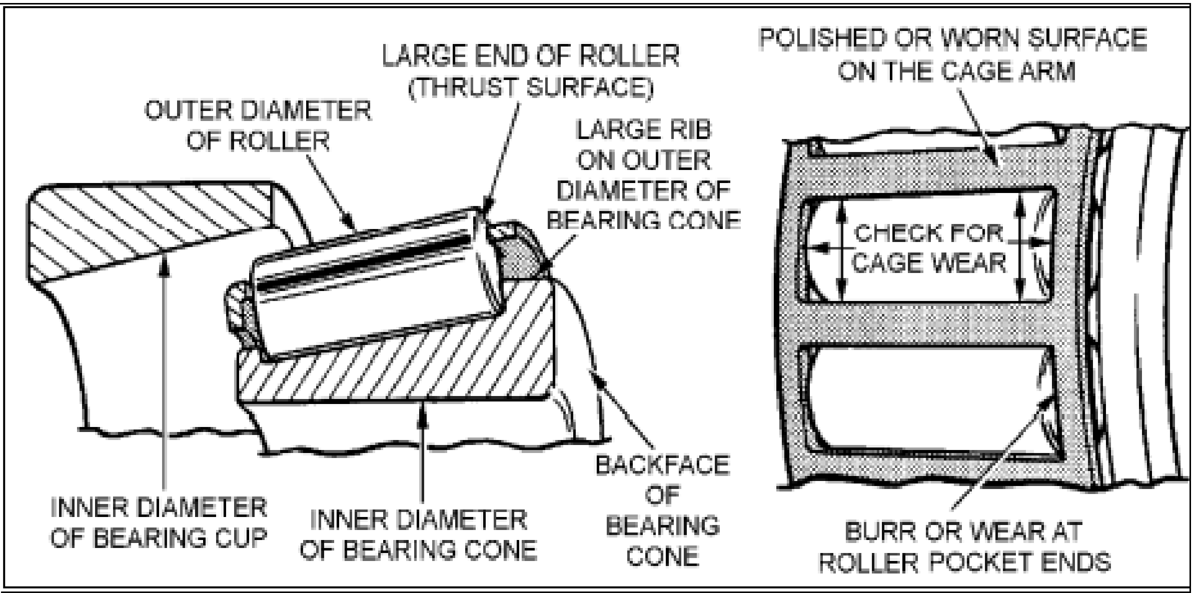
As per OEM's CMM 32-45-21, bearings are required to be visually examined during the tyre change, wheel assembly overhaul and the Phase inspections. A detailed Wheel half inspection is given in the Appendix 1. Relevant portion for bearing inspection is quoted as below:

A) Bearing Inspection *as per CMM 32-45-21*:

Clean the bearings (refer to the CLEANING section).

Visually inspect bearing surfaces of bearing cups (140, 185) and bearing cones (25, 10) as follows (refer to Figure given above).

NOTE: Incorrect bearing grease or axle nut torque can cause some of the defects that follow.



Figure# 5 Inspection Areas of Bearing Cup and Bearing Cone

(1) Spalled Surface - Discard a bearing cone or bearing cup with a spalled surface (pieces of the surface are missing).

(2) Nicks or Dings - Discard a bearing cone or the bearing cup with damage that is deep enough to be felt with a fingernail or with a single-edged razor blade. Small damage that cannot be felt with a fingernail or razor blade is permitted.

(3) Incorrect Colour - Discard a bearing cone or bearing cup that has black, dark blue, and purple stains on the wear surface, which are signs of overheat. Brown or yellow stains that can be removed easily with abrasive cloth (400 grit or finer) are permitted.

(4) Etched Surface - Discard a bearing cone or bearing cup that has water stains that have etched a wear surface. An etched surface is dull and rough. Water stain discoloration without an etched surface is permitted.

(5) Roller End Damage - Discard a bearing cone if the thrust surface on the large end of the rollers has chips, smears, scores, metal pick-up, incorrect color, or other damage. This surface should be smooth, but not shiny.

(6) Scored Bearing Cone - Discard a bearing cone if it has turned sufficiently on the axle to cause wear on the inner diameter of the bearing cone.

(7) Cage Damage - Discard a bearing cone if the cage is dented, bent, or has too much wear in the roller pockets or has a polished or worn surface on the cage arm. Do not straighten a bent cage.

(8) If a bearing cone is damaged in service and is replaced, also replace the mating bearing cup. NOTE: Replacement of the bearing cup is not necessary if a bearing cone was damaged or dented after it was removed from the wheel half.

(9) Inspect each bearing cup (140, 185) for movement in the wheel half assemblies (85, 150). If a 0.002 inch (0,051 mm) feeler gauge can be put into a clearance between the bearing cup and the bottom of the bearing bore, remove the bearing cup to permit inspection and possible repair of the bearing bore.

CAUTION:DO NOT MIX DIFFERENT BRANDS OF GREASE AS THIS CAN CAUSE DECREASED BEARING LIFE.

(10) Immediately fill satisfactory bearing cones and cups with bearing grease (Mobil Aviation Grease SHC 100, Aeroshell 5 or Mobil grease 28). Wrap them in oil proof paper or plastic film until they are installed in the wheel. When bearing parts are examined or filled with grease, use the recommended procedures that follow

B) Bearing Cleaning procedure as per CMM 32-45-21:

A. Soak bearing cones in MIL-PRF-680 Type II or III solvent to remove grease. Flush the bearing cones with solvent and use clean, dry, compressed air to remove all grease.
B. Flush the bearing cones in clean solvent or butyl alcohol. Let the solvent dry.
C. Apply oil to bearing cones and bearing cups to prevent rust, if they will not be examined and packed with grease in less than 2 hours. Repeat point B. above before inspection of the bearing cones.

CAUTION: *BEARING CONES CAN BE DAMAGED BY IMPACT AND BY CONTACT WITH DIRT, DUST, MOISTURE, OR OTHER CONTAMINANTS. HANDLE BEARING CONES CAREFULLY AND WEAR RUBBER GLOVES.*

CAUTION*: BEARING CONES CAN BE DAMAGED IF COMPRESSED AIR IS USED TO SPIN THEM DRY.*

1.6.5 RH MAIN LANDING GEAR WHEEL ASSEMBLY OF VT-JIL

Figure# 6: RH main landing gear axle

Figure# 7 RH Main Landing Gear Bearing

RH main wheel assembly and bearings were inspected by the investigation team post-accident. The wheel assembly was found to be as per IPC and adequately greased.

1.6.6 Other aircraft operated by M/s JSAPL

During laboratory investigation, it was brought to the notice of the investigation team that RH main landing gear wheel bearings of VT-JIL were observed to have reached the limit of their useful life, hence it was decided to assess the condition of the main landing gear wheel bearings of another King Air C90 aircraft VT-EMJ of M/s JSAPL.

Accordingly, an investigation team member carried out a visit at M/s JSAPL maintenance facility at IGI airport, New Delhi on 29.09.2021. During the visit following points were observed:

a) In the presence of investigation team member, LH & RH main wheels were removed and visually examined.

b) All four bearings of LH & RH main wheel assemblies of aircraft VT-EMJ were inspected by M/s JSAPL AME as per approved procedure sheets of M/s JSAPL in the presence of the investigation team member. No abnormalities were found on the bearings.

c) LH & RH main wheels were re-installed on the aircraft VT-EMJ as per approved procedure sheets of M/s JSAPL.

d) It was found that all four bearings of LH & RH main landing gear wheel assemblies were replaced post VT-JIL accident as a precautionary measure by the operator. The removed bearings were declared as unserviceable by M/s JSAPL and disposed off. The same four bearings were later made available to the investigation team on request for laboratory examination in order to ascertain their condition.

e) The investigation team observed that the respective procedure sheets were as per CMM 32-45-21 and approved. Further, AME was found to be aware of all respective procedures of CMM.

f) After the accident, M/s JSAPL also inspected the wheel assemblies of other fixed-wing Super King Air B200 aircraft operated by them. Inspection of the wheel assemblies for Super King Air B200 aircraft was found satisfactory during the inspection.

1.6.7 Hard landing records for VT-JIL

As per available aircraft records with the operator, no hard landing incident was reported on the aircraft VT-JIL for a period of two years preceding the accident.

1.6.8 Pilot Operating Handbook

Normal and abnormal operational procedures and checklists are included in the Pilot Operation Handbook. On review of the Pilot Operating Handbook, there was no reference available with regards to the loss of the main landing gear wheel. Therefore, no operational procedure is available for the crew to carry out gear up belly landing.

Even the landing gear manual extension abnormal procedure does not cover the situation for gear up landing.

The relevant extract of the Pilot Operating handbook is as below:

Emergency Procedures Index

Raytheon Aircraft Company

Emergency Procedures
Model C90A

SECTION 3
EMERGENCY PROCEDURES

TABLE OF CONTENTS

SUBJECT *PAGE*

Figure# 8 Emergency Procedures Index

The above list of emergency procedures does not cover landing gear related emergencies.

Abnormal Procedures Index

Raytheon Aircraft Company

Abnormal Procedures
Model C90A

SECTION 3A
ABNORMAL PROCEDURES

TABLE OF CONTENTS

SUBJECT *PAGE*

Figure# 9 Abnormal Procedures Index

The abnormal procedures above covers landing gear malfunctions for two types of failures:

1. Hydraulic fluid low
2. Landing gear manual extension

Landing Gear system Abnormal Procedures

Raytheon Aircraft Company
Model C90A

Section 3A
Abnormal Procedures

LANDING GEAR SYSTEM

HYDRAULIC FLUID LOW [HYD FLUID LO]

1. Landing Gear . . . . ATTEMPT TO EXTEND NORMALLY UPON ARRIVING AT DESTINATION
2. If Landing Gear Fails To Extend . . . . SEE LANDING GEAR MANUAL EXTENSION

LANDING GEAR MANUAL EXTENSION

If the Landing Gear Fails to Extend After Placing the Landing Gear Control Down, Perform the Following:

1. Landing Gear Relay Circuit Breaker (Pilot's right subpanel). . . . . PULL
2. Landing Gear Control . . . . CONFIRM DN
3. Alternate Extension Handle . . . . UNSTOW AND PUMP
   a. Pump handle up and down until the three green gear-down annunciators are illuminated.
   b. While pumping, do not lower handle to the level of the securing clip as this will result in loss of pressure.

If All Three Green Gear-Down Annunciators are illuminated:

4. Alternate Extension Handle . . . . STOW
5. Landing Gear Controls . . . . DO NOT ACTIVATE
   a. The Landing Gear Control and the Landing Gear Relay Circuit Breaker MUST NOT BE ACTIVATED.
   b. The landing gear should be considered UNSAFE until the airplane is on jacks and the system has been cycled and checked.

If One or More Green Gear-Down Annunciators Do Not Illuminate For Any Reason and a Decision is Made to Land in This Condition:

6. Alternate Extension Handle . . . . CONTINUE PUMPING
   a. Continue to pump until maximum resistance is felt.
   b. When pumping is complete, leave handle at the top of the stroke. DO NOT LOWER AND STOW.

Prior to Landing:

7. Alternate Extension Handle . . . . PUMP AGAIN
   a. Pump the handle again until maximum resistance is felt.
   b. When pumping is complete, leave handle at the top of the stroke. DO NOT LOWER AND STOW.

After Landing:

8. Alternate Extension Handle . . . . PUMP WHEN CONDITIONS PERMIT
   a. Pump the handle again, when conditions permit, to maintain hydraulic pressure until the gear can be mechanically secured.
   b. DO NOT STOW HANDLE.
   c. DO NOT ACTIVATE THE LANDING GEAR CONTROL OR THE LANDING GEAR RELAY CIRCUIT BREAKER.
   d. The landing gear should be considered UNLOCKED until the airplane is on jacks and the system has been cycled and checked.

Figure# 10 Landing Gear System Abnormal Procedures

Landing gear hydraulic fluid low and landing gear manual extension abnormal procedures are as above.

Preflight Inspection (Exterior) Normal Procedures

RIGHT WING

1.	Transfer Pump Sump	DRAIN
2.	Heat Exchanger Inlet	CLEAR
+ 3.	Nacelle Fuel Tank	CHECK; CAP SECURE
4.	Prop	CHECK
5.	Engine Air Intakes	CLEAR
+ 6.	Engine Oil	CHECK QUANTITY; CAP SECURE
7.	Fuel Strainer (Firewall)	DRAIN
8.	Cowling, Doors, and Panels	SECURE
9.	Fire Extinguisher (if installed)	CHECK PRESSURE
10.	Boost Pump Sump	DRAIN
+11.	Landing Gear, Strut, Brake, Wheel Well, and Landing Gear Doors	CHECK
12.	Wheel Well Sump	DRAIN
13.	Outboard Wing Sump	DRAIN
+14.	Wing Fuel Tank	CHECK QUANTITY; CAP SECURE
+15.	Tie-down and Chocks	REMOVE
16.	Deice Boot	CHECK
17.	Wing Tip and Lights	CHECK
18.	Aileron	CHECK
19.	Flaps	CHECK

Figure# 11 Preflight Inspection (Exterior) Normal Procedures

NOTE: After the first flight of each day, the Preflight Inspection may be omitted except for items marked with a "+" (Fuel Tank Caps and Engine Oil Quantity/Filler Cap need not be checked unless system(s) were serviced

LANDING GEAR Indication

Landing gear position is indicated by an assembly of three annunciators in a single unit which has a light transmitting cap that is marked as follows:

<table><tr><td colspan="2">NOSE</td></tr><tr><td>L</td><td>R</td></tr></table>

One light in each segment, when illuminated, makes the segment appear green and indicates that particular gear is down and locked. Absence of illumination with the landing gear control handle down indicates that the landing gear is not safe. Absence of illumination of the three green annunciators and the red in-transit lights with the landing gear handle up indicate that the landing gear is up.

The landing gear annunciator can be checked by pressing the face of the annunciator.

Two red, parallel-wired indicator lights located in the landing gear control handle illuminate to show that the gear is in transit or unlocked. The red lights in the handle also illuminate when the landing gear warning horn is actuated.

LANDING GEAR WARNING SYSTEM

The landing gear warning system is provided to warn the pilot that the landing gear is not down and locked during specific flight regimes. Various warning modes result, depending upon the position of the flaps.

With the flaps in UP or APPROACH position and either or both power levers retarded below a certain power level, the warning horn will sound intermittently and the landing gear control handle lights will illuminate. The horn can be silenced by pressing the GEAR WARN SILENCE button located on the left power lever; the lights in the landing gear control handle cannot be cancelled. The landing gear warning system will be rearmed if the power lever(s) are advanced sufficiently.

With the flaps beyond APPROACH position, the warning horn and landing gear control handle lights will be activated regardless of the power settings, and neither can be cancelled.

1.7 METEOROLOGICAL INFORMATION

METAR at CSIA is provided by IMD every 30 minutes. This information is broadcasted on ATIS.

METAR between 15:00 UTC to 16:30 UTC at Mumbai airport on 06th May 2021.

Mumbai METAR				
Time in (UTC)	**1500**	**1530**	**1600**	**1630**
Wind	290° 03 Knots	210° 03 Knots	200° 04Knots	230° 05 Knots
Visibility	4000	3000	3000	3000
Weather	HZ	HZ	HZ	HZ
Clouds	SCT 020	SCT 020	SCT 020	SCT 020
Temp (℃)	30	30	30	30
Dew Point (℃)	27	26	26	26
QNH (hPa)	1008	1009	1009	1009
Trend	BECMG 3000 HZ	NOSIG	NOSIG	NOSIG

The sunset time of Mumbai was 13:33 UTC.

1.8 AIDS TO NAVIGATION

Runway 27 at CSIA Mumbai, is equipped with ILS (DME collocated with glide path) and DVOR. It also has a secondary surveillance radar for providing route navigation services.

There was no known navigational aid unserviceability reported.

1.9 COMMUNICATIONS

The aircraft was in positive two-way communication on VHF throughout the flight. There were no communication-related errors/ lapses throughout the flight.

The recording of Mumbai ATC on area control frequency of 132.7 MHz for the relevant time when VT-JIL was in contact was not preserved. All ATC communication recordings prior to and post this segment were reviewed. The investigation team determined the missing segment did not have any significance to the investigation.

The crew did not declare the PAN PAN or MAYDAY through radiotelephony. However, the crew did inform the ATC about their aircraft condition and expected actions of a belly landing.

Aerodrome local standby was declared at 12:54 UTC, followed by a full emergency at 13:12 UTC.

The relevant portion of the ATC Tape Transcript from Nagpur to Mumbai is available in Appendix 2.

1.10 AERODROME INFORMATION

1.10.1 MUMBAI AERODROME

The Chhatrapati Shivaji Maharaj International Airport (CSIA) (Reference points 19° 05' 30" N 72° 51' 58" E) is a licensed airport both for IFR and VFR traffic with IATA location Identifier code as BOM and ICAO location Indicator code as VABB. CSIA is being operated, managed and developed by Mumbai International Airport Limited. The Airports Authority of India controls the ATC. The airport is equipped with Surface Movement Guidance and Control System.

The elevation (AMSL) is 12.13m (40 ft). The airport has two cross runways made of Asphalt. The details of these runways are as given below: -

- RWY 27 - 3448m x 60m
- RWY 09 - 3188m x 60m
- RWY 14/32 - 2871m x 45m

As per the electronic Aeronautical Information Publication (e-AIP) of CSIA Airport, declared distances for runways are as under:

	TORA (M)	TODA (M)	ASDA (M)	LDA (M)	RESA (M)
RWY 09	3188	3188	3188	3048	240 x 120
RWY 27	3448	3448	3448	2965	240 x 120

Table# 8: Runway Dimensions

No adverse report for the approach and runway lighting system was received for the relevant time, and the crew confirmed that the approach lights, runway lights and runway became visible well before landing.

1.10.2 AIRCRAFT RESCUE AND FIRE FIGHTING (ARFF)

CSIA has two ARFF stations which are located north of RWY 27.

ARFF Services is the primary rescue and fire-fighting agency for all aircraft incidents and accidents within the airport boundary. In addition, it provides rescue and fire-fighting support to the Greater Mumbai Disaster Management Authority/City Fire Brigade for all aircraft incidents and accidents within the Boundary of Municipal Corporation of Greater Mumbai, as required.

The ARFF services at CSIA are determined as per DGCA CAR Section 4, Series 'B' Part I and ICAO Annexure -14. Accordingly, depending on the aerodrome category, CSIA maintains category 10 for fire and rescue services on an H24 basis.

Although, as per para 9.2.41 of the DGCA CAR Section 4, series 'B', part I and ICAO Annex-14, the number of rescue and fire-fighting vehicles required for maintaining category 10 are 3, CSIA maintains a total of 7 Rescue and fire-fighting vehicles.

As per table 9-2 of the DGCA CAR Section 4, Series 'B', Part I and ICAO Annex-14, the amount of water for foam production and the complementary agents to be provided on the rescue and fire fighting vehicles for category 10 is a minimum of 22,800 litres (for foam meeting performance level C) and complementary agents (DCP) of at least 450 Kg. CSIA was maintaining 36000 litres of water and 600 Kg of DCP in 03 active RFF vehicles before the aircraft emergency was notified to MIAL ARFF services. Table 9-2 of the DGCA CAR Section 4, Series 'B', Part I is available in Appendix 3.

In addition to this, CSIA maintained 48000 litres of water and 900 Kg of DCP in 04 number of rescue and fire fighting vehicles, which were available as a redundancy to the active vehicles.

Also, as per table 9-2 of the DGCA CAR Section 4, Series 'B', Part I and ICAO Annex-14, the discharge rate of foam solution (for foam meeting performance level C) is a minimum of 7900 litres per minute, whereas CSIA was maintaining a discharge rate of 18,000 litres per minute in 03 number of active RFF vehicles and a total of 24,000 litres per minute in standby RFF vehicles.

As per para 9.2.22 of the DGCA CAR Section 4, Series 'B', part I and ICAO Annex-14, a reserve supply of foam concentrate, equivalent to 200 per cent of the quantities identified in table 9-2, shall be maintained on the aerodrome for vehicles replenishment purpose, whereas MIAL was maintaining a reserve of about 700% of foam in its store and 400% in 04 number of standby RFF vehicles.

CSIA was thus maintaining a significantly higher number/volumes of vehicles/ extinguishing agents than as required under the DGCA CAR Section 4, Series 'B', Part I and ICAO Annex-14.

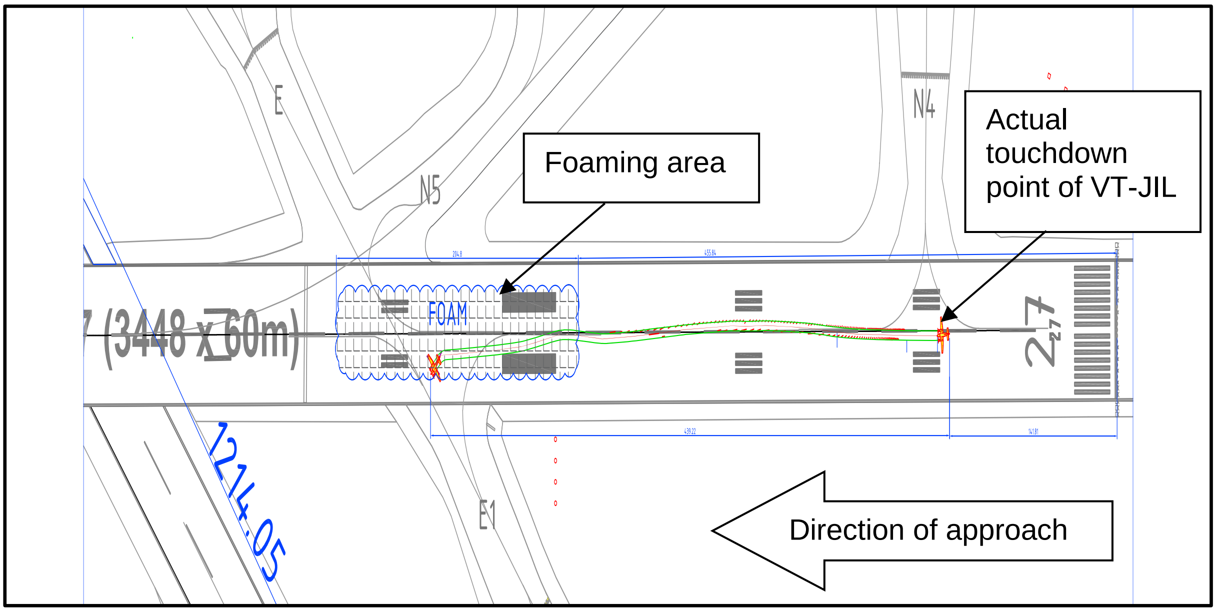
1.10.2.1 REQUIREMENTS FOR FOAMING OF THE RUNWAY

While offering all assistance to the crew, the approach radar also queried whether they would need foam on the runway or any other assistance. After some delay and verification of the landing gear status following the low pass, the crew requested for foaming of the runway as proposed by ATC.

There is no provision/ procedure available in the Aerodrome Manual for foaming/ foam carpeting the runway. The ARFF initially advised ATC that the procedure for foaming of runways was not there anymore as per present ICAO DOC 9137[1] guidance or DGCA CAR. However, after repeated requests from ATC, the ARFF agreed to foam the portion of the runway.

[1]*ICAO DOC 9137 Airport Services Manual Part 1 Rescue and Fire Fighting Fourth Edition dated 2014*

The crew replied to the ATC query that the aircraft would touchdown after 200m from the threshold. Before landing, approximately 205m of the runway, starting from a distance of about 455m from Runway27 threshold, and about 6m on either side of the runway Centerline, was carpeted with the available extinguishing agent.



Figure# 12 Runway Foaming and touchdown point of VT-JIL

The image above depicts the area of foaming carried out by ARFF prior to landing and the touch down point of the aircraft. The aircraft touched down at 79 knots as recorded by A-SMGCS.

Type and quantity of extinguishing agent used was as follows:

Extinguishing agent used for	**Type of Agent**	**Quantity used**	**Used from**
Foaming the runway	Water	Approx. 10,000 litres	CFT 3 & CFT 4 and standby CFTs
	Foam	Approx. 400 litres	CFT 3 & CFT 4 and standby CFTs
On VT-JIL after landing for fire prevention and cooling	Water	Approx. 5,000 litres	CFT 5 & CFT 6 and standby CFTs
	Foam	Approx. 470 litres	CFT 5 & CFT 6 and standby CFTs
The foam used above was not the protein type as mentioned in the ICAO DOC 9137 Airport Services Manual Part 1 Rescue and Fire Fighting Edition Three dated 1990.			

Table# 9: Type and quantity of extinguishing agent used

The required level of water/foam was always maintained for category 10 operations due to more than the adequate number of RFF vehicles, quantities of water, foam & complementary agent available in the RFFs vehicles and reserve of foam compound maintained in store.

The current ICAO DOC 9137 Airport Services Manual Part 1 Rescue and Fire Fighting Fourth Edition dated 2014 does not provide guidance on foaming of runways

for emergency landings. The earlier edition ICAO DOC 9137 Airport Services Manual Part 1 Rescue and Fire Fighting Edition Three dated 1990 provided information which included '*Theoretical Benefits from Foaming of Runways'.*
Ref. Appendix 4.

1.11 FLIGHT RECORDERS

CVR

As per the prevailing DGCA, Civil Aviation Requirement Section 2, Series I Part VI (Issue, 30th October 2018), the aircraft was not required to be fitted with Cockpit Voice Recorder (CVR)).

A Cockpit Voice Recorder (CVR) with 30min of recording capacity was installed on the aircraft. The details are as follows:

Manufacturer: Fairchild Aviation Recorders
Model: A100S
P/N: S100-0080-00
S/N: 01145

The CVR recording was used by investigation team to establish operational aspects.

Relevant portion of CVR transcript is placed in Appendix 5.

FDR

As per the prevailing DGCA, Civil Aviation Requirement Section 2, Series I Part V (Issue, 30th October 2018), states- "*All multi-engined turbine powered aeroplanes of a maximum certificated takeoff mass of 5700kg or less for which the individual certificate of airworthiness is first issued on or after 1st January, 1990, should be equipped with an FDR which should record at least the first 16 parameters listed in Table 1 of Appendix I.*"

M/s JSAPL informed the investigation team that the FDR installation on VT-JIL is not a mandatory requirement and hence was not equipped with Flight Data Recorder.

Required parameters for the aircraft flight path were corroborated using approach surveillance radar.

1.12 WRECKAGE AND IMPACT INFORMATION

1.12.1 OBSERVATIONS DURING RUNWAY INSPECTION POST-ACCIDENT

Following observations were made during runway inspection post-accident:

a. Aircraft touched down on runway centerline at approximately 177m from the displaced threshold of runway 27.
b. Initially, right propeller & belly touched runway surface followed by left propeller.
c. The distance between left and right propeller strike markings were measured to be approximately 4.5m. (Ref. Figure# 13)
d. The distance between two consecutive propeller strike marks at touchdown point was measured to be 0.56m. (Ref. Figure# 13)

Figure# 13 Propeller and belly landing marks at touchdown

e. The propeller strike marks were visible for 116m from touchdown point which later became intermittent with distinct line marking. (Ref. Figure# 14)

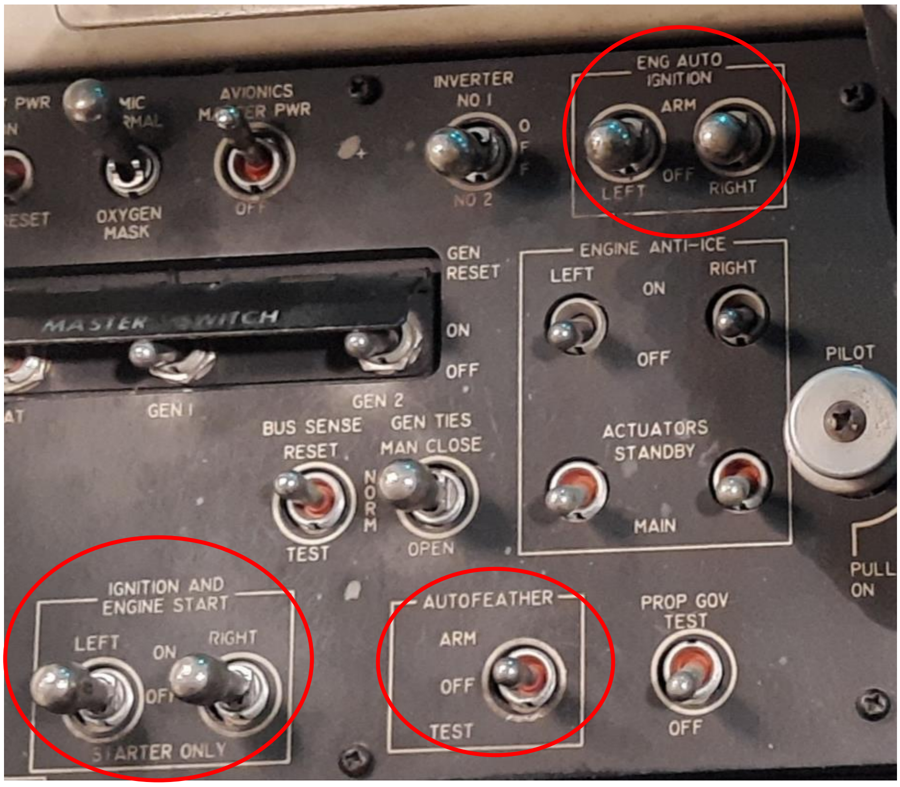
Figure# 14 Distinct line markings by propeller

f. A square metal piece separated from belly, having approximate dimension 15cm x 12cm, was found on the runway 132m from touchdown point after separating from aircraft during landing.
g. Aircraft travelled approximately 387m from touchdown point and finally halted 8m left of runway centreline facing south.

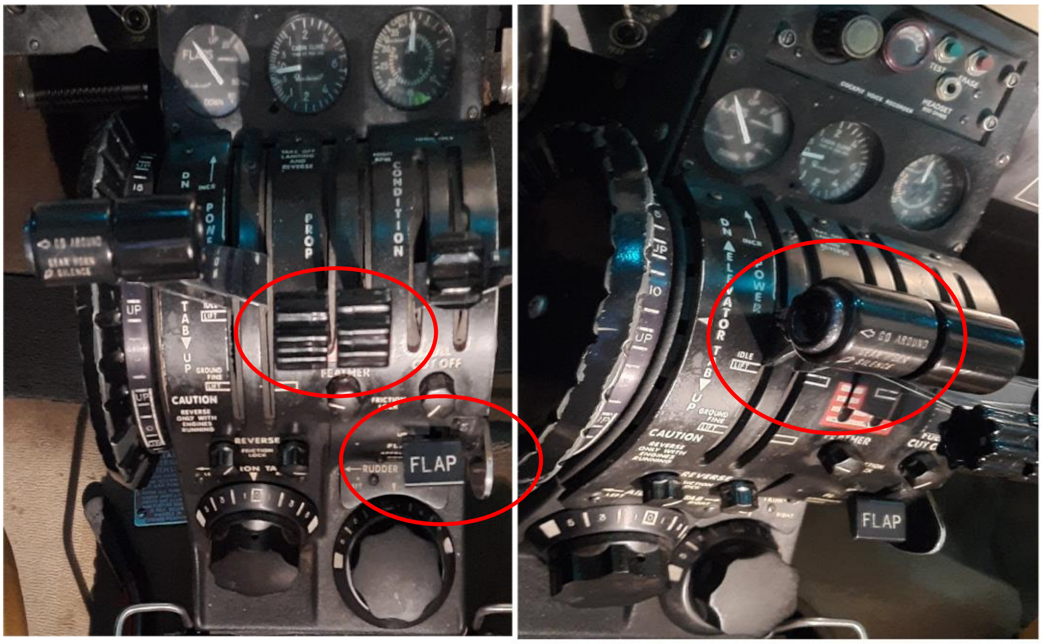
1.12.2 Observations during visit to aircraft post- accident

Following observations were made during visit to aircraft post-accident:

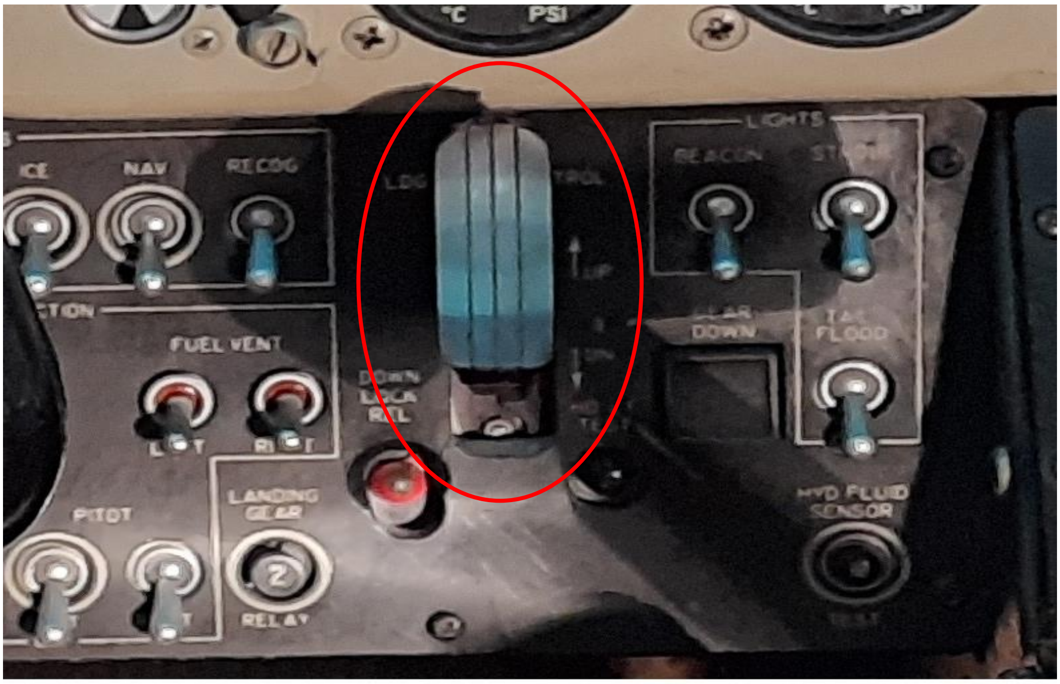
a. Ignition & Engine start switches of both the engines were in OFF position. (Ref. Figure# 15)
b. Auto feather switch was in OFF position. (Ref. Figure# 15)
c. Propeller lever was in feather position. (Ref. Figure# 16)
d. Throttle lever was at IDLE position. (Ref. Figure# 16)
e. Cockpit in-situ inspection revealed the landing gear lever was in UP position depicting retracted landing gears. (Ref. Figure#17)
f. Both fuel boost pumps were in OFF position. (Ref. Figure# 18)
g. Flap lever was observed in UP position and flaps were physically observed to be in retracted position. (Ref. Figure# 16,19 & 20)
h. Propellers of both engines were physically observed & identified to be in feathered position; however, the bent blades depicts that the propellers were rotating during the aircraft contact with the runway surface. (Ref. Figure# 21 & Figure# 22)
i. No evidence of fuel/ oil leak was observed.



Figure# 15 Ignition & Engine start, Auto feather and ENG Auto Ignition switch position being OFF



Figure# 16 Throttle lever position at IDLE, flap lever position at UP and propeller lever position at FEATHER



Figure# 17 Landing gear lever position at UP

Figure# 18 Left and right fuel boost pumps at OFF

Figure# 19 Starboard flaps position being at retracted position

Figure# 20 Port flaps position being at retracted position

Figure# 21 Propellers of both engines in feathered position

Figure# 22 Bent propeller blades

1.12.3 SEPARATED WHEEL AND ITS PIECES AT NAGPUR AIRPORT

LH main wheel got separated from aircraft during take-off and found near runway 32. Metal pieces pertaining to separated LH main wheel were found on runway. Photos of separated LH main wheel and its metal pieces reflecting damage are depicted below:

Figure# 23 Damaged separated wheel and its metal pieces recovered from Nagpur airport

1.12.4 Damage Assessment

Following damage was observed during damage assessment.

Figure# 24 Antennas installed on belly of the aircraft were found damaged due to rubbing.

Figure# 25 Aircraft belly area was found heavily rubbed; fuselage skin was found peeled off.

Figure# 26 Rubbing mark, scratches and cuts of 4" x 1" and 1.5" x 2" was found on LH MLG O/B door. Door hinge assembly was found fully broken due to rubbing.

Figure# 27 In LH wheel well, Bumper block was missing.

Figure# 28 On tail section, drain tube was found damaged.

Figure# 29 All blades of RH propeller were found bowed

Figure# 30 All blades of LH propeller were found bowed.

Figure# 31 LH engine air inlet heating lip had a dent with a dimension 1” x 1”.

Figure# 32 Rubbing and scratching marks were found on LH engine nacelle tank bottom and spread across the dimension 24” x 14”.

Figure# 33 Ventral Fin was found damaged. It was found bent to one side. The dimension of bent is 100” x 2”.

Figure# 34 RH MLG inboard door was found bent with dimension 5” x 1”.

1.13 MEDICAL AND PATHOLOGICAL INFORMATION

Both the crew had undergone pre-flight medical examination before departure as per the requirement of CAR Section 5, Series F, Part III. Both cockpit crew were not under the influence of alcohol.

A post-accident BA test was carried out at CSIA, Mumbai, and the test result was also negative for alcohol.

1.14 FIRE

There was no Fire.

1.15 SURVIVAL ASPECTS

The accident was survivable.

1.16 TESTS AND RESEARCH

1.16.1 CSIR-NAL REPORT

The LH main landing gear wheel assembly (retrieved from Nagpur Airport) and LH Main landing gear strut fitted with axle and other parts of the assembly were submitted to Council of Scientific & Industrial Research- National Aerospace Laboratories (CSIR-NAL), Bangalore, for failure analysis and to establish the cause for wheel separation from the axle.

Subsequently, RH main wheel Brake assembly components (rotors, stator and liners), RH main wheel assembly locking components (washer & nut) and RH main wheel bearings were also submitted to CSIR-NAL, Bangalore, for examination to carry out a comparative study.

CSIR-NAL carried out a detailed failure analysis on all submitted components, and an investigation report was submitted to the investigation team. The investigation report submitted by CSIR-NAL is placed in Appendix 6.

1.16.2 TEST ON MLG BEARINGS OF VT-EMJ OF M/S JSAPL

Given the fact that three out of four main landing gear wheel bearings of VT-JIL were observed to have reached the limit of their useful life of which one bearing had suffered the catastrophic failure, the MLG wheel bearings of the remaining King Air C90 aircraft VT-EMJ of M/s JSAPL were requested by and provided to investigation team on request. In order to ascertain the condition of the MLG wheel bearings of VT-EMJ aircraft, the bearings were sent to the DGCA lab for examination.

1.16.3 Fuel and oil sample lab test

Fuel and oil samples collected from the aircraft VT-JIL post-accident were submitted to DGCA Fuel and Oil laboratory for testing.

On analysis of the samples, the laboratory concluded in its report that the fuel and oil samples passed their respective specification tests.

1.17 ORGANISATIONAL AND MANAGEMENT INFORMATION

M/s JSAPL is a DGCA approved non-scheduled operator. It holds an Air Operator Permit (AOP: 02/2017), valid till 09.02.2024.

The Accountable Manager is at the top of the Organization chart to manage all activities of the organization in accordance with the prevailing Civil Aviation Requirements. The Accountable Manager is also holding the post of Base Maintenance Manager. The Accountable Manager is supported by a Quality Manager, CA Manager and Director Operation and Training. The post of Chief of Flight Safety was lying vacant at the time of the accident.

