AV-15018/24/2015-DG

Government of India

Ministry of Civil Aviation

***

New Delhi, dated the 05th August, 2015

To,

The Aircraft Accident Investigation Bureau,

Safdarjung Airport, New Delhi

(Kind Attn: Shri Bir Singh Rai, DDG)

Subject: Accident to M/s PHHL Bell 407 Helicopter VT-PHH at Katra on 30.12.2012

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Sir,

I am directed to refer to AAIB UO Note No. AV.15013/04/2012-AAIB dated 05.12.2014 and 14.01.2015 and email dated 29.07.2015 on the subject mentioned above and to say that the report submitted by the Committee of Inquiry has been accepted by the Competent Authority. However, the recommendation No. 4(2) made by Committee of Inquiry in the investigation report may be read as under:

*"Operations department of operator shall ensure the compliance of pilot training for critical emergencies on helicopter/simulator such as engine failure, system failure, tail rotor failure etc as per DGCA CAR requirements."*

3. It is requested that the necessary action for implementing the recommendations made by the Committee of Inquiry subject to above modification may kindly be taken at the earliest.

Yours faithfully,

(Deepak Sajwan)

Under Secretary to Govt. of India

# Final Investigation Report on Accident to Pawan Hans Helicopters Limited (PHHL) Bell 407 Helicopter VT-PHH on 30-12-2012 at Katra Valley, Jammu & Kashmir

**COMMITTEE OF INQUIRY VT-PHH**

(Amit Gupta)
Deputy Director (AED)
DGCA Hqrs
Chairman

(Capt. P. K. Chabri)
Member

(Sh. A. X Joseph)
Deputy Director Air Safety,
DGCA Hqrs
Member

(K. Ramachandran)
Air Safety Office (E), AAIB
Secretary

# *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 2012, the sole objective of the investigation of an accident shall be the prevention of accidents and not apportion blame or liability.*

*This document has been prepared based upon the evidences collected during the investigation, opinion 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 could lead to erroneous interpretations.*

# INDEX

# Glossary

| | |
|---|---|
| AAIB | Aircraft Accident Investigation Bureau,India |
| AGL | Above Ground Level |
| A/F | Airframe Hours |
| AOA | Angle of Attack |
| AMSL | Above Mean Sea Level |
| AME | Aircraft Maintenance Engineer |
| ARC | Airworthiness Review Certificate |
| ASB | Alert Service Bulletin |
| ATC | Air Traffic Control |
| AUW | All Up Weight |
| C of A | Certificate of Airworthiness |
| CAR | Civil Aviation Requirements |
| CEB | Commercial Engine Bulletin |
| CSL | Commercial Service Letter |
| CG | Centre of Gravity |
| CPL(H) | Commercial Pilot License (Helicopter) |
| CP | Collective Pitch |
| CRM | Crew Resource Management |
| CVR | Cockpit Voice Recorder |
| CSL | Commercial Service Letter |
| CT | Compressor-to-Turbine Coupling |
| DAW | Director of Airworthiness |
| DDG | Deputy Director General |
| DGCA | Directorate General of Civil Aviation |
| DGR | Dangerous Goods Regulations |
| DFDR | Digital Flight Data Recorder |
| ECU | Engine Control Unit |
| FAA | Federal Aviation Administration |
| FADEC | Full Authority Digital Engine Control |
| FRTOL | Flight Radio Telephone Operator's License |
| FSN | Fuel Spray Nozzle |
| GVHL | Global Vectra Helicorp Limited |
| HCF | High Cycle Fatigue |
| ISRO | Indian Space Research Organization |
| LH | Left Hand |
| L & T | Load & Trim |
| MCD | Magnetic Chip Detector |
| MGT | Measured Gas Temperature |
| NDT | Non Destructive Testing |
| NSOP | Non-Scheduled Operating Permit |
| NTSB | National Transportation Safety Board, USA |
| $N_g$ | Compressor rpm |
| $N_R$ | Rotor rpm |
| $N_p$ | Power Turbine rpm |

| | |
|---|---|
| $N_2$ | Power Turbine rpm |
| PIC | Pilot In Command |
| Pax. | Passenger |
| PHHL | Pawan Hans Helicopters Limited |
| RH | Right Hand |
| rpm | Revolution per minute |
| RT | Radio Telephony |
| RTR (C) | Radio Telephony Restricted |
| SOP | Standard Operating Procedures |
| SHP | Shaft Horse Power |
| SEM | Scanning Electron Microscope |
| VHF | Very High Frequency |
| UTC | Co-ordinated Universal Time |
| | |

| Final Investigation Report on Accident to Pawan Hans Helicopters Limited (PHHL) Bell 407 helicopter VT-PHH on 30/12/2012 at Katra valley, Jammu & Kashmir | | | |
|---|---|---|---|
| 1 | Helicopter | Type | Bell 407 |
| | | Nationality | Indian |
| | | Registration | VT-PHH |
| 2 | Owner | | Pawan Hans Helicopters Limited , New Delhi |
| 3 | Operator | | Pawan Hans Helicopters Limited , New Delhi |
| 4 | Pilot – in –Command | | CPL (H) Holder |
| | Extent of injuries | | Serious |
| 5 | Date & Time of Accident | | 30/12/2012 ; 06 20 UTC |
| 6 | Place of Accident | | Katra Valley, J & K |
| 7 | Last point of Departure | | Katra Helipad, Katra |
| 8 | Intended landing place | | Sanjhi Chhat Helipad, Katra |
| 9 | No. of Passengers on board | | 06 |
| 10 | Type of Operation | | NSOP |
| 11 | Phase of Operation | | Landing |
| 12 | Type of Accident | | Forced landing |
| 13 | Co-ordinates of Accident Site | | Lat 33° 01’ 51” N Long 74° 54’ 17 ” E 2270 feet AMSL |

(All timings in the report is in UTC)

**SYNOPSIS**:

Pawan Hans Helicopters Ltd. (PHHL) Bell 407 helicopter VT-PHH was engaged in an Non- Schedule operation from Katra Helipad to Sanjhi Chhat Helipad at Mata Vaishno Devi Shrine, Katra, Jammu & Kashmir (J & K) on 30-12-2012. The helicopter was under the command of Single Pilot having CPL (H) with 06 passengers on board. Helicopter had carried out 02 sorties prior to the accident flight. While carrying out third sortie, Helicopter took-off from Katra helipad at around 0615 UTC for Sanjhi Chhat helipad to drop the passengers. During flight just short of Sanjhi Chhat helipad, the PIC heard a loud bang and experienced power loss with a drop in rotor RPM ($N_R$). PIC immediately lowered the collective to regain the rotor RPM and subsequently descended from the sector altitude. Subsequently, the FADEC warning was also generated. The PIC tried to control the helicopter by carrying out auto-rotation and simultaneously looked out for a flat land in the valley to carry out a forced landing. PIC controlled the flight during rapid descend and landed on sloping surface next to the river bed at around 0620 UTC. Helicopter made a heavy landing without power and received substantial damage. Weather at the time of accident was fine with visibility more than 5 Kms.

