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**FINAL INVESTIGATION REPORT
OF
SERIOUS INCIDENT TO GO AIR
AIRBUS A320 AIRCRAFT VT-WGJ
AT BANGALORE ON 01/09/2018**

**AIRCRAFT ACCIDENT INVESTIGATION BUREAU
MINISTRY OF CIVIL AVIATION
GOVERNMENT OF INDIA**

FOREWORD

This document has been prepared based upon the evidences collected during the investigation and opinion obtained from the experts. The investigation has been carried out in accordance with Annex 13 to the convention on International Civil Aviation and under Rule 11 of Aircraft (Investigation of Accidents and Incidents), Rules 2017 of India. The investigation is conducted not to apportion blame or to assess individual or collective responsibility. The sole objective is to draw lessons from this incident which may help in preventing such incidents in future.

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LIST OF ABBREVIATIONS

A/C	Aircraft
ACARS	Aircraft Communication Addressing and Reporting System
AGB	Accessory Gear Box
AoA	Angle of Attack
AP	Autopilot
ATC	Air Traffic Control
ATPL	Airline Transport Pilot License
A/THR	Auto thrust
CAS	Computed Air Speed
CG	Centre of Gravity
CL or CLB	Climb
CPL	Commercial Pilot License
DES	Descent
DFDR	Digital Flight Data Recorder
ECAM	Electronic Centralized Aircraft Monitor
EGT	Exhaust Gas Temperature
FCOM	Flight Crew Operating Manual
FCTM	Flight Crew Training Manual
FD	Flight Director
FMA	Flight Mode Annunciator
FWD	Forward
GS/LOC	Glide Slope/ Localiser
IAF	Indian Air Force
IFS	In-flight Services
IFSD	In-flight Shut Down
IFTB	In-Flight Turn Back
LDA	Landing Distance Available
MCT/ FLX	Max Continuous Thrust / Flex
METAR	Meteorological Aerodrome Report
MGB	Main Gear Box
MODs	Modifications
MTOW	Max Takeoff Weight
MSN	Manufacturer Serial Number
NAV	Navigation
NDB	Non Directional Beacon
NEO	New Engine Option
PF	Pilot Flying
PM	Pilot Monitoring
QRH	Quick Reference Handbook
RA	Radio Altitude
SALT	Selected Altitude
SBs	Service Bulletins

SCAS	Selected Computed Air Speed
SD	System Display
SOP	Standard Operating Procedure
SRS	Speed Reference System
TAF	Terminal Area Forecast
THR	Thrust
TL	Thrust Lever
TLA	Thrust Lever Angle
TRK	Track
T/O	Take Off
UTC	Coordinated Universal Time
VLS	Lowest Selectable Speed
VIB	Vibration
VRTG	Vertical 'g' force
VOBL	Bangalore Airport

FINAL INVESTIGATION REPORT ON SERIOUS INCIDENT TO GO AIR AIRBUS A320 AIRCRAFT VT-WGJ AT BANGALORE ON 01/09/2018

1.0 FACTUAL INFORMATION

1.1 History of Flight

On 1st September 2018, Airbus A320 aircraft VT-WGJ was involved in a serious incident while operating flight G8-283 from Bangalore to Pune. The aircraft was under command of an ATPL holder (PF) with a CPL holder acting as Pilot Monitoring (PM). There were 169 passengers on board. The incident occurred in day light conditions. There was no fire or any injury to crew or passengers.

During takeoff roll, engine no. 1, N2 vibrations went very high at a ground speed of 20 knots. The vibrations levels increased to 10.0 units and at 1500 radio altitude, alert on ECAM (Master Caution) came up for high engine vibrations on engine #1 and hence the QRH procedure was carried out after which the N2 vibrations parameters were at normal levels momentarily. The vibrations levels increased again followed by other warnings i.e. Eng 1 OIL CLOG, Eng 1 OIL FILTER DEGRADE, Eng 1 STALL. In addition, AUTO FLT/ AUTO THR was put OFF and a decision was taken by the commander to continue on manual thrust. The warnings were followed by Eng 1 FAIL.

The ECAM procedure to shut down Eng 1 was carried out. The PF decided to return to VOBL (nearest airport) on priority and a PAN PAN call was made. No assistance at the airport was requested. A single engine straight in ILS approach was carried out. Following instructions of the PF, the PM had switched off the Glideslope mode.

During final approach, several callouts were made by the PM with regards to speed and alignment of the aircraft. PF accordingly carried out small adjustments of eng 2 thrust. During approach, in an attempt to flare, attitude was raised. The aircraft pitched up accordingly, but limited by the aircraft protection (α prot) which had been activated, and touched the ground. As per PM, he was aware that it

had resulted in hard landing but he had not conveyed it to PF. The aircraft taxied to bay.

On ground, it was found that the 'g' value at touchdown has reached 2.68, whereas the Manufacturer limitation is 2.6. DFDR output was provided to the manufacturer and computation of landing 'g', based on parameters, (i.e. Landing g, landing weight of the aircraft 64.45T and Rate of Descent at Touch down 13.1 feet/sec) gave a value of 3.25, classifying the event as a 'Severe Hard Landing'. . The occurrence was hence categorised as "severe hard landing".