The post for Director Operations and Training (Fixed Wing) was initially issued in May 2019 and later transferred in March 2021 due to the inclusion of a new type to the fleet. The post of Quality Manager (part 145) was vacant between March 2021 to May 2021. The post holder was approved in May 2021 later resigned in November 2021. The new post-holder has been appointed effective December 2021.

The organization was holding the following DGCA approvals, which were valid as on the date of the accident:

CAMO: Continuing Airworthiness Management Organization with approval reference DDG/NR/MG/110. Under its CAMO approval, it managed the following three types of aircraft: Robinson R-44 Raven II Helicopter, King Air C-90 series and Super King Air B-200.

CAR145: Maintenance organization with approval reference JSA/F-APP/705 for maintaining aircraft with A3, A2 and C5 ratings.

Table#10: M/s JSAPL capabilities under CAR 145 approval

A2	Maintenance of King Air C90 Series aircraft fitted with Pratt & Whitney PT6A-21 engines including Electrical, Instrument and Radio system installed thereon upto and including 800 hours/24 months Inspection Schedule.
A2	Maintenance of Super King Air B200 Series aircraft fitted with Pratt & Whitney PT6A-42 engines including Electrical, Instrument and Radio system installed thereon upto and including 800 hours/24 months Inspection Schedule.
A3	Maintenance of Robinson R44 Raven II helicopter fitted with Lycoming IO-540-AE-1A5 engines including Electrical, Instrument and Radio system installed thereon upto and including 2200 hours/12 years months Inspection Schedule.
A3	Maintenance of Bell 206 L4 Helicopter aircraft fitted with ROLLS ROYCE 250-C30P engine including Electrical, Instrument and Radio system installed thereon upto and including 1200 hours/24 months Inspection Schedule.
C5	To carry out charging /discharging (including initial chagrining) and capacity test of Aircraft Lead Acid and Ni-Cd batteries.

Further to the above, the DGCA has given wheel assembly Shop approval under CAR 145 for King Air C 90 series aircraft and Super King Air B200 aircraft under Class 'Components other than complete Engines or APU' and Ratings 'C14' (Landing Gear) to the Organization vide DEL-11011(12)/19/2019-DAW-NR/565 dated 17.08.2020. Approval was granted for one time for a period of 08 months, valid till 16 April 2021. Approval attached as Appendix 7.

1.17.1 Operator's facility Visit

The investigation team visited M/s JSAPL maintenance facility at Manesar, Gurugram, Haryana to verify the maintenance records pertaining to the overhaul of the accident involved wheel assembly and subsequent phase inspection carried out by M/s JSAPL. During the visit, maintenance records, including tools/ special tools, equipment and consumables issued from stores, were verified to ascertain the veracity of the maintenance carried out. It was found that appropriate maintenance schedules were followed during overhaul of accident involved wheel assembly & subsequent phase inspection by authorized maintenance personnel wherein required tools/ special tools having valid calibration, equipment, consumables having valid service life, etc. were found to be used during maintenance as required by respective maintenance tasks after issuance from stores.

Further, investigation team made the following observations during the visit:

1. At the time of the accident, the post of Chief of Flight Safety was vacant. The post of Chief of Flight Safety with M/s JSAPL has been inconsistent since 2019.
2. Stores were found to be located at a different location than the location reflected in the approved MOE (Part 1, subpart 1.8, page No. 34).

VT-JIL Mandatory occurrences reported to DGCA in the last 12 months prior to the accident:

Two occurrence reports dated 14.09.2020 and 02.05.2020 were submitted to DGCA. 14.09.2020 occurrence report was related with RH main landing gear down lock indication while 02.05.2020 occurrence report was related with LH engine torque.

The detail of occurrence dated 14.09.2020 is as follows:

On 14.09.2020, VT-JIL was scheduled to operate Delhi-Ludhiana-Delhi. The aircraft operated sector Delhi-Ludhiana uneventfully. On the return flight, the RH main landing gear down lock did not illuminate during landing at Delhi. The flight crew carried out a missed approach and completed the emergency checklist. After completing the checklist, the gear light still did not illuminate. The flight crew asked the safety jeep to check the landing gear down, which was confirmed, and the aircraft landed safely. Post landing RH L/G indication light was fluctuating.

Rectification Action Taken: Carried out troubleshooting of snag, light switch assembly was found unserviceable and same was replaced with serviceable assembly (part number 351-33790- 007). Landing gear retraction and extension check carried out were found satisfactory. On 23-09-2020 aircraft was issued a certificate of release to service.

Neither of these occurrences have any direct correlation to the subject accident.

1.18 ADDITIONAL INFORMATION

1.18.1 FAA GUIDANCE

FAA periodically issues guidance to pilots through various documents including Airplane Flying Handbook. Relevant extract of Airplane Flying Handbook [FAA- H-8083-3B] 2016Issued by U.S. Department of Transportation , FEDERAL AVIATION ADMINISTRATION , Flight Standards Service (Link for download) are as below:

Emergency Situations

This chapter contains information on dealing with non-normal and emergency situations that may occur in flight. The key to successful management of an emergency situation, and/ or preventing a non-normal situation from progressing into a true emergency, is a thorough familiarity with, and adherence to, the procedures developed by the airplane manufacturer and contained in the Federal Aviation Administration (FAA) approved Airplane Flight Manual and/or Pilot's Operating Handbook (AFM/POH). The following guidelines are generic and are not meant to replace the airplane manufacturer's recommended procedures. Rather, they are meant to enhance the pilot's general knowledge in the area of non-normal and emergency operations. If any of the guidance in this chapter conflicts in any way with the manufacturer's recommended procedures for a particular make and model airplane, the manufacturer's recommended procedures take precedence.

Landing Gear Malfunction

If all efforts to extend the landing gear have failed and a gear-up landing is inevitable, the pilot should select an airport with crash and rescue facilities. The pilot should not hesitate to request that emergency equipment is standing by.

When selecting a landing surface, the pilot should consider that a smooth, hard-surface runway usually causes less damage than rough, unimproved grass strips. A hard surface does, however, create sparks that can ignite fuel. If the airport is so equipped, the pilot can request that the runway surface be foamed. The pilot should consider burning off excess fuel. This reduces landing speed and fire potential.

If the landing gear malfunction is limited to one main landing gear leg, the pilot should consume as much fuel from that side of the airplane as practicable, thereby reducing the weight of the wing on that side. The reduced weight makes it possible to delay the unsupported wing from contacting the surface during the landing roll until the last possible moment. Reduced impact speeds result in less damage.

If only one landing gear leg fails to extend, the pilot has the option of landing on the available gear legs or landing with all the gear legs retracted. Landing on only one main gear usually causes the airplane to veer strongly in the direction of the faulty gear leg after touchdown. If the landing runway is narrow and/or ditches and obstacles line the runway edge, maximum directional control after touchdown is a necessity. In this situation, a landing with all three gear retracted may be the safest course of action.

If the pilot elects to land with one main gear retracted (and the other main gear and nose gear down and locked), the landing should be made in a nose-high attitude with the wings level. As airspeed decays, the pilot should apply whatever aileron control is necessary to keep the unsupported wing airborne as long as possible. Once the wing contacts the surface, the pilot can anticipate a strong yaw in that direction. The pilot must be prepared to use full opposite rudder and aggressive braking to maintain some degree of directional control.

1.18.2 PHOTOGRAPHS

Figure#35 CCTV image of VT-JIL on initial Take-off roll. All undercarriage extended and wheels visible

Figure#36 CCTV image shows the separation of the left wheel just as the aircraft is airborne

Figure# 37 LHS wheel separated during Take Off roll

Figure# 38 VT-JIL performing low pass at RWY 27 at 13:43UTC

1.19 USEFUL OR EFFECTIVE INVESTIGATION TECHNIQUES

Nil

2 ANALYSIS

General

The investigation focused analysis on two areas that have led to the accident. One area focused on the failure of the component itself, and the other area of focus was the subsequent procedures leading to the belly landing.

The component failure analysis was done through laboratory assessment of available components to determine metallurgical failure initiation and propagation. The maintenance documentation history was reviewed to ascertain compliance to the maintenance procedures by the operator. Similar components of another King Air C90 aircraft with the same operator were also tested to ascertain any latent defects.

The separation of the wheel did not have any immediate impact to the safe operation of the aircraft, however reduced the safety margins for a landing. To determine the safest course of action, the investigation focused on all the procedural aspects followed by the flight crew and the associated agencies at the aerodrome. The investigation team requested information regarding the above from the OEM and state of manufacturer and referenced ICAO documentation for aerodrome procedures.

2.1 AIRCRAFT

2.1.1 SERVICEABILITY OF AIRCRAFT

M/s JSAPL was maintaining the aircraft as per the DGCA approved aircraft maintenance programme and in accordance with the OEM maintenance data. No schedule maintenance was due, and no snags were pending for rectification before the accident flight.

Aircraft's C of R, C of A, ARC and Aero Mobile License were valid as per applicable DGCA CAR. In addition, all relevant Airworthiness Directives, mandatory Service Bulletins, and DGCA Mandatory Modifications on the airframe, engines and propellers were complied with as on date of the accident.

The weight and balance of the aircraft complied with the DGCA CAR. The crew prepared the "Load and Trim" sheet of the accident flight, and the center of gravity was within limits.

The crew carried out the pre-flight inspection before the accident sector, and no abnormality was recorded. As per available documents/ records, aircraft was serviceable.

Post damage assessment was commensurate with a belly landing and subsequent shifting of the aircraft.

2.1.2 AIRCRAFT MAINTENANCE

2.1.2.1 LANDING GEAR

The landing gear on King Air C90A Aircraft VT-JIL (MSN LJ-1573) are retracted and extended by an electrically operated hydraulic system. As per the OEM maintenance manual, the landing gear of King Air C90A aircraft were required to be inspected at an interval of every 8000 cycles/ 6 years. LH MLG was last inspected on 10.06.2015, and RH MLG was last inspected on 27.02.2018. No inspection was due on main landing gears.

2.1.2.2 WHEEL ASSEMBLY

The main landing gear LH and RH wheel assemblies installed on VT-JIL were as per IPC issued by the OEM.

Acquisition

M/s JSAPL procured LH & RH wheel assemblies through a bidding process from another Indian operator on 21.09.2019. Wheel assemblies did not have records of maintenance history at the time of receipt/purchase and were reflected as 'due for overhaul' in the bid. Subsequently, the wheel assemblies were subjected to overhaul at M/s JSAPL's one-time approved CAR 145 wheel assembly shop before their installation on VT-JIL on 07.09.2020.

Overhaul of main landing gear wheel assemblies at M/s JSAPL Shop

DGCA approved M/s JSAPL wheel assembly shop under CAR 145 in Class 'Components other than complete engines or APU' and ratings 'C-14 (Landing Gear)'. At the time of overhaul, the approval of the shop was valid. During the overhaul, the wheel hubs were inspected by another CAR 145 approved shop for penetrant inspection, and on satisfactory examination, wheel hubs were released with CA form 1 from the shop. The LH and RH main landing gear wheel assemblies' outer and inner bearings were visually examined as per maintenance document CMM 32-45-21. During the visual examination, no abnormalities were recorded in all four bearings. The investigation team examined the maintenance records. It was found that the wheel was overhauled as per the approved procedures in accordance with OEM maintenance data by the authorized maintenance personnel at the CAR 145 approved facility. As per the maintenance records, all required tools/ special tools and consumables were utilized to perform respective tasks. The calibration of tools/ special tools and service life of consumables used to perform the overhaul was found to be valid. Both wheel assemblies were released from the shop with CA form 1 issued by the Certifying staff of M/s JSAPL and subsequently installed on VT-JIL on 07.09.2020. The aircraft was released to service on 07.09.2020. No abnormalities were detected from the scrutiny of the maintenance records for the overhaul of both wheel assemblies. Therefore, from documentary evidence, it can be established that both the wheel assemblies were serviceable as per existing regulations prior to installation on VT-JIL.

Inspection of main landing gear wheel assemblies during phase inspection by M/s JSAPL

After performing 23 landings from the overhaul of wheel assemblies, the aircraft was subjected to phase 3 & 4 inspection before its due date 25.02.2021 in accordance with the approved maintenance programme.

Phase 3 & 4 inspection covers visual inspection of wheels for wear, damage and corrosion; and visual inspection of wheel bearings and races for wear, pitting, cracks, discolouration, rust or any other indications of damage as per CMM 32-45-21. During the visual examination in Phase 3 & 4 inspections, no abnormalities were recorded in wheels and bearings of LH & RH wheel assemblies. The investigation team examined the maintenance records and it was found that the phase inspection was carried out as per the approved procedures in accordance with OEM maintenance data by the authorized maintenance personnel at the CAR 145 approved facility. As per the maintenance records, all required tools/ special tools and consumables were utilized to perform respective tasks. The calibration of tools/ special tools and service life of consumables used to perform the phase inspection was found to be valid. The aircraft was released on 25.02.2021 under the CRS issued by authorized maintenance personnel. No abnormalities pertaining to wheel assemblies were detected from the scrutiny of the maintenance records for phase 3 & 4 inspection. Therefore, from documentary evidence, it is established that aircraft VT-JIL was released with both the main wheel assemblies in serviceable condition as per existing regulations after completion of phase 3 & 4 inspection.

Summary

Wheel assemblies were being maintained as required by respective CMM procedures. The authorised maintenance personnel carried out all the scheduled inspections on main wheel assemblies as required by the approved aircraft maintenance programme. No scheduled maintenance was due on the main wheel assemblies as on the date of the accident. None of the documentary evidence reflected any perfunctory maintenance on the wheel assembly. The investigation team found no evidence to indicate defects existed in the outer bearing of the LH wheel assembly, which may have gone unnoticed during maintenance. Further maintenance records do not reveal that the main wheel assemblies or its bearings were replaced after installation on VT-JIL after the overhaul of main wheel assemblies in Sept 2020. Therefore, from documentary evidence, it can be established that main wheel assemblies installed on aircraft VT-JIL were in serviceable condition before the accident flight.

2.1.3 Aircraft Performance

Aircraft performance was not affected by the detachment of LH main wheel. Crew observed all the parameters were normal and decided to continue towards destination.

2.2 CSIR- NAL REPORT

2.2.1 LH Main Landing Gear Wheel Assembly

CSIR-NAL carried out detailed failure analysis, and an investigation report was submitted to the investigation team. Extract from the CSIR-NAL's Failure Analysis report is given below:

1. Examination revealed that all parts/components of the wheel hub assembly on the axle of the port MLG were in order and as per the IPC of the OEM.

2. The inner bearing was functional during the last take-off roll. Examination of the rolling surfaces did not show any significant mechanical damages, and there were no metallurgical abnormalities in the cone and rollers in terms of microstructure or hardness profile.

3. Examination of the damaged components of the port MLG axle assembly confirmed that the primary cause for detachment of the wheel from the axle was the failure in the outer bearing.

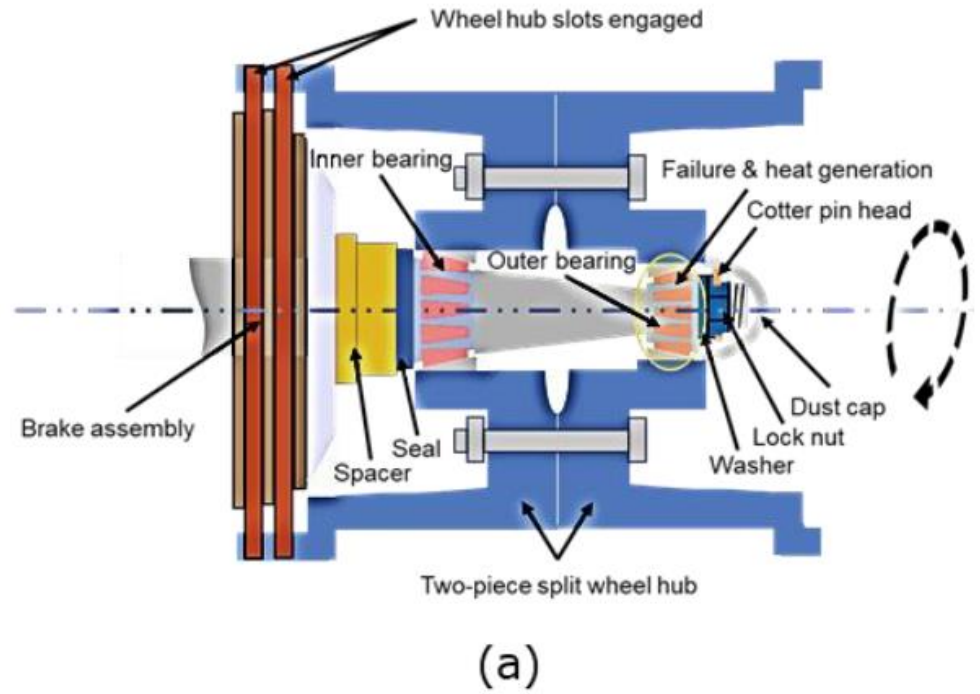
4. Evidence suggested that the cup of the outer bearing had come out of the wheel hub bore under rotational force. As a result, the locking action on the wheel hub was lost and thereby allowed the wheel to move inboard. As a result, the wheel hub moved out from the inner bearing with the cup in position in the bore. While coming out from the bearing, the wheel hub impacted the axle resulting in fracture along the bore circumference and creating a dent on the axle. Subsequently, the cup of the bearing came out of the bore under rotational force, as evident from the deep circular marks on the bore surface. Once the cup was dislodged, the load was directly on the wheel hub bore surface, leading to deformation and outward flow of material.

5. Laboratory investigation showed that the primary failure in the port MLG that was responsible for the detachment of the wheel was the failure in the outer bearing. Investigation revealed that the failure occurred over a period of time wherein there was continuous deterioration in the bearing and frictional heat generation. At the final stage of failure, the heat generation was so much so that the wheel lock assembly comprising lock-nut, washer and bearing cone got fused into a single body. During the last take-off roll at Nagpur, there was a seizure in the bearing, and the whole lock assembly along with the bearing cone rotated on the axle in the direction of the wheel rotation. Concurrently, the bearing cup rotated in the wheel hub bore and got dislodged from its position. This allowed the wheel to move axially inboard while the aircraft was on take-off roll, and eventually, the wheel came off the axle when the aircraft took-off.

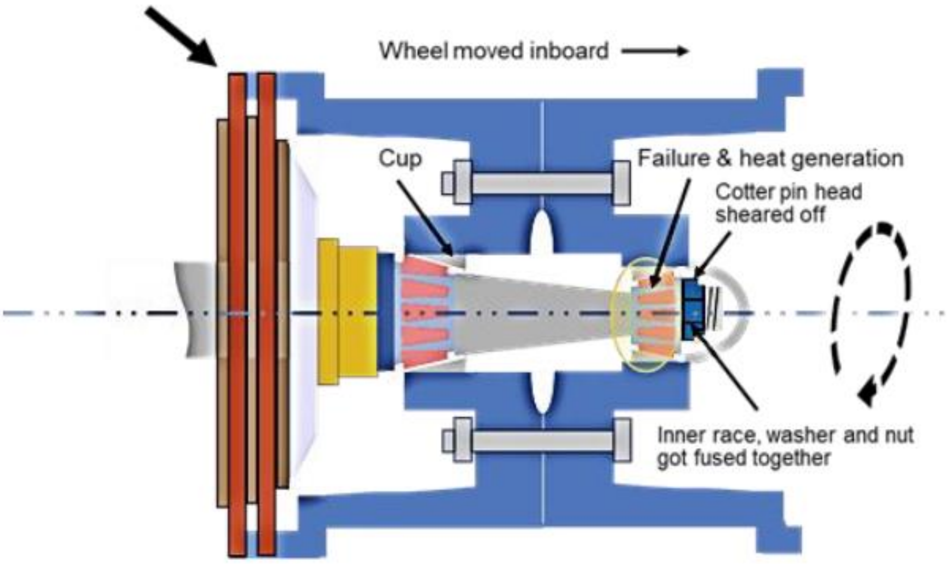
6. The evidence of failure initiation on the available parts of the bearing were completely destroyed due to excessive heat generation and severity of material damage within the bearing.

7. The sequence of events as established at CSIR-NAL reflects that detachment of wheel from the port MLG of the aircraft occurred as a consequence of excessive frictional heat generation and subsequent structural failure of the outer bearing

and dislodgement of the bearing cup from the wheel hub bore. Because of this failure, the retaining action of the bearing for the wheel hub was lost, and the wheel was free to move axially away from its normal position during the last take-off roll. The damages to only the cup of the inner bearing were found to be consistent with the axial movement of the wheel as the outer bearing failed. As the wheel moved inboard, it fell off from the inner bearing and impacted the axle leading to a fracture in the wheel hub bore and dislodgement of the bearing cup. A deep dent was created at the location of impact on the bottom surface of the axle in the fully extended position of the MLG. As the aircraft rolled, the wheel continued to move inboard and it came out of the axle and got detached from the MLG at the time of take-off. Figure below shows a schematic representation of the sequence of events [(a)→(b)→(c)→(d)→(e)→(f)] that led to the dislodgement of the wheel from the axle.

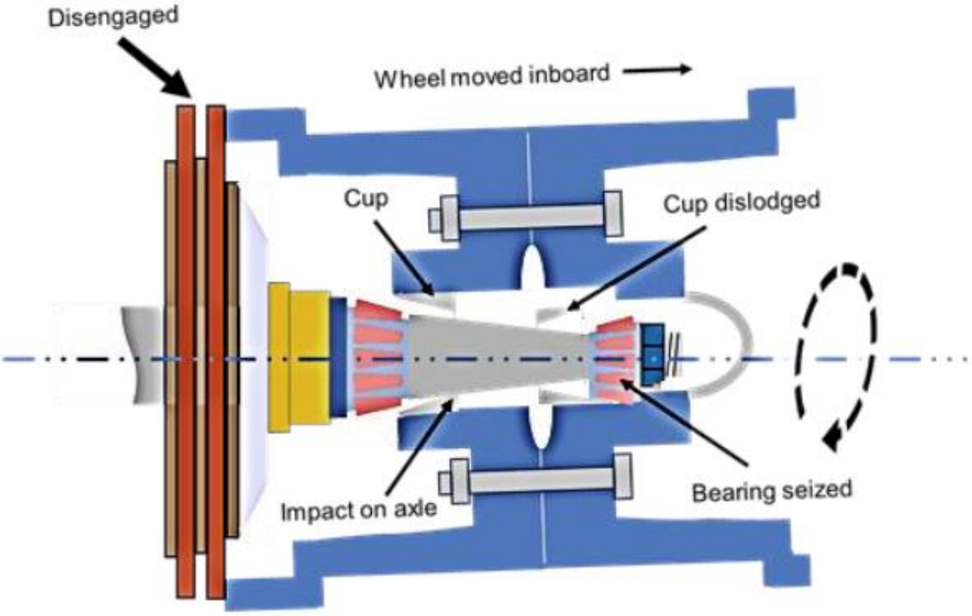


Failure in outer bearing and heat generation



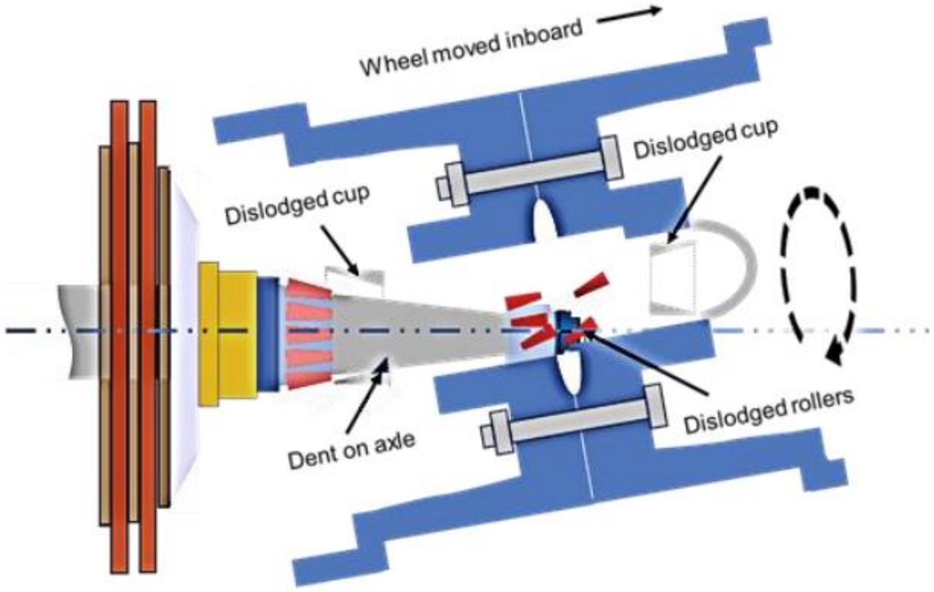
(b)

Wheel started moving inboard leading to cotterpin head sheared off. Heat generation in outer bearing resulted into fusing of inner race, washer and nut together



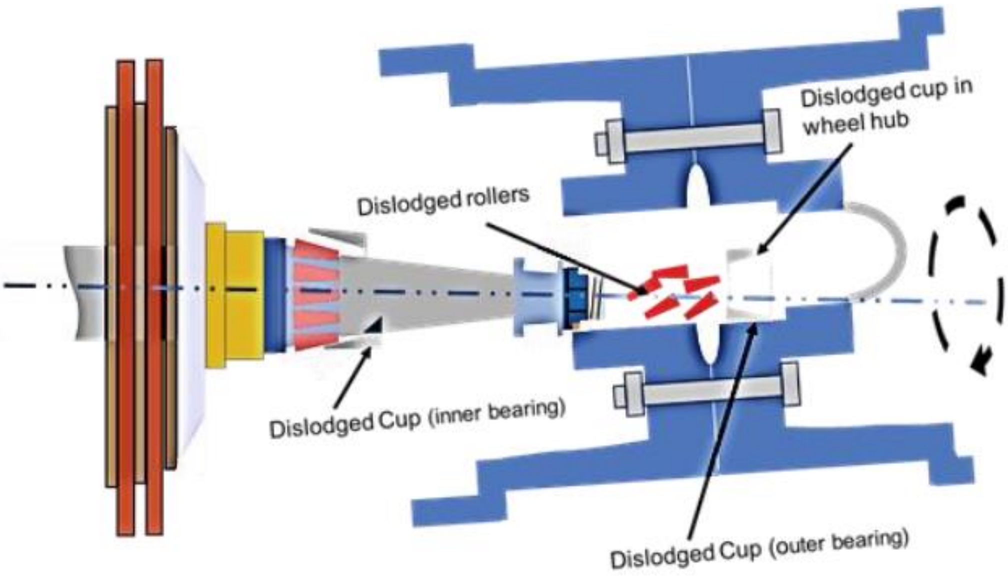
(c)

Seizure of outer bearing. Outer bearing cup dislodged, inner bearing cup impacted on axle and wheel got disengaged from brake assembly as the wheel continued moving inboard



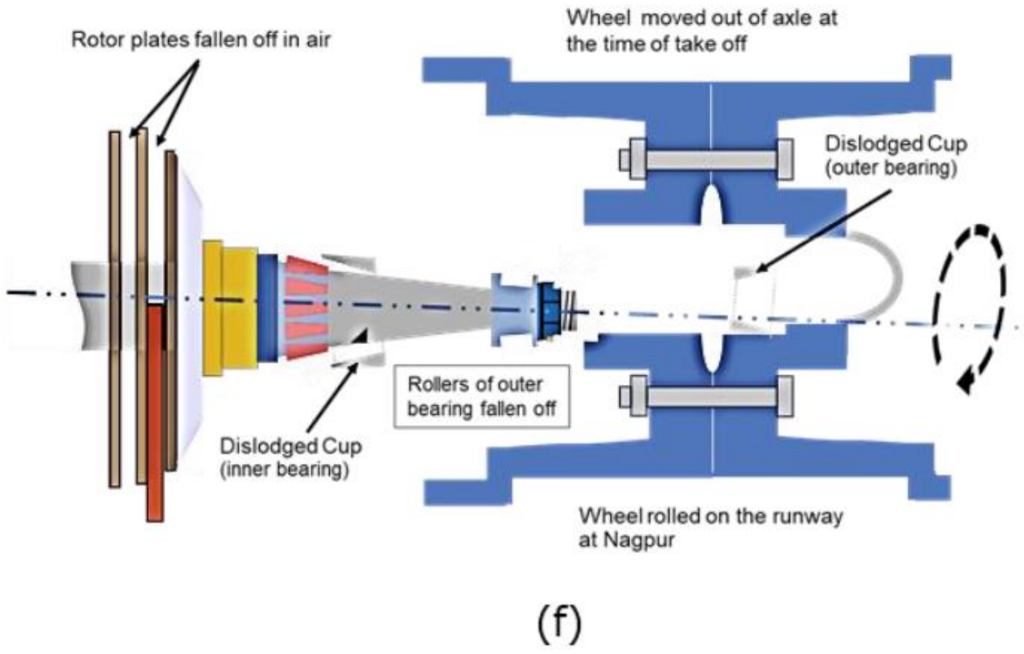
(d)

Outer bearing rollers, outer bearing cup and inner bearing cup dislodged. Dislodged inner bearing cup made dent on axle. Wheel continued moving inboard



(e)

Wheel continued moving inboard with dislodged outer bearing rollers, outer bearing cup and inner bearing cup



Wheel moved out of axle causing damage to hub surface. Rollers of outer bearing fallen off and could not be recovered at Nagpur airport

Figure# 39 Schematic representation of sequence of events leading to dislodgement of wheel from the port MLG axle (a)→(b)→(c)→(d)→(e)→(f)

Further, to carry out a comparative analysis, components of RH main landing gear wheel assembly were also submitted to CSIR-NAL. Examination (non-destructive) carried out on the bearings of the starboard (RH) axle assembly showed the presence of widespread pitting and spalling on the rollers' surfaces.

This indicates that the bearings of the starboard axle assembly have reached the limits of their useful life under the prevailing operating conditions. This means that bearings of starboard MLG axle would also have failed anytime if continued in service.

2.2.2 ANALYSIS OF CSIR-NAL REPORT

Traces of continuous deterioration in the outer bearing of LH wheel assembly was found. The rolling surfaces of the inner bearing of LH wheel assembly was found to be without metallurgical abnormalities and did not show any major mechanical damages; however, the RH wheel assembly bearings indicated spalling/other defects.

The lab established that the failure in the LH MLG outer bearing occurred over a period of time. Structural failure of the outer bearing of the LH wheel assembly resulted in the separation of the LH MLG wheel from its axle. However, as the evidence of failure initiation on the available parts of the bearing were completely destroyed due to excessive heat generation and severity of material damage within the bearing, the exact cause of its failure could not be established during laboratory investigation.

However, the laboratory investigation report mentioned one or more of the following as the probable reasons for deterioration of the rolling surfaces in the bearings: (i) lubrication related issues, (ii) contamination (ingression of moisture and/or dirt), (iii) overload (operational and/or assembly related), (iv) usage beyond useful technical life.

The investigation team focused on the four probable causes provided by CSIR-NAL to determine the most probable cause.

(i) <u>Lubrication related issues</u>: For the affected wheel assembly, the adequacy of lubrication prior to the accident could not be established as the evidence of failure initiation on the available parts of the bearing were completely destroyed due to excessive heat generation and severity of material damage within the bearing. The investigation team inspected the RH main wheel assembly after accident and observed that adequate lubrication was evident on the RHS wheel assembly. Based on the above observation, it may be inferred that the LH Main wheel assembly would have probably been lubricated adequately.

(ii) <u>Contamination (ingression of moisture and/or dirt)</u>: Issues related to contamination in bearings could not be established from the available aircraft maintenance records. Further, it was derived that the wheel assemblies, including bearings, were being maintained as required by respective CMM procedures. The presence of contamination on bearings subsequent to release of aircraft from phase inspection could not be established due to lack of evidence.

(iii) <u>Overload (operational and/or assembly related):</u> The abnormal/hard landing were not recorded in any aircraft documents, including sector reports/ tech-logs, for 24 months preceding the date of the accident of the aircraft. Maintenance records were also checked, and no inspection/ maintenance related to hard landing was carried out on the aircraft for the last two years from the accident date. Since there is no FDR/ FOQA programme requirement for this aircraft category, the aircraft's abnormal/hard landing history could not be ascertained. Issues related to assembly related overload could not be established from the available aircraft maintenance records.

(iv) Usage beyond useful technical life: The operator carried out all the scheduled inspections on main wheel assemblies as required by the approved aircraft maintenance programme. No scheduled maintenance was due on the main wheel assemblies as on the date of the accident. Furthermore, none of the documentary evidence reflected any perfunctory maintenance on the wheel assembly. The above is indicative that the accident involved bearings were within their useful technical life as required by OEM before the accident flight.

The CSIR-NAL report does not indicate any design/ manufacturing-related defects on the bearings.

In view of the above discussion and absence of corroborating evidence, the root cause of the bearing failure could not be conclusively established. The probable cause for catastrophic failure of the LH main wheel outer bearing may be either contamination or operational overload or a combination of both.

2.3 INSPECTION OF OTHER AIRCRAFT OPERATED BY M/S JSAPL

The investigation team inspected the remaining King Air C 90 aircraft (VT-EMJ) and Super King Air B200 aircraft registered with M/s JSAPL in order to assess any correlation between the wheel assemblies within the same operator.

All bearings installed on both aircraft were found to be without any abnormalities. The bearings of the VT-EMJ were replaced as a precautionary measure on 17.05.2021.

The removed bearings of VT-EMJ were disposed by M/s JSAPL and later provided to the investigation team on request. Since the removal, bearings remained in disposed state till the time they were subjected to examination in the DGCA lab.

The investigation report on four bearings revealed no significant fractures on surfaces (rollers, cage, and cone assembly) on bearing units. The cone bore of tapered bearing units was also in satisfactory condition, and dimensions were within the prescribed limits. However, it concluded that the tapered bearing units experienced atmospheric corrosion under a corrosive environment.

No structural abnormalities were observed during laboratory examination. Furthermore, no remarks/observations with respect to the condition of removed bearings were made by AME during replacement. In such a scenario, there is no conclusive evidence to establish that the corrosion was either present or not present on bearings at the time of removal from VT-EMJ on 17.05.2021. Therefore, the investigation team opines that the corrosion of bearings is most likely to be attributed to the environment in which the bearings were kept in disposed state for a considerable duration.

In view of the above discussion, the investigation team verified all in-service aircraft wheel assemblies of M/s JSAPL met prescribed maintenance standards. The removed bearings of VT-EMJ showed signs of corrosion, which were most likely due to atmospheric conditions since the part was in disposed state for a considerable period.

2.4 FLIGHT OPERATIONS

2.4.1 CREW QUALIFICATIONS

The crew were suitably licensed, qualified and current to operate the aircraft. Additionally, the crew had all the mandatory training and currency requirements and operated within the FDTL. The PIC was a Designated Examiner for the type, but the flight was operated as a routine line flight.

2.4.2 OPERATIONAL PROCEDURES

2.4.2.1 CREW PERSPECTIVE

The crew of VT-JIL aircraft were faced with a unique challenge. They were informed of a failure that was neither evident to them through aircraft annunciation nor had they felt any obvious abnormality during the entire flight. On referring the Pilot Operating Handbook, the crew realised that the Pilot Operating Handbook did not have prescriptive guidance to this situation. Therefore, the crew had to resort to decision making based on their experience and discussion of experiences the peer group had encountered. Given the situation, the crew, especially the PIC, favoured the decision of a belly landing. All possible options were discussed, and crew resource management was displayed reasonably, including seeking guidance from personnel on the ground. The crew discussed the options assessing the patient's condition with the doctor and then elected a gear-up landing to be the best option. The briefing for the gear-up landing was carried out, and the pilot in command informed the co-pilot that he would be asking for the engines to be cut just as they approached the runway. This task sharing was discussed again on the final approach and carried out as briefed. The crew, after touchdown, efficiently carried out the evacuation on the runway. The patient was transferred to an ambulance which was standing by in a timely and efficient manner. However, the crew did re-enter the aircraft without any permission asked for or provided by the firefighting services.

The options for carrying out gear down landing with the missing wheel and the outcome of such a landing could not be established. The FAA and the OEM do not provide any guidance to a comparative analysis. The FAA handbook suggests that the crew may elect a gear up belly landing in case one main landing gear fails. However, no guidance is available on a missing wheel. Other Pilot Operating Handbooks for other OEMs have guidance for landing on a flat tyre for similar category aeroplanes. However, there are no standards defined for issuing guidance to pilots by OEMs for this particular failure.

2.4.2.2 CVR ANALYSIS

The CVR recording consisted of 30 minutes and began as the aircraft was at the end of its holding pattern and ready to commence the approach. The relevant briefings were not recorded, but the crew reiteration to the briefings, including operational procedures and passenger evacuation as discussed, is recorded. A review for approach speeds and the securing of the engines prior to touchdown was also discussed. The Pilot Monitoring duties were done by First Officer, including standard callouts. The First Officer also called out minor variations of speed. The approach was flown stabilized on ILS 27 with the landing gear warning horn sounding in the background.

The crew frequently communicated with each other in the Hindi language. However, this had no adverse effect on communication between the crew.

- The crew had decided that the landing gear would remain UP, resulting in the landing gear warning horn and no landing lights available.
- Air conditioning was switched off to prevent smoke and fire retardant ingestion into the cabin.
- Throttles were retarded to IDLE for the flare manoeuvre followed by fuel boost pumps OFF, and ignition & engine start switches OFF.
- The propeller was feathered just before touchdown.

Cockpit observations

Inspection of the aircraft & cockpit immediately after the ARFF team had completed their tasks and declared the accident site safe corroborated the points listed above.

The controls and switches in the cockpit were commensurate to the discussion in the flight deck as recorded in the cockpit voice recorder.

- The landing gear lever was in UP position depicting retracted landing gears.
- The throttle lever was at IDLE position.
- Both the fuel boost pumps were in the OFF position.
- The propeller lever was in the feather position. Auto feather switch was in OFF position.
- The Ignition & Engine start switches of both the engines were in the OFF position.
- Flap lever was observed in UP position, and Flaps were physically observed to be in the retracted position. Additionally, no damage was observed on the trailing edges of flaps indicating flaps were retracted prior to touchdown.

2.5 HUMAN FACTORS AND DECISION MAKING

2.5.1 LACK OF OPERATIONAL GUIDANCE

The Crew of VT-JIL were faced with a unique failure condition. The ATC informed the crew that there was a wheel missing while there was no abnormal indication in the flight deck. The crew understood that the situation was not a time-critical emergency and utilized the time available to ascertain whether the missing wheel did, in fact, belong to their aircraft by requesting pictures to be sent to the operator's key personnel. Once the wheel was confirmed to belong to the aircraft, the crew carried out a low pass to ascertain which wheel was missing since their cockpit indications were normal. Upon ascertaining the port wheel was missing, the crew assessed their options while stating the belly (gear up) landing would be preferred.

There is no clear guidance to the pilots either through the Pilot Operating Handbook or any other ready reference document to guide the pilots for this kind of abnormal situation. However, the Pilot training usually covers the failure of the landing gear to extend, and there is a documented procedure to deal with this situation.

The PIC assessed three options:

Option1: was to carry out a ditching manoeuvre in the sea near the coastline, but the same was ruled out due to low light conditions.