Ministry of Civil Aviation vide order No. AV 15018/01/2013-DG dated 21st Feb 2013 constituted a committee of inquiry to investigate the cause of the accident under Rule 11 (1) of Aircraft (Investigation of Accidents and Incidents), Rules 2012. The committee includes Sh. Amit Gupta as Chairman, Sh. A. X Joseph and Capt. P. K. Chabri as member and Sh. K. Ramchandran as Secretary.

The Committee of inquiry determines the probable cause of accident as "Helicopter experienced power loss due to High cycle fatigue (HCF) failure of single 3rd Stage Turbine blade. The pilot attempted for forced landing which eventually resulted into an accident".

# 1. FACTUAL INFORMATION:

## 1.1 History of Flight:

On 30-12-2012 Pawan Hans Helicopters Ltd. (PHHL) Bell 407 helicopter VT-PHH was engaged in an NSOP operation from Katra Helipad to Sanjhi Chhat Helipad at Mata Vaishno Devi Shrine, Katra, Jammu & Kashmir (J & K). Katra Helipad is located at 2800 feet AMSL and Sanjhi Chhat Helipad is at 6000 feet AMSL.

The helicopter was under the command of PIC having a valid CPL (H). There were 06 passengers on board. Prior to the accident flight the helicopter had carried out 02 sorties from Katra to Sanji Chhat and no defect was reported on the helicopter.

Duration of each sortie from Katra- Sanjhi Chhat- Katra is approx 6 minutes wherein the engine/rotor are kept running during embarkation and disembarkation of passengers. Helicopter took-off from Katra helipad at around 0615 UTC for Sanjhi Chhat helipad to drop the passengers. As per the PIC report, the take-off from Katra helipad was normal, however during flight just short of Sanjhi Chhat helipad the PIC heard a loud bang and experienced power loss with a drop in rotor RPM ($N_R$). PIC immediately lowered the collective to regain the rotor RPM and subsequently descended from the sector altitude. During descend FADEC warning was also generated. PIC tried to control the helicopter by carrying out auto-rotation and simultaneously looked out for a flat land in the valley to carry out a forced landing. PIC controlled the flight during rapid descend and landed on sloping surface next to the river bed at around 0620 UTC. Helicopter made a heavy landing without power and received substantial damage.

M/s Global Vectra Helicorp Limited (GVHL) who was also operating shuttle service from Katra Helipad to Sanjhi Chhat helipad observed VT-PHH going down from its circuit altitude and deviating from the track. On observing this PIC of GVHL helicopter

immediately informed PHHL operations on company frequency. PHHL immediately launched the standby helicopter for search and rescue of VT-PHH. The rescue helicopter saw VT-PHH lying in the valley next to the river bed. The rescue helicopter landed in an open space next to the accident helicopter and air lifted PIC and one passenger who had suffered injury due crash landing. The rescue helicopter made a second sortie to the accident site and rescued two more lady passengers from the accident site to Katra Helipad for immediate medical assistance. The PIC and 04 passengers sustained serious injuries. Rest of the passengers went to the helipad by road. All the 06 passengers were taken to the hospital for medical attention.

Weather at the time of accident was fine with visibility more than 5 Kms with calm winds. There was no Inflight or post impact fire. The helicopter sustained substantial damage due crash landing.


**Google Earth Map of Katra Helipad (A), Sanjhi Chhat Helipad (B) and Accident Site VT-PHH on River Bank (C)**

**1.2 Injuries to Persons** :

| Injuries | Crew | Passengers | Others |
|---|---|---|---|
| Fatal | NIL | NIL | NIL |
| Serious | 01 | 04 | NIL |
| Minor | NIL | 01 | NIL |
| None | NIL | 01 | NIL |

**1.3 Damage to Helicopter**:

The helicopter was substantially damaged during crash landing. Following damages were observed on the helicopter:-

1. Main Rotor Hub Assy: Main rotor Yoke found in damaged condition.
2. Wind shield: Both LH & RH wind shield and Bottom plexi glasses found in broken condition.
3. Exhaust Duct: Duct found in damaged condition with crack and burnt hole.
4. Turbine module found burnt and damaged at few places.
5. Combustion chamber mounting at turbine assembly was found splitted at the top.
6. Air duct from engine fairing and compressor were dislodged and clamps fallen inside deck.
7. Vertical fin lower part was fully damaged.
8. Both Tail Rotor blades were fully damaged.
9. RH side of the belly portion was having multiple cracks below PIC door, pax door and above pax door.
10. LH side below pax cabin, belly structure found depressed.
11. VHF antenna at belly section found broken
12. The cross tubes were bend and both the skids spread due impact force.

**1.4 Other Damages:** Nil

## 1.5 Personnel Information:

### 1.5.1 Pilot- in- Command

| | |
|---|---|
| Age | 53 years 03 months, Male |
| License | CPL (H) Holder |
| Date of Issue and Valid up to | 06/02/2008 & 05/02/2013 |
| Class | Helicopter |
| Endorsements as PIC | Bell 407 |
| Date of Joining Company | 15/07/2007 on Deputation from Air Force and from 28/06/2010 Employment to PHHL. |
| Instrument Rating | Nil |
| RTR | Valid |
| Date of FRTOL issue & validity | 12/03/2007 & 02/12/2017 |
| Date of Med. Exam. | 03/09/2012 |
| Validity of Medical Exam. | 02/03/2013 |
| Date of last line/Route Check | 17/11/2012 |
| Date of last English language Proficiency | 30/03/2011 |
| Date of last CRM | 5-12- 2012 |
| Date of last Dangerous Goods Awareness Training and validity | 16/05/2012 & 15/05/2014 |
| Date of last Monsoon training and validity | 17/05/2012 & 16/05/2013 |
| Date of last refresher and validity | 16/04/2012 & 15/04/2013 |
| Familiarity with Route/ Airport flown for last 12 months and since joining the company. | Since 2008 |
| Total flying experience | 5991:20 hrs |
| Total Experience on type | 2832:30 hrs |
| Total Experience as PIC on type | 2520:15 hrs |
| Last flown on type | 30/12/2012 |
| Total flying experience during last 01 Year | 563:50 hrs |
| Total flying experience during last 180 days | 197:25 hrs |

| | |
|---|---|
| Total flying experience during last 90 days | 134:00 hrs |
| Total flying experience during last 30 days | 01:50 hrs |
| Total flying experience during last 07 Days | 01:50 hrs |
| Total flying experience during last 24 Hours | 01:50 hrs |
| Rest period before the accidental flight | 17 hrs |
| Date of last Simulator Training for critical emergencies and validity | Not carried out |

There was no Flight Duty Time Limitation violation in respect of operating crew. He was not involved in any Accident/ Serious Incident previously.

**1.6 Helicopter Information** :

Bell 407 is a single engine helicopter manufactured by M/s Bell Helicopter, Canada with standard seating configuration for one pilot and six passengers. Helicopter is fitted with RR 250-C47B engine manufactured by M/s Rolls Royce, USA. The helicopter is certified in transport category, for day operation under VFR. The maximum operating altitude of this helicopter is 20000 feet density altitude and maximum takeoff weight is 2267 kg. Helicopter length is 12.62 meter and width is 2.28 meter, height of this helicopter is 3.10 meter. The helicopter is approved in the "Transport" category under sub category "Passenger".