The aircraft remained on ground for almost 6 months for maintenance activity.

1.2 Injuries to Person

INJURIES	CREW	PASSENGERS	OTHERS
FATAL	Nil	Nil	Nil
SERIOUS	Nil	Nil	Nil
MINOR/ NONE	Nil / 06	Nil / 169	Nil

1.3 Damage to Aircraft

The DFDR data of the flight was sent to Airbus for analysis. The Airbus engineering team analyzed the DFDR data and it was confirmed that the landing was "Severe hard landing" as the g value has gone up to 3.25. Following the DFDR data analysis, the Airbus engineering team recommended for "Structural Inspection for severe hard landing" on the following parts of Aircraft.

- Landing gear
- Vertical Tail plane.
- Wing
- Centre Fuselage & Centre wing box.
- Fuselage Cargo Door (FWD & AFT) surrounding structure.
- Forward & Aft Cargo Door.
- Bulk Cargo Door
- Emergency Exit Hatches.

After inspections, both main landing gears were removed, as recommended by the supplier, Safran.

1.4 Other Damage

NIL

1.5 Personnel Information

1.5.1. Pilot in Command (Pilot Flying)

SI No.	Item	Description
1.	Age	47 yrs
2.	License	ATPL
3.	License validity	13/03/2021
4.	Medical	Valid
5.	Last route check done on	29/11/2017
6.	IR date	23/03/2018
7.	FRTTO license valid upto	13/03/2021
8.	Total flying hours	6096
9.	Flying hours as Commander on A320	675:00
10.	Flying done in last 1 year	820:00
11.	Flying done in last 6 months	424:00
12.	Flying done in last 3 months	226:00
13.	Flying done in last 1 month	73:00
14.	Flying done in last 7 days	12:00

Pilot Flying (PF) had earlier flown turboprops (HS 748) with Indian Air Force. He was a Qualified Flying Instructor (QFI) with IAF.

1.5.2 Co-Pilot (Pilot Monitoring)

SI No.	Item	Description
1.	Age	42 yrs
2.	License	CPL
3.	License Validity	Valid
4.	Medical	Valid

5.	Last route check done on	30/11/2017
6.	IR date	30/05/2018
7.	FRTTO license valid upto	17/06/2020
8.	Total flying hours	945.49
9.	Flying hours on A320	633:32
10.	Flying done in last 1 year	633:32
11.	Flying done in last 6 months	388:58
12.	Flying done in last 3 months	231:22
13.	Flying done in last 1 month	77:22
14.	Flying done in last 7 days	15:51

Pilot Monitoring (PM), a CPL holder was with IFS for 10 years in two different airlines before joining the present airline as Trainee First officer in July 2017.

1.6 Aircraft Information

Airbus A320 Neo MSN 7737, Indian Registration VT-WGJ, was delivered in November 2017 and is equipped with P & W Neo Engines. At the time of occurrence, this Aircraft had logged 3096 hrs and 1969 cycles since new.

1.6.1 Operational Aspects

Following are the relevant extracts from FCOM/ QRH :-

- ✚ With A/THR engaged, when a thrust lever is set below the CL detent, the thrust of the associated engine is limited to the thrust lever position. Normal operation of the A/THR system requires the thrust levers to be:
 - In the CL detent for the two-engine configuration.
 - ✓ If they are not set in the CL detent, “LVR CLB” flashes white on the FMA. If one lever is in the CL detent and other one is not, then LVR ASYM is displayed in amber
 - TL of operating engine in MCT detent when in the one-engine-out configuration (one TL at idle is considered one engine operation)..
 - ✓ If the appropriate lever is not set in the MCT detent, “LVR MCT” flashes white on the FMA

- ✚ High engine vibration requires the flight crew to monitor engine parameters, especially the EGT, and cross check with the other engine. Thrust can be reduced if conditions permit to do so, in order to maintain vibrations below the amber threshold of 5 UNITS.
- ✚ The ENG SD page is automatically displayed between 1st engine take-off thrust and till 1500 ft RA. (The relevant SD page is automatically displayed as soon as a fault or malfunction triggers a caution or warning message.) When the cockpit unit (Units) value of vibrations exceeds 5 Units, the Units values on the Engine SD page change from GREEN to AMBER. The high vibration ECAM caution is inhibited below 1500ft RA.



N1, N2 VIBRATIONS

- Green : The vibration of the LP(HP) rotor is in normal range.
- Amber : The level of LP(HP) rotor vibration is excessive.

- ✚ The maximum level of vibration that can be recorded on the DFDR is 10UNITS.

- ✚ As per stall procedure, whenever engine stall (In flight) is detected by Flight Crew before FADEC or instructed by ECAM, the thrust lever of the affected engine should be set to idle.
- ✚ When one engine TL is at idle, it is considered as single engine operation and the other engine thrust lever at that time should be set to MCT. The ECAM caution 'THR LEVERS....MOVE' would be displayed and in addition, the FMA will display 'LEVER MCT' flashing in white. A master caution is repeated every 5 seconds if one lever is at idle and the other is not at the MCT detent.