Option2: was to carry out a landing with the landing gear extended. However, this option was not preferable since the PIC was convinced that the directional control would not be possible after touchdown and the aircraft may swerve off the runway sides. In addition, the drainage lines along the runway edge would result in the aircraft coming to rest in an abnormal attitude which would impede evacuation procedures, especially with a patient onboard.

Option 3: was to carry out a landing with the landing gear retracted (belly landing). The PIC recalls having heard veterans discussing the same as the only option with a gear problem.

The crew continued to seek feedback from the Operator, Other experienced Pilots as they delayed the approach to reduce fuel.

The crew received three different inputs from the three different sources, which were relayed to them by the ATC.

Input 1: was from a pilot to follow the prescribed checklist of the aircraft.

Input 2: The operator asked the crew to shift the weight distribution to the right side and land with the landing gear down while attempting to delay the left-hand gear from contacting the runway as much as possible.

Input 3: was received from another type-rated pilot to carry out a belly landing only and provided details on what must be done to ensure the belly landing is successful. The PIC used the third input as a confirmatory input since it was aligned with his mental picture of the solution.

During the investigation, the investigation team assessed all the above factors that were available with the crew for decision making. The investigation team ascertained that the crew utilized the available time to assess inputs received and evaluate their options.

The first input received had no added value as an input, given that there was no checklist or procedure to guide the pilots.

While the second input from the operator exists for a certain type of aircraft, this type of landing technique was not documented for the aircraft type being flown.

The third input provided by the type rated pilot for the belly landing was more assuring. With more operational details, factors to be considered for the landing and precautions after the aircraft comes to a stop.

Given the lack of documented guidance from the OEM or any other authority, the crew had to resort to their knowledge & experience for the given situation. The crew utilized good CRM principles by obtaining inputs from different personnel and arriving at a decision. The investigation team could not establish whether a belly landing was a safer option than landing with available gear for the aircraft type. The OEM and other agencies dealing with aircraft certification would be in a better position to provide input regarding the same. Till the time of preparation of the report, no information was received from such agencies.

2.6 AIR TRAFFIC CONTROL

The ATC facilitated all the requests made by the crew while ensuring all current operations remained unaffected. This included coordination with the company and other personnel as required by the crew.

The ATC offered all possible assistance to the aircraft. They facilitated and coordinated for the aircraft to carry out a low pass while ensuring there were qualified observers who could correctly identify the potential failures. The ATC coordinated with the Operator and other personnel as requested by the crew in order to have complete support available to the crew. Coordination between the crew and ATC, ATC and other aerodrome services like airside and ARFF was maintained at an optimal level throughout the emergency.

Approach ASR during initial contact queried whether the crew required foaming on the runway. Although the intent of the ATC controller may have been to provide all possible assistance to the aircraft, the controller was unaware of the fact that the aerodrome did not possess the required foam type, nor was the foaming of the runway a documented procedure by the aerodrome operator nor a requirement by the regulator. The crew responded by first prioritizing to determine the missing wheel and extent of damage, if any, by carrying out a low pass. Subsequently, after determining the wheel was missing and deciding to carry out belly landing, the crew requested fir foaming of the runway as proposed by ATC.

The crew asked for holding time to burn fuel to reduce the fire hazard. At 15:01 UTC, the crew advised ATC that they needed to remain in holding for 15 minutes before commencing the approach. While the ATC acknowledged this, the runway foaming continued for a significant period, during which the aircraft was required to hold for an additional 15 minutes approximately after being ready to commence the approach. Although this did not prove critical for the subject accident, the hazards associated with time taken for foaming the runway include aircraft becoming critical on fuel.

ICAO DOC 9137 Airport Services Manual Part 1 Rescue and Fire Fighting Edition Three dated 1990 states that the decision to foam the runway should be from the PIC, assuming they are familiar with all foaming related considerations, which were later removed in the fourth edition dated 2014.

Mumbai ATC preserved the recordings for the accident flight, including the tower, approach, hotline communications and the same were made available for investigation. The portion of recordings for area control on frequency 132.7MHz was preserved for the incorrect timings. The timings recorded for 132.7MHz were commensurate with approach and tower timings. This resulted in 132.7MHz not capturing the relevant portion of VT-JIL communications. The investigation team determined that the omitted portion of recordings did not adversely affect the investigation in any way.

2.7 AERODROME

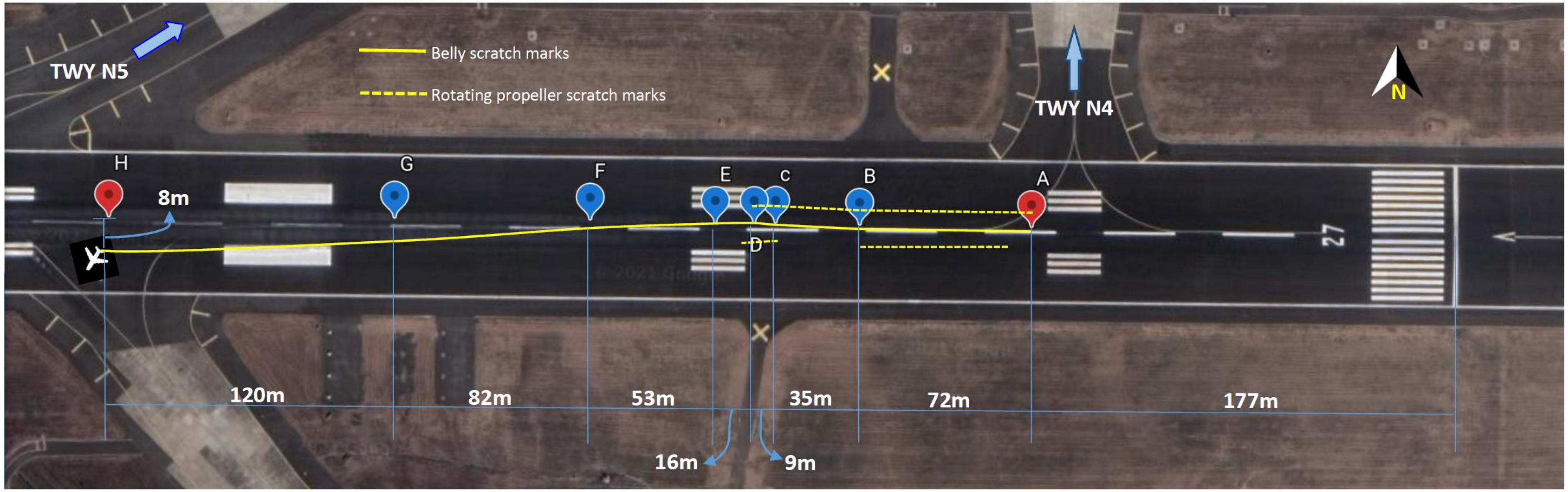
The aerodrome held a valid license on the date of the accident. All facilities at the aerodrome were serviceable, and no significant NOTAM of unavailability/ degradation of facilities was issued, which could adversely affect the accident aircraft.

2.7.1 WITNESS MARKINGS OF AIRCRAFT ON RUNWAY 27 AT MUMBAI

The aircraft landed at 15:40 UTC at approximately 117m from the displaced threshold of runway 27 with rotating propellers. The aircraft finally halted within the runway at approximately 564m from the displaced threshold opposite TXY N5. The aircraft came to rest 8m left of the runway centerline facing south.

Runway inspection post the accident was carried out. Witness marks for propeller and fuselage were plotted against runway markings and are depicted in the image below.

Track followed by aircraft from touchdown to final halt (Not to Scale)

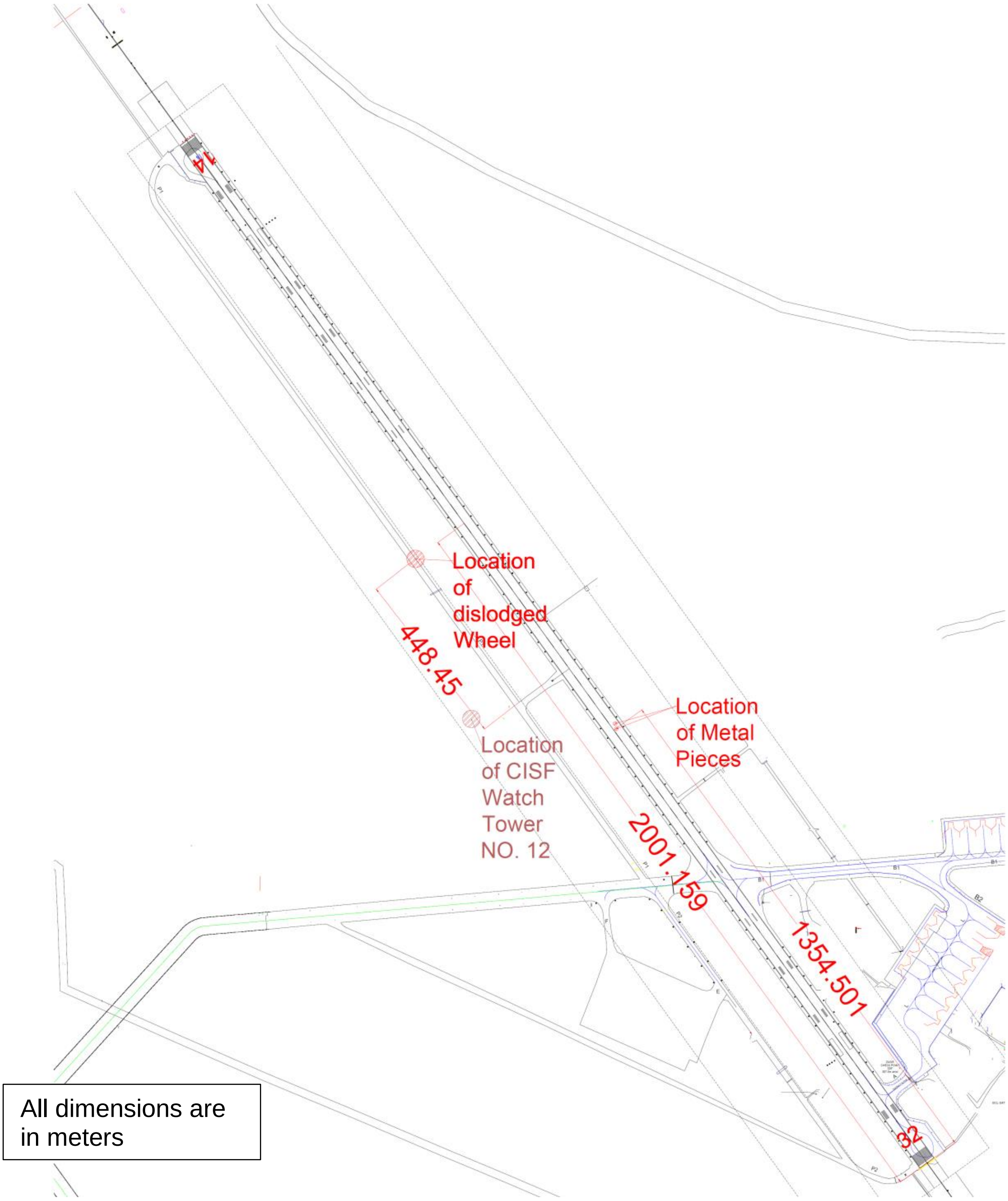


Figure# 40 Representation of ground track of aircraft post-touchdown

Nomenclature:

- A- Aircraft touchdown with slight right bank with RH propeller and fuselage contacting together followed by LH propeller shortly afterwards
- B- Aircraft moved towards right crossing runway centre line with LH propeller marking disappeared and RH propeller markings reflecting reduction in propeller rotational speed (distance between consecutive propeller hit markings increased)
- C- LH propeller marking evident again
- D- Maximum lateral deviation of aircraft from runway centreline was observed, i.e. 3m right of the runway centreline
- E- A metal piece, separated from belly, was found on runway (depicting scratch marks on it) at a distance of 3m right of the runway centreline
- F- Aircraft moved towards left crossing runway centre line
- G- Foam application was evident
- H- Final halt of aircraft, i.e. 8 m left of runway centreline facing south

2.7.2 WRECKAGE MAPPING OF SEPRATED WHEEL ON RUNWAY 32 AT NAGPUR



Figure# 41 Wreckage mapping of separated wheel at Nagpur airport

The above grid map image shows the location of the LH Main wheel and its metal pieces after separation from aircraft.

In order to find out other missing parts of the LH main wheel assembly, an extensive search operation was carried out at Nagpur airport in coordination with aerodrome safety team. The missing parts of the LH main wheel assembly could not be recovered during search operation.

2.7.3 Calculation of Propeller RPM Using Propeller Witness Marks

Propellers of both engines were physically observed & identified to be in feathered position; however, the bent blades depict that the propellers were rotating during the aircraft contact with the runway surface.

The strike marks on the runway at touchdown points and the propeller inspection revealed that both the propellers were rotating at the time of touchdown. The aircraft touched down on the runway at 79 knots, and the distance between two consecutive propeller strike markings at touchdown was measured to be 0.56m (1.84ft).

The spacing of propeller strike marks on the ground provides useful evidence, particularly if the aircraft's ground speed at touch down is known. In order to determine the approximate propeller speed in rpm at the time of contact with the ground, the following formula is used:

$$RPM = \frac{V_{(kts)} \times 101.3}{D \times N}$$

Where

D = distance in feet between two consecutive propeller strike markings

N = number of propeller blades

$V_{(kts)}$ = aircraft ground speed at touch down

$$RPM = \frac{79 \times 101.3}{1.84 \times 4} = 1087.3 \sim \underline{\mathbf{1087}}$$

At the time of touchdown, propellers were calculated to be rotating at approximately 1087rpm, which is below the propeller feathering range. From the calculated rpm value, it is derived that the engines were below IDLE power, and feathering mode was selected before the touchdown. The same is corroborated with the crew and CVR.

2.7.4 Aircraft Rescue and Fire Fighting (ARFF)

The ARFF was initially contacted, alerting them of an emergency aircraft expected for landing and were put on local standby. ATC later informed them that runway foaming would be required. The ARFF advised against this since they did not have the type of foam needed to carry out the foaming of the runway. Upon repeated requests from the ATC, the ARFF agreed to discharge the regular foam on the runway surface for the expected touchdown zone and a margin as advised by the ATC. The ARFF agreed to foam the runway while being aware that the foam type is not correct, only to ensure that the crew were at ease prior to an emergency landing. While the intention was good, it provided a false sense of assurance to the crew and the ATC. The ARFF eventually foamed the runway with regular foaming agents and not the protein foam, which was recommended as per *ICAO DOC 9137 (1990)* for foaming of the runway for belly landing of aircraft. The time taken to foam the runway after the due deliberation was completed, exceeded the time the pilots had asked for holding by approximately 15 minutes. This exercise was neither necessary nor provided any proven additional safety margins.

ICAO DOC 9137 Airport Services Manual Part 1 Rescue and Fire Fighting Edition Three dated 1990 included a chapter (15) addressing the “Foaming of Runways for Emergency Landings”. The chapter included the Theoretical benefits from foaming of runways, operational problems, and the techniques for foaming. The runway foaming agent requires the protein foam type to be prepared and applied to the runway surface prior to the landing. “Fluroprotein foam, film forming fluoroprotein foam and aqueous film forming foam are not considered suitable for runway foaming operations due to their short drainage time.”

The foam applied by the ARFF at Mumbai did not meet the standard of the protein foam as documented above.

The requirement for Foaming of Runways for Emergency Landings has been removed from ICAO DOC 9137 Airport Services Manual Part 1 Rescue and Fire Fighting Fourth Edition dated 2014 and has not been a requirement by the Indian regulator.

The ARFF teams discharged firefighting foam on the aircraft once it had come to a stop to prevent post-event fire. The ARFF ensured that the firefighting capability for the aerodrome was maintained throughout the emergency and even after the emergency once the aerodrome resumed operations on the secondary runway.

2.8 WEATHER

The weather information at Mumbai is updated every 30 minutes, and all updates were provided to the crew through ATC and ATIS.

The weather was not a factor in the emergency landing. The runway selected for landing ensured adequate headwind and no significant crosswind for the landing.

The time of the day was such that the low pass was carried out with just enough daylight to ascertain the missing LH main wheel visually. The landing, however, was conducted after sunset with reference to the runway lights. This is because the aircraft landing lights are installed on the nose gear, and since the landing was carried out with the gear up, the additional illumination through the landing lights was not available.

2.9 COMMUNICATIONS

Positive communication was established and maintained throughout the emergency between the ATC and the Aircraft. The ATC and other dependent agencies were in positive contact, and information transfer was carried out efficiently and in a timely manner. There were no communications related errors or lapses.

2.10 AIDS TO NAVIGATION

All Navigation facilities at the aerodrome were available and serviceable. The crew carried out an ILS approach to Runway 27.

2.11 SURVIVAL ASPECTS

The aircraft suffered substantial damage to the lower fuselage of the aircraft. However, the cabin remained intact, and the normal exit door was used for egress. The door operated normally, and the occupants evacuated without any injury to any personnel. The patient being carried was moved to the hospital expeditiously.

2.12 ORGANIZATIONAL FACTORS

Organisation approvals granted by DGCA under CAR M, CAR 145 and AOP were valid as on the date of the accident.

M/s JSAPL has the organisation structure and post holders as required by the regulation and the operators' manuals. The positions of Accountable Manager, Quality Manager (CAMO), Continuous Airworthiness Manager and Base Maintenance Manager have been consistent and serving more than 18 months prior to the accident. However, the position of Chief of Flight Safety has been inconsistent since 2019 and was lying vacant as on the date of the accident.

Table#11: Details of availability of approved CoFS with M/s JSAPL

Post holder (CoFS)	**Approval Date**	**Resignation Date**	**Duration**
1	May 2019	March 2020	11 months
2	November 2020	March 2021	5 Months
Vacant	At the date of the accident, the post lay vacant for two months		
3	July 2021	October 2021	4 months

The positions of Quality Manager (part 145) and the Chief of Flight Safety have been at a higher attrition rate than the others within the company. However, the Operator has endeavoured to keep the positions filled in a reasonable time post exit of the post holders through recruitment and subsequent applications to the regulator.

During the visit to M/s JSAPL facilities, the CAR 145 store was found on the ground floor of the maintenance facility; however, the CAR 145 maintenance facility layout as appended in the approved MOE (MOE Issue 4 Revision 4 dated Nov. 2020 approved by DGCA on 21.12.2020) reflected the stores' location on the first floor. It could be inferred that the earlier store location was on the first floor as reflected in the layout in approved MOE which was later relocated to the ground floor as observed on the day of visit. Such changes in the approved facility require to be processed as per procedures stipulated in para 1.10.3 'CHANGES OF APPROVED LOCATION' of the approved MOE by the Quality Manager. M/s JSAPL provided no such documentary evidence to the investigation team to substantiate that change in location of the store was with the approval of DGCA.

3 CONCLUSIONS

3.1 FINDINGS

3.1.1 FLIGHT OPERATIONS

1. Both cockpit crew members were appropriately licensed to undertake the flight. The medical of both cockpit crew members were valid. Both had undergone pre-flight & post-flight medical checks, including the BA test, which was negative for alcohol.
2. All relevant briefings were completed, and passengers were advised regarding the evacuation procedures.
3. The Pilot Operating Handbook (POH) and other OEM Manuals do not provide guidance to pilots for separation of wheel from aircraft.
4. The options for carrying out gear down landing with the missing wheel and the outcome of such a landing could not be established.
5. The crew explored all possible ways by obtaining inputs from different personnel for decision making.
6. The crew utilized the available time to assess options and evaluate inputs received and decided to carry out a belly landing. The third input provided by the type rated pilot for the belly landing was more assuring and with more operational details, factors to be considered for the landing and precautions after the aircraft comes to a stop.
7. There were no communications related errors or lapses.
8. The investigation team could not establish whether a belly landing was a safer option than landing with available gear for the aircraft type. Additionally, till the time of preparation of the report, no input was received from the OEM and other agencies dealing with the certification of the aircraft.
9. The approach was flown stabilized on ILS 27.
10. The weather at the time had no bearing on the accident.

3.1.2 AIRCRAFT

1. The Certificate of Airworthiness, Certificate of Registration and Airworthiness Review Certificate of the aircraft were valid on the date of the accident.
2. All maintenance schedules, mandatory modifications and checks were carried out as per the requirements.
3. No snags were pending for rectification before the accident flight.
4. The “Load and Trim” sheet of the accidental flight was prepared, and the center of gravity was within the limit.
5. Aircraft performance was not affected by the detachment of the LH wheel. The crew observed all the parameters were normal throughout the flight.
6. Post damage assessment was commensurate with a belly landing and subsequent shifting of the aircraft.
7. The aircraft was not equipped with a flight data recorder (FDR), and it was not mandatory requirement as per existing regulations.
8. The cabin remained intact, and the normal exit door was used for egress.
9. Fuel and oil samples passed their respective specification tests in laboratory examination.

10. The King Air C90A aircraft VT-JIL main landing gear LH and RH wheel assemblies installed on VT-JIL were as per IPC issued by the OEM.
11. Wheel assemblies, including bearings, were maintained as required by respective AMM/ CMM procedures.
12. None of the documented evidence reflected any perfunctory maintenance on the wheel assembly. In addition, the investigation team found no evidence to indicate defects existed in the outer bearing of the LH wheel assembly, which may have gone unnoticed during maintenance.
13. From documentary evidence, it can be established that main wheel assemblies installed on aircraft VT-JIL were in serviceable condition before the accident flight.
14. The aircraft landed at 15:40 UTC at approximately 117m from the displaced threshold of runway 27 with rotating propellers and came to a stop within the runway at approximately 564 m from the displaced threshold opposite to N5. The aircraft was 8m left of the runway centerline facing south.
15. Propellers of both engines were physically observed & identified to be in the feathered position.
16. At the time of touchdown, propellers were calculated to be rotating at approximately 1087rpm, which is below the propeller feathering range.
17. The CSIR-NAL report does not indicate any design/ manufacturing-related defects on the bearings.
18. Laboratory investigation showed that the primary failure in the port MLG that was responsible for the detachment of the wheel was the failure of the outer bearing.
19. As the evidence of failure initiation on the available parts of the bearing were completely destroyed due to excessive heat generation and severity of material damage within the bearing, the exact cause of its failure could not be established during laboratory investigation.
20. Traces of continuous deterioration in the outer bearing of LH wheel assembly was found. The rolling surfaces of the inner bearing of LH wheel assembly was found to be without metallurgical abnormalities and did not show any major mechanical damages; however, the RH wheel assembly bearings indicated spalling/other defects.
21. Laboratory investigation report mentioned one or more of the following as the probable reasons for deterioration of the rolling surfaces in the bearings: (i) lubrication related issues, (ii) contamination (ingression of moisture and/or dirt), (iii) overload (operational and/or assembly related), (iv) usage beyond useful technical life.
    (i) Based on the RH main wheel assembly inspection, it may be inferred that the LH Main wheel assembly would have probably been lubricated adequately.
    (ii) Issues related to contamination in bearings could not be established due to lack of evidence.
    (iii) The aircraft’s abnormal/hard landing history could not be ascertained. Additionally, assembly-related overload issues could not be established from the available aircraft maintenance records.
    (iv) The accident involved bearings were within their useful technical life as required by OEM before the accident flight.
22. In the absence of corroborating evidence, the root cause of the bearing failure could not be conclusively established. The probable cause for catastrophic failure of the LH main wheel outer bearing may be either contamination or operational overload, or a combination of both.
23. There was no fire.
24. There were no injuries to any of the occupant onboard.
25. The accident was survivable.

3.1.3 ATC

1. Positive communication and coordination between the crew and ATC, ATC, and other aerodrome services like airside and ARFF were maintained optimally throughout the emergency.
2. ATC provided prompt and effective assistance to the flight crew.
3. ATC confirmed LH main wheel missing following a low pass.
4. Approach ASR during initial contact queried whether the crew required foaming on the runway. The controller was unaware of the fact that the aerodrome did not possess the type of foam needed, nor was the foaming of the runway a documented procedure by the aerodrome operator nor a requirement by the regulator.
5. While the ATC acknowledged the 15-minute holding time required by the crew for burning fuel, the runway foaming continued for a significant period, during which the aircraft was required to hold for an additional 15 minutes approximately after being ready to commence the approach. Although this did not prove critical for the subject accident, the hazards associated with time taken for foaming the runway include aircraft becoming critical on fuel.
6. The portion of recordings for area control on frequency 132.7MHz was preserved for the incorrect timings.

3.1.4 Aerodrome

1. The aerodrome held a valid license on the date of the accident.
2. All aerodrome Navigation facilities, approach aids and lighting facilities were operating normally at the time of the accident.
3. Subsequent to the evacuation, the crew did re-enter the aircraft without any permission asked for or provided by the firefighting services.
4. ICAO DOC 9137 Airport Services Manual Part 1 Rescue and Fire Fighting Edition Three dated 1990 Ch. 15 states that the decision to foam the runway should be from the PIC, assuming they are familiar with all foaming related considerations.
5. The requirement for foaming the runway has been removed and Present ICAO DOC 9137 fourth edition dated 2014 no longer provides any guidance for foaming of the runway.
6. DGCA, India does not have any requirement for foaming of the runway.
7. The ARFF advised against foaming of the runway since they did not have the required foam type to carry out the foaming of the runway. However, upon repeated requests from the ATC, the ARFF agreed to discharge the regular foam on the runway surface for the expected touchdown zone and a margin as advised by the ATC.
8. Before landing, approximately 205m of the runway, starting from a distance of about 455 m from Runway27 threshold, and about 6m on either side of the runway centerline, was carpeted with an available extinguishing agent.
9. The runway foaming requirements need a specific protein foam to be prepared and applied to the runway surface prior to the landing; however, The ARFF eventually foamed the runway with regular foaming agents and not the protein foam.
10. The ARFF ensured that the firefighting capability for the aerodrome was maintained throughout the emergency and even after the emergency once the aerodrome resumed operations on the secondary runway.

3.1.5 ORGANIZATION

1. The positions of Quality Manager (part 145) and the Chief of Flight Safety have been at a higher attrition rate than the others within the company.
2. The Chief of Flight Safety post has been inconsistent since 2019 and was lying vacant as on the date of the accident.
3. The investigation team verified all in-service aircraft wheel assemblies pertaining to M/s JSAPL met prescribed maintenance standards. Additionally, the bearings of VT-EMJ were replaced shortly after the accident of VT-JIL as a precautionary measure.
4. Changes in the approved store facility was not processed as per procedures stipulated in para 1.10.3 'CHANGES OF APPROVED LOCATION' of the approved MOE.

3.2 PROBABLE CAUSE OF THE ACCIDENT

The root cause of the failure of bearing could not be conclusively established. However, the probable cause for catastrophic failure of the LH main wheel outer bearing may be either contamination or operational overload or a combination of both.

The investigation team could not establish whether a belly landing was a safer option than landing with available gear for the aircraft type. Additionally, till the time of preparation of the report, no input was received from the OEM and other agencies dealing with the certification of the aircraft.

Therefore, the probable cause of LH main landing gear wheel separation was due to the catastrophic failure of the outer bearing on the LH main wheel assembly within the component's service life leading to a belly landing in the absence of prescriptive guidance to the pilots.

4 SAFETY RECOMMENDATIONS

4.1 The DGCA may liaise with the state of manufacture to assess adequate guidance is documented in the Pilot Operating Handbook (POH), and accordingly, prescribe crew training for this particular failure.

4.2 The DGCA may undertake a onetime assessment of POH guidance and crew training for similar category aircraft flying in India.

4.3 The DGCA may evaluate the requirements for runway foaming for similar emergencies.

4.4 The DGCA may review ATC and ARFF training requirements and standards to ensure they are aware of regulatory requirements and aerodrome capabilities with regards to such emergencies.

4.5 Mumbai ATC to ensure adherence to all documented procedures to preserve relevant recordings.

4.6 All aerodrome operators may incorporate documented procedures and compliance for ARFF to safely hand over the accident site to authorized personnel only.

4.7 The operator may address the high attrition rate of key post holders highlighted in this report.

4.8 The operator may expeditiously intimate and seek required regulatory approvals prior to effecting changes in the approved facilities.

4.9 DGCA may carry out a detailed audit of the operator facilities to ensure the required standards are met.

Capt. Gaurav Pathak
Investigator In-Charge

Amit Kumar
Investigator

Pathik Vaghela
Investigator

Date: 15.02.2022

APPENDICES

CLEANING

NOTE: Refer to IPL Figure 1 on page 1005 for identification of the parts.

EQUIPMENT AND MATERIALS:

NOTE: Equivalent replacements can be used for listed items.

- Degreasing solvent (MIL-PRF-680 Type II or III)
- Butyl alcohol
- Brushes (solvent resistant)
- Compressed air
- Abrasive blasting equipment
- Walnut hulls (A-A-1722 Type II or III)
- Plastic media (MIL-P-85891)
- Paint remover Cee-Bee E-1092T (that will not damage magnesium, steel, or the anodize layer)
- Surface treatment (SAE-AMS-M-3171 Type VIII or III)
- Goggles
- Water

WARNING: EYE INJURY FROM FLYING PARTICLES OR SOLVENT SPRAY IS POSSIBLE WHEN COMPRESSED AIR IS USED TO CLEAN THE PARTS. MAKE SURE THAT THE PRESSURE IS NOT MORE THAN 30 P.S.I.G. (2 BARS). EYE PROTECTION IS NECESSARY.

WARNING: BUTYL ALCOHOL IS FLAMMABLE AND IS DANGEROUS TO THE SKIN, EYES, AND RESPIRATORY TRACT. KEEP AWAY FROM HEAT AND OPEN FLAME. SKIN AND EYE PROTECTION IS NECESSARY. PREVENT REPEATED CONTACT WITH BUTYL ALCOHOL OR CONTACT FOR A LONG TIME. GOOD GENERAL AIR FLOW IS USUALLY SUFFICIENT.

WARNING: SOLVENT (MIL-PRF-680 TYPE II OR III) IS DANGEROUS TO THE SKIN, EYES, AND RESPIRATORY TRACT. SKIN AND EYE PROTECTION IS NECESSARY. PREVENT REPEATED CONTACT WITH THE SOLVENT OR CONTACT FOR A LONG TIME. GOOD GENERAL AIR FLOW IS USUALLY SUFFICIENT.

1. CLEAN THE METAL PARTS:

CAUTION: THE SURFACE TREATMENT LAYER ON MAGNESIUM PARTS WILL BE DAMAGED IF SAND IS USED IN THE ABRASIVE BLAST PROCEDURE OR IF A WIRE BRUSH IS USED TO CLEAN THE PARTS.

CAUTION: FULLY CLEAN THE TIE BOLTS (75) AND THE TIE BOLT NUTS (65). CONTAMINATION IN THE THREADS OF THESE PARTS CAN PREVENT FULL INSPECTION OF THESE PARTS AND CAN CAUSE INCORRECT TIE BOLT PRELOAD.

Clean the metal parts with MIL-PRF-680 Type II or III solvent and a soft-bristle brush. Make sure that the bolt (75) and nut (65) threads are fully clean. Use clean, dry compressed air to dry the parts.

CLEANING

2. CLEAN THE NON-METAL PARTS:

CAUTION: SOLVENT SUCH AS NAPHTHA, THINNER, MIL-PRF-680 TYPE II OR III ETC. CAN DAMAGE PLASTIC OR RUBBER SEALS AND PREFORMED PACKINGS. USE ONLY SPECIFIED MATERIALS TO CLEAN THE PARTS.

Use a soft, clean cloth that is moist with butyl alcohol or a mild soap and water solution to clean all non-metal parts.

3. CLEAN THE BEARINGS:

CAUTION: BEARING CONES CAN BE DAMAGED BY IMPACT AND BY CONTACT WITH DIRT, DUST, MOISTURE, OR OTHER CONTAMINANTS. HANDLE BEARING CONES CAREFULLY AND WEAR RUBBER GLOVES.

CAUTION: BEARING CONES CAN BE DAMAGED IF COMPRESSED AIR IS USED TO SPIN THEM DRY.

A. Soak bearing cones in MIL-PRF-680 Type II or III solvent to remove grease. Flush the bearing cones with solvent and use clean, dry, compressed air to remove all grease.

B. Flush the bearing cones in clean solvent or butyl alcohol. Let the solvent dry.

C. Apply oil to bearing cones and bearing cups to prevent rust, if they will not be examined and packed with grease in less than 2 hours. Repeat paragraph 3.B. above before inspection of the bearing cones.

4. PAINT REMOVAL (if necessary) by one of the two procedures that follow:

NOTE: It is necessary to remove paint and primer before penetrant inspection. It is not necessary to remove the paint or primer for eddy current inspection.

A. Abrasive Blast:

CAUTION: THE SURFACE TREATMENT LAYER ON MAGNESIUM PARTS CAN BE DAMAGED IF SAND IS USED IN THE ABRASIVE BLAST PROCEDURE OR IF A WIRE BRUSH IS USED TO CLEAN THE PARTS.

(1) Seal or mask threaded holes.

(2) Blast the parts (MIL-STD-1504) with plastic media (MIL-P-85891) (maximum media hardness of 3.5 MOH) or use walnut hulls (A-A-1722 Type II or III) (grain soft abrasive walnut hulls, Grade 20/30). This method will not remove the surface treatment layer and it is not necessary to mask or remove the bearing cups.

CLEANING

WARNING: SURFACE TREATMENT (SAE-AMS-M-3171 TYPE VIII OR III), IS DANGEROUS TO THE SKIN, EYES, AND RESPIRATORY TRACT. SKIN AND EYE PROTECTION IS NECESSARY. PREVENT REPEATED CONTACT WITH THE SURFACE TREATMENT OR CONTACT FOR A LONG TIME. GOOD GENERAL AIR FLOW IS USUALLY SUFFICIENT.

(3) If incorrect use of plastic media has damaged the surface treatment layer, apply surface treatment (SAE-AMS-M-3171 Type VIII or III) to the damaged areas.

B. Chemical Removal:

WARNING: PAINT REMOVER CEE-BEE E-1092T IS DANGEROUS TO THE EYES, SKIN AND RESPIRATORY TRACT. SKIN AND EYE PROTECTION IS NECESSARY. PREVENT REPEATED CONTACT WITH THE PAINT REMOVER OR CONTACT FOR A LONG TIME. GOOD GENERAL AIR FLOW IS USUALLY SUFFICIENT.

CAUTION: THE SURFACE TREATMENT LAYER ON MAGNESIUM PARTS CAN BE DAMAGED IF SAND IS USED IN THE ABRASIVE BLAST PROCEDURE OR IF A WIRE BRUSH IS USED TO CLEAN THE PARTS.

(1) Remove the bearing cups (140, 185) if the wheel halves will be put fully into the paint remover (refer to the REPAIR section for cup removal).

(2) Apply paint remover that can remove urethane paint and will not damage magnesium, steel, or the surface treatment layer. Apply the paint remover to the wheel half as recommended by the manufacturer. A stiff-fiber bristle brush can also be used to help remove paint.

(3) Flush the wheel half with clean, cold water to remove the paint remover.

(4) Use clean, dry, compressed air to remove all water from the wheel half.

CHECK

NOTE: Refer to IPL Figure 1 on page 1005 for identification of the parts.

EQUIPMENT AND MATERIALS:

NOTE: Equivalent replacements can be used for listed items.

- Penetrant inspection equipment (ASTM E1417 Type I)
- Magnetic particle inspection equipment (ASTM E1444)
- Torque wrenches (accurate to 4% or better)
- Grease seal inspection fixture (Figure 903)
- Eddy current inspection equipment
- Petrolatum (Vaseline) (VV-P-236)
- Bearing grease, Mobil Aviation Grease SHC100 product code 530063, Mobilgrease 28, or Aeroshell 5

NOTE: There are two levels of inspection:

TIRE CHANGE INSPECTION - Inspections that are done at every tire change (refer to this section, paragraph 1)

WHEEL NON-DESTRUCTIVE TEST (NDT) INSPECTION - additional NDT inspections that are done at the specified time (refer to Figure 501 and paragraph 3).

NOTE: If the wheel assemblies are in use more than two years between tire changes, it is recommended to inspect the wheel in increments of years as an alternative to number of tire changes (refer to Figure 501A).

TIRE CHANGE NUMBER	PENETRANT OR EDDY CURRENT INSPECTION	MANDATORY PENETRANT INSPECTION OF THE FULL WHEEL HALVES
5	X	
8, 11, 14, 17	X	
21 and Thereafter (Every Tire Change)	X	
20 and Thereafter (Every Third Tire Change)		X

Figure 501. Minimum Inspection Frequency

CHECK

INSPECTION SCHEDULE IN YEARS	PENETRANT OR EDDY CURRENT INSPECTION	MANDATORY PENETRANT EXAMINATION OF THE FULL WHEEL HALVES
AT 2, 4, 6, 8	X	
AT 11 and Thereafter (Every Two Years 13, 15, 17)	X	
At 10 and Thereafter (Every Two Years 12, 14, 16)		X

Figure 501A. Inspection Table Based on Time (If 2 years or more between tire changes)

1. TIRE CHANGE INSPECTION:

NOTE: Replace all preformed packings at each tire change or wheel NDT inspection.

A. Wheel Half Inspection:

(1) Visually inspect the wheel half assemblies (85, 150) for damage caused by nicks, dents, cracks, corrosion, and damage. Repair damage. Do not repair worn, polished areas that are rubbed by the tire (refer to the REPAIR section). Discard a wheel half that shows signs of rolling contact with the runway.

(2) Visually inspect the wheel half assemblies for corrosion. Corrosion is most likely to occur in the tubewell and beadseat areas (where the tire touches the wheel), in holes, and other areas where moisture and contamination can collect. Repair corroded areas (refer to the REPAIR section).

(3) Visually examine the wheel half assemblies for areas where the paint or surface treatment is worn through to bare metal. If the wheel will not be overhauled at this time, apply surface treatment and paint to the worn areas (refer to paragraphs 5, 6, and 7 in the REPAIR section).

B. Examine for a loose valve stem nut (45). Torque a loose valve stem nut to 30 - 40 pound-inches (3,4 - 4,5 Nm).

C. Visually examine each bolt (75) for cracks, surface damage, and thread damage. Discard a defective bolt.

CHECK

D. Nut Inspection:

(1) Visually examine each nut (65, 110, 155) for thread damage and cracks. Discard a damaged nut.

(2) Examine nuts (65, 110, 155) for self-locking function. Install a clean, dry nut on a clean dry bolt (75, 120, 165) as far as possible by hand. If the end of the bolt extends beyond the top of the nut, measure the back-off torque of the nut as follows:

Turn the nut onto a bolt two or three threads past the end of the nut. Use a torque wrench to remove the nut and measure the back-off torque.

(a) Replace the tie bolt nut (65) if the back-off torque is less than 6.5 pound-inches (0,73 Nm).

(b) Replace the balance weight nut (110, 155) if the back-off torque is less than 2.0 pound-inches (0,23 Nm).

E. Bearing Inspection:

Clean the bearings (refer to the CLEANING section). Visually inspect bearing surfaces of bearing cups (140, 185) and bearing cones (25, 10) as follows (refer to Figure 502).

NOTE: Incorrect bearing grease or axle nut torque can cause some of the defects that follow.