**Construction:**

The structure of the helicopter Bell 407 is bonded aluminium honeycomb and semi-monocoque structure with composite side panels and aft fuselage skins Doors (five), one hinged double door & co- pilot door on left side, pilot & passengers on right side. All doors are composite material and Landing gear was tubular skid type with replaceable skid shoes. The tail structure includes Tail boom, monocoque structure with vertical fin and fixed stabilizer and Tail skid (tail rotor guard).

Bell 407 helicopter VT-PHH S/No. 53210 was manufactured on Oct 1997. Certificate of Registration No. 2938, under Category 'A' which was issued on 27/01/1998 in the name of Pawan Hans Helicopters Limited (PHHL).As on 30th December, 2012 Bell 407 helicopter VT-PHH has logged 7093.53 A/F Hrs.

The certificate of Airworthiness Number 2347 was issued under "normal" category sub-division "passenger" issued by DGCA on 27/01/1998 & was valid upto 4/12/2013. ARC Ref No. DDG/NR/ARC/2012/290 was issued on 24/12/2012 and valid upto 23/12/2013. The helicopter was flown with Aeromobile Licence No. A-020/031-RLO (NR) valid upto 31st Dec 2013. This helicopter was operated under Non-scheduled operator's permit No. 02/1998 and is valid on date of accident. The Bell 407 helicopter and Engine are being maintained under continuous maintenance as per maintenance program consisting of calendar period based maintenance and Flying Hours / Cycles based maintenance as per maintenance program approved by Office of DDG, DGCA, Delhi.

Last major inspection 100 Hrs / 90 days inspection was carried out at 7086.17 A/F Hrs on 3/12/2012 for renewal of Airworthiness Review Certificate (ARC). The 180 days Radio inspection was carried out on 25/11/2012 at 7065:57 hrs. All lower inspections, after last flight inspection and pre-flight checks were carried out as and when due before the accident.

The helicopter was last weighed on 28/02/2008 at Safdarjung Airport and the weight schedule was duly approved by DAW, DGCA, Delhi. As per the approved weight schedule the Empty weight is 1362.9 kgs. Maximum Fuel capacity is 456.8 kgs. Empty weight CG is 129.62 inch aft of reference datum. Maximum landing weight of helicopter was 2267 kgs.

All the concerned Airworthiness Directive, Service Bulletins, DGCA Mandatory Modification on this helicopter and its engine have been complied with as & when due.

The last fuel microbiological test was carried out on 4/08/2012 at DGCA approved facility and the colony count was within acceptable limits.

As per the Pilot defect register (PDR) last defect was reported after flight on 29/12/2012 on hydraulics system. As per PDR "After hydraulic switch is put off in flight, collective stuck up in same position". The defect rectification was carried out on 30/12/2012 morning and thereafter test flight of 20 minutes was carried out. No defect was reported after the flight.

Load & Trim (L & T) sheet was made by PIC. As per L & T, all up weight (AUW) of Helicopter was approx 4825.4 lbs. As per SOP of PHL at Sanjichhat AUW up to 5000 lbs at 30°C is allowed.

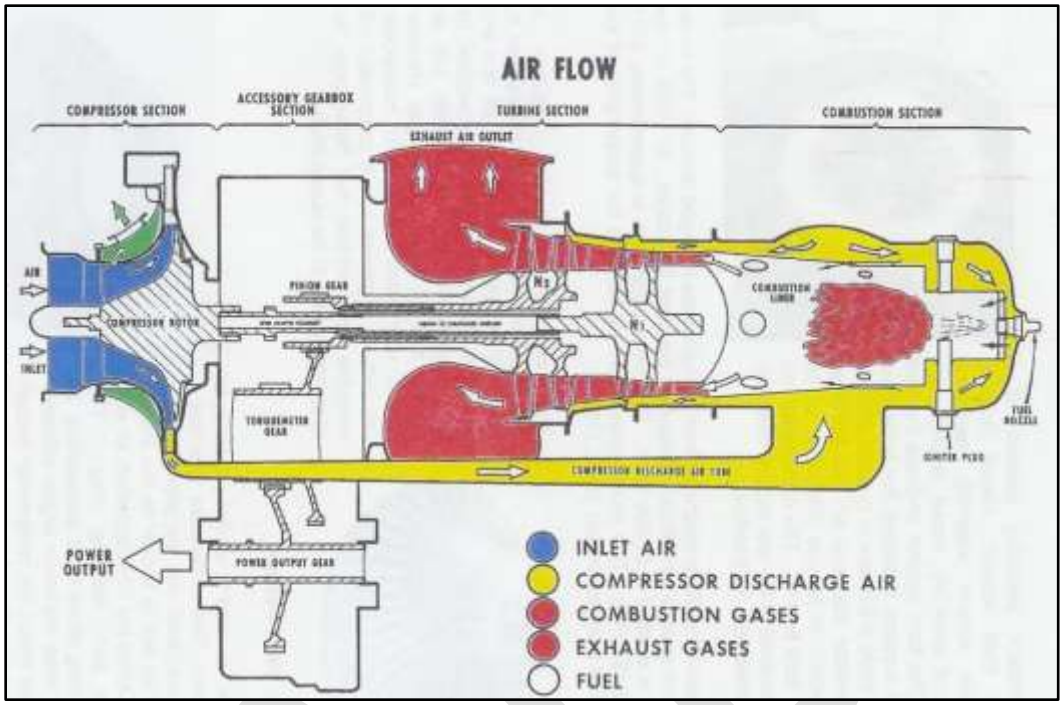
Prior to release for flight the Daily Inspection Schedule and Transit Inspection schedules was carried out by the certified Aircraft Maintenance Engineer.

**ENGINE**

The Bell 407 helicopter is fitted with one R R 250- C47B engine having S/No. CAE 847232 manufactured by Rolls Royce, USA. The Engine had logged 5889.41 Engine Hrs since new, 534:37 hrs since overhaul and 6137 cycles respectively. The last major inspection 100 hrs/90 days was carried out on 3/12/2012 at 5882.06 Engine Hours, 6128 Cycles for renewal of Airworthiness Review Certificate.

The engine was earlier installed on Bell 407 helicopter VT-PHI and was removed due "crack observed on compressor shroud" at 5680:26 Engine Hrs /6035 cycles on 06/12/2011.

The 2000 hrs Engine Inspection schedule and compressor replacement was carried out by PHHL and thereafter the engine was installed on VT-PHH on 25/10/2012 at 6984:37 Airframe hours.




The details of components are

| Component | Serial Number | TSO | Total Time |
|---|---|---|---|
| **Engine** | CAE 847741 | 534:37 | 5889:41 |
| **Gearbox** | CAG 47232 | - | 5889:41 |
| **Compressor** | CAC 44345 | 499:12 | 4381:39 |
| **Turbine** | CAT 45072 | 534:37 | 2529:57 |
| **HMU** | JGALM0084 | 1207:16 | 1207:16 |

**MAIN ROTOR BLADES**

The Bell 407 helicopter VT-PHH is fitted with Four Main Rotor Blades having an On-Condition life. The details are as below:

| S/No | PART No. | SERIAL No. | COMPONENT HRS |
|---|---|---|---|
| 1. | 407-015-001-111 | A – 1099 | 7093.53 hrs |
| 2. | 407-015-001-111 | A – 1658 | 6636.50 hrs |
| 3. | 407-015-001-111 | A – 1582 | 6277.35 hrs |
| 4. | 407-015-001-111 | A - 1150 | 2951.02 hrs |

**BRAKES**

There is No parking brake or pedal brakes installed for helicopter operation.