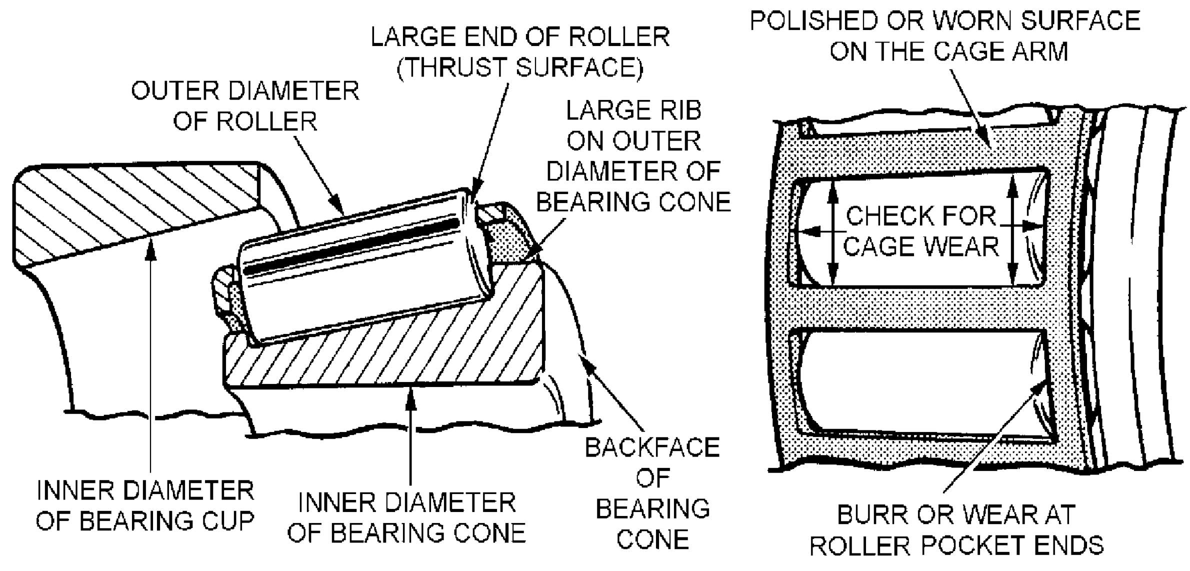


Figure 502. Inspection Areas of Bearing Cup and Bearing Cone

CHECK

(1) Spalled Surface - Discard a bearing cone or bearing cup with a spalled surface (pieces of the surface are missing).

(2) Nicks or Dings - Discard a bearing cone or the bearing cup with damage that is deep enough to be felt with a fingernail or with a single-edged razor blade. Small damage that cannot be felt with a fingernail or razor blade is permitted.

(3) Incorrect Color - Discard a bearing cone or bearing cup that has black, dark blue, and purple stains on the wear surface, which are signs of overheat. Brown or yellow stains that can be removed easily with abrasive cloth (400 grit or finer) are permitted.

(4) Etched Surface - Discard a bearing cone or bearing cup that has water stains that have etched a wear surface. An etched surface is dull and rough. Water stain discoloration without an etched surface is permitted.

(5) Roller End Damage - Discard a bearing cone if the thrust surface on the large end of the rollers has chips, smears, scores, metal pick-up, incorrect color, or other damage. This surface should be smooth, but not shiny.

(6) Scored Bearing Cone - Discard a bearing cone if it has turned sufficiently on the axle to cause wear on the inner diameter of the bearing cone.

(7) Cage Damage - Discard a bearing cone if the cage is dented, bent, or has too much wear in the roller pockets or has a polished or worn surface on the cage arm. Do not straighten a bent cage.

(8) If a bearing cone is damaged in service and is replaced, also replace the mating bearing cup (refer to the REPAIR section).

NOTE: Replacement of the bearing cup is not necessary if a bearing cone was damaged or dented after it was removed from the wheel half.

(9) Inspect each bearing cup (140, 185) for movement in the wheel half assemblies (85, 150). If a 0.002 inch (0,051 mm) feeler gauge can be put into a clearance between the bearing cup and the bottom of the bearing bore, remove the bearing cup to permit inspection and possible repair of the bearing bore (refer to Figure 604)

CAUTION: DO NOT MIX DIFFERENT BRANDS OF GREASE AS THIS CAN CAUSE DECREASED BEARING LIFE.

(10) Immediately fill satisfactory bearing cones and cups with bearing grease (Mobil Aviation Grease SHC 100, Aeroshell 5 or Mobilgrease 28). Wrap them in oil proof paper or plastic film until they are installed in the wheel. When bearing parts are examined or filled with grease, use the recommended procedures that follow:

CHECK

(a) Keep a clean work area. Wrap clean bearing cones in new oil-proof paper or plastic film to prevent the collection of contamination.

(b) Hold clean bearing parts with rubber gloves.

(c) Clean the bearing cones only with a clean cloth that has no lint.

(d) Keep the grease supply clean. Discard contaminated grease.

F. Seal Assembly Inspection:

(1) Visually examine the rubber lip on the seal assembly (20). Discard a seal that is bent or has a rubber lip that is cracked, nicked, gouged, damaged by heat, or is too hard or too worn to work correctly.

(2) Use the fixture as shown in Figure 503 to measure the lip height of each seal assembly (20). Discard a seal with a lip height that is less than the minimum.

NOTE: Seal assemblies need time (8 hours) after they are removed to return to their correct shape.

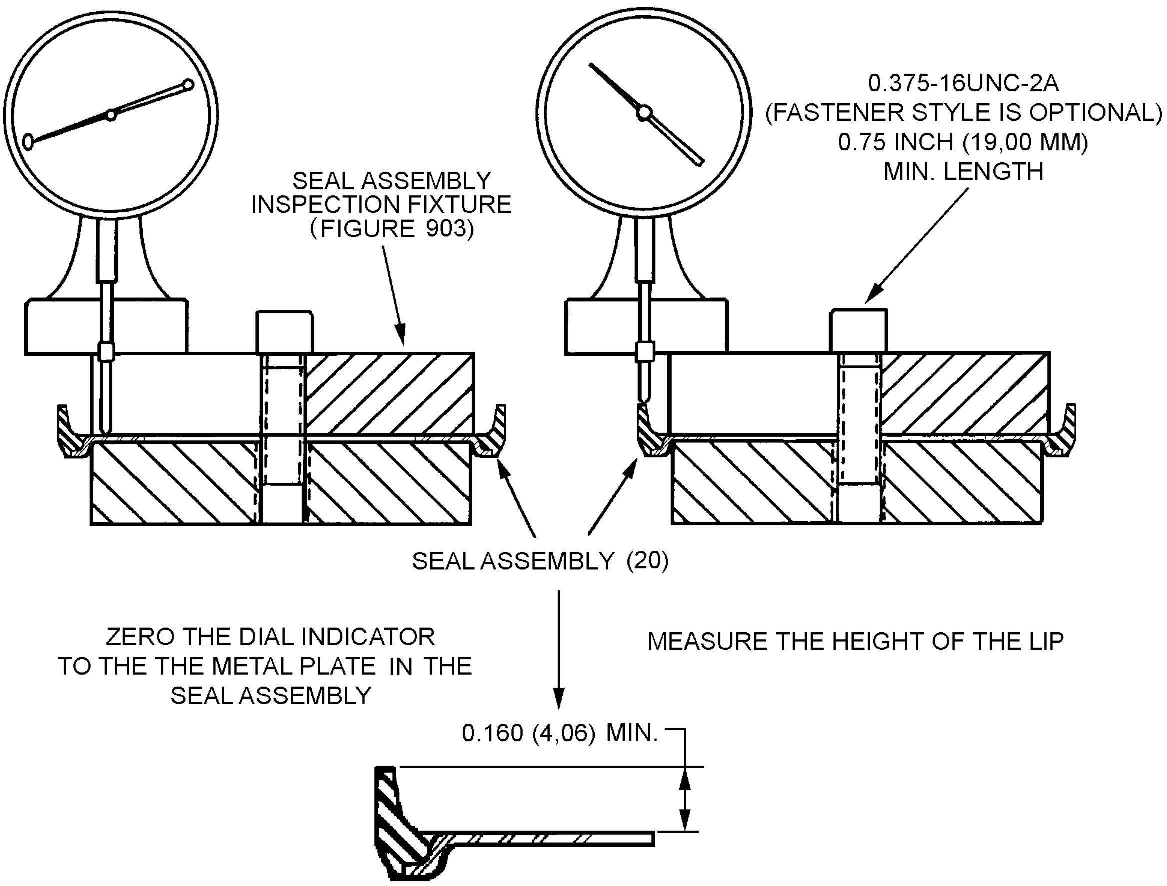


Figure 503. Measure Lip Height of Seal Assembly

CHECK

G. Visually inspect the preformed packings (80) and the grommet (55) for cracks, gouges, and cuts. Discard a defective preformed packing or grommet. Satisfactory preformed packings and grommets must have a slight stretch to be installed.

NOTE: It is recommended to replace preformed packings and the grommet at each tire change and wheel assembly overhaul.

NOTE: Preformed packings are compressed during use and need time (48 hours) after they are removed to return to their correct shape.

H. Torque Key Inspection:

(1) Visually examine each torque key (100) for wear and loss of chrome plating on the non-wear surfaces. If the plating is gone, replace the torque key.

(2) Examine the each torque key (100) in the area where the brake disk lugs contact the key. Replace a torque key that is cracked, broken, or worn to less than the minimum thickness of 0.075 inch (1,91 mm) (refer to Figure 504).

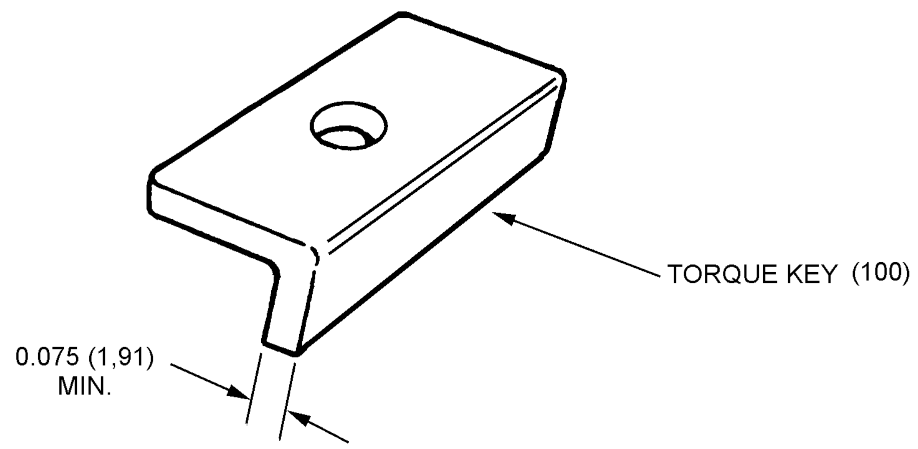


Figure 504. Torque Key Inspection

I. Examine the internal threads on Heli-Coil inserts (105) installed in the inner wheel half assemblies (85). Replace a damaged Heli-Coil insert (refer to the REPAIR section).

Tape Transcript		
Time	Transmitted By	Description
11:21:41	VTJIL	NAMASKAR SIR STAND NUMBER SEVEN REQUESTING STARTUP CLEARANCE FOR MUMBAI LEVEL REQUESTED TWO HUNDRED WE ARE TWO PLUS THREE TOTAL FIVE THROUGHSECURITY
11:21:51	CONTROLLER	VICTOR INDIA LIMA ROGER QNH ONE ZERO ZERO SIX HECTAPASCAL STARTUP APPROVED RUNWAY THREE TWO REPORT ADC FIC
11:35:03	CONTROLLER	VICTOR TANGO JULIET INDIA LIMA CLEARANCE READBACK CORRECT RUNWAY THREE TWO CLEARED FOR TAKEOFF WINDS ONE THREE ZERO DEGREE ZERO SIX KNOTS
11:35:09	VTJIL	ROLLING SIR VICTOR INDIA LIMA
11:36:12	VTJIL	NAGPUR VICTOR INDIA LIMA TURNING LEFT
11:36:16	CONTROLLER	VICTOR INDIA LIMA ROGER AIRBORNE THREE SIX CONTACT APPROACH ONE TWO ZERO DECIMAL FOUR
11:47:42	VTJIL	CLIMB TO LEVEL TWO HUNDRED VICTOR INDIA LIMA
11:58:35	CONTROLLER	VICTOR TANGO JULIET INDIA LIMA NAGPUR RADAR IN CASE OF VHF CONTACT LOSS WITH NAGPUR AFTER DUBOX CONTACT MUMBAI CONTROL WHEN IN RANGE ONE THREE TWO DECIMAL SEVEN AND RELAY POSITION TO AURANGABAD ONE TWO TWO DECIMAL THREE
11:58:52	VTJIL	ROGER SIR WILL DO THAT ONE THREE TWO SEVEN ONE TWOTWO THREE
12:04:24	CONTROLLER	VICTOR INDIA LIMA NAGPUR RADAR
12:04:28	VTJIL	GO AHEAD SIR
12:04:30	CONTROLLER	VICTOR INDIA LIMA CONFIRM ALL OPERATIONS NORMAL
12:04:32	VTJIL	ALL OPERATIONS NORMAL SIR
12:04:35	CONTROLLER	VICTOR INDIA LIMA ROGER JUST FOR INFORMATION SOMETHING FOUND ON RUNWAY JEEP HAS PROCEEDED FOR INSPECTION WE WILL LET YOU KNOW
12:04:44	VTJIL	PLEASE
12:15:12	VTJIL	NAGPUR VICTOR INDIA LIMA
12:15:15	CONTROLLER	VICTOR INDIA LIMA NAGPUR RADAR
12:15:18	VTJIL	WAS THERE ANYTHING ON RUNWAY VICTOR INDIA LIMA
12:15:24	CONTROLLER	STANDBY JUST RECONFIRMING FROM TOWER
12:16:22	CONTROLLER	VICTOR INDIA LIMA NAGPUR RADAR
12:16:26	VTJIL	GO AHEAD SIR VICTOR INDIA LIMA
12:16:29	CONTROLLER	AFFIRM A AWHEEL FOUND ON RUNWAY
12:16:34	CONTROLLER	OBSERVED BY SECURITY PERSON THAT SOMETHING FALLEN DOWN ON YOUR WHILE YOUR DEPARTURE
12:16:42	CONTROLLER	VICTOR TANGO JULIET INDIA LIMA OPS JEEP REPORTED WHEEL ON THE RUNWAY
12:16:50	VTJIL	WAS THERE AIRCRAFT WHEEL ON THE RUNWAY VICTOR INDIA LIMA
12:16:56	CONTROLLER	AFFIRM ONE SECURITY PERSONNEL OBSERVED SOMETHING HAS FALLEN FROM THE AIRCRAFT AND AFTER INSPECTION THEY GOT ONE LEFT SIDE WHEEL AS PER OPS THREE
12:17:10	VTJIL	SIR CAN YOU PLEASE DO ME A FAVOUR

12:17:15	CONTROLLER	GO AHEAD
12:17:16	VTJIL	CAN YOU PLEASE SEND THE PHOTO OF THE WHEEL TO MY ENGINEERING TEAM I WILL FORWARD YOU THE NUMBER
12:17:25	CONTROLLER	GO AHEAD
12:17:28	VTJIL	STANDBY SIR
12:17:35	CONTROLLER	SIR THE NUMBER IS XXXXXXXXX MISTER XXXXXX VICTOR INDIA LIMA
12:17:46	CONTROLLER	CONFIRM XXXXXXXXX
12:17:51	VTJIL	XXXXXXXXXXXX
12:17:57	CONTROLLER	XXXXXXXXXXXX
12:18:01	VTJIL	AFFIRM SIR VICTOR INDIA LIMA
12:18:03	CONTROLLER	ROGER WE WILL SEND THE ONE PICTURE OF TYRE TO YOUR TEAM
12:19:30	CONTROLLER	VICTOR INDIA LIMA WE HAVE INFORMED TOWER TO FORWARD THE PICTURE TO YOUR ENGINEERING TEAM ON THE GIVEN NUMBER
12:20:09	VTJIL	NAGPUR VICTOR INDIA LIMA
12:20:16	VTJIL	NAGPUR VICTOR INDIA LIMA HOW DO YOU READ
12:20:19	CONTROLLER	VICTOR INDIA LIMA READIBILITY FIVE
12:20:23	VTJIL	SIR THERE IS ONE MORE NUMBER XXXXXXXXXX THIS IS OUR ACCOUNTABLE MANAGER CAN YOU PLEASE INFORM HIM ALSO
12:20:35	CONTROLLER	STAND BY SIR SAY AGAIN GO AHEAD WITH THE NUMBER
12:20:40	VTJIL	SIR XXXXXXXXXXX MISTER XXXXX VICTOR INDIALIMA
12:20:47	CONTROLLER	XXXXXXXXXXXX
12:20:53	VTJIL	AFFIRM SIR CAN YOU PLEASE CONFIRM WITH OUR ENGINEERING TEAM WHICH WHEEL IS THAT MAIN WHEEL OR NOSE WHEEL
12:21:00	CONTROLLER	STANDBY
12:22:34	CONTROLLER	VICTOR INDIA LIMA AS PER OPS JEEP IT WAS REAR WHEEL
12:22:41	VTJIL	ROGER SIR COPIED REAR WHEEL VICTOR INDIA LIMA
12:23:29	CONTROLLER	VICTOR INDIA LIMA NAGPUR RADAR
12:23:31	VTJIL	GO AHEAD SIR VICTOR INDIA LIMA
12:23:32	CONTROLLER	REPORT ESTIMATE DESTINATION ETA
12:23:37	VTJIL	STANDBY SIR VICTOR INDIA LIMA
12:23:51	VTJIL	SIR ESTIMATING BRAVO BRAVOBRAVO ONE THREE TWO NINER VICTOR INDIA LIMA
12:23:56	CONTROLLER	ONE THREE TWO NINER
12:23:58	VTJIL	YES SIR ONE THREE TWO NINER BRAVO BRAVOBRAVO VICTOR INDIA LIMA
12:24:02	CONTROLLER	COPIED
12:26:38	CONTROLLER	VICTOR INDIA LIMA RADAR SERVICES TERMINATED WHEN IN RANGE CONTACT MUMBAI ONE THREE TWO DECIMAL SEVEN
13:20:24	VTJIL	MUMBAI VTJIL
13:20:26	ASR	VTJIL NAMASKAR SIR, DESCEND TO FLIGHT 110
13:20:29	VTJIL	NAMASKAR SIR, DESCEND TO LEVEL 110, VT-JIL
13:22:08	ASR	VTJIL CONTINUE DESCEND TO FLIGHT 80.
13:22:11	VT-JIL	CONTINUE DESCEND TO LEVEL 80 VT-JIL.
13:23:20	ASR	VTJIL MUMBAI
13:23:22	VT-JIL	GO AHEAD SIR VT-JIL

13:23:30	VT-JIL	MUMBAI VTJIL GO AHEAD SIR
13:23:33	ASR	VTJIL MUMBAI
13:23:36	VT-JIL	GO AHEAD SIR VT-JIL
13:23:50	ASR	VTJIL MUMBAI
13:23:54	VT-JIL	MUMBAI VTJIL GO AHEAD SIR
13:24:02	ASR	VTJIL DO YOU NEED FOAM ON THE RUNWAY OR ANY OTHER ASSISTANCE PLEASE ADVISE
13:24:08	VT-JIL	SIR WE NEED FIRST WE WOULD LIKE TO RECONFIRM WHETHER SOMETHING HAPPENED TO THIS AIRCRAFT, WE ARE REQUESTING FOR A LOW-PASS & WE WILL BE WAITING FOR OBSERVATION WHETHER WHEEL IS NOT REAR WHEEL OR NOSE WHEEL HAS GONE. IF SO THEN WE WILL BE REQUESTING FOR EMERGENCY LANDING. FOR WHICH WE REQUIRE ALL THE ASSISTANCE. FIRE TENDER AND EVERYTHING.
13:24:45	ASR	COPIED SIR AS PER NAGPUR IT IS ONE OF THE REAR WHEEL NOT THE FRONT WHEEL. SO THAT IS THE INFORMATION ANYWAY WE WILL ADVISE YOU AFTER THE LOW PASS AND CONFIRM FOAM WILL BE REQUIRED ON THE RUNWAY.
13:24:58	VT-JIL	I THINK WE WLL BE REQUIRING FOAM ALSO AND ANY MESSAGE RECEIVED FROM OUR ENGINEERING TEAM OR FROM COMPANY SIR.
13:25:04	ASR	SURE, WE WILL ADVISE IT AS SOON AS POSSIBLE AS OF NOW NO INFORMATION RECEIVED EXCEPT THAT NAGPUR HAD ADVISED US THAT IT IS LIKELY ONE OF THE REAR WHEELS.
13:25:12	VT-JIL	ARE WE SURE ABOUT LEFT OR RIGHT WHEEL
13:25:18	ASR	NO SIR, NOT SURE, THAT IS NOT SURE, WE WILL ADVISE AFTER THE LOW PASS
13:25:26	VT-JIL	DO YOU HAVE ACCOUNTABLE MANAGER OR ENGINEERING TEAM NUMBER
13:25:27	ASR	WE HAVE THE NUMBER AND WE ARE COORDINATING SIR.
13:25:30	VT-JIL	KINDLY COORDINATE & AFTER THE LOW PASS WILL BE DECIDING WHETHER WE GO FOR A BELLY LANDING OR WE COME ON 2 WHEELS.
13:25:39	ASR	ROGER AND YOUR PREFERRED RUNWAY IS RUNWAY 27
13:25:45	VT-JIL	RIGHT NOW 27 IF ANYTHING REQUIRED WE CAN GO FOR ANOTHER. REQUESTING WIND SIR.
13:25:50	ASR	WIND IS 270 DEGREES /10 KNOTS.
13:25:52	VT-JIL	YEAH, I THINK WILL BE PREFERRING 27 ONLY.
13:25:56	ASR	27 ONLY. BEST OF LUCK, WE WILL ADVISE
13:26:56	ASR	VTJIL TURN LEFT HEADING 185
13:27:02	VT-JIL	TURN LEFT HEADING 185 VT-JIL
13:30:07	ASR	VT-JIL DESCEND TO LEVEL 70.
13:30:10	VT-JIL	DESCEND TO LEVEL 70 VT-JIL

13:33:03	ASR	VT-JIL TURN RIGHT HEADING 230 TO INTERCEPT LOCALISER RUNWAY 27
13:33:08	VT-JIL	TURN RIGHT HEADING 230 TO INTERCEPT RUNWAY 27 LOCALISER VT-JIL.
13:33:30	ASR	VT-JIL DESCEND TO LEVEL 55 TRANSITION LEVEL
13:33:33	VT-JIL	DESCEND TO LEVEL 55 TRANSITION LEVEL VT-JIL
13:34:08	VT-JIL	ON LOCALISER 27 VT-JIL
13:34:10	ASR	ROGER
13:34:38	ASR	VT-JIL DESCEND TO 3800 FT. QNH1007
13:34:44	VT-JIL	DESCEND TO 3800 FT. QNH1007 VT-JIL
13:35:42	ASR	VT-JIL RADAR
13:35:44	VT-JIL	GO AHEAD SIR
13:35:48	ASR	ALTITUDE YOU WILL BE CARRYING OUT LOW PASS SIR
13:35:50	VT-JIL	WE WOULD LIKE TO WILL BE AROUND 500FT. SO THAT SOMEBODY FROMTOWER CAN VISUALISE SIR.
13:36:03	ASR	500 FEET COPIED SIR
13:36:09	VT-JIL	WILL IT BE GOOD 500 FT. OR YOU WANT US TO GO LOWER
13:36:28	ASR	VT-JIL DESCEND TO 2900 FT. CLEARED FOR LOW PASS RUNWAY 27
13:36:34	VT-JIL	DESCEND TO 2900 FT. CLEARED FOR LOW PASS RUNWAY 27 VT-JIL.
13:38:17	ASR	9 MILES FROM TOUCHDOWN, I AM RELEASING
13:38:24	TWR	OK. RWY HEADING PAR JAYGA PHIR
13:38:27	ASR	RWY HEADING THIK HAI. HE IS ASKING IF YOU WANT HER BELOW 500FT OR 500 FT IS ENOUGH. ENGINEERING TEAM IS THERE. YOU CAN CHECK IT WITH THEM. THEEK HAI.
13:38:40	ASR	VT-JIL POSITION 8 MILE TO TOUCHDOWN CONTACT TOWER 118.1
13:38:44	VT-JIL	118.1 VT-JIL
13:38:50	VTJIL	TOWER VTJIL NAMASKAR
13:38:54	TOWER	VTJIL MUMBAI TOWER NAMASKAR CONTINUE APPROACH RUNWAY 27 WIND 280 DEGREES/ 10 KNOTS.
13:39:01	VT-JIL	CONTINUE APPROACH RUNWAY 27 WINDS COPIED VT-JIL
13:39:06	VT-JIL	MUMBAI VT-JIL ARE YOU ABLE TO SEE OUR UNDER CARRIAGE AT 500 FT.
13:39:15	TOWER	VT-JIL CONTINUE APPROACH WILL INFORM SIR, WE ARE COORDINATING.
13:39:18	VT-JIL	WILCO SIR OR WE CAN GO LOWER ALSO
13:39:29	VT-JIL	THERE IS A 3 GREEN SIGN IN THE COCKPIT AND NO ABNORMAL SIGN
13:39:40	TOWER	THREE GREEN SIGN COPIED
13:40:40	TOWER	VTJIL CONFIRM YOU ARE COMFORTABLE BELOW 500FT.

13:40:44	VT-JIL	WE ARE COMFORTABLE SIR
13:40:50	VT-JIL	WE ARE NOW 3.3 MILES
13:41:01	TOWER	VTJIL ALTITUDE AT YOU DISCRETION SIR
13:41:05	VT-JIL	WILCO SIR AND WE WILL BE REQUESTING FOR RADAR VECTOR AFTER LOWPASS
13:41:16	TOWER	VTJIL ROGER CARRY OUT LOW PASS FOR RUNWAY 27 AFTER CARRYING OUT CLIMB STRAIGHT AHEAD ON RUNWAY HEADING AND CONTACT DEPARTURE 127.9
13:41:26	VT-JIL	WHAT ALTITUDE DO YOU WANT ME TO MAINTAIN?
13:41:30	TOWER	CLIMB STRAIGHT AHEAD 1700 FT. SIR
13:41:33	VT-JIL	ROGER
13:41:34	TOWER	1700 FT. SIR
13:41:36	VT-JIL	1700 FT.
13:41:38	TOWER	VTJIL 1700 FT.
13:41:42	VT-JIL	COPIED SIR 1700 FT.
13:43:26	TOWER	VTJIL CONTINUE RUNWAY HEADING FLIGHT 70 CONTACT DEPARTURE 127.9
13:43:33	VT-JIL	127.9
13:43:42	VT-JIL	MUMBAI VTJIL CLIMBING RUNWAY HEADING TO FLIGHT 70
13:43:53	VT-JIL	SIR WHAT ABOUT OUR LANDING GEAR SITUATION VT-JIL
13:43:56	ASR	YEAH WAITING FOR THAT
13:44:10	ASR	VT-JIL RADAR
13:44:12	VT-JIL	GO AHEAD SIR, VT-JIL
13:44:14	ASR	AS INFORMATION RECEIVED YOU REAR PORT WHEEL IS MISSING.
13:44:19	VT-JIL	COPIED SIR REAR PORT WHEEL IS MISSING VT-JIL
13:44:24	VT-JIL	MUMBAI VT-JIL REQUESTING FULL EMERGENCY & WE WOULD LIKE TO COMEFOR LANDING. AND ANY MESSAGE RECEIVED FROM COMPANY SIR
13:44:38	ASR	STANDBY STANDBY WE WILL ADVISE SIR
13:44:45	VT-JIL	WE WILL CLIMB TO 70?
13:44:47	ASR	STOP CLIMB AT LEVEL 55 VT-JIL
13:44:49	VT-JIL	STOP CLIMB AT 55 VT-JIL
13:44:51	ASR	VT-JIL TURN RIGHT HEADING 360
13:44:54	VT-JIL	RIGHT HEADING 360 VT-JIL
13:45:24	ASR	VT-JIL CONFIRM YOU DUMP YOUR FUEL.
13:45:28	VT-JIL	WE ARE READY FOR APPROACH REQUESTING FOR FOAMING ON RUNWAY FIRST AND WE REQUEST EXPERT ADVISE FROM OUR COMPANY. WHETHERWE WILL DOING BELLY LANDING OR WILL HAVE TO COME ON CARRIED ONWITH PORT WHEEL NOT AVAILABLE.
13:45:51	ASR	ROGER SIR
13:46:00	VT-JIL	AND WILL PREFER BELLY LANDING FOR RUNWAY 27
13:46:05	ASR	ROGER SIR PREFERABLE BELLY LANDING

13:46:07	VT-JIL	PLEASE LET US KNOW AFTER CONSULTING COMPANY WE ARE ON A HEADING 360 (--- GARBLED---)
13:46:21	ASR	VT-JIL TURN RIGHT HEADING 060
13:49:02	ASR	VT-JIL WE ARE WAITING FOR INSTRUCTION FROM COMPANY
13:49:08	VT-JIL	COPIED SIR & MEAN WHILE PLEASE NOTE DOWN DGCA AUTHORITYMR.XXXX NUMBER ALSO. HE WILL ABLE TO GUIDE US.
13:49:20	VT-JIL	CONFIRM READY TO COPY NUMBER
13:49:21	ASR	YES SIR GO AHEAD
13:49:22	VT-JIL	XXXXXXXXXX CAPTAIN XXXXXXXXXX DGCA (--- GARBLED---) FOR US
13:53:54	VTJIL	MUMBAI VTJIL
13:53:57	VTJIL	WE ARE STILL AWAITING FOR THE INSTRUCTIONS SIR
13:54:00	VTJIL	ROGER SIR MEANWHILE WE ADVISE FOR A BELLY LANDING WITH FULLFOAMING OF THE RUNWAY, ALL EMERGENCY SERVICES LIKE FIRE FIGHTING& MEDICAL SERVICES. THIS IS AIR AMBULANCE TYPE--- (GARBLED---)VT-JIL
13:54:10	ASR	ALL COPIED WE WILL INFORM TO THE CONCERNED.
13:54:17	VTJIL	AND REQUESTING LEFT HEADING, ANY LEFT HEADING, WE CAN HOLD NORTH OF THE FIELD. THERE IS WEATHER IN FRONT OF US.
13:54:27	ASR	VT-JIL ROGER, HOLD TO THE LEFT OUTBOUND TIME 1 MINUTE.
13:57:05	VTJIL	MUMBAI VT-JIL ANY JOY WITH CAPTAIN XXXXX, DGCA (--- GARBLED---)
13:57:12	ASR	(--- GARBLED---) I WILL ADVISE.
13:58:16	ASR	VT-JIL RADAR
13:58:18	VTJIL	GO AHEAD SIR VT-JIL
13:58:20	ASR	AS PER CHECKLIST WHICH IS THE PREFERRED APPROACH FOR YOU SIR
13:58:25	VT-JIL	SIR WE ARE BELLY LANDING ONLY VT-JIL
13:58:58	ASR	VT-JIL ASR XXXXXXXX IS ASKING AS PER CHECKLIST YOUR PREFERRED LANDING.
13:59:00	VTJIL	WE DONOT HAVE ANY CHECKLIST. WITHOUT WHEEL (--- GARBLED---) NOTHING IS THERE. IF THE FRONT WHEEL IS NOT COMING OUT WE WILLHAVE TO DO A BELLY LANDING ONLY, BELLY LANDING IS ALWAYSPREFERRABLE.
13:59:30	VTJIL	IF ONE WHEEL IS NOT AVAILABLE NOTHING IS WRITTEN. THIS IS VERYUNUSUAL
14:00:49	VTJIL	NOW WE ARE LEFT WITH 700+ 700 BOTH TANKS, 1400 FUEL AVAILABLE INTHE AIRCRAFT.
14:01:01	VTJIL	AND CHECK LIST WILL BE, WE WILL BE DOING BELLY LANDING PREFERABLYTILL WE GET ANY OTHER

		INFORMATION, VT-JIL.
14:01:50	VTJIL	FUEL REMAINING IS 1 HOUR 20 MINUTES.
14:03:38	ASR	VT-JIL FIRE SERVICES DONOT HAVE ENOUGH FOAM TO SPREAD ON THERUNWAY. THEY CANNOT COVER PARTIAL RUNWAY AS WELL.
14:04:07	VTJIL	OK
14:05:30	VTJIL	AND MUMBAI VT-JIL ANY INFO FROM OUR COMPANY
14:05:37	ASR	WE ARE COORDINATING SIR, STANDBY
14:05:43	VTJIL	ANY JOY WITH OUR ACCOUNTABLE MANAGER OR ENGINEERING HEAD.
14:10:04	VTJIL	MUMBAI WRITE DOWN A PHONE NUMBER IT IS OF CAPTAIN XXXXX, HE IS ANEXAMINER ON (---GARBLED---) C90 & TELL HIM ABOUT THE SITUATION & ASK ABOUT (--- GARBLED---)
14:10:22	VTJIL	MUMBAI VT-JIL CONFIRM READY TO COPY THE NUMBER.
14:10:25	ASR	GO AHEAD PLEASE
14:10:27	VTJIL	XXXXXXXXX
14:10:34	VTJIL	XXXXXXXXX
14:10:40	ASR	CAN YOU PLEASE SAY THE NAME OF PERSON
14:10:45	VTJIL	CAPTAIN XXXXXX
14:10:48	ASR	XXXXXXXXX
14:10:55	VTJIL	AND CONFIRM NO INFORMATION FROM OUR COMPNY SIR
14:10:58	ASR	NO INFORMATION SIR OUR WSO IS COORDINATING.
14:11:02	VTJIL	THANKYOU VERY MUCH. THE BEST OPTION WILL BE BELLY LANDING ONLY.BEFORE TOUCHDOWN WE WILL SWITCH OFF OUR ENGINES SO THAT IT WILLNOT CATCH ANY FIRE & AFTER LANDING WE WILL BE REQUIRING IMMEDIATE ASSISTANCE WHEN WE STOP
14:11:18	ASR	VT-JIL ROGER
14:11:24	VTJIL	WE ARE INBOUND IN THE HOLD.
14:12:38	ASR	VT-JIL RECONFIRM PORT WHEEL IS MISSING
14:12:40	VTJIL	THAT IS AFFIRMATIVE.
14:12:43	VTJIL	AFTER LOW PASS ATC GUYS ALSO CONFIRM.
14:12:47	ASR	VT-JIL ROGER WE ARE COORDINATING WITH CAPTAIN XXXXXXX
14:14:54	ASR	VT-JIL RADAR
14:14:56	VT-JIL	GO AHEAD SIR
14:14:57	ASR	THERE IS A MESSAGE FROM Mr. XXXXXX FROM COMPANY CONFIRM YOU ARE ABLE TO COPY
14:15:04	VT-JIL	YES PLEASE
14:15:06	ASR	SHIFT ALL THE WEIGHT AND FUEL ON RIGHT SIDE AND LAND ON THE NOSEWHEEL AND RIGHT LANDING GEAR AFTER LANDING SHUT DOWN ENGINETHAT IS THE MESSAGE
14:15:22	VT-JIL	WILCO SIR

14:15:26	ASR	AND TRY TO MAINTAIN BALANCE AS PER THEM
14:15:34	VT-JIL	COPIED SIR, AND ARE YOU ABLE TO CONTACT CAPTAIN XXXXX
14:15:36	ASR	WE ARE COORDINATING ON THE PHONE NOW
14:23:40	ASR	VT-JIL RADAR
14:23:42	VT-JIL	GO AHEAD VT-JIL
14:23:44	ASR	THERE IS A MESSAGE FROM CAPTAIN XXXXX CONFIRM READY TO COPY
14:23:51	VT-JIL	GO AHEAD SIR
14:23:54	ASR	HE SUGGESTED BELLY LANDING AND BURN FUEL TO MINIMUM & BEFORETOUCHDOWN SHUT BOTH THE ENGINES. LOCK THE HARNESS & TIGHT ANDCONTROL AIRCRAFT ON RUDDER & LAND AT MINIMUM APPROACH SPEED.
14:24:17	VT-JIL	ROGER SIR MESSAGE COPIED VT-JIL. WE WERE ALSO PLANING THE SAME. THAT'S WHY WE CONVEYED TO YOU THAT MOSTLY IT WILL BE BELLY LANDING. WE ARE JUST CONSUMING THE FUEL FOR SOME TIME SO THAT WE LAND WITH MINIMUM FUEL
14:24:38	ASR	REQUEST ENDURANCE AT THIS TIME.
14:24:40	VTJIL	ROGER NOW IT IS 600, 600 POUNDS, TOTAL 1200 POUNDS AVAILABLE, TIMEIS 1 HOUR 15 MINUTES
14:25:37	ASR	VT-JIL THERE IS ONE MORE MESSAGE FROM FIRE SERVICES
14:25:43	VT-JIL	GO AHEAD SIR VT-JIL.
14:25:44	ASR	THEY ARE NOT HAVING FOAM FOR SPREADING ON THE RUNWAY SIR. THEREIS NO FOAM BEFORE LANDING THEY CANNOT SPREAD ON RUNWAY.
14:25:54	VT-JIL	CALL YOU SIR VT-JIL
14:28:22	TWR	SIR LOOKING TO BRING ONLY ONE DEPARTURE AT A TIME. AFTER 20 MILESCHECK NO DEPARTURE, I SAY AGAIN NO DEPARTURE.
14:28:30	ASR	YES YES
14:33:52	TWR	SIR KINDLY CONFIRM THE AIRCRAFT WOULD BE ATTEMPTING BELLY LANDING WITH GEARS DOWN OR GEARS UP.
14:34:00	ASR	ACHA MAIN POOCHTA HUN.
14:34:06	ASR	VTJIL RADAR
14:34:10	VT-JIL	GO AHEAD SIR VT-JIL
14:34:12	ASR	THERE IS ONE MORE MESSAGE FROM CAPTAIN XXXXX. HE SAID POSITIVELY DO NOT ATTEMPT TO LAND ON TWO WHEELS AND AFTER LANDING SWITCH OFF THE BATTERY WHENEVER POSSIBLE.
14:34:20	VTJIL	SAY AGAIN.
14:35:30	ASR	THERE IS ONE MORE MESSAGE FROM CAPTAIN XXXX. HE SAID POSITIVELY DO NOT ATTEMPT TO LAND ON TWO WHEELS AND AFTER LANDING SWITCH OFF THE BATTERY WHENEVER POSSIBLE.

14:46:48	TWR	CONFIRM ANY DANGEROUS GOODS ONBOARD?
14:46:55	ASR	DANGEROUS GOODS POOCHTA HU MAIN.
14:48:52	ASR	VTJIL RADAR
14:48:55	VT-JIL	GO AHEAD SIR VT-JIL
14:48:59	ASR	AS PER FIRE SERVICES, THEY SAID THAT THEY WILL PROVIDE FOAM WHEN YOU WILL TOUCHDOWN FROM THE SIDE AND FROM THE BACK. ADVISE AT WHAT DISTANCE YOU WILL BE MAKING TOUCHDOWN FROM THE BEGINNING OF THE RUNWAY AND WHEN YOU WILL BE MAKING AN APPROACH. AT WHAT TIME YOU WILL MAKE AN APPROACH APPROXIMATE.
14:49:39	VT-JIL	STANDBY SIR.
14:49:50	VTJIL	STANDBY SIR, WE WLL BE WAITING TO BURN MORE FUEL SO THAT WE WILLHAVE LESS CHANCE TO CATCH FIRE AFTER LANDING AND WE WILL REMAINANOTHER 20 MINUTES IN THE AIR.
14:50:10	VTJIL	REQUESTING LOW LEVEL VECTORS SO THAT (---GARBLED---) NEGATIVE SIRDISREGARD.
14:51:09	ASR	VT-JIL RADAR CAN YOU FLY HEADING 120 HOLD YOU ACROSS THE LOCALISER SO THAT WHEN YOU ARE READY YOU CAN INTERCEPT LOCALISER.
14:51:17	VTJIL	AFFIRM SIR HEADING 120.
14:53:38	TWR	SIR FIRE WANTS TO KNOW IF THE AIRCRAFT WILL DO THE LANDING WITHGEAR DOWN OR GEAR UP?
14:53:42	ASR	WO BATAYA NAHI USNE. MAI POOCHTA HU.
14:56:31	ASR	VTJIL RADAR
14:56:33	VTJIL	GO AHEAD
14:56:35	ASR	SOME MORE ADVISE GIVEN BY CAPTAIN XXXXX.CONFIRM READY TO COPY.
14:56:44	ASR	AS PER HIM PERFECTLY SAFE TO LAND C90 ON BELLY, RUNWAY IS BEINGFOAMED TRY AND TOUCH DOWN IN FOAM ZONE & EMERGENCY & EXITDOORS TO BE KEPT CLEAR OF OBSTACLES. ALL PASSANGERS IN BRACEPOSITION, HARNESS INCLUDING SHOULDER HARNESS FOR PILOT TO BE KEPTLOCKED AND TIGHT. NO LOOSE ARTICLE, OXYGEN, BAGGAGE, MEDICALEQUIPMENT IN CABIN. LAND WITH MINIMUM FUEL PREFERABLY FOR 1OVERSHOOT, ABOUT 300 TO 350 POUNDS. ALL TORCHES, MOBILE PHONESKEPT ON TO BE USED AFTER LANDING. WHEELS UP LANDING TO BE DONE.SWITCH OFF AFTER FLARE OUT AND BEFORE TOUCH DOWN. SWITCH OFF CAN BE DONE AT 50 FT. IN CASE SPEED IS HIGHER. AFTER TOUCHDOWNCONTROL DIRECTION WITH RUDDER, SWITCH OFF BATTERY AFTER LANDINGAT THE EARLIEST. USE MOBILE PHONE AFTER LANDING. QUICK EXIT FROMAIRCRAFT AFTER LANDING.

14:58:20	VTJIL	THANKYOU SIR MESSAGE COPIED VT-JIL
14:59:10	ASR	VT-JIL SHOULD I REPEAT THE MESSAGE FROM CAPTAIN XXXXXX
14:59:11	VTJIL	SIR YOU CAN GO AHEAD BUT WE HAVE ALREADY PREPARED WHATEVER HE IS SAYING AS A DGCA EXAMINER. I HAVE ALREADY BRIEFED MY PIOLTMONITORING FOR THE SAME BUT YOU CAN GO AHEAD AGAIN WITH THEMESSAGE
14:59:32	ASR	ROGER IAM REPEATING THE SAME POINT AS PER HIM PERFECTLY SAFE TOLAND C90 ON BELLY, RUNWAY IS BEING FOAMED TRY AND TOUCH DOWN IN FOAM ZONE &EMERGENCY & EXIT DOORS TO BE KEPT CLEAR OF OBSTACLES. ALL PASSANGERS IN BRACE POSITION, HARNESS INCLUDING SHOULDER HARNESS FOR PILOT TO BE KEPT LOCKED AND TIGHT. NO LOSE ARTICLE, OXYGEN, BAGGAGE, MEDICAL EQUIPMENT IN CABIN. LAND WITH MINIMUM FUEL PREFERABLY FOR 1 OVERSHOOT, ABOUT 300 TO 350 POUNDS. ALL TORCHES, MOBILE PHONES KEPT ON TO BE USED AFTER LANDING. WHEELS UP LANDING TO BE DONE. SWITCH OFF AFTER FLARE OUT AND BEFORE TOUCH DOWN. SWITCH OFF CAN BE DONE AT 50 FT. IN CASE SPEED IS HIGHER. AFTER TOUCHDOWN CONTROL DIRECTION WITH RUDDER, SWITCH OFF BATTERY AFTER LANDING AT THE EARLIEST. USE MOBILE PHONE AFTER LANDING. QUICK EXIT FROM AIRCRAFT AFTER LANDING.
15:01:22	VTJIL	COPIED SIR MESSAGE COPIED VT-JIL.
15:01:32	ASR	VT-JIL CAN YOU TURN RIGHT HEADING 200.
15:01:34	VTJIL	HEADING 200.
15:01:50	VTJIL	WE WOULD LIKE TO REMAIN 15 MINUTES MORE IN THE AIR TO BURN MOREFUEL SO THAT WE ARE AT 350 EACH.
15:02:02	ASR	15 MINUTES FROM NOW THAT IS 1517 YOU WILL COMMENCE DESCEND FOR APPROACH, CONFIRM
15:02:11	VTJIL	WILCO SIR, & FOAMING ZONE WOULD BE LIKE FROM WHERE THEY HAVESPREAD FOAM
15:02:26	ASR	AT WHAT DISTANCE WILL YOU BE LANDING FROM THE BEGINNING OFRUNWAY? ACCORDINGLY, THEY WILL FOAM APPROXIMATELY.
15:02:34	VT-JIL	AFTER 200M FROM THE THRESHOLD WE WILL BE ABLE TO LAND.
15:02:48	VTJIL	& WE ARE SURE THAT WE WILL GO FOR A BELLY LANDING AS DECIDEDEARLIER & WE WILL BE REQUESTING FOR IMMEDIATE ASSISTANCE, FIREFIGHTING AND AMBULANCE ON OUR BELLY LANDING
15:03:10	ASR	ROGER SIR COPIED

15:03:12	VTJIL	AND PASSANGERS HAVE ALREADY BEEN BRIEFED REGARDING EMERGENCYEVACUATION PROCEDURE AND WE WILL LET YOU KNOW WHEN WE AREREADY TO GO FOR LANDING.
15:04:30	ASR	ROGER
15:04:55	ASR	VT-JIL TURN RIGHT HEADING 230.
15:05:00	VTJIL	HEADING 230.
15:05:35	ASR	CONFIRM YOU WILL BE LANDING WITH LANDING GEAR UP OR DOWN &CONFIRM ANY DANGEROUS GOODS ON BOARD.
15:05:46	VTJIL	WE WILL BE BELLY LANDING WITHOUT WHEELS WITH LANDING GEAR UP AND OXYGEN CYLINDER ON BOARD.
15:06:10	ASR	VT-JIL TURN RIGHT HEADING 360.
15:06:14	VTJIL	RIGHT HEADING 360 VT-JIL
15:07:22	ASR	VT-JIL RADAR.
15:07:25	VTJIL	SIR VT-JIL
15:07:30	ASR	WE CONVEYED TO FIRE STATION THAT YOU WILL MAKE AN ATTEMPT TOTOUCH DOWN AFTER AROUND 200 METERS. FROM THRESHOLD.
15:08:36	ASR	VT-JIL RADAR
15:08:38	VTJIL	GO AHEAD VT-JIL
15:08:39	ASR	CAUTION FOR INSET CENTER LINE RUNWAY LIGHTS CAT II LIGHTS WILL BEAVAILABLE AFTER THRESHOLD FOR ABOUT 900 METERS. THEY MAY CAUSE A FRICTION, AS A CAUTION.
15:09:15	VTJIL	ROGER SIR COPIED VT-JIL
15:10:00	APAC	VT-JIL WILL MAKE A BELLY LANDING WITH WHEELS UP AND OXYGEN CYLINDERAS DANGEROUS GOODS ONBOARD AND THEY WILL TRY TO TOUCHDOWNWITHIN 200M FROM THRESHOLD.
15:10:20	TWR	COPIED SIR
15:10:46	ASR	& IL CAN YOU PLEASE RECONFIRM THAT YOUR TOUCHDOWN POSITION WILL BE WITHIN 200 METERS. FROM THE DISPLACED THRESHOLD
15:11:00	VTJIL	AFFIRM SIR VT-JIL
15:12:02	ASR	VT-JIL TURN LEFT TURN LEFT HEADING 180.
15:12:03	VTJIL	TURN LEFT HEADING 180 VT-JIL.
15:12:07	ASR	& TIME IS 1512, CONFIRM YOU WILL BE DESENDING AT TIME 1517.
15:12:12	VTJIL	AFFIRM SIR VT-JIL.
15:13:08	ASR	VT-JIL AT YOUR DISCRETION WHEN READY DESCEND TO 3800 FT. QNH 1008.
15:13:15	VTJIL	DESCEND TO 3800 FT. QNH 1008 VT-JIL.
15:15:10	ASR	VT-JIL QNH CHANGE, QNH NOW 1009. CAN YOU LET ME KNOW APPROXIMATETRACK MILES REQUIRED FROM NOW.
15:15:38	VTJIL	APPROXIMATELY 26 MILES FROM PRESENT

		POSITION, QNH CHANGE, QNH1009
15:15:45	VTJIL	QNH 1009 COPIED VT-JIL
15:15:58	ASR	26MILES FROM TOUCHDOWN
15:16:02	TWR	COPIED SIR
15:16:10	ASR	VT-JIL TURN RIGHT HEADING 360.
15:16:12	VTJIL	RIGHT HEADING 360.
15:17:05	VTJIL	VT-JIL CAN YOU GO AHEAD WITH YOUR ENDURANCE. AT PRESENT FOAMING ISGOING ON.
15:17:18	VTJIL	SIR WE HAVE ENDURANCE OF 45 MINUTES VT-JIL.
15:17:22	ASR	CAN YOU WAIT FOR ANOTHER 15 MINUTES FOR COMPLETION OF FOAMING.
15:17:28	VTJIL	AFFIRM SIR WE CAN WAIT VT-JIL
15:17:32	ASR	TURN LEFT HEADING 180.
15:17:34	VTJIL	LEFT HEADING 180.
15:19:06	ASR	WHEN FOAMING IS COMPLETE WE WILL IMMEDIATELY PUT YOU ONLOCALISER.
15:19:08	VTJIL	AFFIRM SIR VT-JIL
15:29:12	VTJIL	HOW MUCH TIME MORE WE HAVE TO HOLD VT-JIL
15:29:17	ASR	STANDBY SIR COORDINATING AND YOUR POSITION IS 13 MILES EAST OFMUMBAI STANDY BY COORDINATING
15:29:35	ASR	SHE IS READY FOR APPROACH. HOW MUCH TIME IS REQUIRED MORE?
15:29:39	TWR	WAIT SIR
15:30:08	ASR	VT-JIL DESCEND TO 2900 FT.
15:30:12	VTJIL	DESCEND TO 2900 FT. VT-JIL
15:30:45	ASR	VT-JIL TURN LEFT HEADING 360.
15:30:47	VTJIL	LEFT HEADING 360. VT-JIL
15:31:20	ASR	VT-JIL CONTINUE TURNING LEFT HEADING 300.
15:31:23	VTJIL	HEADING 300 VT-JIL.
15:31:28	ASR	FOAMING WILL BE COMPLETED IN ANOTHER 2 TO 3 MINUTES
15:31:30	VTJIL	AFFIRM SIR VT-JIL
15:31:42	ASR	VT-JIL CONTINUE TURINING LEFT HEADING 300 TO INTERCEPT LOCALISERRUNWAY 27.
15:13:46	VTJIL	CONTINUE TURNING LEFT HEADING 300 TO INTERCEPT LOCALISER RUNWAY27 VT-JIL
15:32:00	ASR	LOCALIZER PER LAGAYA HAI. AROUND 13 MILES HAI TOUCHDOWN ME.
15:32:04	TWR	OK
15:32:06	ASR	WOH READY HO GAYE NA WOH LOG?
15:32:10	TWR	YES SIR FOAMING COMPLETE
15:32:14	ASR	VT-JIL CLEARED FOR ILS APPROACH RUNWAY 27
15:32:18	VT-JIL	CLEARED FOR ILS APPROACH RUNWAY 27 VT-JIL
15:33:04	VT-JIL	ON LOCALISER RUNWAY 27 VT-JIL
15:33:06	ASR	VT-JIL ROGER POSITION 12 MILES FROM TOUCHDOWN

15:33:24	ASR	11 MILES FROM TOUCHDOWN ON LOCALIZER NOW. WILL CHANGEOVER TOYOU
15:33:27	TWR	COPIED SIR
15:34:24	ASR	VT-JIL CONFIRM ESTABLISED SIR
15:34:28	VTJIL	AFFIRM SIR ESTABLISED RUNWAY 27 VT-JIL.
15:34:32	ASR	VT-JIL 08 MILES FROM TOUCHDOWN CONTACT TOWER 118.1
15:34:36	VT-JIL	118.1 VT-JIL THANKYOU SIR
15:34:40	TOWER	ALL STATION STOP TRANSMITTING MAYDAY.
15:34:47	VTJIL	MUMBAI VTJIL
15:34:49	TOWER	VTJIL NAMASKAR CONTINUE APPROACH RUNWAY 27 WIND 210 DEGREES/ 04 KNOTS.
15:34:55	VT-JIL	CONTINUE APPROACH RUNWAY 27 VT-JIL.
15:35:02	TOWER	VTJIL WIND 210 DEGREES/03 KNOTS RUNWAY 27 CLEARED TO LAND. GOODLUCK
15:35:07	VT-JIL	CLEARED TO LAND RUNWAY VT-JIL THANKYOU SIR.
15:36:06	TOWER	ALL FOLLOW ME MONITOR GROUND NOW
15:36:10	TOWER	ONE FOLLOW ME TO REMAIN WITH TOWER
15:36:25	FM2	MUMBAI TOWER FOLLOW ME 2.
15:36:30	TOWER	AIRCRAFT AROUND 3 MILES
15:36:41	TOWER	EMERGENCY AIRCRAFT AT 3 MILES
15:36:44	FOLLOW ME2	COPIED SIR FOLLOW ME 2
15:39:55	UNKNOWN	TOWER REQUESTING FOR ENTRY RWY27
15:39:59	TOWER	ROGER ENTER RUNWAY VIA N1 ESTIMATING LOCATION AROUND GRIDNUMBER E9
15:40:11	TOWER	ALL CFT VEHICLES CLEARED TO ENTER RUNWAY PROVIDE NECESSARY ASSISTANCE
15:40:30	TWR	VTJIL CONFIRM ALL OPERATION NORMAL
15:41:06	FOLLOW ME 2	TOWER FOLLOW ME2 REQUEST TO CROSS RWY32 ALONGWITH AMBULANCE
15:41:08	TWR	ROGER ROGER CROSS RWY 32 NOW

Table 9-1. Aerodrome category for rescue and fire fighting

Aerodrome category (1)	Aeroplane overall length (2)	Maximum Fuselage Width (3)
1	0 m up to but not including 9 m	2 m
2	9 m up to but not including 12 m	2 m
3	12 m up to but not including 18 m	3 m
4	18 m up to but not including 24 m	4 m
5	24 m up to but not including 28 m	4 m
6	28 m up to but not including 39 m	5 m
7	39 m up to but not including 49 m	5 m
8	49 m up to but not including 61 m	7 m
9	61 m up to but not including 76 m	7 m
10	76 m up to but not including 90 m	8 m

Table 9-2. Minimum usable amounts of extinguishing agents

Foam meeting performance level A			Foam meeting performance level B		Foam meeting performance level C		Complementary agents	
Aerodrome Category	Water (L)	Discharge rate foam solution/ minute (L)	Water (L)	Discharge rate foam solution/ min (L)	Water (L)	Discharge rate foam solution/ min (L)	Dry chemical powders (kg)	Discharge Rate kg/sec
1	2	3	4	5	6	7	8	9
1	350	350	230	230	160	160	45	2.25
2	1000	800	670	550	460	360	90	2.25
3	1800	1300	1200	900	820	630	135	2.25
4	3600	2600	2400	1800	1700	1100	135	2.25
5	8100	4500	5400	3000	3900	2200	180	2.25
6	11800	6000	7900	4000	5800	2900	225	2.25
7	18200	7900	12100	5300	8800	3800	225	2.25
8	27300	10800	18200	7200	12800	5100	450	4.5
9	36400	13500	24300	9000	17100	6300	450	4.5
10	48200	16600	32300	11200	22800	7900	450	4.5

Note- The quantities of water shown in columns 2 and 6 are based on the average overall length of aeroplanes in a given category.

9.2.19The complementary agents shall comply with the appropriate specifications of the Bureau of India Standards (BIS) / International Organization for Standardization (ISO).*

* ISO Publications 5923 (Carbon Dioxide), 7201 (Halogenated Hydrocarbons) and 7202 (Powder).

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Chapter 15

Foaming of Runways for Emergency Landings

15.1 GENERAL

15.1.1 A number of emergency landings (mostly wheels-up landings or aircraft with defective nose gear) have occurred on runways where protein foam* has been applied with the thought that such action would mitigate the extent of damage likely to result and reduce the likelihood of fire occurring following the impact. Some of these operations were successful. Some foam runway operations, however, did not accomplish their purpose. In most of these latter cases, aircraft missed or overran the foam blanket. Similar aircraft emergency landings have occurred on runways where foam was not applied and in a number of these cases no major fires occurred and the damage sustained by the aircraft was moderate.

15.1.2 The effectiveness of runway foaming is not fully substantiated by the real evidence of operational incident studies. The airport authority may still wish to provide the facility, however, to meet specific requests from aircraft operators and pilots and it will then be necessary to fully appreciate the operational problems.

15.1.3 There has been some speculation on whether runway foaming should be provided for a wheels-up landing of a turbo-jet aircraft, since the foam cannot affect the ignition source of the hot jet exhaust. A survey made by ICAO showed that States that provide the special equipment for runway foaming will deploy it for any emergency situation involving landing gear whenever the pilot feels that foam can increase safety during the landing operation.

15.2 THEORETICAL BENEFITS FROM FOAMING OF RUNWAYS

15.2.1 There appear to be four theoretical benefits from foaming of runways for emergency landings. They are:

a) *Reduction in aircraft damage.* The foam will likely reduce the extent of damage to an aircraft which may be forced to make a wheels-up emergency landing, or, where the nose gear is defective.

b) *Reduction in deceleration forces.* The foam will reduce the coefficient of friction of the runway and thus decrease (by permitting slippage) either the deceleration forces imposed on the aircraft and its occupants or its ground looping tendencies.

c) *Reduction in friction spark hazard.* The foam or water retained by the foam at the runway interface will likely reduce the known friction spark hazard of certain aircraft metals on dry runways. Such friction sparks constitute a possible ignition source following impact-imposed damage to an aircraft's fuel tanks or system.

d) *Reduction in fuel spill fire hazard.* The foam will reduce the extent of the fire hazard in the event of a fuel spill following impact-imposed damage to an aircraft's fuel tanks or system.

15.2.2 Analysis of the four basic possible or theoretical benefits described in 15.2.1 may suggest the following conclusions:

a) *Reduction in aircraft damage.* A number of well-executed emergency landings on foam-coated runways have been accomplished with minimum damage to the aircraft involved. Unfortunately, these incidents do not prove that, conversely, the damage would have been appreciably greater had no foam been used. Controlled emergency landings on dry runways have also been completed with relatively minor damage to the aircraft. A number of variables are indicated:
   1) the design of the aircraft (such factors as "crush-resistance" of the fuselage, whether the aircraft is of high or low wing design, the hazard presented by propeller fragmentation, etc.);

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* Fluroprotein foam, film forming fluoroprotein foam and aqueous film forming foam are not considered suitable for runway foaming operations due to their short drainage time. Throughout this chapter, the general term "foam" relates to protein foam.

2) the skill of the pilot (the ability to land the aircraft under emergency conditions, either by virtue of the pilot's training, or psychological or physical state at the time the emergency occurs);
3) the type and condition of the runway surface;
4) the landing mass of the aircraft; and
5) the weather, temperature and visibility conditions, etc.

The data available from a study of emergency landings made with, and without, the application of foam show that no significant reduction is achieved in the risk of fire or in the extent of damage by the foaming of runways. There was no evidence to show that pilots gained any psychological advantage from the presence of foam.

b) *Reduction in deceleration forces.* The braking action of a foamed runway will normally be poorer than that obtained when the runway is wet and thus permitting potential slippage. It is to be noted that from what is known to date, the braking action of an aircraft on a foamed runway will only be slightly worse than that on a wet runway, assuming non-freezing weather.

c) *Reduction in friction spark hazard.* Scale research tests have shown that aluminium alloy metals produce no friction sparks capable of igniting aircraft fuel vapours under the simulated bearing pressures and contact speeds likely to be encountered in actual aircraft emergencies on either dry or foam-covered concrete or asphalt runway surfaces. According to these same scale research tests, properly applied foam is capable of holding a water layer at the runway interface which is effective in suppressing sparks in from 57 to 100 per cent of these tests where magnesium alloys, stainless steel and other aircraft steels produced sparks capable of igniting aircraft fuel vapours from friction with dry asphalt or concrete runways. Titanium friction sparks, capable of igniting aircraft fuel vapours, could not be effectively suppressed by runway foaming in any of the scale research tests and constitute the greatest hazard. The roughness of runway surfaces was found to be a factor in the production of the incendiary sparks generated by abrasion of all the metals (except aluminium) and the friction impact with expansion joints between concrete slabs was found to result in momentary increases in the energy release from the sparks.

d) *Reduction in fuel spill fire hazard.* From all that is known of the fire suppression qualities of foam and the scale research tests, it is clear that a foamed runway would have no appreciable effect on the fire hazard of fuel vapours in the atmosphere over the foam. These vapours could still be ignited above the foam blanket by an engine fire, electric arcs or sparks, static discharges or other ignition sources. Should liquid fuel be released over the foam blanket, it will fall through and spread under the foam, reducing the release of flammable vapours. In case of ignition, the burning area may be reduced, depending on the age and condition of the foam blanket. Fire fighting crew members should be prepared to fight such a fire.

15.3 OPERATIONAL PROBLEMS

15.3.1 There are other considerations which should be evaluated to determine the feasibility of using foaming of runways for emergency landings in any individual case. They are:

a) the actual nature of the airborne emergency; i.e. whether the aircraft cannot lower its main gear, whether only one gear is down and cannot be retracted, whether one or more tires or wheels have been damaged or lost, whether the nose gear is "cocked", or a combination of two or more of these circumstances or some other related condition exists;

b) the time element available for accomplishing the production and distribution of the foam covering which may take up to an hour or more. This will be related to the nature of the aircraft emergency, the safety factors involved in the aircraft remaining airborne during the foam laying operation, the number and the nature of the foam-making appliances available. Normally the time required to lay a runway foam blanket permits the dumping of fuel by the flight crew, where considered necessary or desirable, to reduce the hazard during the emergency landing;

c) the reliability of information on the landing techniques to be used. This will be related to wind and visibility conditions, pilot experience and skill, visual and radio aids available for approach and landing, and aircraft operational problems under the existing emergency conditions;

d) the foam-making capability and adequacy of the equipment available on the airport for runway foaming plotted against the prudent holding time of the aircraft involved in the emergency. Airports not having adequate equipment should not attempt to lay a foam blanket. Rescue and fire fighting equipment at an airport should not be employed in runway foaming operations to the extent that its ability to deal with any concurrent or subsequent aircraft accident fire situation would be impaired (see 15.3.3). Where the runway foaming facility is to be provided, it is essential that additional supplies of foam liquid for use in this operation be made available;

e) the effect the foam laying and clean-up operations will have upon the aircraft movements at the airport — particularly at an airport with a single runway or an airport with only one runway operational — and how this will affect the safety of all aircraft operations in progress;

f) whether the ambient weather conditions make the laying of a foam blanket feasible. Runway foaming should not be laid during heavy rain or snowfall conditions. In very cold weather, the freezing of the water element draining from the foam blanket could create serious braking problems during the emergency landing and in subsequent use of the runway; and

g) the length of the runway and the nature and condition of the runway surface at the time the emergency occurs. Runway slope and runway surface temperature will also affect the protein foam water drainage time.

15.3.2 Considering the factors mentioned in the preceding paragraph, it is clear that initiation of a request to foam a runway for any given flight emergency situation should be a flight operational decision. The request to take such action should thus come from the pilot-in-command of the aircraft or the aircraft operator, assuming that they are familiar with the aforementioned considerations.

15.3.3 The designation of one airport in a region or predetermined geographical area to which aircraft might be safely dispatched when in need of runway foaming is recommended. Selection of these regional airports should be based not only on the availability of adequate runway foaming equipment and supplies, emergency aircraft rescue and fire fighting services, and allied support services (cranes and aircraft repair services), but also on the physical condition of the runways to be employed, the climatic conditions, aircraft traffic interruption effects, and the security force of the airport to ensure control of curious spectators in the event of public awareness of the impending emergency landing. Further, in selecting an airport at which runway foaming will be provided, it is essential also to assess the availability of off-airport services and agencies which would be required to support the airport rescue and fire fighting services and other on-airport agencies when an aircraft accident has occurred. This assessment must embrace fire, police, ambulance and hospital services, and would ideally include the availability of doctors, medical teams and mortuary facilities.

15.3.4 Determination as to the feasibility of applying foam to a runway at a designated airport is a decision which the airport manager or representative must make in consultation with the officer-in-charge of the rescue and fire fighting service after receipt of the official request for such services from the pilot or aircraft operator and an evaluation of the fire protection and other airport operational problems involved. Due to the fact that aircraft operations will normally continue elsewhere on the airport and the existing danger that circumstances beyond the control of the pilot of the distressed aircraft may require an emergency landing before the foam blanket is ready, or before the foam-making units have been replenished, it is essential that the minimum number of rescue and fire fighting vehicles recommended in 2.10, carrying at least the minimum amounts of extinguishing agents recommended in 2.3, be maintained in fully operational condition to perform their emergency function.

15.4 TECHNIQUES OF RUNWAY FOAMING

If after evaluating the theoretical and operational problems involved as discussed in 15.2 and 15.3, foaming of a runway is to be accomplished in an attempt to safeguard a particular emergency landing, the following basic principles are advanced for consideration by those responsible. Each case of runway foaming will differ depending on the numerous variables involved.

a) Radio contact should be maintained between ground personnel co-ordinating the runway foaming operation and the pilot of the distressed aircraft to ensure full understanding and knowledge of the operating plans and the protection established.

b) Primary aircraft rescue and fire fighting vehicles should not be used to foam runways unless the number of such vehicles held in reserve is sufficient to provide the minimum protection recommended in Chapter 2 for that particular airport. Auxiliary tank trucks, equipped to dispense foam through ground sweep nozzles or special boom nozzles or other additional specialized foaming equipment preferably designed to deliver the foam from devices discharging to the rear of the sides of the truck, should be used for runway foaming.

c) A time study should be conducted to work out the scheduling of the foam-laying operation and the vehicle reload requirements. Under any conditions, adequate extra quantities of foam compound must be preplanned and prearrangements for rapid vehicle re-servicing made. This time study should be made prior to any emergency.

d) Experience has shown that, when making a gear-up landing, the aircraft contacts the runway much farther from the threshold than normal. This is due to increased lift caused by "ground effect" and, in some cases, by the reduced stalling speed of the aircraft with the gear up. The point of aircraft touchdown can be 150 m to 600 m farther down the runway than normal, depending on the size and speed of the aircraft involved. The foam pattern should be positioned on the runway as requested by the pilot-in-command. In general, it should be located as follows:
   1) for malfunctioning nose gear, the pattern should be laid starting at a point from the threshold equal to one-half the distance available for landing; and
   2) for a wheels-up landing, the pattern should be laid starting at a point from the threshold equal to one-third the distance available for landing.

e) The length, width and depth of the foam pattern will vary with the type of emergency, the type of aircraft, the quantities of agent available and the time factors involved. Table 15-1 may be used for estimating the approximate amounts of water and foam liquid required to produce a certain foam blanket pattern for the anticipated emergency. The requirements for longer or wider patterns may be readily estimated from the figures in Table 15-1.

f) When visibility conditions are such that the pilot cannot distinguish from the air where the foam applied to the runway starts, a reference point should be established in a clearly distinguishable manner to indicate where the foam pattern commences to aid the pilot in getting the aircraft positioned for the landing.

g) All unnecessary persons should be advised to stay clear until evacuation and occupant counts have been accomplished and full fire control or fire preventive measures taken. This is a function of airport police or security, and may be augmented by local police and volunteers.

h) Aging of the foam prior to use for a period of 10 to 15 minutes is desirable to permit water to drain from the

Table 15-1. Water and protein foam liquid requirements for runway foaming[a)]

	Malfunctioning nose wheel	*Wheels-up landing* 2-engine propeller	*2-3 engine jet*	*4-engine propeller*	*4-engine jet*
Distance to threshold			*See 15.3.1d)*		
Width of pattern	8 m	12 m	12 m	23 m[b)]	23 m[c)]
Length of pattern	450 m	600 m	750 m	750 m	900 m
Runway area covered	3 600 m²	7 200 m²	9 000 m²	17 250 m²	20 700 m²
Water required	14 400 L	28 800 L	36 000 L	69 000 L	82 800 L
Protein foam liquid required			*See notes d) and e)*		
3% type	432 L	864 L	1 080 L	2 070 L	2 484 L
6% type	864 L	1 728 L	2 160 L	4 140 L	4 968 L

Notes:
a) These figures are based on applying water as foam at a minimum rate of 4 L/m² of runway surface. The approximate equivalent foam blanket thickness is 5 cm for expansion 12 and 3.8 cm for expansion 8.
b) The width of the foam pattern shown in the table will provide a pattern width sufficient to extend beyond the outboard engines of most 4-engined propeller-driven aircraft.
c) The width of the foam pattern shown in the table will provide a pattern width sufficient to extend beyond the inboard engines of most 4-engined jet aircraft.
d) If the foam proportioning system used in laying the foam pattern is set to operate on higher than 3 or 6 per cent concentration, the amount of foam liquid must be increased accordingly.
e) Due to variations in foam-metering devices, possible inaccurate proportioning of the foam-liquid concentrate and the varied characteristics of local water supplies, it is normally prudent to increase the amount of foam-liquid concentrates to above those theoretically required, figuring perhaps on 10 per cent foam-liquid concentrate for the 6 per cent type and 5 per cent for the 3 per cent type.

foam and create effective runway surface wetting within the foam pattern. Aging of the foam for too long a period (say over 2½ hours) prior to use on a hot summer day may be disadvantageous due to excessive drying and water runoff.

i) To be effective, a continuous layer of foam in the proposed slide path is essential as any interruptions, holes or breaks might result in the formation of incendiary sparks of sufficient duration and intensity to cause ignition of any flammable vapours present.

j) Depth of the foam should preferably be 5 cm to achieve even distribution, so that the foam has good "holding" characteristics, that is, that the foam is capable of holding the water at the runway interface without excessive drain-off due to runway longitudinal and/or transverse slope. Special regard should be given to the presence of runway grooving or of porous friction courses as they may affect drain-off characteristics. A foam depth of less than 5 cm may be satisfactory if continuous, if it drains properly, and if it has the ability to retain the water content at the runway surface. Foam expansions of 8 to 12 appear to be satisfactory for this purpose.

k) Following foam laying operations, rescue and fire fighting personnel should leave the operational runway and take up standby positions out of range of all collision hazards. After the aircraft touches down, rescue and fire fighting vehicles should follow the aircraft and be ready to operate.

Chapter 14

TRAINING

14.1 GENERAL

14.1.1 Personnel whose duties consist solely of the provision of RFF services for aircraft operations are infrequently called upon to face a serious situation involving life-saving at a major aircraft fire. They will experience a few incidents and a larger number of standbys to cover movements of aircraft in circumstances where the possibility of an accident may reasonably be anticipated but will seldom called upon to put their knowledge and experience to the test. It follows, therefore, that only by means of a most carefully planned and rigorously followed programme of training can there be any assurance that both personnel and equipment will be capable in dealing with a major aircraft fire should the necessity arise. The core training programme can be organized into nine faculties as follows:

a) fire dynamics, toxicity and basic first aid;

b) extinguishing agents and firefighting techniques;

c) handling of vehicles, vessels and equipment;

d) airfield layout and aircraft construction;

e) operational tactics and manoeuvres;

f) emergency communication;

g) leadership performance;

h) physical fitness; and

i) auxiliary modules (e.g. rescue in difficult terrain, response to biological/chemical threats etc.)

14.1.2 The core training curriculum should include initial and recurrent instruction. The scope of instruction should vary with the degree of intelligence of the trainees. In most cases the simpler this form of instruction is kept, the more successful it is likely to be. In no case should enthusiasm engendered by the interest value of the subject be allowed to carry the instruction beyond its practical application. Nevertheless, the officer responsible for the training programme must endeavour to maintain the interest and enthusiasm of the crew at all times. In certain respect this will not be too difficult. There are many factors affecting RFF procedures at an aircraft accident which may be anticipated, staged, and practised so that the officer has an opportunity of sustaining the interest indefinitely. Each new type of aircraft brings with it new problems which must be assessed and incorporated in the training programme. As certain routine aspects of training may become less interesting over a long period it is therefore essential that the officer ensure each crew member realizes the need for such training. For example, it is a fundamental practice in the RFF service that each crew member, when on duty, be satisfied that the equipment which may be used is serviceable. This particular aspect of a crew member's duty could deteriorate after a long period of comparative inaction unless that person is really convinced of the importance of this task.

14.1.3 The entire training programme must be designed to ensure that both personnel and equipment are at all times fully efficient. This represents a very high standard of achievement but anything less than full efficiency is unacceptable and may be dangerous both to those in need of aid and also to those who are seeking to give such aid. In addition, the training programme must also be designed to build cohesiveness between key functional units of a RFF team in order to deliver a consistent level of proficiency during emergencies. To ensure a high standard of operational readiness, RFF services should develop a competency audit framework to assess the effectiveness of RFF training at both individual and team levels.

14.2 FIRE DYNAMICS, TOXICITY AND FIRST AID

14.2.1 All RFF personnel should have a general knowledge of the cause of fire, the factors contributing to the spread of fire and the principles of fire extinction. Only when armed with this knowledge can they be expected to react effectively when confronted with a serious fire situation. It must be known, for instance, that certain types of fire require a cooling agent while others need a blanketing or smothering action. RFF training should also touch on the toxicity of thermal decomposition products. This will enable fire fighters to better understand the importance and limitations of their protective equipment. In doing so, fire fighters will avoid a false sense of security and take extra precautions when leading the occupants of the aircraft through a dangerous atmosphere. In addition, every member of the rescue team should, if at all possible, be trained and periodically recertified in basic medical first aid, as a minimum. The prime reason for this qualification is to ensure that casualties are well handled so as to avoid the infliction of additional suffering and/or injury in the removal of the occupants from a crashed aircraft.

14.3 EXTINGUISHING AGENTS AND FIREFIGHTING TECHNIQUES

14.3.1 It is essential that a thorough knowledge should be acquired of the agents employed. In particular, every opportunity should be taken to practice the application of agents on fires in order to understand by experience not only the virtues but also the limitations of each agent. Each occasion of a routine equipment test should be used for a training exercise in the proper handling of equipment and the correct application of the particular agent involved. The combination of routine test procedures with training periods will minimize the costs involved in the discharge of extinguishing agents.

14.3.2 To carry out fire suppression at different phases of combustion, RFF personnel should be well versed in three types of extinguishment. 1) Direct straight stream firefighting method using a straight stream or solid hose stream to deliver water directly onto the base of the fire. 2) Indirect firefighting method; used in situations where the temperature is increasing and it appears that the cabin or fire area is ready to flash over. Attack is made from a small fuselage openings such as slightly opened exits or openings made in cabin windows. Indirect method is based on the conversion of water spray into steam as it contacts the super-heated atmosphere. Firefighters direct the stream in short bursts of water at the ceiling to cool super-heated gases in the upper levels of the cabin or compartment. This method can prevent or delay flashover and allow the firefighters time to apply a direct stream to the base or seat of the fire. 3) 3-dimensional method is deployed in the event that the fire is fuel fed, as in the case of an engine fire. Firefighter one directs semi-fog at the fire while firefighter two discharges dry chemical or clean agent into the semi-fog stream starting at ground level and moving upward to the source of the fire. In cases of deep seated aircraft fires, penetrating nozzles could be used. Penetrating nozzles could be in the form of vehicle turrets (monitors) or handlines capable of injecting extinguishing agents that provide wide angle coverage.

14.4 HANDLING OF VEHICLES, VESSELS AND EQUIPMENT

14.4.1 All RFF personnel must be capable of handling their vehicles, vessels, and equipment, not only under drill-ground conditions, but also in rapidly changing circumstances. The aim must always be to ensure that every individual is so well versed in the handling of all types of vehicles, vessels, and equipment that, under emergency conditions, operation of these mission-critical resources will be automatic, leaving capacity to deal with unexpected scenarios. This can be accomplished in the initial stage of training by employing the snap “change-round” technique during standard drills, and later by training involving the use of two or more fire vehicles simultaneously. Particular attention should be paid to pump operations, high-reach extendable turrets, and other specialized rescue equipment. RFF crew should also be adequately trained in handling complex instrumental panels onboard vehicles and vessels. This form of training is, of course, a continuing commitment.

14.4.2 Possessing in-depth knowledge of all vehicles, vessels, and equipment is essential in order to ensure thorough maintenance which is essential to guarantee operational efficiency under all circumstances. It is important that every fire fighter be satisfied that any piece of equipment which may be used will work satisfactorily and, in the case of ancillary equipment, it is in its correct stowage position. The importance of correct stowage of small equipment to ensure that it can be instantly located cannot be over-stressed. Officers responsible for training are advised to hold periodic locker drills where individual crew members are required to produce a particular item immediately. All vehicles, vessels, and equipment must be regularly tested or inspected and records must be maintained of the circumstances and results of each test.

14.5 AIRFIELD LAYOUT AND AIRCRAFT CONSTRUCTION

14.5.1 A thorough knowledge of the airport and its immediate vicinity is essential. To counter the effects of complacency, it is recommended that vehicle operators practice mental mapping techniques to supplement routine on-site familiarization. The training programme should encompass those areas of operations dealing with:

a) thorough familiarization of the movement area so vehicle drivers can demonstrate their ability to:

1) select alternative routes to any point on the movement area when normal routes are blocked;

2) know the existence of ground which may become from time to time impassable in any part of the area to be covered by the service;

3) recognize landmarks which may be indistinctly seen;

4) operate vehicles over all types of terrain during all kinds of weather. The training programme may be conducted using vehicles other than the RFF vehicles provided they are radio controlled and have similar operating characteristics;

5) select the best routes to any point on the airport; and

6) use detailed grid maps as an aid in responding to an aircraft accident or incident; and

b) the use of guidance equipment when it is available. Normally air traffic control may be assistance in providing information on the location of the accident site and position of other aircraft or vehicles on the airport which may obstruct or impair vehicle movement.

14.5.2 The importance of this aspect of training cannot be over-emphasized. RFF personnel may be call upon to effect a rescue from an aircraft cabin in conditions of great stress working in an atmosphere heavily laden with smoke and fumes. If self-contained breathing apparatus is supplied, careful training in its use is essential. It is essential that every person have an intimate knowledge of all types of aircraft normally using the airport. Appendix 1 provides an electronic link to the websites of the various aircraft manufacturers. The websites contain diagrams that provide, *inter alia*, general information on principles of rescue and firefighting procedures as well as detailed information of concern to rescue and firefighting personnel on representative aircraft commonly used in the market. The knowledge cannot be acquired solely on a study of the diagrams. There is no substitute for a periodic inspection of the aircraft. Due to the complexity of modern aircraft and the variety of types in service, it is virtually impossible to train RFF personnel on all the important design features of each aircraft although they should become familiar with the types normally used at the airport. Priority training should be given to the largest passenger aircraft as it is likely to carry the highest number of occupants and incorporate unique features such as upper deck seating capacity. Information about the following design features is of special importance to RFF personnel to ensure effective use of their equipment:

a) location and operation of normal and emergency exits;

b) seating configuration;

c) type of fuel and location(s) of fuel tank(s);

d) location of batteries and isolation switches; and

e) position of break-in points on the aircraft.