Main Rotor Brake is installed for stopping of the Main Rotor Blades at a predetermined operation during shutting down of engine.

## 1.7 Meteorological Information:

There is no Metrological office situated at Katra, Jammu. However, the Met briefing was obtained telephonically from Udhampur Air force station. Also Met information was obtained using satellite picture and weather forecast. As per PIC, visibility at the time of accident was more than 05 Kms with winds calm.

## 1.8 Aids to Navigation:

There was no Navigational aid available at both Helipads. Helicopter flying from Katra to Sanji Chhat helipad was carried out using ground references. Wind Director Indicator (windsock) and 'H' marking were available at both helipads.

## 1.9 Communication:

There is no Air Traffic Services (ATC) available at Katra to control the Helicopter Operations. As per SOP all helicopters going from Katra to Sanji Chhat and from Sanji Chhat to Katra shall maintain lateral separation. Helicopters has to give R/T calls on 127.9 MHz / 122.95 MHz and maintain visual contact while passing 07 way points between Katra helipad and Sanji Chhat helipad.

## 1.10 Aerodrome Information:

Katra and Sanji Chhat helipads are constructed out of concrete are marked with a letter "H", so as to be visible from the air. The coordinates of Katra helipad are N32 59 19.0 E 74 56 52.0 situated at 2800 feet above mean sea level (AMSL) and coordinates of Sanji Chhat helipad are N 33° 02' 00" E 74° 56' 00" situated at 6000 feet AMSL . Katra helipad had dimension of 40 X 40 meters and 03 helicopters can be parked. Sanji Chhat helipad had dimension of 30 X 30 meters and 01 helicopter can be parked at a time. The emergency services covering fire and medical are available at both the helipads.

## 1.11 Flight Recorders :

Cockpit Voice Recorder (CVR) and Digital Flight Data Recorder (DFDR) were not fitted on helicopter neither required as per existing Civil Aviation Requirements.

## 1.12 Wreckage & Impact Information:

After experiencing the power loss, PIC tried to control the helicopter and located a flat land in the valley to carry out a forced landing. PIC controlled the flight during rapid descend and landed on sloping surface next to the river bed at around 0620 UTC. Helicopter made a heavy landing without power and received substantial damage. The wreckage of the helicopter was confined to final resting position on the sloping surface in upright position and there was no inflight disintegration of any part.

**Landing of Helicopter at River Bed short of flat Ground**

Due to heavy landing, helicopter received substantial damage .The fuselage exhibited extensive vertical impact damage. The cross tubes bent and landing skids was spread but not fractured. The tail rotor had hit the ground and subsequently the tail drive shaft had failed in torsional overload, and tail rotor blades were severed approximately mid-span consistent with sudden stoppage of the tail rotor blade impact with terrain. The tail boom exhibited no evidence of contact by the main rotor blades. The vertical fin was found fractured near it's attachment point due ground contact. The tail rotor gear box and vertical fin attachment casting exhibited a large crack consistent with vertical fin ground contact.

Out of four main rotor blade, the blue main rotor blade exhibited maximum damage due impact with ground. The blue blade tip was fractured and bent back opposite the direction of normal counter- clockwise rotation. Both upper and lower magnetic chip detectors (MCD) were removed for inspection. On lower MCD minor contamination (light fuzz or paste) and upper MCD shows contamination chips (silvers and a few small less than 1mm) was observed.


**Landing of helicopter on sloping surface**

The wreckage was shifted from accident site to Safdarjung Airport, New Delhi. Detail examination of wreckage was carried out with Rolls Royce and Bell Helicopter representative on 18-19th February 2013.

Inspection of the engine exterior didn't revealed any obvious signs of damage from ground impact but exhibit evidence of uncontained turbine burst. Fractured pieces of power turbine wheel and turbine outer shroud were observed.

Boroscope inspection of Engine was carried out by Rolls Royce Representative. The Inspection reveals 3rd Stage and 1st Stage turbine burst.

## 1.13 Medical & Pathological Information:

The PIC and 04 passengers were airlifted by the rescue helicopter to the nearest hospital. The PIC was then shifted to Airforce hospital, Udhampur. PIC suffered Spinal injuries on L#1. Prior to the accident flight the PIC had undergone the preflight medical check for alcohol and same was found negative. Post flight medical check for alcohol couldn't be carried out as PIC suffered serious injuries.

The 04 passenger's suffered Head Injuries and Spinal Injuries due impact.

**1.14 Fire:** There was no pre or post impact fire.

**1.15 Survival Aspects**: The accident was survivable. .

## 1.16 Test and Research:

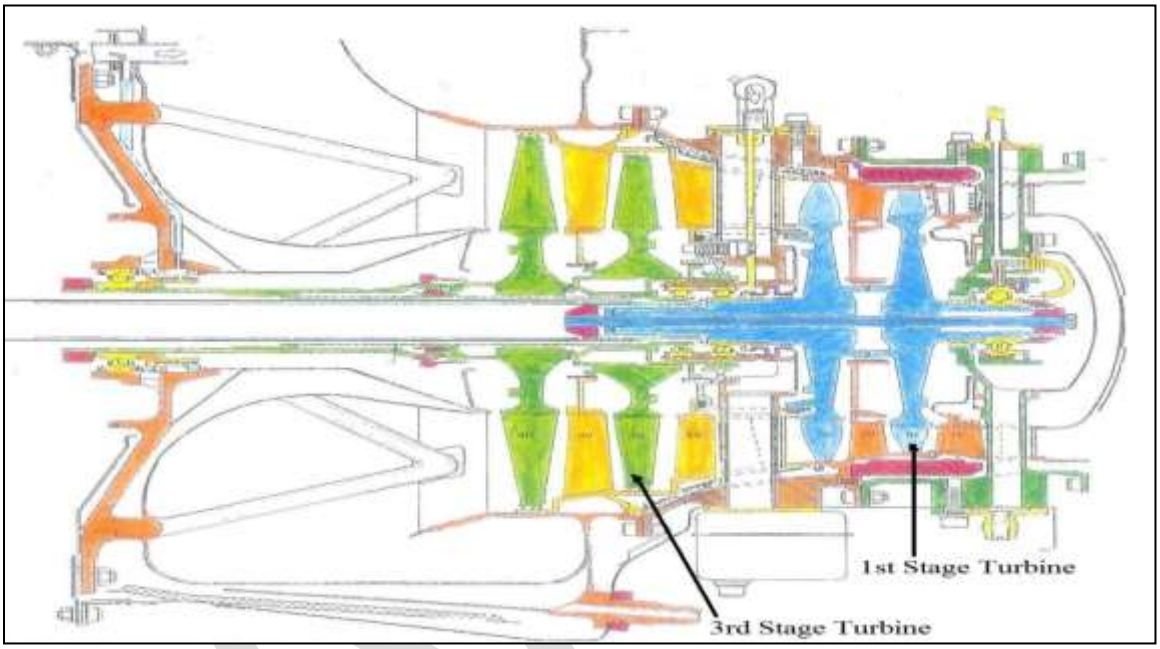
The helicopter experience power loss during flight due which the PIC had to carry force landing. The suspected engine was eternally examined at Delhi and Baroscopic inspection was carried out. During Baroscopic Inspection internal damage was observed. The engine Serial No. CAE 847232 was then shipped to manufacturer facility Rolls-Royce facility, Indianapolise, USA for detailed strip examination.

### 1.16.1 Engine Strip Examination

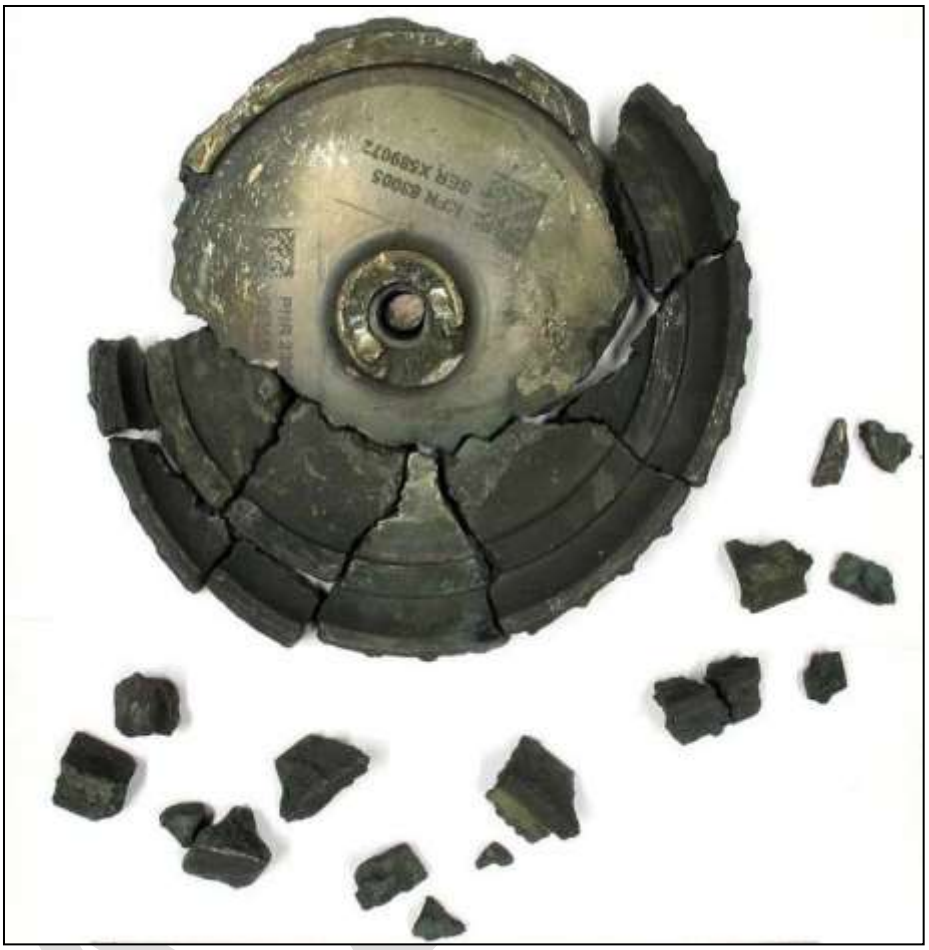
The engine was dis-assembled at Rolls-Royce facility on 21st August 2013. NTSB, USA was requested to associate in the investigation. The representative from FAA & Bell helicopters also participated during disassembly of engine.

The Rolls Royce 250- C47B is a reverse –airflow modular- type turboshaft free turbine engine. It consists of a compressor, a gearbox, a turbine assembly, and a combustion chamber. The turbine rotor stages are numbered 1 through 4, with the 1st stage at rear and the 4th stage at the front.The turbine assembly consists of 2-stage gas producer turbine 1st

and 2nd stage wheels that drive the compressor and a 2-stage turbine 3rd and 4th stage wheels that drives the rotor system through the reduction gearbox. The turbine rotor assemblies are not mechanically coupled, but they are gas coupled i.e. exhaust gases flow through the four turbines. There are nine main bearings numbered 1 through 8 in a front to rear direction.



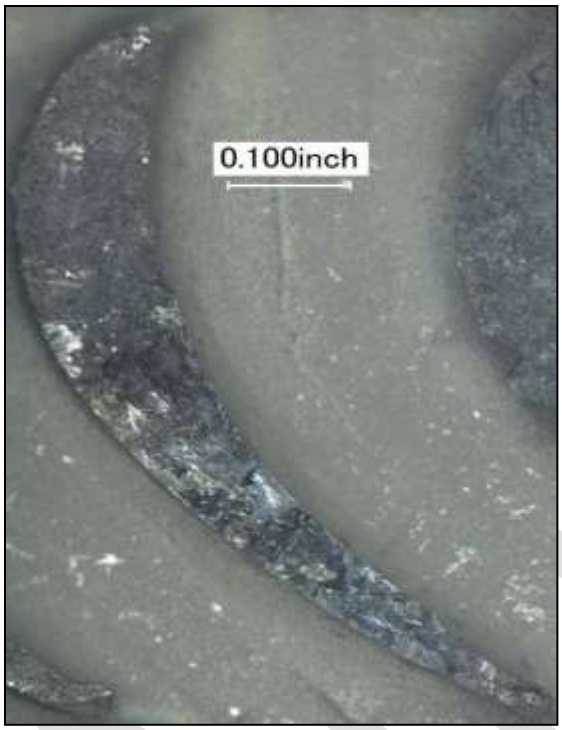

The 1st Stage Turbine wheel was fragmented into multiple pieces from an apparent overspeed burst, which is consistent with a decoupling of the gas generator turbine from the compressor. The 1st stage turbine Energy Absorption Ring was bulged from contact by the 1st stage turbine wheel. The gas-producer turbine support was bulged and fractured axially at the 12 o'clock position.



**First Stage Turbine Wheel**

The 3rd stage turbine wheel had liberated all of its blades at the root. Detailed examination of the 3rd stage turbine blade fractures revealed a single blade had failed in high cycle fatigue (HCF). All other blades had fractured in overload. The high cycle fatigue fracture of the single 3rd stage turbine blade was determined to be the initiating event of the engine failure.


**3rd Stage Turbine Wheel**




Metallurgical examination of the fatigue-fractured blade revealed the fatigue crack progressed approximately 0.48 inch from the trailing edge before final fracture and separation of the blade in overload. The total cross sectional area of the blade measured approximately 0.0593 square inches, and the cross sectional area of the overloaded portion of the fracture measured approximately 0.0308 square inches

Scanning Electron Microscope (SEM) examination of the fatigue fracture revealed rub damage on the suction side and a Stage I fatigue facet on the pressure side of trailing edge. No surface anomalies were noted on the walls of the blade near the facet. These fracture features are consistent with high cycle fatigue initiation and propagation of the crack.

During investigation it was found that that 3$^{rd}$ stage turbine wheel blade fractured in high cycle fatigue at the trailing edge hub location due to operation of one or more natural frequencies of the wheel. Failure of first blade led to a rapid failure of turbine wheel as remaining blades fractured in overload.