14.5.3 As far as is practicable, RFF personnel should be allowed to operate the emergency exits and should certainly be fully conversant with the method of opening all the main doors. Generally speaking, the majority of the doors open forward. Some containing stairs will swing downwards and, on some wide-bodied aircraft, the doors retract into the ceiling area. Most large aircraft are fitted with inflatable emergency evacuation slides affixed to cabin doors and large emergency exit windows. If the emergency evacuation slides are not automatically disengaged, or if the system equipment malfunctions, the slides may become inflated when the exit is opened. The doors of large aircraft are normally operated from the inside. There are occasions, however, when responding RFF personnel may have to open doors from the outside of the aircraft to gain access to the cabin interior. In view of the variables noted above, the opening of the normal and emergency exits may be hazardous for the airport fire fighter if the appropriate cautionary measures are not taken. For example, it is hazardous to open armed aircraft doors if the fire fighter is standing on a ladder or to rest the ladder against the door to be opened.

14.5.4 Aircraft operators and flight crew members should be requested to co-operate to the fullest extent in arranging inspection by RFF personnel the different types of aircraft using the airport. An elementary knowledge of aircraft construction is highly desirable since such knowledge is invaluable if, as a last resort, forcible entry is necessary. The co-operation of the appropriate staff of the airline operators should be sought on this aspect of training.

14.5.5 All aircraft carry small portable fire extinguishers that could be of use to rescuers. Extinguishers containing carbon dioxide, a halon agent or water are usually located on the flight deck, in galleys and at other points within the cabin. All extinguisher positions are indicated and the extinguisher body normally carries a label stating the type of fire for which its contents are suitable. Water and other beverages found in the buffet compartment provide an additional source of water for extinguishment purposes. It should be emphasized that these extinguishing agents are of secondary value and should not be relied on.

14.6 OPERATIONAL TACTICS AND MANOEUVRES

14.6.1 When personnel are well versed in the handling of firefighting equipment they should receive training in operational tactics to be adopted at aircraft fires. This training is a continuing commitment and must be absorbed to the point where compliance with the initial action called for is instinctive, in the same sense that hose-running to a well-trained regular fire fighter is automatic and will therefore, follow even when working under stress. Only when this is achieved will the officer-in-charge be in a position to assume complete control of the situation. Operational tactics training is designed to deploy personnel and equipment to advantage in order to establish conditions in which aircraft occupants may be rescued from an aircraft which is involved in, or liable to become involved in, fire. The objective is to isolate the fuselage from the fire, cool the fuselage, establish and maintain an escape route and achieve the degree of fire control necessary to permit rescue operations to proceed. This is fundamental and must be stressed in the training programme. The service to be provided is primarily a life saving organization, one, however, that must be trained in firefighting because aircraft involved in a serious accident are frequently involved in fire. The firefighting operations must be directed to those measures which are necessary to permit rescue to be carried out until all the occupants of the aircraft are accounted for. This includes precautionary measures at those incidents where no fire has broken out. When the life saving commitment has been met it is necessary, of course, to utilize all available resources to secure protection of property.

14.6.2 The main attack on the fire should usually be by means of mass application of foam in an endeavour to achieve maximum cooling and the rapid suppression of the fire. Since, however, foam, like every other agent, has limitations, a suitable back-up agent must be available to deal with those pockets of fire which are inaccessible to direct foam application. This will generally be provided in the form of dry chemical powder. The use of these should be confined to running liquid fuel fires, fires in enclosed spaces such as wing voids, or for dealing with a special fire such as a fire in an engine nacelle or undercarriage well.

14.6.3 Points which should be covered in the operational tactics training programme are described below.

14.6.4 *The approach.* Equipment should approach the accident site by way of the fastest route in order to reach the site in the shortest possible time. This is quite frequently not the shortest route because generally speaking it is preferable where possible to travel on a made-up surface than to approach over rough ground or grassland. The essence is to ensure that RFF vehicles get there and are not subjected to unnecessary hazards en route. When nearing the scene of the accident a careful watch must be maintained for occupants who may be dashing away from the aircraft or who may have been flung clear and are lying injured in the approaches. This applies particularly at night and calls for competent use of spot or search lights.

14.6.5 *Positioning of equipment.* The positioning of equipment both from the airport and from any supporting local fire department is important in many respects and regard should be given to several factors. Correct positioning of equipment must permit the equipment operator an over-all view of the fire area. The equipment must not be placed in a position of hazard due to fuel spills or ground slope or wind direction. It must not be positioned too close to the fire or to other equipment and thus restrict working space (this applies particularly to foam tenders and their attendant auxiliary water tenders). Other factors which should be taken into account are the location of aircraft occupants relative to the fire, impact of wind, fire, personnel and fuel tanks and location of emergency exits.

14.6.6 In certain circumstances it may be advantageous to leave the equipment on hard standing, though this may mean an additional length of fire hose. More time can be lost attempting to reach a closer position to the fire by negotiating rough ground than would be taken to run an additional length of fire hose. Moreover, if parked on hard standing the equipment is capable of being moved rapidly if conditions demand. Aircraft accidents frequently occur in circumstances where equipment cannot be positioned in the immediate vicinity. Consequently it is recommended that all firefighting and rescue equipment should be designed so that it can be brought to bear at some distance from the parent equipment. Operational tactics training can do much to reduce the problems of positioning equipment, can be conducted at very little cost and should be performed frequently to develop acceptable practices. For this particular phase of operational tactics training it is not always necessary to produce water of foam; it is an example of how “dry drills” can help to raise efficiency standards.

14.6.7 In order to achieve the main initial objective of isolating and cooling the fuselage and to safeguard the escape route it is evident that the positioning of foam streams is of the utmost importance. The number of streams available will vary with the type and the scope of the equipment provided.

14.6.8 Foam streams should be positioned as close as possible to the fuselage, the initial discharge being directed along the line of the fuselage and then directed to drive the fire outwards. When selecting the ideal position for the stream it should always be remembered that the wind has considerable influence upon the rate of fire and heat travel. The position should be chosen with this in mind, thus utilizing the wind, wherever possible, to assist in the main objective. Except in exceptional circumstances, foam streams should not be directed long the line of the wind towards the fuselage as this may tend to flush free fuel into the danger area. Similarly, care must be exercised to avoid the possibility of one stream disturbing the foam blanket laid down by another stream.

14.6.9 There are two basic methods of applying foam. One is to use a long straight stream to allow fall on the desired area. The other is to apply a diffused stream at close range. Often foam can be applied to a fire area by deflecting it from another surface such as the contour of the fuselage or main plane. Whenever foam, dry chemical powder, or other complimentary agent equipment is being subjected to a periodic routine check the opportunity should be taken to train emergency crew members in the methods of application. It is important that this be carried out on a fire so that each person will obtain an assessment of the value as well as the limitations, of each agent so applied, and be familiar with the heat conditions that will be experienced. These drills should be carried out at intervals of not more than one month. Increasingly, firefighting equipment is designed to provide high output through monitor/turrets to deal with accidents involving the largest aircraft currently in service. Monitor/turret operators must be highly skilled in the application of foam to be able to avoid wastage, through misdirection of aim, to know when to change from straight stream to diffused stream, and to readily appreciate how to avoid damage or injury to others by the potential force of the foam stream.

14.6.10 It is vital that the RFF fleet manoeuvres in a coordinated formation and concentrate foam streams at areas where large numbers of passengers may be trapped. With precision manoeuvres, continuous mass application of foam will be met with least wastage. For this reason, officers responsible for training should decide which particular pattern of equipment positioning is best suited to their available resources and then take steps to train crew members in its positioning and layout. At a fire there is little time for individual briefing of crew members and the initial layout may well be adjusted to cope with the existing circumstances, but it is necessary for the crew members to know exactly what their first action should be well in advance through a predetermined tactical plan as dictated by the circumstances. It should always be remembered that this layout of equipment should be standard practice at an aircraft accident even when fire has not broken out and that at least one monitor/turret should be staffed and in readiness to go into instant action should the occasion arise.

14.6.11 The main objective of the firefighting activity must be to extinguish the fire and secure it against reignition in the shortest possible time. It is also pertinent that RFF crew maintain a good sense of situational awareness at all times during an emergency. This demands skill, teamwork and understanding by all those involved. The first responding fire vehicle may carry agents which can achieve some rapid knockdown of an area of the fire, but this will in most cases require the early support of any other vehicle to continue the effort and secure the entire area against reignition and to promote the necessary cooling effect in the vicinity of the passenger compartment. The entire effort must be concentrated on this area since the misapplication of foam or other agents is wasteful and could mean the difference between the success or failure of the operation. Where foam production through a monitor/turret is undertaken with the vehicle in motion (i.e. pump and roll mode), considerable skill is required to achieve maximum effect.

14.6.12 Great care must be exercised by monitor operators in the application of foam in straight streams in the vicinity of escape slides deployed from the aircraft. RFF personnel must also anticipate that evacuating occupants may become distressed and disoriented by the presence of dry chemical powder clouds or by the impact of foam streams and should therefore conduct their operations so as to minimize these effects.

14.6.13 The training programme should provide instruction in search procedures, not only in enclosed spaces of an aircraft, but also for procedures for systematic searching of the area in the immediate vicinity of an aircraft accident and also in the path of the aircraft. As a broad principle, it should be taught that the persons involved in a fire are most frequently found near an exit, i.e. doors and windows, or will have sought shelter, however inadequate in lavatories and lockers, etc. Rescue is always best effected by way of a normal channel, if available. For example, it is easier to carry a person through a doorway than to manipulate that person through a window. The main cabin door of an aircraft should always be attempted first. Should the door be jammed, it will usually be found quicker to force it by applying leverage at the right spot than to achieve entry and rescue through another form of opening. Success in this form of operation requires a full knowledge of the locking mechanism and direction of travel of the door concerned. Only when everything else has failed should forcible entry be attempted. External markings are now provided on many aircraft showing suitable points at which entry can be made.

14.6.14 Pressurized cabins will offer tough resistance to penetration by forcible entry tools, although entry can be made by a person well trained in the use of such tools and possessing a working knowledge of aircraft construction. The practice of providing power-operated saws and other similar forms of forcible entry tools on all airports normally handling this type of traffic has increased. All operational staff should be trained in rescue procedures. The working space inside a cabin is somewhat restricted and it will generally be found advisable to limit the number of rescuers working inside the aircraft and to work on a chain principle. Where possible, the airport emergency plan should provide for the availability to staff other than RFF personnel, for the handling of casualties from the moment they are removed from the aircraft. All rescue staff should be trained in lifting and carrying casualties, and other forms of rescue.

14.7 EMERGENCY COMMUNICATION

14.7.1 Emergency communication refers to the information flow between various responding agencies during an emergency. Accurate and relevant information provides the RFF crew with shared real-time knowledge. This in turn empowers RFF teams to plan or initiate rescue efforts in an integrated manner. To ensure swift and accurate transmission of information, it is stressed that RFF staff be adequately trained in operating the primary and secondary communication systems installed at the fire stations and fire vehicles / vessels. Equally important, RFF personnel should learn to converse succinctly using appropriate telephony language. RFF personnel should also be trained to communicate with the flight crew through internationally accepted ground-to-aircraft hand signals.

14.8 LEADERSHIP PERFORMANCE

14.8.1 The leadership qualities exhibited by an RFF team commander often determines the outcome in an emergency response. The commander leads and motivates his staff in achieving peak performance under challenging operating environment. In this regard, a robust leadership training program should be instituted to better prepare RFF leaders in assuming command during crises.

14.9 PHYSICAL FITNESS

14.9.1 During protracted rescue operations, the ability of RFF personnel to perform strenuous activities over an extended period of time influences the overall operational effectiveness. Therefore fire fighters must be aerobically and anaerobically fit to withstand the rigours of a variety of operations. Clearly, physical fitness training requirements should be designed to commensurate with the equivalent fitness intensity generated in the performance of RFF operations which include the use of breathing apparatus, hand lines, ladders, heavy equipment and other associated rescue operations such as casualty handling.

14.10 AUXILIARY MODULES

14.10.1 Depending on the aerodrome operating environment, it may be necessary for RFF crew to be trained in dealing with difficult environments such as water rescue and handling biological / chemical threats. While RFF services should continue to strengthen their core capabilities, it is worthwhile to explore and train beyond the immediate operational responsibilities to deal with unexpected contingencies at or in the vicinity of the airport.

Chapter 15

AIRCRAFT FUELLING[1] PRACTICES

15.1 INTRODUCTION

15.1.1 The airport authority, the aircraft operator and the fuel supplier each has responsibilities in respect of the safety measures to be taken during fuelling operations. Some guidance on these safety measures is given below. It is important to note that this material is not intended to replace fuel supplier operator procedures which are usually developed to meet requirements imposed by special equipment, national regulations, etc. The material includes the following subjects:

a) general precautionary measures to be taken during fuelling operations; and

b) additional precautionary measures to be taken when passengers remain on board or embark/disembark during refuelling operations.

Note.- Further information on internationally accepted petroleum and aviation industry fuel practices, including fuel quality control and operations, can be found in Doc 9977, Manual on Civil Aviation Jet Fuel Supply.

15.2 GENERAL PRECAUTIONARY MEASURES TO BE TAKEN DURING AIRCRAFT

FUELLING OPERATIONS

The following general precautionary measures should be taken during aircraft fuelling operations:

a) aircraft fuelling operations should be done outdoors; and

b) bonding and/or grounding, as appropriate, should be done in accordance with 16.4;

c) aircraft fuelling vehicles should be positioned so that:
   1) accessibility to aircraft by RFF vehicles is not interrupted;
   2) a cleared path is maintained to permit rapid removal of fuelling vehicles from an aircraft in an emergency;
   3) they do not obstruct evacuation from occupied portions of the aircraft in the event of a fire; and
   4) the vehicle engines are not under the wing;

d) all vehicles performing aircraft servicing functions other than fuel servicing (e.g. baggage trucks, etc.) should not be driven or be parked under aircraft wings while fuelling is in progress;

[1] Throughout this chapter the term fuelling requirements encompasses refueling and defueling.

e) open flames and lighted open flame devices should be prohibited on the apron and in other locations within 15 m of any aircraft fuelling operation. Included in the category of open flames and lighted open flame devices are the following:
   1) lighted cigarettes, cigars, pipes;
   2) exposed flame heaters;
   3) welding or cutting torches, etc.; and
   4) flare pots or other open flame lights;

f) cigarette lighters or matches should not be carried or used by anyone while engaged in aircraft fuelling operations;

g) extreme caution should be used when fuelling during lightning and electrical storms. The fuelling operations should be suspended during severe lightning disturbances in the immediate vicinity of the airport;

h) when any part of an aircraft undercarriage is abnormally heated, the airport RFF service should be called and fuelling should not take place until the heat has dissipated; and

i) portable fire extinguishing equipment suitable for at least initial intervention in the event of a fuel fire and personnel trained in its use shall be readily available and there shall be a means of quickly summoning the rescue and fire-fighting service in the event of a fire or major fuel spill. It should be ensured by regular inspection and maintenance that this equipment is maintained in a fully serviceable condition.

15.3 ADDITIONAL PRECAUTIONARYMEASURES TO BE TAKEN WHEN PASSENGERS REMAIN ON BOARD OR EMBARK/DISEMBARK DURING REFUELLING OPERATIONS

15.3.1 Because of the importance of reducing transit times and for security reasons, some States allow passengers to remain on board during refuelling operations while others allow passengers to embark and disembark. However, an aircraft shall not be refuelled when passengers are embarking, on board or disembarking unless it is properly staffed by qualified personnel ready to initiate and direct an evacuation of the aeroplane by the most practical and expeditious means available.

15.3.2 When aircraft refueling operations take place while passengers are embarking, on board of disembarking, ground equipment shall be positioned so as to allow:

   a) the use of a sufficient number of exits for expeditious evacuation; and
   b) a ready escape route from each of the exits to be used in an emergency.

15.3.2 The following additional precautions must be observed during refuelling operations while passengers remain on board or embark/disembark.

a) passengers should be warned that refuelling will take place and that they must not smoke, operate switches or otherwise produce sources of ignition;

b) the illuminated “No smoking” signs and exit lighting should be switched on;

c) aircraft equipped with integral stairs should have them deployed, or if aircraft stairways are used, these should be positioned at each of the main doors normally used for passenger embarkation or disembarkation which should be open or ajar and free from obstruction.

d) if, during refuelling, the presence of fuel vapour is detected in the aircraft interior, or any other hazard arises, refuelling and all cleaning activities using electrical equipment within the aircraft should be stopped until conditions permit resumption; and

e) where passengers are embarking or disembarking during refuelling their route should avoid areas where fuel vapours are likely to be present and this movement should be under the supervision of a responsible person.

Chapter 16

AVAILABILITY OF RFF INFORMATION

16.1 GENERAL

16.1.1 In accordance with Annex 14 Volume 1, 2.11 there is a need for the airport or appropriate authorities responsible for RFF services to make available to the appropriate air traffic services units and aeronautical information services units information concerning the level of protection normally provided at the airport for aircraft RFF purposes. Changes in the level of protection should also be reported.

16.1.2 The level of protection normally available at an airport should be expressed in terms of the category of the RFF services as described in Table 2-3 of this manual, in accordance with the types and amounts of extinguishing agents normally available at the airport.

16.1.3 Changes in the level of protection normally available at the airport for RFF (RFF category) should be notified to the appropriate air traffic services units and aeronautical information units to enable those units to provide the necessary information to aircraft using that particular airport. When such a change has been identified the above units should be advised accordingly and as soon as practical to do so. A change in RFF category may be the result of, *inter alia*, unavailability of extinguishing agents, unavailability of equipment to deliver the agents or unavailability of enough personnel to operate the equipment.

16.1.4 Notification of changes to RFF category should be initiated even for short durations if it is known or likely to affect aircraft movements at the aerodrome.

16.1.5 Notification to industry should also include the hours of operations for a RFF service as well as any special services or resources, such as the availability of a water rescue service, a dedicated emergency radio frequency or similar.

The CVR transcript below is for the relevant portion only.
ATC – includes all ATC services such as approach radar and Tower frequencies
A/C – is VT-JIL. Where VIL is used in the transcript it refers to VT-JIL
INT – is inter cockpit communication (between the pilots and pilot to Passenger)
PIC – is the Pilot in command
F/O – is the First Officer

VT-JIL CVR Transcript (Relevant Portion)

	Transmission		
UTC	**From**	**To**	**Transcript**
15:17:05	ATC	A/C	VIL go ahead with your endurance at present… Foaming is going on
	PIC	INT	Kya maang raha hai who?
	F/O	INT	Endurance pooch raha hai……one hour ki hai
	ATC	A/C	Can you wait another 15 minutes for completion of foaming?
	F/O	ATC	Affirm Sir, We can wait
15:17:30	ATC	A/C	VIL roger..Turn left heading 180
	F/O	ATC	Left Heading 180 VIL
15:17:59	PIC	INT	Inko bata diya ki kaise karna hai?
	F/O	INT	Bata diya Sir….
15:18:10	PIC	INT	3800 hain na?
	F/O	INT	3800 Sir...
15:18:20	PIC	INT	15 bol raha hai ki kitna bol raha hai?
	F/O	INT	15 Sir ……. 15 minutes
15:18:35	ATC	A/C	VIL turn left heading 360
	F/O	ATC	Left heading 360 VIL
	F/O	INT	Accha Sir….Jab landing gear up hoga aur hum low jayenge toh aircraft "Terrain Terrain " Chillayega……. So we don't have to distract…. Yeh terrain terrain bolega
15:19:00	ATC	A/C	VIL we are coordinating with Fire services as and when foaming is complete we will immediately put you on localiser
	F/O	ATC	Affirm Sir…VIL
15:19:52	ATC	A/C	VIL turn left heading 340
15:20:21	PIC	INT	Altitude fail hogay tumhara…..nazar aaya kya ho raha hai?
	F/O	INT	Nahiaara Sir
	F/O	INT	Hum apni flight pe concentrate karte hain Sir
	PIC	INT	Arrey…As soon as we touch down …fuel shut down and immediately Evacuate. Evacuate. Evacuate
15:20:50	ATC	A/C	VIL turn left heading 300
	F/O	ATC	Left heading 300 VIL
15:22:10	ATC	A/C	VIL turn left heading 180
15:22:21	PIC	INT	RT is with you hai na
	F/O	INT	Yes Sir….RT is with me
15:22:25	PIC	INT	Final approach course set 270
	F/O	INT	Final approach course is set for me and set for you as well
	PIC	INT	When we are going for landing we will be doing ILS approach ……Ekbaar

			ATIS le lo
	ATIS	A/C	ATIS 15:15 obtained
15:23:30	ATC	A/C	VIL turn left heading 360
	F/O	ATC	Left heading 360 VIL
15:24:10	PIC	INT	ATIS monitored now
	F/O	INT	Yes Sir…..QNH 1009 set my side
	F/O	INT	Ek bar yeh lights check kare Sir? Fuel warning ki light nahi aa rahi
	PIC	INT	Now we can go for landing yaar.. Bol do
	F/O	INT	Nahi Sir….Abhi runway ki foaming kar rahe hai…They are foaming the runway
	PIC	INT	usne 10 minute kaha th yeh kitne minute kaha
	F/O	INT	15 minutes ….One Five Minutes
15:25:34	ATC	A/C	VIL turn left heading 180
	F/O	ATC	Left heading 180 VIL
15:25:41	PIC	INT	Bol do we are ready now…… 400..400 reh gaye haina
	F/O	INT	800 pound reh gaya hamare paas
	F/O	INT	500 pound ki consumption hai…to ek ghante ki to hai hamare paasabh
15:26:41	F/O	INT	and they have advised us to ….centre line jo hai uspe light lageen hai uspe… woh light hamare jahaaz se rub kar ke friction create karegi….toh who light avoid karni hai ….so we have to keep slightly left or right from the lights
15:27:06	F/O	INT	Speed maintaining 150 and altitude 3800 all operations normal and monitoring all instruments
15:27:15	ATC	A/C	VIL turn left heading 360
	F/O	ATC	Left heading 360
	PIC	INT	Time kya hogaya?...
	F/O	INT	9 bajne mein 3 - 4 minute hain Sir abhi
	PIC	INT	30 minutes hogay
	F/O	INT	haanji Sir
15:29:05	ATC	A/C	VIL turn left heading 180
	F/O	ATC	Left heading 180 VIL
	F/O	ATC	And how much more time you require VIL?
	ATC	A/C	Standby Sir…Coordinating….13 miles east of Mumbai…..Standby Sir..Coordinating
	PIC	INT	Kya heading batayi …180?
	F/O	INT	180 Sir
	ATC	A/C	VIL descend to 2900 feet
	F/O	ATC	2900 feet VIL
15:30:25	F/O	INT	Descend to 2900'……right now it is 3700'
15:30:43	PIC	INT	On Track
	ATC	A/C	VIL turn left heading 360
	F/O	ATC	Left heading 360
	PIC	INT	2900 descend karna hai na

	F/O	INT	Sir 2900 Sir
	ATC	A/C	VIL continue turn left heading 300
	F/O	ATC	continue left 300 VIL
15:31:26	ATC	A/C	And foaming will be complete in another 2 to 3 minutes
	F/O	ATC	Roger VIL
	F/O	INT	Approaching 2900' Sir
	ATC	A/C	VIL continue left heading 300 intercept localiser runway 27
	F/O	ATC	continue left 300 to intercept localiser VIL
15:32:11	ATC	A/C	VIL cleared for ILS approach runway 27
	F/O	ATC	Cleared for ILS approach Runway 27 VIL
	PIC	INT	Kya hua
	F/O	INT	Approach mode daba de Sir ek minute
	PIC	INT	Haan daba do fir
	F/O	INT	Daaba diya
	PIC	INT	On localiser bol dijiye
	F/O	INT	Localiser 27 Sir
15:33:01	F/O	ATC	On localiser 27 VIL
	ATC	A/C	VIL roger position 12 miles from touchdown
15:33:17	F/O	INT	Runway in sight Sir
	PIC	INT	Visual…confirm kar lo
	F/O	INT	We will take flaps Sir? We don't have to….can we switch on the lights sir?...Taxi light so they can locate us
	PIC	INT	Jab undercarriage hi bahar nahi ayega to kaise….
	F/O	INT	Haan Sir
15:34:09	F/O	INT	On Glide Sir
	PIC	INT	A/C Bandh Kar Dijiye
	F/O	INT	A/C Off
15:34:23	ATC	A/C	VIL confirm established Sir?
	PIC	INT	Ya
			Affirm Sir Established Runway 27 VIL
15:34:30	ATC	A/C	VIL 8 miles from touchdown…contact tower 118.1
			118.1 VIL
	INT	INT	Landing Gear Horn sounds and continues
	F/O	ATC	Mumbai VT-JIL
	ATC	A/C	VT-JIL namashkar continue approach runway 27 winds 210 degrees 04 knots
	F/O	ATC	Continue approach for runway 27 VIL
15:35:04	ATC	A/C	VIL winds 210 degrees 03 Knots runway 27 cleared to land
	F/O	ATC	Cleared to land runway 27 VIL
	PIC	INT	Balance karne ka kaun sahai
	F/O	INT	Koi nahi Sir …chodo Samne dekhte hai….Speed …Speed… On Glide…and we are 7 miles to go..

15:35:44	F/O	INT	Sir Speed…Check speed
	PIC	INT	I am disengaging
	F/O	INT	Affirm Sir …Sir resetting pitch trim
15:36:01	F/O	INT	Speed 110 Sir
	PIC	INT	Auto feather off…..Auto Ignition off
	F/O	INT	Nahi Sir Auto Ignition abhi nahi Sir….Once we are sure of runway….abhi nahi abhi nahi Sir…Abhi kuch nahi….Once we are sure of runway..usse pehle kuch nahi….Then Props Feather
	PIC	INT	Fuel is now….
	F/O	INT	And we will try to maintain centreline
15:36:51	F/O	INT	Speed 110 Sir
	F/O	INT	Sir Props forward
	PIC	INT	Usse kuch hoga nahin na
15:37:27	F/O	INT	Sir you maintain the centreline …I will switch of the….
	PIC	INT	Main karta hoon
	F/O	INT	Speed 110 and we are 1000' above ground in my radio altimeter
15:38:20	INT	INT	Auto call "Too Low Gear" "Too Low Gear"
	F/O	INT	Speed 100 Sir…Speed badha lo Sir
15:38:46	F/O		Speed 100…..95 Speed
	INT	INT	200
	PIC	INT	Cut kar do
	F/O	INT	Cut the Power….Fuel cut
	PIC	INT	Yaya
	F/O	INT	Fuel cut Sir
15:39:18	INT	INT	Contact sound
	F/O	INT	Props Fully feathered
15:39:33	**End of recording**		

CSIR-NAL Report No: MSD-FA-1688-09-2021

Investigation into Accident to Beechcraft King Air C-90A Aircraft VT-JIL

Submitted to

AAIB, Ministry of Civil Aviation, Government of India

Submitted by

Failure Analysis & Accident Investigation Group
Council of Scientific and Industrial Research (CSIR)
Materials Science Division
National Aerospace Laboratories
Bangalore 560 017, INDIA

September 2021

Information

Subject:…………………..	Investigation into accident to Beechcraft King Air C-90A aircraft VT-JIL
Submission Date:…….	24 June 2021
Issue Date:…………….	21 September 2021
Customer:………………	AAIB, Ministry of Civil Aviation, Government of India
Reference(s):…………	Amit Kumar, Safety Investigation Officer, Aircraft Accident Investigation Bureau, Ministry of Civil Aviation, Government of India, Safdarjung Airport, New Delhi 110003; ref: email dated 07 June 2021
Total No. of pages:…	Thirty six (36)
Investigating Team:..	K. Raghavendra, M. Madan, V. Venkatesh, M. Sujata, S.K. Bhaumik
Approved By: …………	S.K. Bhaumik SKBhaumik
Keywords: ………………	AAIB; MoCA-India; Beechcraft King Air C-90A aircraft VT-JIL; MLG wheel detachment; bearing failure

Executive Summary

The Beechcraft King Air C-90A aircraft VT-JIL met with an accident on 06 May 2021. The aircraft was on an ambulance flight from Nagpur to Mumbai. The aircraft made a belly landing at Mumbai airport as its port main landing gear (MLG) wheel got detached during take-off roll and fell off at Nagpur. The detached port MLG wheel hub assembly and the removed port MLG strut fitted with axle and other parts of the assembly were submitted to CSIR-National Aerospace Laboratories, Bangalore for analysis and for establishing the cause for detachment of the wheel from the axle. The findings of the laboratory investigation are presented in this report.

Examination of the damaged components of the port MLG axle assembly confirmed that the primary cause for detachment of the wheel from the axle was the failure in the outer bearing. Investigation revealed that the failure occurred over a period of time wherein there was continuous deterioration in the bearing and frictional heat

generation. At the final stage of failure, the heat generation was so much so that the wheel lock assembly comprising lock-nut, washer and bearing cone got fused into a single body. During the last take-off roll at Nagpur, there was seizure in the bearing and the whole lock assembly along with the bearing cone rotated on the axle in the direction of the wheel rotation. Concurrently, the bearing cup rotated in the wheel hub bore and got dislodged from its position. This allowed the wheel to move axially inboard while the aircraft was on take-off roll, and eventually, the wheel came off the axle when the aircraft took-off. The evidences of failure initiation on the available parts of the bearing were completely destroyed due to excessive heat generation and severity of material damage within the bearing.

Laboratory examination (non-destructive) carried out on the bearings of the starboard axle assembly showed presence of widespread pitting and spalling on the rollers' surfaces. This indicates that the bearings of the starboard axle assembly have reached the limits of their useful life under the prevailing operating conditions. This means that bearings of starboard MLG axle would also have failed anytime if continued in service. Therefore, conjecture can be drawn that probably, similar deterioration of the rolling surfaces had occurred in the outer bearing of the port axle as well, prior to the catastrophic failure.

Laboratory studies showed that the rotor plates of the brake assembly on port axle have fractured by fatigue mechanism. It appears that during the progression of failure in the outer bearing, there was concurrent misalignment in the wheel assembly. This appears to have resulted in obstruction in the movement of the rotor plates leading to generation of fatigue cracks. Hence, the fatigue fracture of the rotor plates of the brake assembly is consequential and secondary in nature.

1.0. The Accident

The Beechcraft King Air C-90A aircraft VT-JIL operated by M/s Jet Serve Aviation Pvt. Ltd. met with an accident on 06 May 2021. The aircraft was on an ambulance flight from Nagpur to Mumbai. The aircraft made a belly landing at Mumbai airport as its port main landing gear (MLG) wheel got detached during take-off roll and fell off at Nagpur.

It is reported that upon confirmation of missing port MLG wheel, crew decided to carry out belly landing and burnt extra fuel to make the aircraft lighter. In the meanwhile, foam carpeting was carried out at Mumbai airport on Pilot's instruction to minimize the possibilities of fire. The aircraft landed on its belly with all landing gears in retracted position. After touchdown, the aircraft dragged on the runway for approximately 387 m prior to coming to halt. The aircraft belly, propellers and lower portion of nacelle suffered damages due to impact and friction during landing (refer Fig.1).

Figure 1: Beechcraft King Air C-90A aircraft VT-JIL after belly landing at Chatrapati Shivaji Maharaja International Airport (CSMIA), Mumbai *(Photo: AAIB, MoCA)*

2.0. Eye-witness Account

The Beechcraft King Air C-90A aircraft VT-JIL took off from Nagpur airport after refueling. According to eye-witness account of CISF personnel on duty, at the moment of take-off of the aircraft, the port MLG wheel got detached and the wheel went rolling at least half a kilometer ahead, towards the left of the runway before coming to a halt. The aircraft, however, took off unaffected. The incident was immediately reported to airport authorities.

3.0. Identification of Failure

The detached port MLG wheel hub assembly and outer bearing cup (retrieved from Nagpur airport), and port MLG strut fitted with axle and other parts of the assembly (removed from the aircraft) were submitted to CSIR-National Aerospace Laboratories, Bangalore for analysis and for establishing the cause for the detachment of wheel from the axle (refer Fig.2).

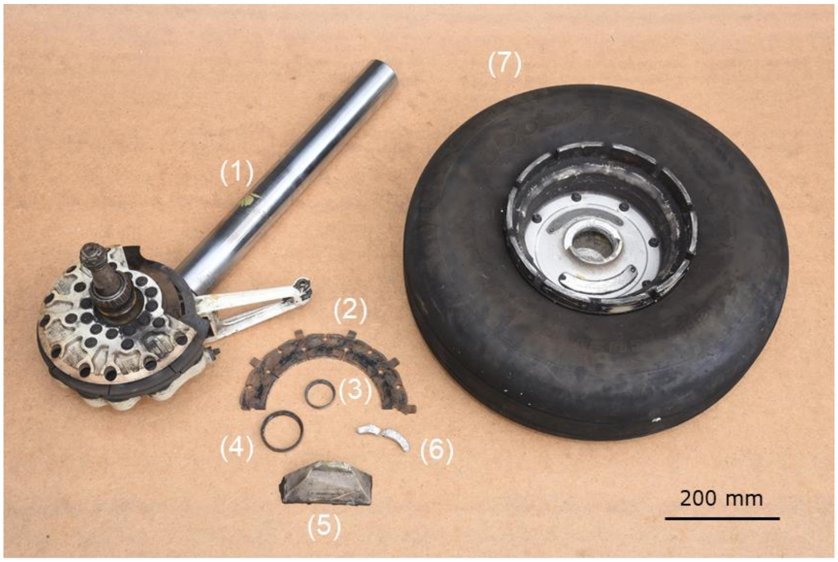


Figure 2: (1) Port MLG strut with axle assembly, (2) broken rotor plate of brake assembly, (3) cup-outer bearing, (4) cup-inner bearing, (5) balancing weight, (6) fractured part of wheel hub bore, (7) wheel

3.1. Damages to port MLG

3.1.1. Assembly on the axle of port MLG

Examination revealed that all parts/components of the wheel hub assembly on the axle of the port MLG were in order and as per the IPC of the OEM (refer Fig.3).

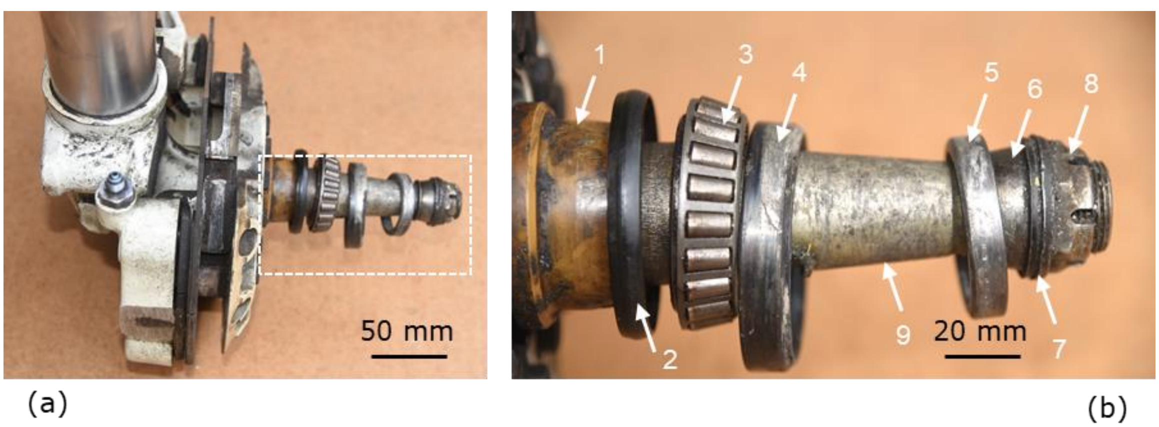


Figure 3: (a) Axle assembly, and (b) magnified view of the region marked in (a); (1) retainer, (2) seal, (3) inner bearing cone assembly, (4) inner bearing cup, (5) outer bearing cup, (6) outer bearing cone, (7) washer, (8) nut, (9) axle

3.1.2. Wheel hub assembly

Figure 4(a) shows inboard surface of the detached wheel. There were no damages to the inboard surface of the wheel and the dust cap was found to be in position. The tyre was found to be in good condition without any damage (refer Fig.4(b)). The face of the drive flange (slotted) of the wheel hub was found to have rubbed with the rotor/stator plates of the brake assembly during movement of the wheel inboard. The wheel hub assembly was dis-assembled for further examination (refer Fig.5).

Figure 6(a) shows the bore on the outer surface of the half hub at the inner bearing location. There was loss of material from about half of the bore circumference by fracture. Gross fractographic features indicated that the fracture occurred under impact load. This was confirmed through fractography study wherein the fracture surface showed presence of intergranular fracture features typical of overload failure under impact in cast Mg-alloys used for wheel hub applications (refer Fig.7). Figure 8(a) shows the bore on the inner surface of the half hub. Outward flow of material from the bore can be seen. The bore surface was found to have deformed with formation of circular groove (refer Fig.6(b) and 8(b)).

Figure 9(a) shows the bore on the outer surface of the half hub at the outer bearing location. No distress was observed on this face of the bore. The circular marks seen in Fig.10(a) occurred when the half hub inner surface rotated in contact with the lock-nut assembly while the wheel was moving out of the axle. The bearing bore surface was found severely damaged with material flow and formation of deep circular groove (refer Fig.9(b) and 10(b)).

Figure 11(a) shows the dust cap in dis-assembled condition. The cap did not have any damage except for circumferential rubbing marks on the edge (refer Fig.11(b)). The rubbing of the dust cap occurred with lock nut assembly on the axle.

Metallurgical examination of the material of construction showed that the wheel hub was made of a cast Mg-alloy of nominal composition Mg-8.3Al-0.8Zn (refer Fig.12).