Failure of 3rd Stage Turbine resulted in fracture of Turbine-to-Compressor Coupling (CT). This fracture disconnected the gas producer Turbine from compressor resulting 1st Stage turbine wheel burst due overspeed. Data from ECU indicates that 1st Stage Turbine burst 54 sec after the initial 3rd Stage turbine blade failure.

Rolls-Royce has issued an alert Commercial Service Letter (CSL) A- 6144 in June 2013 regarding operations in the Power Turbine speed avoidance range (Keep Out Zone) and time restricted overspeed zones to minimize the possibility of power turbine failure. Also as mentioned in report, Rolls-Royce plans to release two design changes that will increase the operating speed natural frequency margin on the initial change and further increase the frequency margin and also improve the vibration margin on the second design change.

### 1.16.2 Engine Control Unit (ECU)

Extraction of the ECU data revealed the ECU data page was not updated with installation of the ECU in the Helicopter. Various engine serial numbers stored in the ECU did not correlate with the actual engine components. This is a clerical oversight and does not affect the performance of the ECU or engine. Examination of ECU data revealed engine operation was normal and consistent initially with normal climbing flight profile.

Thereafter, the ECU recorded a 4% decrease in main rotor speed ($N_R$) and 1% decrease in power turbine speed with an accompanying decrease in engine torque, fuel flow and inter-turbine measured gas temperature. Collective pitch remains constant at 68% during this transient period.

Subsequently, the main rotor speed drops dangerously low, and the PIC responds by bottoming the collective pitch (drops from 66% to 8%). The main rotor speed recovers and subsequently over speeds. The engine responds to the over speed by reducing fuel

flow from 400pph to the minimum stop of 36pph. A corresponding drop in Measured Gas Temperature reflects the reduction in fuel flow to the engine.

Data reveals that the PIC begins to pull up the collective as the helicopter continues to descend. Main rotor speed again begins to decay and the engine again responds by increasing fuel flow. Main rotor speed slowly drops and then slowly increases as the PIC continues to manipulate the collective while descending. The gas generator turbine speed (Ng) remains at roughly 107% throughout this time period.

The data suggests that this is the point at which the 1st stage turbine wheel bursts. Gas generator speeds drop rapidly and torque values drop to zero, suggesting the torque meter line was severed by liberated turbine debris. The loss of torque signal causes the ECU to revert to manual mode.

The engine begins to rapidly spool down. Both the gas generator turbine and power turbine speeds decay rapidly. The PIC continues to manipulate the collective pitch in order to maintain main rotor speed within acceptable parameters. However, even though the engine is no longer producing power, temperatures within the engine continue to climb, reaching temperatures in excess of 1900 degrees Fahrenheit. This is consistent with a brief, fuel-fed fire within the engine during the decent. The PIC pulls full up collective, presumably for landing. Main rotor speed decays below flying speed and the ambient pressure ceases to increase, all of which indicate the helicopter is on the ground.

### 1.16.3 Fuel, Engine Oil & Transmission Sample Report

A sample of fuel from the fuel Bowzer of Indian Oil (from which refueling of Helicopter was carried out before accident) was taken and subjected to full specification test at the Physical & Chemical lab (Fuel lab) in Directorate General of Civil Aviation (DGCA). As per the examination report, there was no abnormality in the sample and it passed the entire specification test.

A sample of Engine Oil and Transmission Oil was drained from helicopter and subjected to specification test at Physical & Chemical lab (Fuel lab). As per the examination report, there was no abnormality observed in the sample.

## 1.17. Organizational & Management Information:

M/s Pawan Hans Helicopters Ltd (PHHL) is a Public Sector Undertaking (PSU) having Non- Scheduled Operating Permit (NSOP) No. 02/1998 and valid on date of accident. PHHL holds the largest number of helicopters under NSOP having at present 48 helicopters including MI-172, Bell 206, Bell 407, AS 350 B3, AS 365 N, AS 365 N3. It has the biggest operation for off shore flying on oil rig platforms . PHHL also provides Helicopter Services to various State Governments and Heli- Pilgrimage Operations.

## 1.18 Additional Information:

### 1.18.1 Bell Alert Service Bulletin

In March 2004**,** Bell Helicopters had issued an Alert Service Bulletin (ASB) 407-04-64 regarding "inspection of Rolls-Royce model 250-C47B third-stage turbine wheels .The same was issued in compliance of Rolls Royce Rolls-Royce alert Commercial Engine Bulletin (CEB) A-72-6050. This inspection requires a visual and NDT inspection for any crack on one of the turbine blades. In March 2005, Bell helicopters has released ASB 407-04-65 advising $N_2$ steady-state Operation avoidance between 68.0% and 86.0 % in Helicopter Flight Manual (FM).

In June 2005, Bell released ASB 407-05-67 superseding earlier ASB 407-05-65 and included Rolls-Royce CEB A-72-6054. The CEB indicates new $N_2$ steady-state avoidance range between 68.4% to 87.1%. Bell Helicopters has revised Flight manual and a placard showing this range was installed on Instrument Panel.

### 1.18.2 Rolls- Royce Alert Commercial Service Letter

Rolls Royce Rolls-Royce has issued an alert Commercial Service Letter A- 6144 in June 2013 to heightened awareness to operations in the Power Turbine speed avoidance range (Keep Out Zone) and time restricted overspeed zones to minimize the possibility of power turbine failure. It contains warning that "to prevent possible power turbine failure, transient operation only is permitted between 68.4% and 87.1% $N_2$". All other operation in this range is prohibited and must be logged in the applicable section of the engine log book. Transient Operation is defined as no dwell at an $N_P$ speed of more than 1 second duration.

### 1.18.3 Salient Engine Maintenance related Observations during Strip Examination.

The 2000 hrs Engine Inspection schedule and compressor replacement was carried out by PHHL and engine was installed on VT-PHH on 25/10/2012 at 6984:37 Airframe hours. After 2000 hrs Inspection the helicopter had flown 109:11 hours and the engine failed during flight on 30-12-2012.

Salient findings were found by Rolls – Royce while examination on Engine and are not considered cause to the accident by Rolls –Royce.

1. Examination of the compressor revealed the compressor vent tube had been fitted with a non-standard and un-approved shim around the outer diameter of the lower castellated slip fitting. This 'home made' shim appeared to have served the purpose of providing additional circumference to the fitting in order to allow the use of a too-large P-clamp retention fitting.

2. The fuel spray nozzle (FSN) exhibited excessive shimming. A total of eight shims were present, with five of the shims being .062" thick and three shims being .031" thick, for a total of 0.403". This resulted in only two of the FSN's threads to be engaged on the FSN boss. The RR-250-C47B Overhaul and Maintenance Manual stipulate a minimum of three full threads must be engaged on the FSN. If this is not possible, a different inner combustion liner or FSN must be fitted. The fuel

spray nozzle exhibited normal carbon coating of the spray face. The nozzle was not disassembled.

3. Extraction of the ECU data revealed the ECU data page was not updated with installation of the ECU in the aircraft. Various engine serial numbers stored in the ECU did not correlate with the actual engine components. This is a clerical oversight and does not affect the performance of the ECU or engine.

### 1.18.4 High Cycle Fatigue (HCF)

Fatigue is the weakening of a material caused by repeatedly applied loads. It is the progressive and localized structural damage that occurs when a material is subjected to cyclic loading. The nominal maximum stress values that cause such damage may be much less than the strength of the material typically quoted as the ultimate tensile stress limit, or the yield stress limit.

Fatigue occurs when a material is subjected to repeated loading and unloading. If the loads are above a certain threshold, microscopic cracks will begin to form at the stress concentrators such as the surface, persistent slip bands (PSBs), and grain interfaces. Eventually a crack will reach a critical size, the crack will propagate suddenly, and the structure will fracture. The shape of the structure will significantly affect the fatigue life; square holes or sharp corners will lead to elevated local stresses where fatigue cracks can initiate. Round holes and smooth transitions or fillets will therefore increase the fatigue strength of the structure.

Fatigue life of a component is defined as the number of stress cycles of a specified character that it sustains before failure of a specified nature occurs. Fatigue life is influenced by a variety of factors, such as temperature, surface finish, metallurgical microstructure, presence of oxidizing or inert chemicals, residual stresses, scuffing contact (fretting), etc.

High Cycle Fatigue (HCF) is associated with components which require more than $10^4$ cycles to failure where stress is low and deformation is primarily elastic.

### 1.18.5 Autorotation

Autorotation is a state of flight where the main rotor system of a helicopter turns by the action of air moving up through the rotor rather than engine power driving the rotor. In normal powered flight, air is drawn into the main rotor system from above and exhausted downward, but during autorotation, air moves up into the rotor system from below as the helicopter descends. The upward flow of air through the rotor provides sufficient thrust to maintain $N_R$ throughout the descend. The PIC controls the $N_R$ by adjusting the position of collective lever. The descend is arrested by raising the collective lever to increase the main rotor angle of attack (AOA) and to use inertia stored in the main rotor blades to again produce lift, allowing the helicopter to land safely or minimize an impact.

Autorotation is permitted mechanically because of both a freewheeling unit, which allows the main rotor to continue turning even if the engine is not running, as well as curved main rotor blades such that when the collective pitch is fully down the inner part of the blade has negative pitch relative to the horizontal plane and can be spun up by the relative wind. It is the means by which a helicopter can land safely in the event of complete engine failure.

The most common reason for autorotation is an engine malfunction or failure, but autorotation can also be performed in the event of a complete tail rotor failure, or following loss of tail-rotor effectiveness, since there is virtually no torque produced in an autorotation. In all cases, a successful landing depends on the helicopter's height and velocity at the commencement of autorotation

At the instant of engine failure, by immediately lowering collective pitch, which must be done in case of an engine failure, the PIC reduces lift and drag and the helicopter begins an immediate descend, producing an upward flow of air through the rotor system. This upward flow of air through the rotor provides sufficient thrust to maintain rotor rpm throughout the descend. Since the tail rotor is driven by the main rotor transmission during autorotation, heading control is maintained as in normal flight.

Several factors affect the rate of descend in autorotation: density altitude, gross weight, rotor rpm, and forward airspeed. The PIC primary control of the rate of descend is

airspeed. Higher or lower airspeeds are obtained with the cyclic pitch control just as in normal flight. When landing from an autorotation, the kinetic energy stored in the rotating blades is used to decrease the rate of descend and make a soft landing. A greater amount of rotor energy is required to stop a helicopter with a high rate of descend than is required to stop a helicopter that is descending more slowly. Therefore, autorotative descends at very low or very high airspeeds are more critical than those performed at the minimum rate of descend airspeed.

### 1.18.6 Simulator Refresher Training

DGCA has issued CAR Section 7 Series B Part XIV dated 30th November 2006 on "Recurrent training requirements for Helicopter Pilots". As CAR all pilots have to undergo Recurrent checks consisting of Ground training, Simulator Training, Emergency and Survival Training, CRM training and Dangerous Goods Training. The Simulator Refresher Training for critical emergencies consists of at least 5 hours of mandatory practice of critical emergencies in simulator such as engine failure, system failure, tail rotor failure etc. which cannot be practiced or simulated in actual flying shall be carried out by a pilot on specific type of flight simulator once in two years.

As per records submitted by PHHL the involved pilot had not undergone Simulator Refresher Training to practice critical emergencies on Bell 407.

### 1.18.7 Helicopter Operations at Katra- Sanji Chhat

There are regular helicopter shuttle services from Katra to Sanji Chhat. Helipad at Katra and Sanji Chhat were maintained by Mata Vaisno Devi Shrine Board. Single engine helicopters were used for day VFR operations. Normally, two helicopters operate on rotation basis simultaneously and contact each other on common frequency. Few flat force landing fields free of obstructions shall be constructed which will be used in case of emergencies. DGCA has issued an Air Safety Circular 07 of 2013 on "Seasonal Helicopter Operations- Safety Guidelines".

### 1.18.8 Standard Operating Procedure (SOP)

PHHL was using an SOP for Katra- Sanji Chhat Helicopter Operations. The SOP contains details of operations requirements including overdue actions. As per Air Safety Circular 07 of 2013, Para 2.1.4 and 2.1.5, Sketch / Map of force landing fields to be supplemented to SOP. Same was not found attached in SOP.

**1.19 Useful and Effective Techniques**: NIL

## 2. ANALYSIS :

### 2.1 Serviceability of Helicopter

The helicopter VT -PHH was having Certificate of Airworthiness ( C of A) valid till 4/12/2013 and Annual Airworthiness Review Certificate (ARC) was issued on 24/12/2012 and valid upto 23/12/2013.

Last major inspection 100 Hrs / 90 days inspection was carried out at 7086.17 A/F Hrs on 3/12/2012 for renewal of Airworthiness Review Certificate. 180 days Radio inspection was carried out on 25/11/2012 at 7065:57 hrs.

The helicopter was last weighed on 28/02/2008 at Safdarjung Airport and the weight schedule was duly approved by DAW, DGCA, Delhi. As per the approved weight schedule the Empty weight is 1362.9 kgs. Maximum Fuel capacity is 456.8 kgs. Empty weight CG is 129.62 inch aft of reference datum. Maximum landing weight of helicopter was 2267 kg.

Last defect was reported after flight on 29/12/2012 for hydraulics system as “After hydraulic switch is put off in flight, collective stuck up in same position”. The defect was duly rectified on 30/12/2012 morning and a test flight of 20 minutes was carried out. Nothing abnormal was reported and all the engine parameters were well within the limits. There after helicopter was released for flights.

Daily Inspection Schedule and Transit Inspection schedules were carried out before flight on 30-12-2012. Prior to the accident flight the helicopter had flown for approx. 32 minutes including 20 mins of test flight after defect rectification, nothing abnormal was reported.

As per L & T, all up weight (AUW) of Helicopter was approx 4825.4 lbs which was well with limit.

In view of the above it is inferred that the helicopter was fully airworthy & safe to undertake flight.

## 2.2 Weather

The visibility at the time of accident was more than 05 kms with winds calm.