(a) (b)

Figure 4: (a) Inboard surface of the wheel, and (b) tyre showing no damages

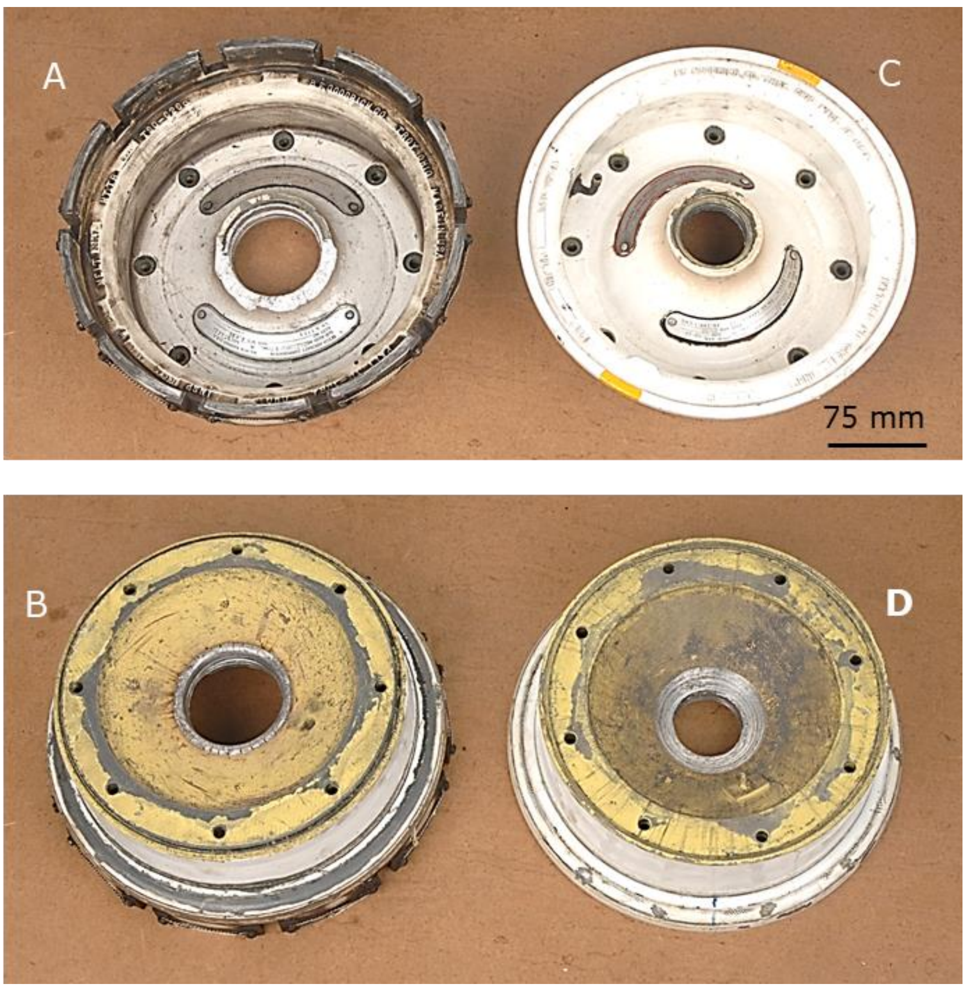
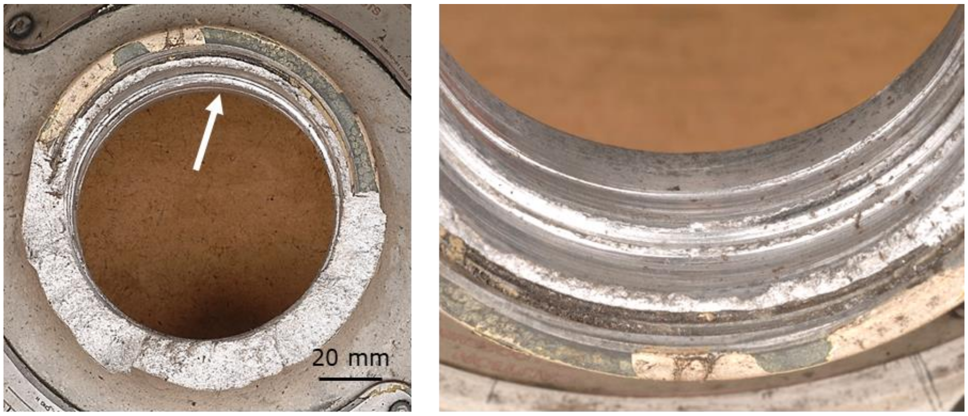
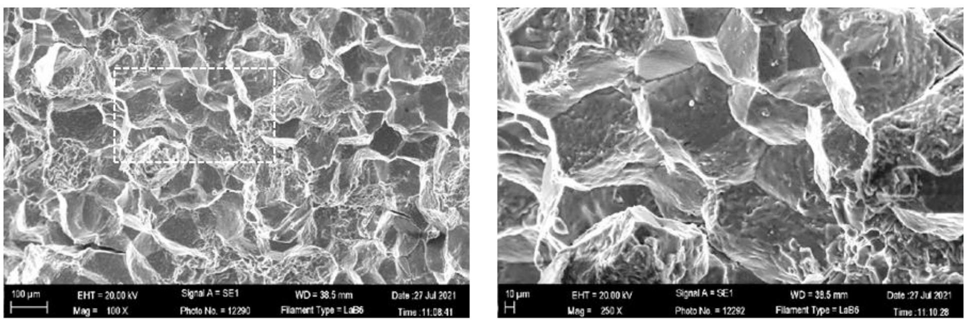


Figure 5: Two views of dis-assembled wheel hub assembly



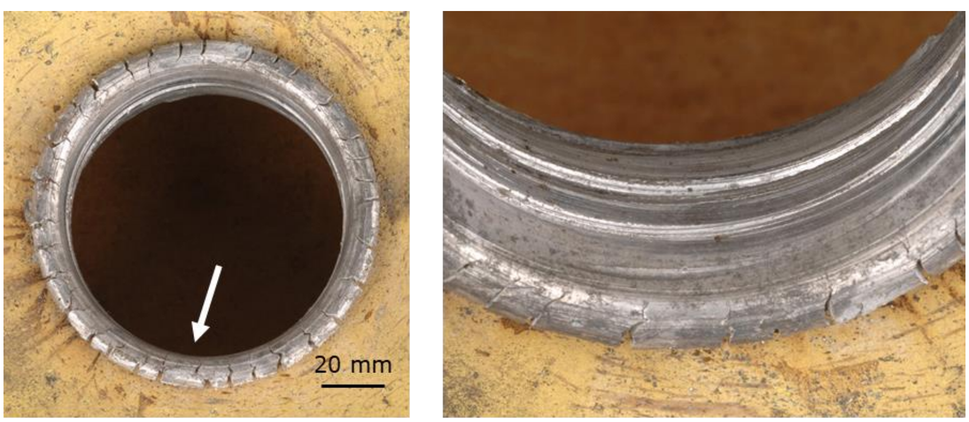
(a) (b)

Figure 6: (a) Close-up view of the half hub bore marked 'A' in Fig.5 showing fracture along the circumference, and (b) bore surface in the region marked by an arrow in (a); note circular groove on the bore surface



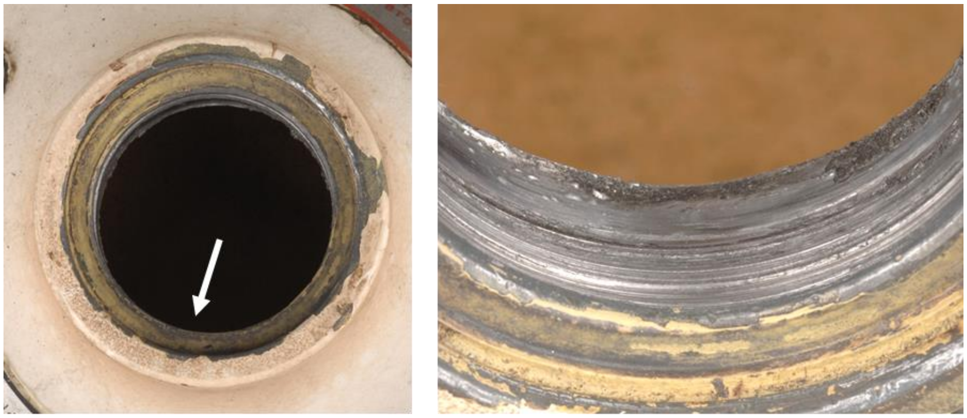
(a) (b)

Figure 7: (a) Secondary electron fractograph showing intergranular fracture in the wheel hub bore, typical of overload fracture in cast Mg-alloy, and (b) magnified view of the region marked in (a)



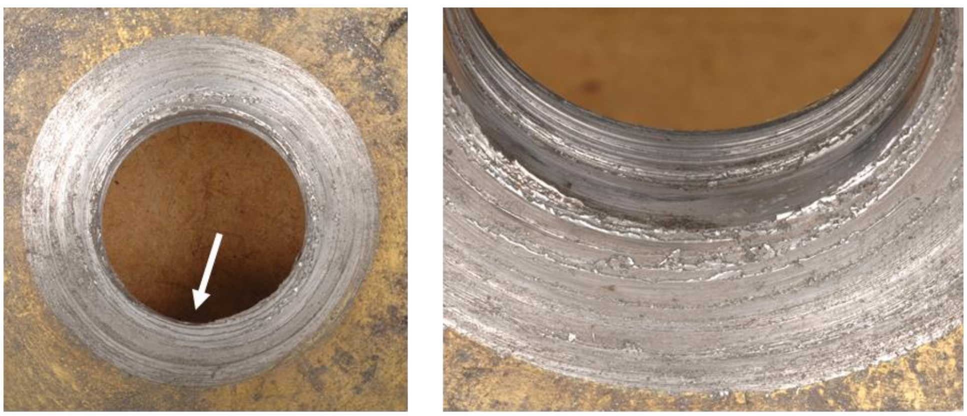
(a) (b)

Figure 8: (a) Close-up view of the half hub bore marked 'B' in Fig.5, and (b) bore surface in the region marked by an arrow in (a); note deep circular groove and outward flow of material



(a) (b)

Figure 9: (a) Close-up view of the half hub bore marked ‘C’ in Fig.5, and (b) bore surface in the region marked by an arrow in (a)



(a) (b)

Figure 10: (a) Close-up view of the half hub bore marked ‘D’ in Fig.5, and (b) bore surface in the region marked by an arrow in (a); note deep circular groove on the bore surface

(a) (b)

Figure 11: (a) Dust cap of the wheel hub assembly, and (b) close-up view of the region marked by arrow in (a) showing rubbing marks

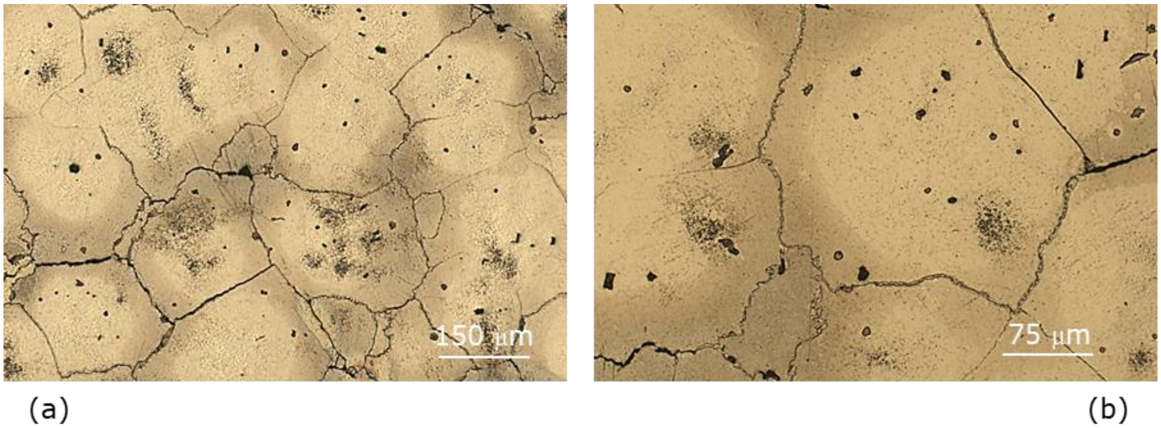


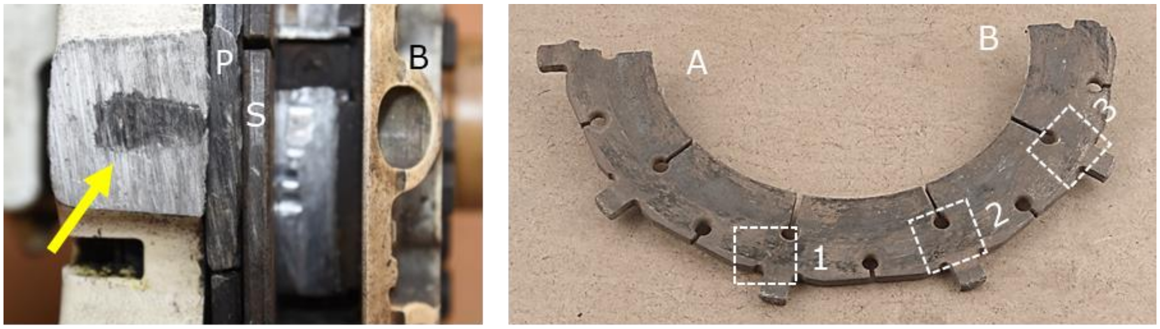
Figure 12: (a-b) Optical microstructure of wheel hub material consisting of α Mg-rich grains with β-phase at the grain boundaries

3.1.3. Brake assembly

The brake assembly was found damaged and both the rotor plates were found missing (refer Fig.13(a)). It is reported that during post-accident check on the MLG extension and retraction, one-half of a rotor plate had fallen off from the assembly (refer Fig.13(b)). The other fragments of the rotor plates could not be retrieved and they appeared to have fallen off in air. While the pressure and the stator plates were available with all the shoes in place, shoes of the backing plate were found missing.

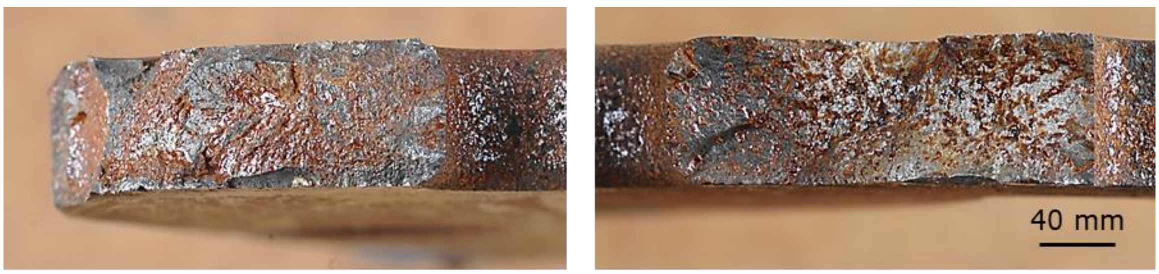
Figure 14 shows the fracture surfaces of the rotor plate. The features on the fracture surfaces were found to be mostly obliterated due to rubbing and rusting. Gross fracture features, however, were indicative of progressive mode of crack propagation followed by overload fracture.

Further examination of the rotor plate showed presence of incipient cracks at three locations (refer Fig.15). Two of these cracks were pull opened for identification of the mechanism of crack initiation and propagation. The resulting fracture surfaces of a typical crack are shown in Fig.16. The fracture surfaces showed clearly delineated crack arrest marks or beach marks with wavy crack fronts, typical of fatigue mode of crack propagation. This was further confirmed through scanning electron fractography study wherein fatigue striations were observed in the progressive crack propagation zones (refer Fig.17(c)). In the freshly opened region, the fracture surface showed cleavage fracture features (refer Fig.17(d)).



(a) (b)

Figure 13: (a) Brake assembly with pressure plate (P), stator (S) and backing plate (B), and (b) one-half of fractured rotor plate that had fallen off during post-accident extension-retraction check; note damage on the structure due to friction with the runway surface shown by an arrow in (a)

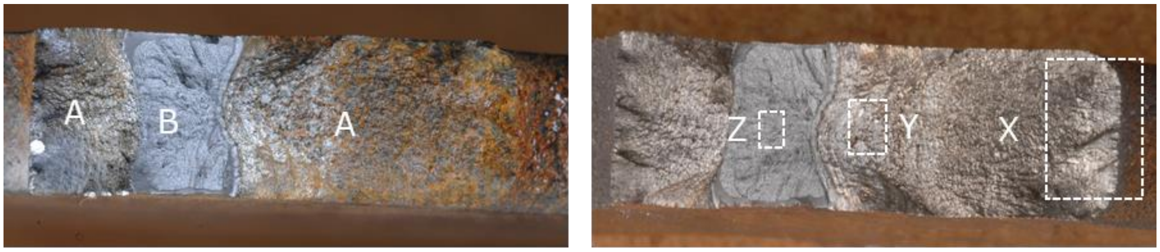


(a) (b)

Figure 14: (a-b) Close-up views of the fracture surfaces marked 'A' and 'B' respectively in Fig.13(b); note obliteration of fracture features because of rubbing and rusting

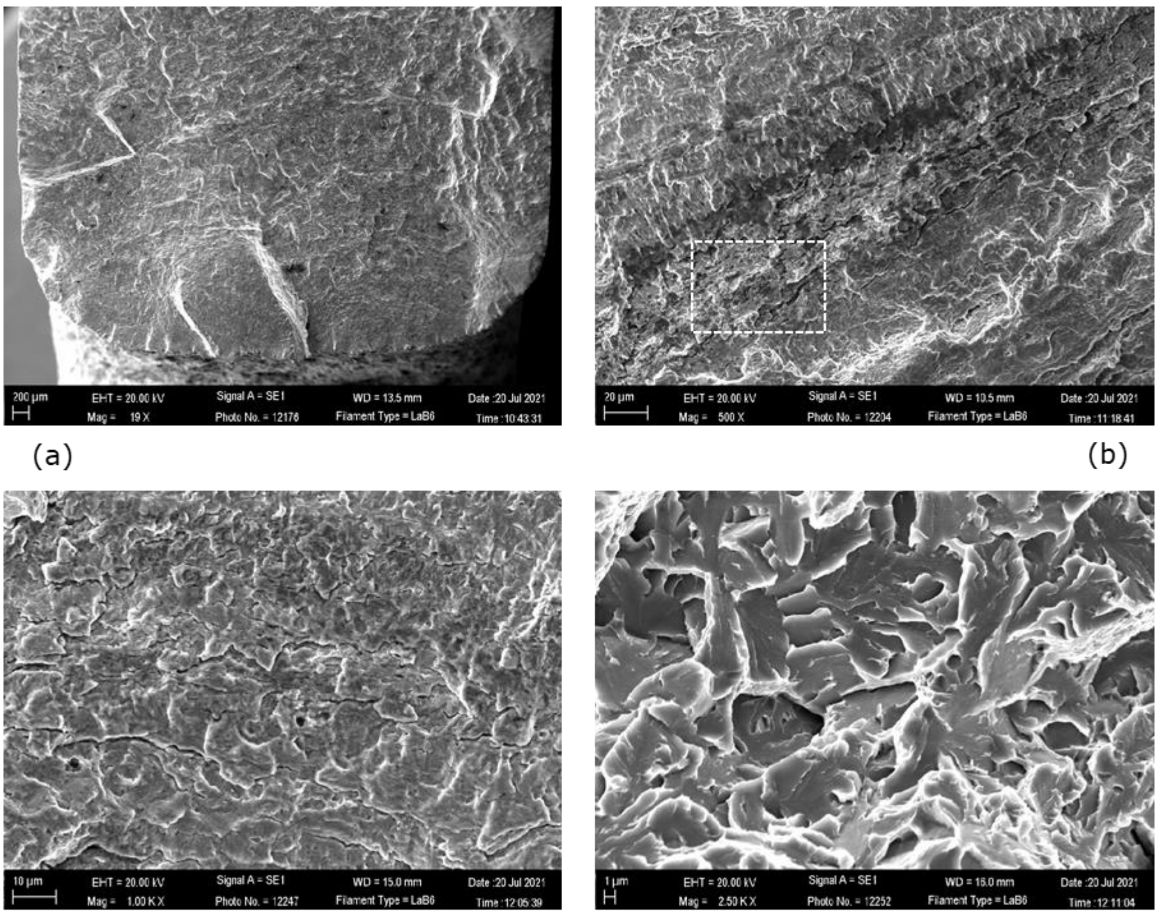
(a) (b) (c)

Figure 15: (a-c) Close-up views of the regions marked '1' through '3' respectively in Fig.13(b) showing incipient cracks in the rotor plate



(a) (b)

Figure 16: (a) One of the mating crack surfaces of the incipient crack shown in Fig.15(a) showing existing crack surface (marked 'A') and freshly opened surface (marked 'B'), and (b) the fracture surface after cleaning by repetitive use of replicating tape



(a) (b) (c) (d)

Figure 17: Secondary electron fractographs: (a) crack origin region marked 'X' in Fig.16(b), (b) fractograph of the region marked 'Y' in Fig.16(b) showing crack arrest marks or beach marks, (c) magnified view of the region marked in (b) showing fatigue striations, and (d) cleavage fracture in freshly opened region marked 'Z' in Fig.16(b) *(fractographs recorded after rotating the fracture surface 90^{0}CW with respect to the orientation in Fig.16(b))*

3.1.4. Damages on the axle

The axle of the MLG was sectioned from a location ahead of the inner bearing seal and removed from the assembly for detailed examination. It can be seen that the inner bearing had moved inboard from its position on the axle (refer Fig.18(a)). The deep dent mark seen on the axle was the result of impact of the wheel hub bore with the axle (refer Fig.18(b)). The dent location was on the bottom surface of the axle in fully extended position of the MLG. The impression was created by the cup of the inner bearing as shown in Fig.19(a-b). Discolouration of the dent surface shows that the cup along with the wheel rotated at this location for some time prior to its dislodgement from the wheel hub bore. On the rest of the axle, there were circular marks resulting from smearing of material from the wheel hub bore while the wheel was moving out of the axle during detachment. The locking assembly was found firmly stuck on the axle and hence, could not be removed by unwinding.

(a) (b)

Figure 18: (a) Axle assembly in as-received condition, and (b) magnified view of the region marked in (a) showing dent on the axle; note discolouration on the dent surface due to frictional heat generation during rotation of the inner bearing cup along with the wheel hub on the axle

3.1.5. Inner bearing

The inner bearing carried the identification "Timken 19268". The cup of the bearing had dislodged from the wheel hub under rotational force as evident from the smeared material of the wheel hub on the outer surface of the cup.

The cup was found to be severely damaged with flow of material on the raceway and severe heat effects (refer Fig.20). The nature of damages on the cup suggests that they occurred when the wheel came out of the cone assembly and was rotating on the axle during detachment. The damages, therefore, were secondary in nature.

(a) (b)

Figure 19: (a-b) Photographs showing the orientation of wheel hub while impacting on the axle

Figure 21(a-b) show the cone assembly on the axle, and after removal from the axle. The bearing was found freely rotating without any restriction. For further study, the bearing was disassembled by sectioning (refer Fig.22(a)). The surface of the rolling elements (rollers) presented a golden yellow to light blue colouration (refer Fig.22(b)). The discolouration of the rolling surface was due to heat generation during service. Examination of the rolling surfaces did not show any major mechanical damages (refer Fig.22(b-c)). The inner surface of the cone did not show any damage indicating that there was no relative movement between the bearing cone and the axle during service (refer Fig.22(d)).

Metallurgical examination confirmed that the rolling elements of the bearing were made of case-hardened steel (refer Fig.23, Table 1). The surface hardness of the bearing elements was achieved through carburizing treatment. Examination revealed that there were no metallurgical abnormalities in the cone and rollers in terms of microstructure or hardness profile. (refer Fig.23-24). However, the cup of the bearing showed substantial decrease in hardness due to heat effects (refer Fig.24). Metallography study showed that as a result of rotation of the cup on the axle under load, not only there was heat generation but also deformation and flow of material (refer Fig.25).

(a) (b)

Figure 20: (a) Damaged cup of the inner bearing, and (b) outer surface and raceway of the cup showing smeared wheel hub material on the outer surface and damages on the raceway

(a) (b)

Figure 21: Cone assembly of the inner bearing (a) in as-received condition on the axle, and (b) after removal from the axle

Figure 22: (a) Cone assembly of the inner bearing after dis-assembly, (b) rollers' surface, (c) raceway, and (d) inner surface of the cone fitted onto the axle

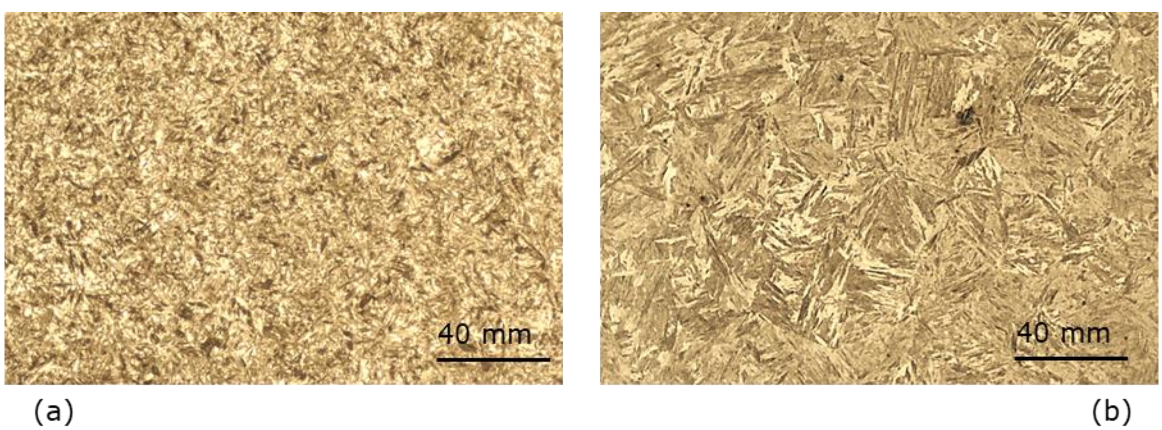


Figure 23: Optical microstructure of (a) case, and (b) core of rollers, typical of case-hardening microstructures; similar microstructures were observed on the cone of the bearing as well

Table 1: Results of semi-quantitative composition analysis of the elements of the inner bearing; analysis carried out using energy dispersive X-ray (EDX) analyser

Element	Composition, wt.%		
	Roller	Cone	Cup
C	*	*	*
Si	0.2	0.1	0.2
Cr	0.9	1.2	1.1
Mn	0.7	0.9	1.3
Fe	98.2	97.8	97.4

* Carbon cannot be determined accurately by EDX analysis

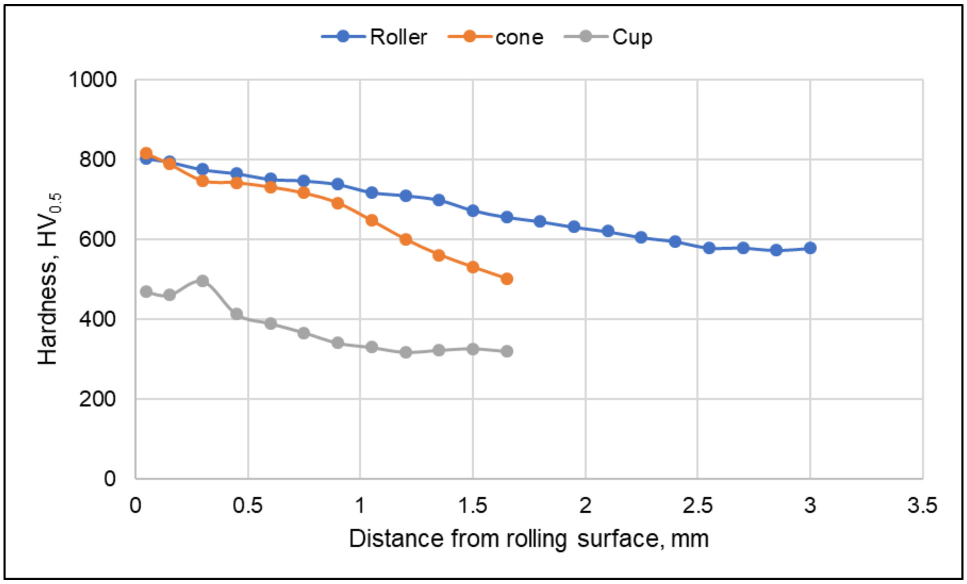


Figure 24: Hardness as a function of distance from the rolling surface of rollers, cone and cup of the inner bearing

3.1.6. Outer bearing

The cup of the outer bearing got dislodged from the wheel hub under rotational force and it suffered severe heat damages (refer Fig.26). The rollers and the cage of the bearing were found missing and could not be retrieved. The cone of the bearing was found stuck with the axle along with the lock assembly. The raceway surface of the cone was found severely damaged due to sliding of the rolling elements and frictional heat generation. There was loss of material from the surface accompanied by plastic flow of material (refer Fig.27(a)). Inner surface of the cone showed signatures of adhesion with the axle (refer Fig.27(b)).

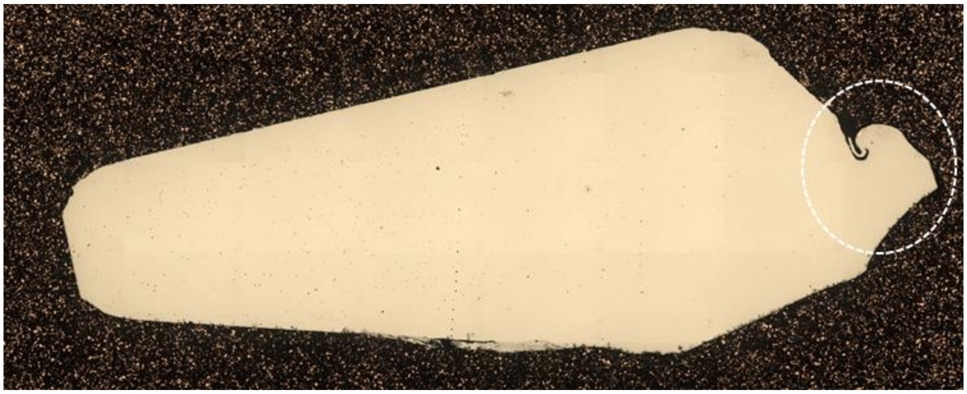


Figure 25: Cross section of the inner bearing cup showing deformation and flow of material at the region of contact with the axle during rotation under load

For further study, one-half of the lock assembly was removed from the axle by sectioning using electro discharge machining (EDM) (refer Fig.28(a-c)). The exposed bearing seating area on the axle is shown in Fig.28(d)). Adhesion of bearing cone material on the axle surface can be seen. The axle surface also showed deep scoring marks due to relative rotational movement between the cone and the axle.

Figure 29 shows the longitudinal section of the bearing cone along with the washer and the nut. Examination revealed that all these components fused together and formed a single body. It can be seen that the temperature in the bearing was so high that the washer got deformed and firmly bonded with the nut and the cone under the load that acted in the axial direction. The deformation in the washer and the nut also facilitated movement of the bearing cone in inboard direction.

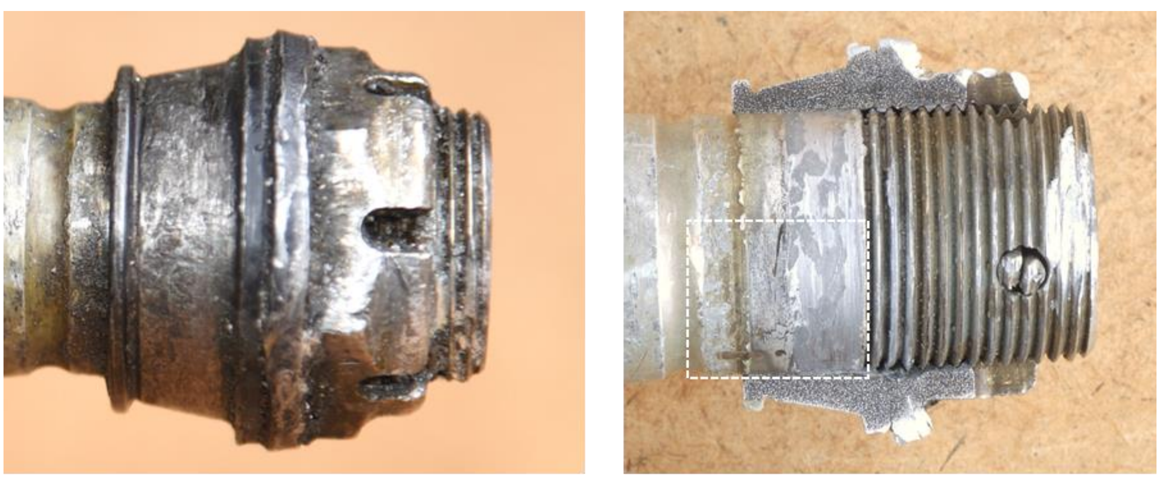
Results of semi-quantitative composition analysis of cup and cone of the outer bearing are given in Table 2. Results of hardness survey conducted on the cone and cup are shown in Fig.30. Comparative study with the inner bearing showed that the hardness of the cone and cup of the outer bearing decreased substantially because of severe heat effects. However, examination did not reveal any gross deformation in the cup as seen in the case of inner bearing cup (refer Fig.25 and Fig.31).

(a) (b) (c)

Figure 26: (a) Damaged cup of the outer bearing, and (b) outer surface, and (c) raceway of the cup showing smeared wheel hub material on the outer surface and damages on the raceway

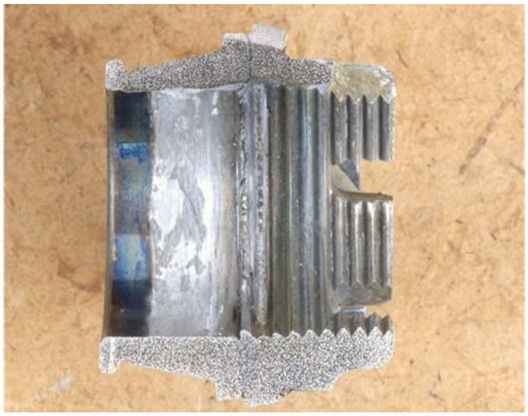
(a) (b)

Figure 27: (a) Raceway of the cone of outer bearing showing damages, and (b) inner surface of the cone showing adherence of material



(a) (b)

Figure 28: Contd…



(c)

(d)

Figure 28: (a) Lock assembly with cone of the outer bearing, and (b) exposed surface of the axle at the bearing seating after removal of half of the assembly by EDM shown in (c), and (d) close-up view of the region marked in (b) showing adhesion of material

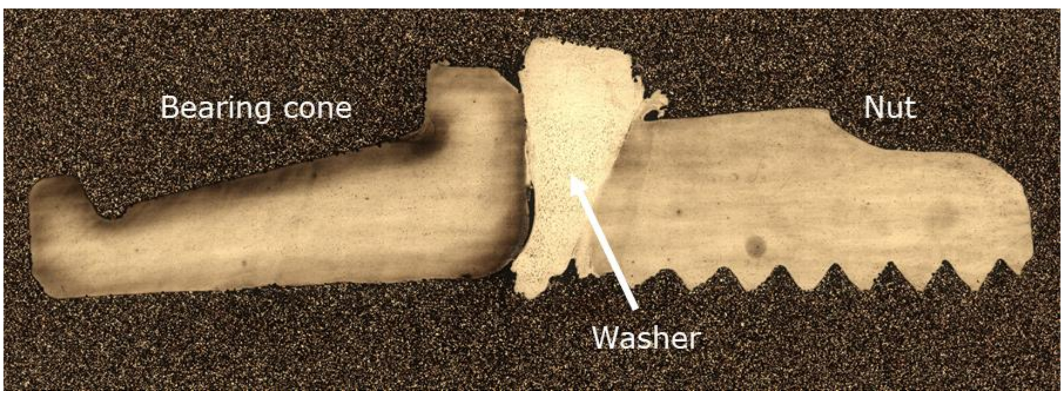


Figure 29: Longitudinal section of the outer bearing cone with washer and nut

Table 2: Results of semi-quantitative composition analysis of the elements of the outer bearing; analysis carried out by using energy dispersive X-ray (EDX) analyser

Element	Composition, wt.%	
	Cone	Cup
C	*	*
Si	0.2	0.2
Cr	1.2	1.1
Mn	1.7	1.5
Fe	96.9	97.2

* Carbon cannot be determined accurately by EDX analysis

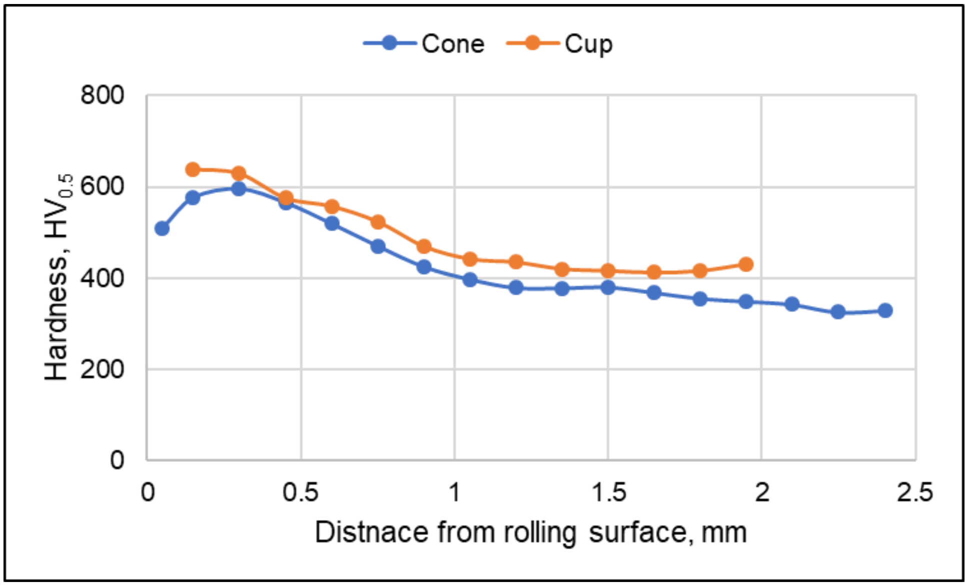


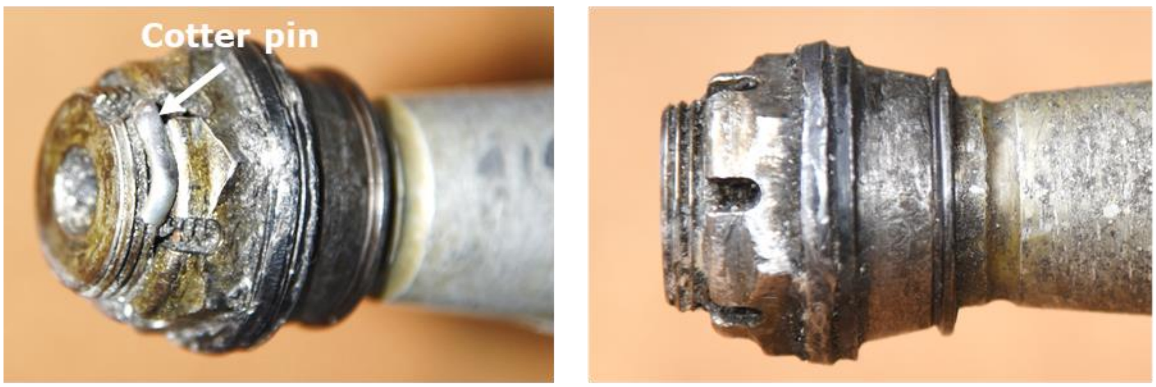
Figure 30: Hardness as a function of distance from rolling surface of cone and cup of the outer bearing

Figure 31: Cross section of the outer bearing cup; note no gross deformation or change in the shape

3.1.7. Axle lock assembly

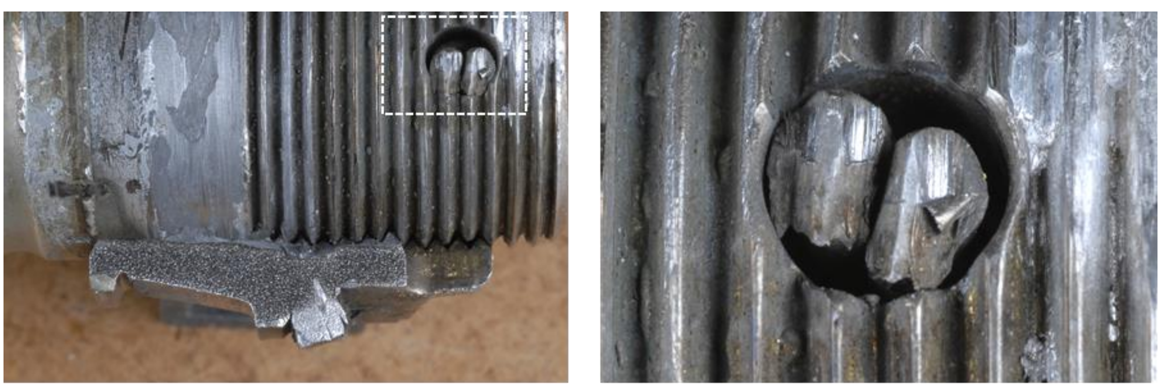
Figure 32 shows two views of the lock assembly on the axle. The assembly contained all the parts as per the IPC of the OEM. None of the parts was missing while assembling the wheel on the axle. However, examination revealed that only one arm of the cotter pin was available with the assembly while the other arm and the head of the cotter pin got sheared off. Examination of the threaded region on the axle showed formation of threads on the sheared surface of the pin (refer Fig.33). This indicates that the lock assembly as a whole rotated on the axle and the shearing of the cotter pin occurred during this time. The direction of rotation was in the direction of wheel rotation.