## 2.3 Pilot Handling of the helicopter

The PIC was having valid license and medical. On 30-12-2012, PIC successfully flew approx 32 minutes. While carrying out 3$^{rd}$ Sortie from Katra to Sanji-Chhat PIC heard loud bang just short of Sanji Chhat (around 6000 AMSL) and experienced power loss with a drop in rotor RPM ($N_R$). PIC immediately lowered the collective to regain the rotor RPM and subsequently descended from the sector altitude. During this period, the FADEC warning was also generated. PIC tried to control the helicopter by carrying out auto-rotation and looked out for a flat land in the valley to carry out a forced landing. PIC controlled the flight during rapid descend and landed on sloping surface next to the river bed at around 0620 UTC. Helicopter made a heavy landing without power and received substantial damage. PIC and 04 passengers received serious injuries in the accident.

PIC had not undergone Training for critical emergencies on simulator such as engine failure, system failure, tail rotor failure etc as per DGCA CAR. Also, PHHL operations department had also not ensured the compliance of simulator refresher training requirements.

## 2.4 SOP and Helicopter Operation

As per Air Safety Circular 07 of 2013, Para 2.1.4 and 2.1.5, Sketch / Map of force landing fields to be supplemented to SOP. Same was not mentioned in the SOP. Since helicopter operations at Mata Vaisno Devi Shrine is perennial operations , few flat force landing fields free of obstructions may be identified and duly circulated to all the operator which can be used in case of emergencies.

## 2.5 Engine Strip- Examination

The involved engine was dis-assembled at Rolls-Royce facility, USA on 21st August 2013. During examination it was found that 3rd Stage and 1st Stage Turbine burst.

The 3rd stage turbine wheel had shed all of its blades at the root. Detailed examination of the 3rd stage turbine blade fractures revealed a single blade had failed in high cycle fatigue (HCF). All other blades had fractured in overload. The high cycle fatigue fracture of the single 3rd stage turbine blade was determined to be the initiating event of the engine failure. The 1st Stage Turbine wheel was fragmented into multiple pieces from an overspeed burst.

Investigation revealed that the 3rd Stage single turbine blade had failed in High Cycle fatigue (HCF). Failure of first blade led to a rapid failure of turbine wheel as remaining blades fractured in overload conditions.

As per manufacturer strip inspection report, 3rd stage turbine wheel blade fractured in high cycle fatigue at the trailing edge hub location due to operation on one or more natural frequencies of the wheel. The engine failed during flight which eventually resulted into the accident.

### 2.6 Circumstances Leading to Accident.

On 30-12-2012, Bell 407 helicopter was engaged in flying between Katra- Sanjhi Chhat. While carrying out third sortie just short of Sanjhi Chhat helipad, PIC heard loud bang and experienced power loss with a drop in rotor RPM ($N_R$). He tried to control the helicopter and subsequently descended from the sector altitude searching for a flat land in the valley to carry out a forced landing. During this period the FADEC warning was also generated. PIC controlled the flight during rapid descend and landed on sloping surface next to the river bed at around 0620 UTC. Helicopter made a heavy landing without power and received substantial damage. Weather at the time accident was fine with visibility more than 5 Kms.

Search and rescue was carried out by another PHHL helicopter. PIC & 04 passengers received serious injuries and were shifted to hospital. There was no pre and post impact fire. All persons survived in the accident.

## 3. CONCLUSION :

### 3.1 Findings :

1. The Certificate of Airworthiness and the Certificate of Registration of the helicopter was valid on the date of accident.

2. The certificate of flight release was valid at the time of accident.

3. The helicopter and Engines were being maintained under continuous maintenance approved by Office of DDG (NR), DGCA, Delhi.

4. The PIC was having valid license, medical and in the regular employment of PHHL.

5. Helicopter took off from Katra Helipad at 0615 UTC with Six Passenger and one PIC. While carrying out third sortie just short of Sanjhi Chhat helipad, PIC heard a loud bang and experienced power loss with a drop in rotor RPM ($N_R$).

6. The PIC immediately lowered the collective to regain rotor RPM ($N_R$) and tried to control the helicopter.

7. The PIC descended from the sector altitude searching for a flat land in the valley to carry out a forced landing. During this period the FADEC warning was also generated.

8. The PIC controlled the flight during rapid descend and landed on sloping surface next to the river bed at around 0620 UTC. Helicopter made a heavy landing without power and received substantial damage.

9. Search and rescue was carried out by another standby PHHL helicopter. All persons survived in the accident. PIC & 04 passengers received serious injuries and were shifted to hospital. Other 02 passengers went to the helipad by road. There was no pre and post impact fire.

10. Weather at the time accident was fine with visibility more than 5 Kms and winds calm.

11. Last defect reported was after flight on 29/12/2012 for hydraulics system and defect rectification was carried out on 30/12/2012 morning. Thereafter, test flight of 20 minutes was carried out satisfactorily and no other defect was reported.

12. Helicopter had flown approx. 32 minutes of flight on 30-12-2012 including 20 mins of test flight after defect rectification.

13. The involved engine was strip examined at manufacture facility, Rolls-Royce , USA on 21st August 2013. During examination it was found that 3rd Stage and 1st Stage Turbine burst.

14. During investigation, it was found that 3rd Stage Turbine burst due to failure of single blade in high cycle fatigue (HCF) at the trailing edge hub location due to operation on one or more natural frequencies of the wheel.

15. All other blades of 3rd stage turbine had fractured in overload. Failure of 3rd Stage Turbine resulted in fracture of Turbine-to-Compressor Coupling (CT) resulting 1st Stage turbine wheel burst due overspeed.

16. Bell Helicopters and Rolls- Royce have issued instructions regarding the Power Turbine speed avoidance range (Keep Out Zone). It contains warning that "to prevent possible power turbine failure, transient operation only is permitted between 68.4% and 87.1% $N_2$.

17. Maintenance lapses were pointed out by Rolls Royce during strip Inspection, though they are not contributory to accident.

18. As per Air Safety Circular 07 of 2013, Para 2.1.4 and 2.1.5, Sketch / Map of force landing fields to be supplemented to SOP. Same is not part of PHHL SOP.

19. Training Records of PIC reveals that he had not undergone simulator refresher for critical emergencies such as engine failure, system failure, tail rotor failure etc as per DGCA CAR Section 7 Series B Part XIV. The PHHL operations department had not ensured the compliance of simulator training requirements as per CAR.

## 3.2 Probable Cause of Accident :

Helicopter experienced power loss due to High cycle fatigue (HCF) failure of single 3rd Stage Turbine blade. The pilot attempted for forced landing which eventually resulted into an accident.

## 4. Safety Recommendations :

1. Few flat force landing fields free of obstructions may be identified around Katra-Sanjhi Chhat helipad and duly circulated to all the operator which will be used in case of emergencies.

2. Operations department of operator shall ensure the compliance of pilot training for critical emergencies on simulator such as engine failure, system failure, tail rotor failure etc as per DGCA CAR requirements.

3. DGCA may ensure that the proper maintenance procedures are followed / complied during maintenance by PHHL / helicopter operators.

(Capt. P. K. Chabri)
Ops. Member

3/12/14
(A. X Joseph)
Deputy Director Air Safety,
DGCA Hqrs
Member

03/12/2014
(Amit Gupta)
Deputy Director (AED)
DGCA Hqrs
Chairman

Date: 3rd December 2014
Place: New Delhi


**Damage to Helicopter**


**Damage to Main Rotor**

**Damage to Tail Rotor**

**Damage to Engine**