The hardness of the nut and washer was measured to be 350 $HV_{0.5}$ and 110 $HV_{0.5}$ respectively.



(a) (b)

Figure 32: (a-b) Two views from diametrically opposite locations of the lock assembly on the axle; note absence of head of the cotter pin in (b)



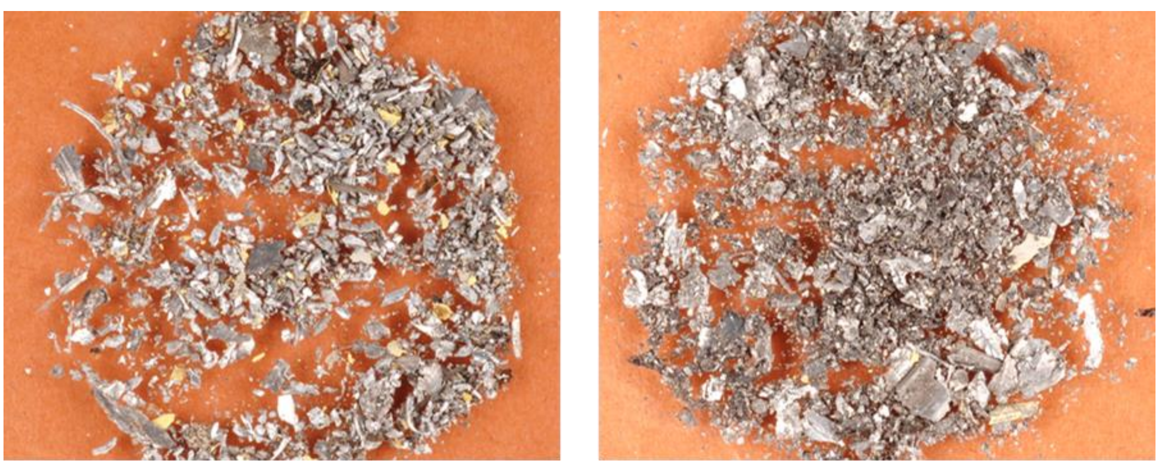
(a) (b)

Figure 33: (a) Sheared cotter pin in the locking hole, and (b) magnified view of the region marked in (a) showing thread formation on the sheared surface of the cotter pin

3.1.8. Debris collected from inside the dust cap

To remove greasy material, the debris collected from inside the dust cap was dissolved in acetone. By decanting the solution, the sediment was collected and examined. Examination revealed that the sediment contained fine particles and chips. The particles and chips collected were nothing but the debris generated from the wheel hub and/or the outer bearing. This is stated based on the fact that except for the wheel hub, the outer bearing, and the sheared parts of locking pin, there was no loss of material from any of the components of the axle assembly.

By using a magnet, the magnetic and non-magnetic particles/chips in the debris were separated (refer Fig.34). However, composition analysis revealed that most of the chips, irrespective of whether magnetic or non-magnetic, showed predominantly magnesium (Mg) on the surface (refer Table 3). Since Mg or Mg-alloy is non-magnetic in nature, the magnetic behaviour of the chips could be explained only if magnetic material was smeared with a layer of Mg on the surface. To examine this, a sample was prepared wherein a few chips were mounted in bakelite and polished metallographically. Examination of this sample confirmed that the debris which were magnetic in nature, contained chips from the bearing elements with smeared layer of Mg-alloy on the surface (refer Fig.35 and Table 4). Examination also confirmed that substantial fraction of the fine particles in debris contained iron (Fe) indicating that they got generated from the bearing elements (refer Fig.36 and Table 5).

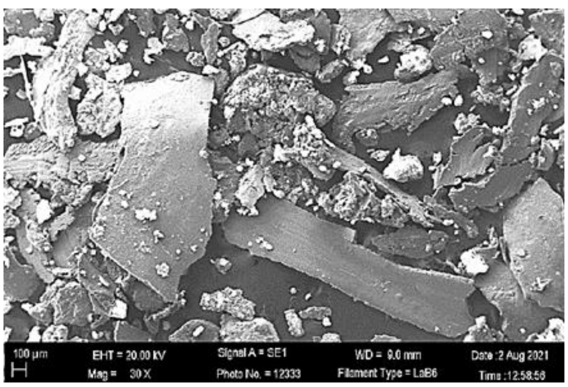


(a) (b)

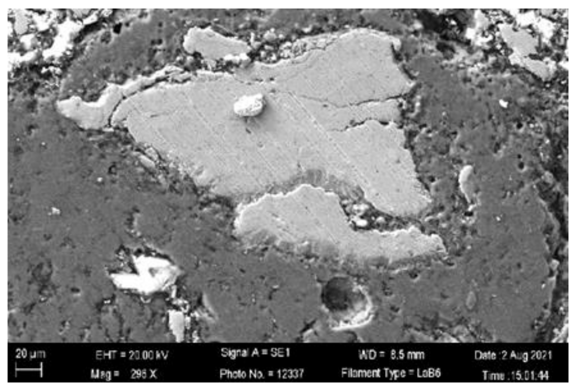
Figure 34: Debris collected from the dust cap after cleaning in acetone, and separation using a magnet: (a) non-magnetic, and (b) magnetic

Table 3: Results of semi-quantitative composition analysis carried out on randomly selected chips shown in Fig.34; analysis carried out by EDX

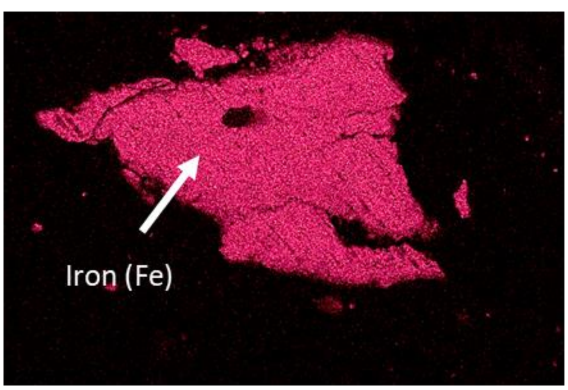
Element	Composition. Wt.%					
	Non-magnetic (refer Fig.34(a))			Magnetic (refer Fig.34(b))		
	Chip-1	Chip-2	Chip-3	Chip-1	Chip-2	Chip-3
Al	7.4	10.6	8.8	0.7	0.1	2.6
Si	0.1	0.4	-	0.2	0.2	-
Cr	-	-	-	1.1	0.9	-
Mn	-	-	-	-	1.3	-
Zn	0.8	0.8	0.7	-	-	-
Mg	91.7	88.2	90.5	6.6	1.7	31.9
Fe	-	-	-	91.4	95.7	65.5



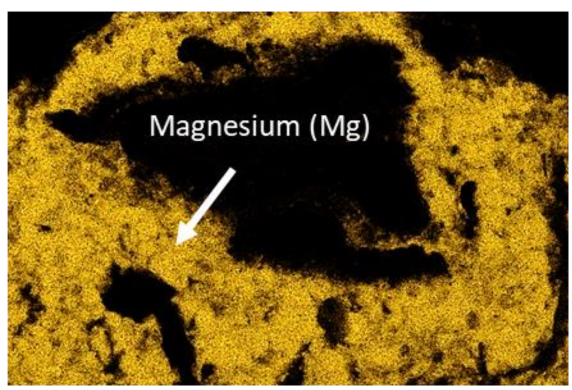
(a)



(b)



(c)



(d)

Figure 35: (a) Secondary electron (SE) image of magnetic chips, (b) metallographic section of a typical chip, and (c-d) X-ray dot mapping for elements Fe and Mg respectively on the region shown in (b); dark region in (c) and (d) represents absence of the element mapped

Table 4: Results of semi-quantitative composition analysis carried out on metallographically prepared sample

Element	Composition, wt.%	
	Bright region in Fig.35(b)	Dark grey region in Fig.35(b)
Al	0.4	9.8
Si	0.5	-
Cr	1.7	-
Mn	1.3	-
Zn	-	1.0
Fe	94.2	1.4
Mg	1.8	87.8

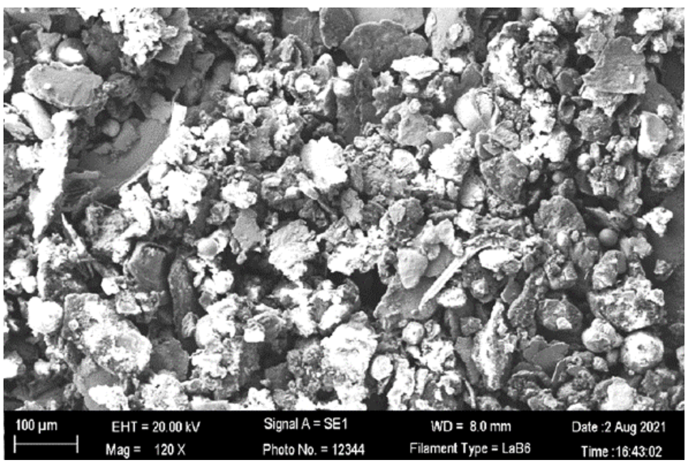


Figure 36: SE image of fine particles in the debris collected from the dust cap

Table 5: Results of semi-quantitative composition analysis carried out on randomly selected fine particles shown in Fig.36

Element	Composition. Wt.%					
	Mg-rich			Fe-rich		
	Particle-1	Particle-2	Particle-3	Particle-1	Particle-2	Particle-3
Al	10.5	7.9	11.1	-	0.2	-
Si	-	1.2	-	0.1	0.2	-
Cr	-	-	-	0.9	0.8	1.3
Mn	-	-	-	0.7	0.2	0.2
Zn	1.1	-	0.2	-	-	-
Mg	87.6	56.9	87.3	1.0	2.1	7.0
Fe	0.8	34.0	1.4	97.3	96.5	91.5

3.2. Examination of starboard MLG components

Subsequent to the investigation on the damaged components of port MLG, the following components of starboard MLG were referred to the laboratory for examination. It was directed that studies on these components be carried out by non-destructive methods only.

(i) Brake assembly components: brake rotors (2 Nos.), stator (1 No.), liners (3 Nos.)

(ii) Wheel assembly locking components: washer (1 No.), nut (1 No.)

(iii) Bearings: outer bearing (1 No.), inner bearing (1 No.)

3.2.1. Brake assembly components

Figure 37 shows the brake assembly components received for investigation. Examination revealed no incipient cracks in any of the rotor or stator plates. No abnormalities were observed in any of the components except for normal wear and tear.

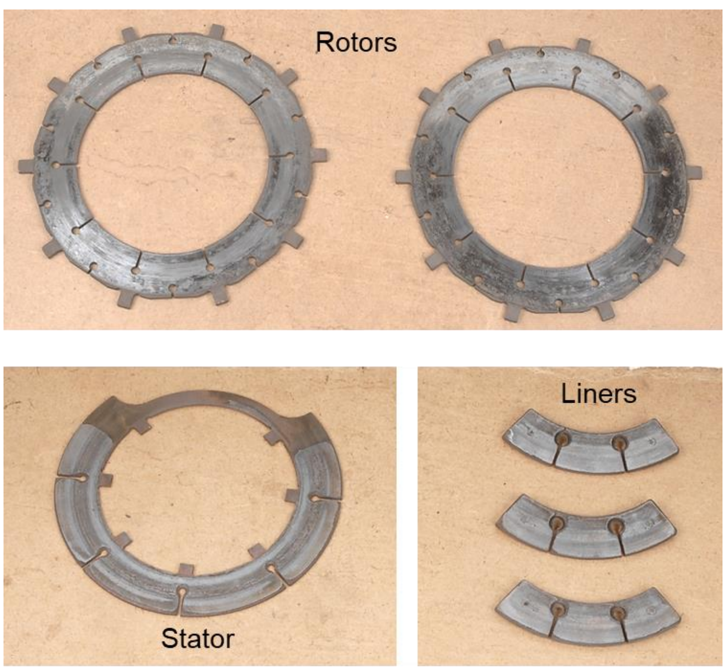


Figure 37: Components of the starboard axle brake assembly received for examination

3.2.2. Components of locking assembly

Figure 38 shows the washer and the nut of the starboard MLG axle lock assembly. Examination did not show any abnormalities in any of these components. The threads on the nut were found in good condition.

Figure 38: Washer and nut of the starboard axle lock assembly

3.2.3. Bearings

The bearings were examined physically and they were found rotating freely without any restriction. The bearings were cleaned ultrasonically in acetone and subjected to visual, stereo-binocular, and scanning electron microscopy examination, wherever possible without dis-assembly. Only the rollers' surfaces of the bearings were accessible for examination.

3.2.3.1. Outer bearing

Figure 39(a) shows the outer bearing of the starboard MLG wheel assembly. Visual and stereo-binocular examinations revealed that the roller surfaces had dull appearance and deep scoring marks, indicative of overall deterioration of the rolling surfaces (refer Fig.39(b-d)). Further examination of the roller surfaces in SEM showed widespread pitting and spalling. The typical damages observed on the rollers are summarized in Fig.40-42.

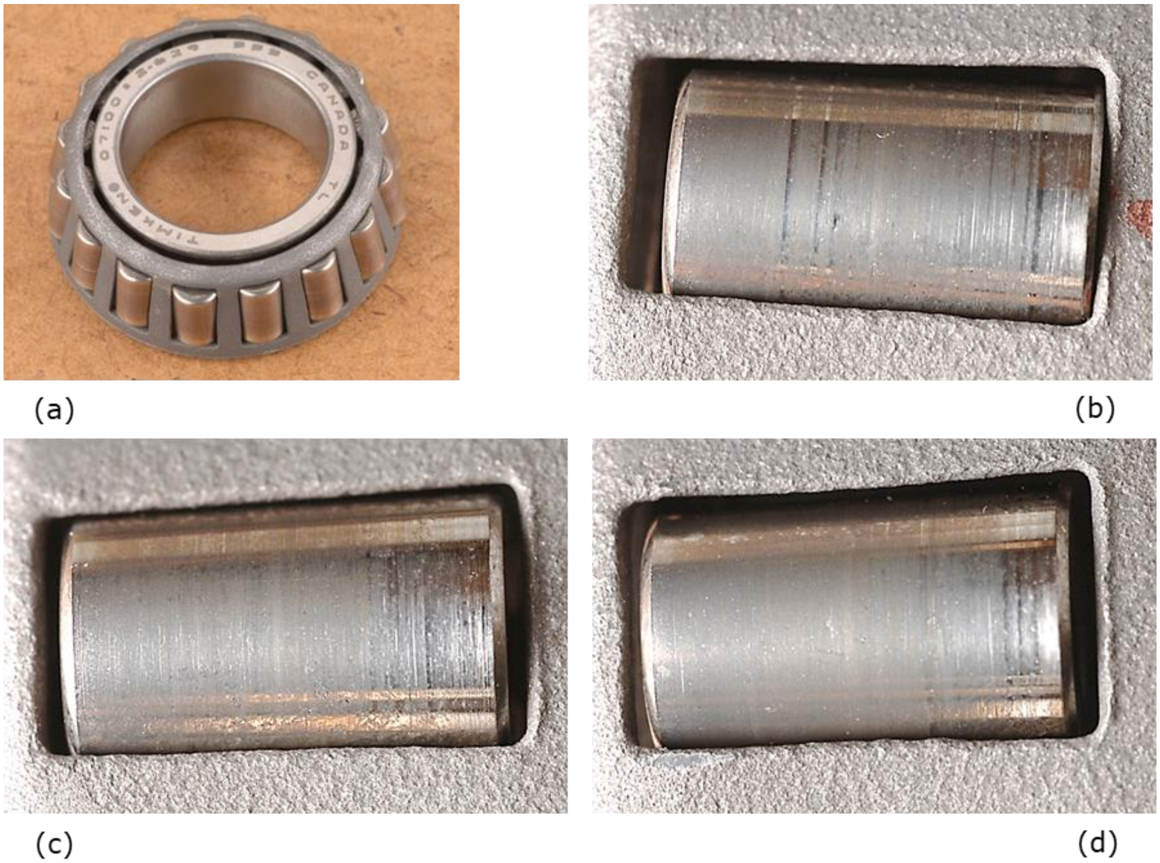


Figure 39: (a) Cone assembly of the outer bearing, and (b-d) appearance of surface of three typical rollers

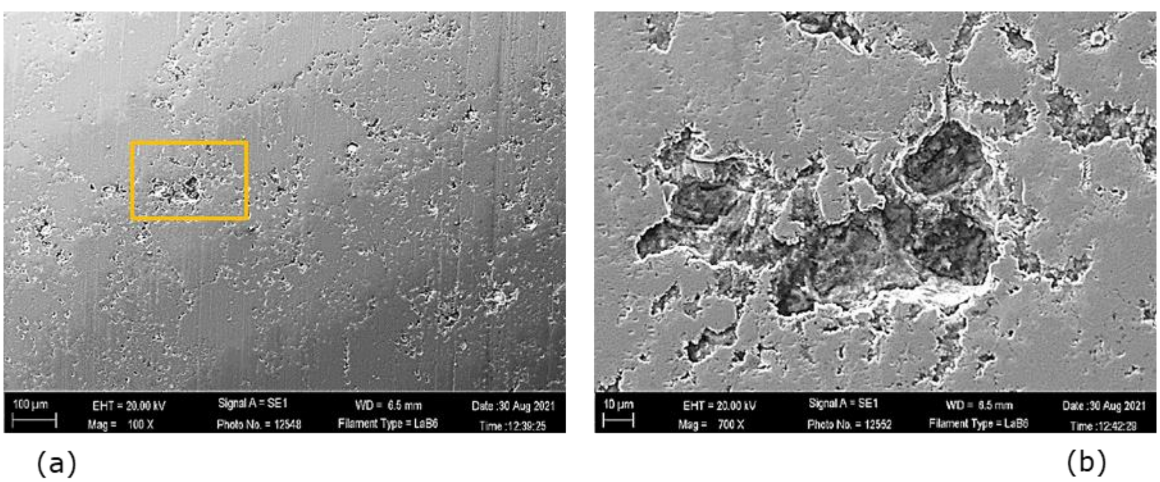
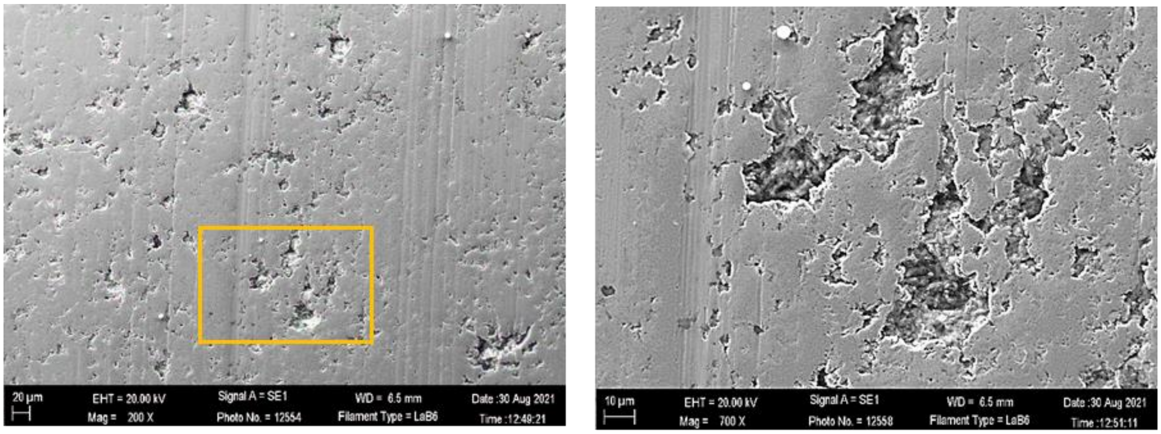
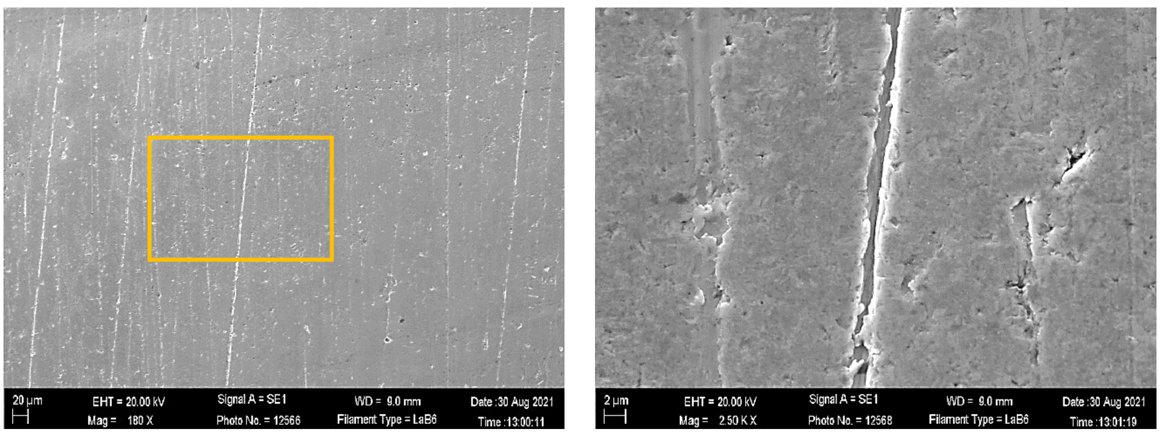


Figure 40: Secondary electron images on a typical roller of outer bearing of starboard MLG wheel assembly showing (a) widespread pitting on the roller surface, and (b) magnified view of the region marked in (a) showing spalling



(a) (b)

Figure 41: Secondary electron images on a typical roller of outer bearing of starboard MLG wheel assembly showing (a) widespread pitting on the roller surface, and (b) magnified view of the region marked in (a) showing spalling



(a) (b)

Figure 42: Secondary electron images on a typical roller of outer bearing of starboard MLG wheel assembly showing (a) deep scoring marks, and (b) magnified view of the region marked in (a)

3.2.3.2. Inner bearing

Figure 43(a) shows the inner bearing of the starboard MLG wheel assembly. Similar to the outer bearing, the rollers of this bearing were also found to be dull in appearance with widespread pitting, spalling and deep scoring marks. In comparison to outer bearing, the damages to the rollers of the inner bearing were found to be more severe in nature (refer Fig.43(b-f)).

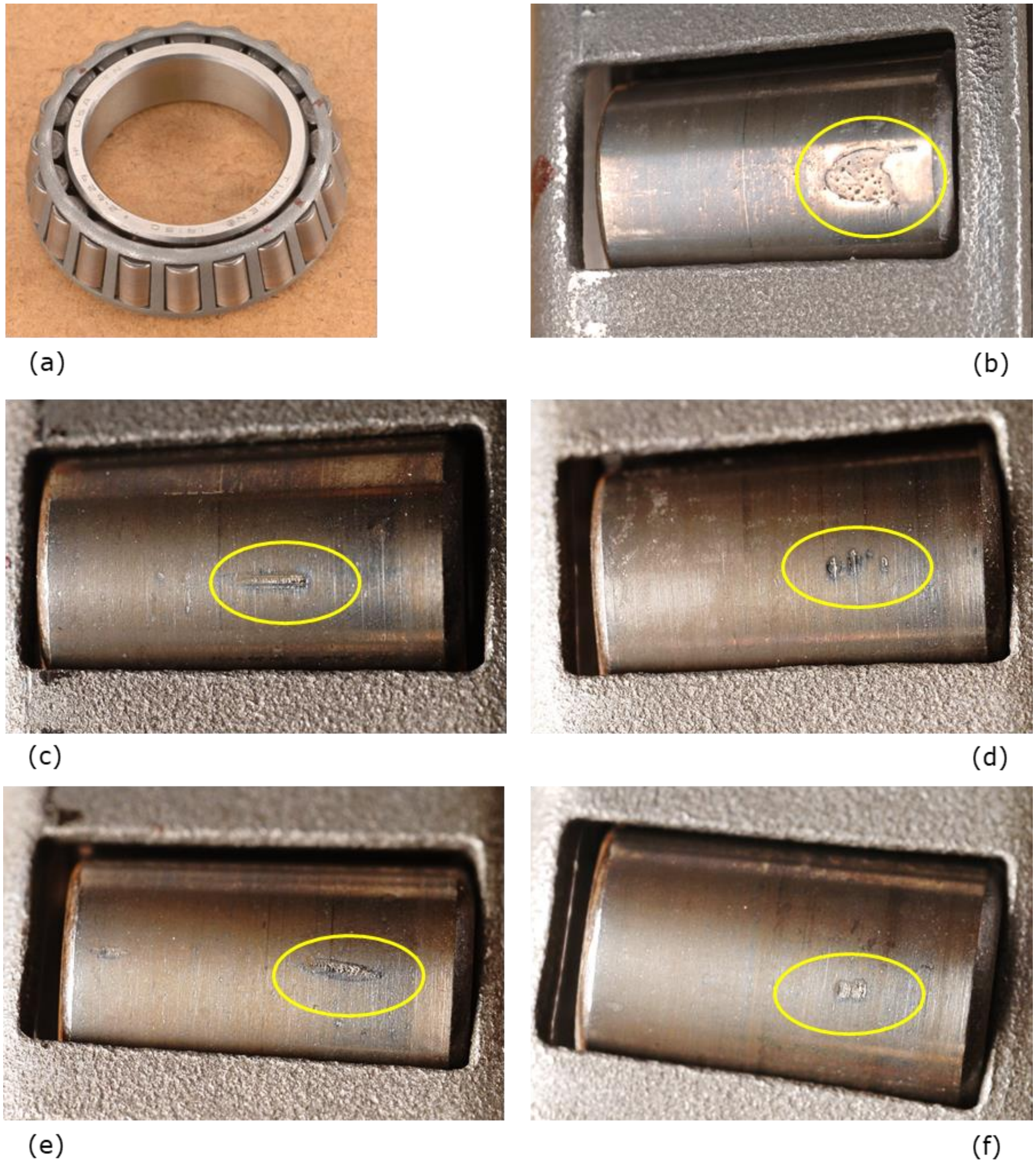


Figure 43: (a) Cone assembly of the inner bearing, and (b-f) appearance of surface and damages on five typical rollers; severely damaged regions are encircled

4.0. Analysis of Failure

4.1. Assembly on the axle of port MLG

Examination confirmed that all components for assembling the wheel on the axle of the port MLG were in order as per the IPC of the OEM.

4.1.1. Damages to bearings

Evidences showed that the inner bearing was functional during the last take-off roll. The damages seen on the cup of the bearing occurred only when the wheel moved inboard following loss of locking action on the wheel hub.

The damages to the outer bearing, however, were very severe. The frictional heat generation in the bearing was so high that the cone, washer and nut got fused together. Also, there was adhesion between the cone and the axle. Generation of significant fraction of the debris with particle size less than 50 μm indicated that there was progressive deterioration on the rolling surfaces of the bearing. The deterioration of the rolling surfaces resulted in frictional heat generation leading to substantial decrease in hardness of both cone and the cup. Considering the severity of damages on the outer bearing elements as a whole, it appears that the bearing was running in distressed condition for a prolonged period of time.

4.1.2. Damages to wheel hub assembly

Evidences suggested that the cup of the outer bearing had come out of the wheel hub bore under rotational force. As a result, the locking action on the wheel hub was lost and thereby, allowed the wheel to move inboard. The damages seen on the inner surface of the half hub at the outer bearing location were caused by the lock assembly as the wheel was coming out of the axle.

The wheel hub moved out from the inner bearing with the cup in position in the bore. While coming out from the bearing, the wheel hub impacted on the axle resulting in fracture along the bore circumference and creation of a dent on the axle. Subsequently, the cup of the bearing came out of the bore under rotational force as evident from the deep circular marks on the bore surface.

Once the cup was dislodged, the load was directly on the wheel hub bore surface leading to deformation and outward flow of material.

4.1.3. Damages to axle lock assembly

The axle lock assembly was in order with all components in position, but got damaged due to generation of excessive heat in the outer bearing. Investigation showed that the components of the lock assembly got fused together and prior to the final failure, the assembly along with the cone of the outer bearing rotated in the direction of the wheel rotation leading to shearing off of the cotter pin.

4.1.4. Damages to brake assembly

Fractography study confirmed that the rotor plates of the brake assembly on port axle had fractured by fatigue mechanism. Evidences suggested that during the progression of failure in the outer bearing, there was concurrent misalignment in the wheel assembly. This appears to have resulted in obstruction in the movement of the rotor plates leading to generation of fatigue cracks. Hence, the fatigue fracture of the rotor plates of the brake assembly is consequential and secondary in nature.

4.2. Components of axle assembly of starboard MLG

Non-destructive examination carried out indicated damages to the roller surfaces of both inner and outer bearing. The damages were in the form of pitting, spalling and deep scoring marks. As per the laboratory assessment, these bearings are not fit for further deployment.

5.0. Primary failure

Laboratory investigation showed that the primary failure in the port MLG that was responsible for detachment of the wheel was the failure in the outer bearing. Failure in the bearing occurred over a period of time, and during the last take-off roll, the frictional heat generation was very high resulting in fusion between all contacting surfaces of the components of the bearing lock assembly, that is, bearing cone, washer and lock-nut. At the final stage of failure, the whole lock-assembly including the cone of the bearing rotated in the direction of wheel rotation leading to shearing off of the cotter pin. Concurrently, the cage of the outer bearing broke followed by dislodgement of rollers and bearing cup from the wheel hub bore.

6.0. Sequence of events

Detachment of wheel from the port MLG of the aircraft occurred as a consequence of excessive frictional heat generation and subsequent structural failure of the outer bearing and dislodgement of the bearing cup from the wheel hub bore. Because of this failure, the retaining action of the bearing for the wheel hub was lost and the wheel was free to move axially away from its normal position during the last take-off roll. The damages to only the cup of the inner bearing was found to be consistent with the axial movement of the wheel as the outer bearing failed. As the wheel moved inboard, it fell off from the inner bearing and impacted on the axle leading to fracture in the wheel hub bore and dislodgement of the bearing cup. A deep dent was created at the location of impact on the bottom surface of the axle in fully extended position of the MLG. As the aircraft rolled, the wheel continued to move inboard and it came out of the axle and got detached from the MLG at the time of take-off of the aircraft. Figure 44 shows a schematic representation of the sequence of events that led to the dislodgement of the wheel from the axle.

Analysis suggests that the fracture in the rotor plates of the brake assembly occurred because of excessive load resulting from misalignment of the wheel on the axle following the failure of the outer bearing. The fractured parts of the rotor plates had fallen off in air and only one-half of a plate was available with the brake assembly.

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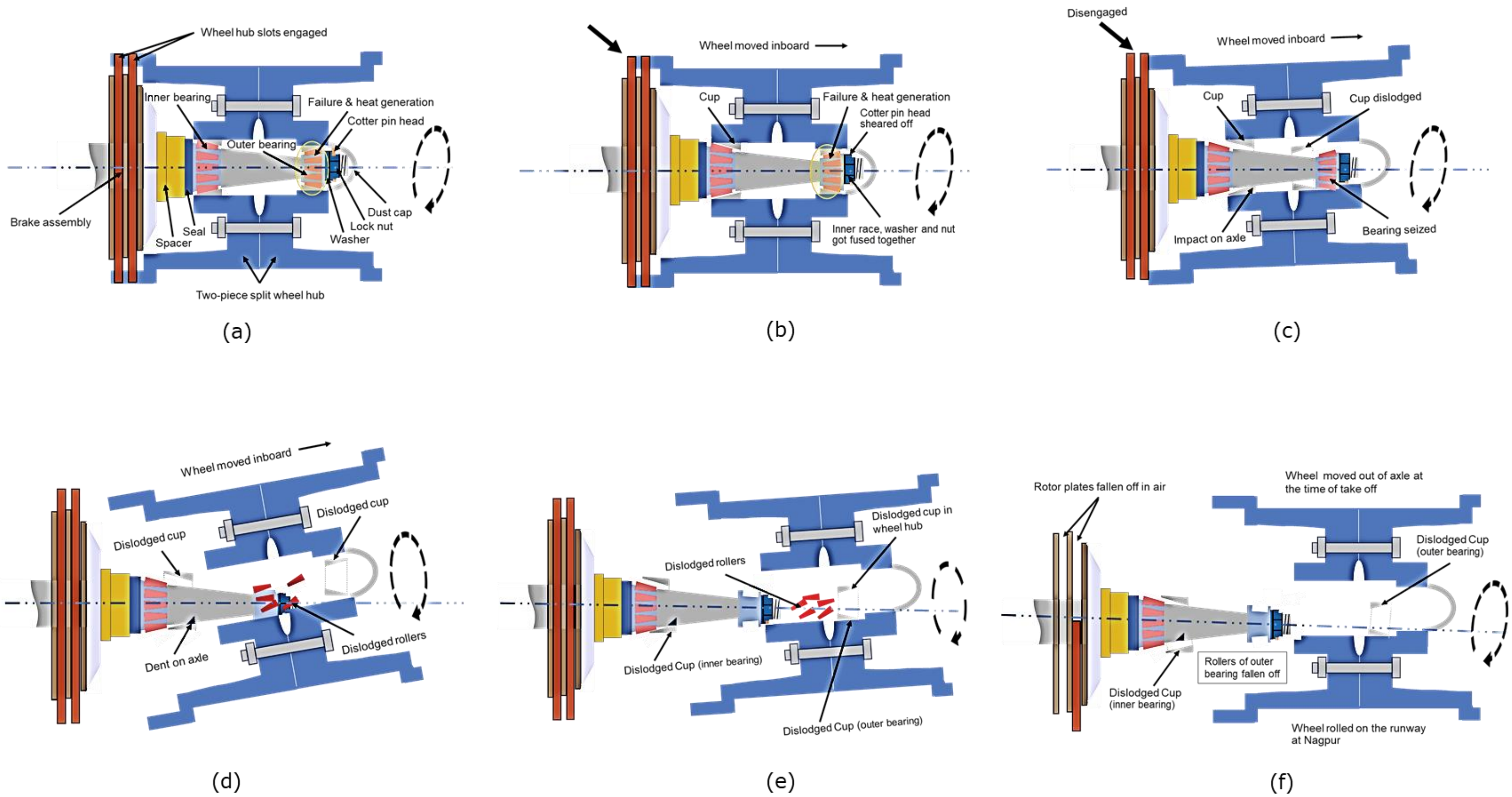

Figure 44: Schematic representation of sequence of events leading to dislodgement of wheel from the port MLG axle: (a) → (b) → (c) → (d) → (e) → (f)

7.0. Probable cause(s) of outer bearing failure

Evidences of failure initiation on the available parts of the outer bearing of port MLG wheel assembly were completely destroyed due to excessive heat generation and severity of material damage within the bearing. However, non-destructive examination carried out on the bearings of the wheel assembly of starboard MLG showed presence of widespread pitting and spalling on the roller surfaces. This indicates that the bearings of the starboard axle assembly have reached the limits of their useful life under the prevailing operating conditions. This means that these bearings would have also failed anytime if continued in service. Therefore, conjecture can be drawn that probably, similar deterioration of the rolling surfaces had occurred in the outer bearing of the wheel assembly of the port MLG as well prior to the catastrophic failure. The probable reasons for deterioration of the rolling surfaces of the bearings can be one or more of the following:

(a) Lubrication related issues
(b) Contamination (ingression of moisture and/or dirt)
(c) Overload (operational and/or assembly related)
(d) Usage beyond useful technical life

8.0. Conclusions

(a) The primary reason for detachment of wheel from the port MLG of the Beechcraft King Air C-90A aircraft VT-JIL was the failure in the outer bearing. The failure in the bearing occurred over a period of time. Evidences of failure initiation on the available parts of the bearing were completely destroyed due to severity of material damage and heat generation within the bearing.

(b) Examination carried out on the outer and inner bearings of the wheel assembly of starboard MLG showed damages to roller surfaces in the form of pitting, spalling and deep scoring. These bearings were found to be not fit for further deployment.

(c) Based on (b) above, conjecture can be drawn that probably, similar deterioration of the rolling surfaces had occurred in the outer bearing of the wheel assembly of the port MLG as well prior to the catastrophic failure.

(d) The probable reasons for deterioration of the rolling surfaces in the present bearings can be one or more of the following reasons: (i) lubrication related issues, (ii) contamination (ingression of moisture and/or dirt), (iii) overload (operational and/or assembly related), (iv) usage beyond useful technical life.

Appendix "7"

सभी पत्राचार उपमहानिदेशक नागर विमानन के शीर्षक से प्रेषित किये जायें. नाम से नहीं।
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Northern Region, G+5 Building, 1st & 2nd Floor
I.G.I. Airport (Terminal-1) New Delhi-110037

Ref. No:- DEL-11011(12)/19/2019-DAW-NR/ 565

Dated- 17-08-2020

To,

The Quality Manager
M/s Jet Serve Aviation Pvt. Ltd.
Indraprasth Aerospace& Knowledge Park
Sect.77, Gurugram, Haryana

SUBJECT: Approval for Overhaul /Servicing of MLG, NLG Nose Wheel, Main Wheel and Brake assembly installed on King Air C 90 series and Super King Air B 200 aircraft.

Dear Sir,

Reference may be made to your letter No. JSA/DGCA/145/2019-20/020 dated 20/01/2020.Approval is hereby granted as given below-

CLASS	RATINGS	LIMITATIONS
Components Other than Complete Engines or APU	C 14 (Landing Gear)	**King Air C 90 series aircraft.** MLG P/N-90-810039-1/90-810039-2 and NLG P/N-101-820029-5/101-820029-27/101-820029-31 Main Wheel P/No. 3-1208-1 Nose Wheel P/No. 3-1481 Brake Assy. P/No. 2-1574 installed thereon.
		Super King Air B 200aircraft. MLG P/N-101-810171-1/101-810171-3/ 101-810172-1 & NLG P/N-101-820020-3/101-820020-11/101-820020-15 Main Wheel P/N- 101-8200-57 Nose Wheel P/No. 101-8026-5 and Brake Assy. P/N- 101-8002-3 installed thereon .

The subject approval is hereby granted by this office for a period of 08 Months valid till **16 April 2021** with the following conditions-

1. The approval is valid for one time only and above components installed on aircraft owned and operated by M/s Jet Serve Aviation Pvt. Ltd.
2. The approval requires compliance with the procedures specified in the approved MOE.
3. The approval is valid whilst M/s Jet Serve Aviation Pvt. Ltd. remains in compliance with approved MOE, CAR 145 and other relevant directives issued by DGCA from time to time.

Please acknowledge the receipt.

Yours faithfully

(D.K Das)
Director of Airworthiness
For Deputy Director General of Civil Aviation (NR)