AUTO FLT A/THR LIMITED

Applicable to: ALL

Ident.: PRO-ABN-AUTO_FLT-S-00016943,0001001 / 21 MAR 16

ANNUNCIATIONS

Triggering Conditions:

L2 This alert triggers when A/THR is active but thrust levers are set below CL detent (2 engines), or MCT detent (1 engine).
This caution is repeated every 5 s as long as the thrust lever are not moved.

Flight Phase Inhibition:

Ident.: PRO-ABN-AUTO_FLT-S-00018689,0001001 / 21 MAR 16

THR LEVERS.....MOVE

L2 Thrust lever must be set in the relevant detent.

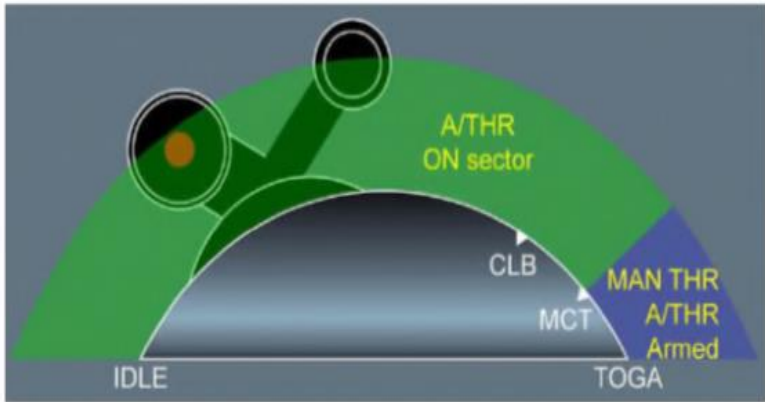
- ✚ When the AP is in OP DES mode, it manages the aircraft trajectory to target the selected CAS, but the aircraft trajectory can only be level flight or descent.

- ✚ ENG1 FAIL ECAM caution is triggered when the engine core speed falls below idle, whereas 'ENG SHUTDOWN' is triggered when the engine Master Switch is set to OFF by the flight crew. As per the FCTM, in the event of an engine failure, thrust levers should be set to MCT.

OPERATIONS WITH ONE ENGINE INOPERATIVE

Ident: AS-FG-10-2-00018247.0001001 / 20 MAR 17
Applicable to: ALL

The above-noted principles also apply to an one-engine inoperative situation, except that A/THR can only be active, when thrust levers are set between IDLE and MCT.



In case of engine failure, the thrust levers will be in MCT detent for remainder of the flight. This is because MCT is the maximum thrust that can usually be commanded by the A/THR for climb or acceleration, in all flight phases (e.g. CLB, CRZ, DES or APPR).
With AP OFF, pilots may feel that the directional control is more difficult because the A/THR changes the thrust setting. The choice between using, or not using A/THR after engine failure is a personal one. As far as the speed control is concerned, the A/THR is usually more accurate than a pilot.

The stabilization criterion is given below. This requires that the flight crew must initiate a Go Around, if approach is not stabilized.

STABILIZATION CRITERIA

Ident.: PRO-NOR-SOP-18-A-00014487.0002001 / 09 FEB 18

Applicable to: ALL

The stabilization height is defined as one of the following:

- 1 000 ft above airfield elevation (AAL) in Instrument Meteorological Conditions (IMC), or
- 500 ft above airfield elevation (AAL) in Visual Meteorological Conditions (VMC), or
- Any other height defined in Operator policies or regulations.

In order for the approach to be stabilized, all of the following conditions must be satisfied before, or at the stabilization height:

- The aircraft is on the correct lateral and vertical flight path
- The aircraft is in the desired landing configuration
- The thrust is stabilized, usually above idle, and the aircraft is at target speed for approach

Note: In IMC, a later speed and thrust stabilization can be acceptable provided that:

- It is in accordance with Operator policies and regulations
- The aircraft is in deceleration toward the target approach speed
- The flight crew stabilizes speed and thrust as soon as possible and not later than 500 ft AAL.

- The flight crew does not detect any excessive flight parameter deviation.

If one of the above-mentioned conditions is not satisfied, the flight crew must initiate a go-around, unless they estimate that only small corrections are required to recover stabilized approach conditions.

Note: If the predicted tailwind at landing is greater than 10 kt, decelerated approach is not permitted, and the aircraft speed should be stabilized at around VREF + 5 kt in final.

Following is the Normal Standard Operating Procedures (Approach) given in FCOM:

AT GREEN DOT SPEED

CAUTION	The flight crew should avoid extended flight in icing conditions with the slats extended.
----------------	---

FLAPS 1..... ORDER
 FLAPS 1.....SELECT

- At high weights, if the green dot speed is close to VFE NEXT, the flight crew may select a lower speed.
- FLAPS 1 should be selected more than 3 NM before the Final Descent Point.
- Check deceleration toward "S" speed.
- For decelerated approaches, the aircraft must reach or be established on the final descent with FLAPS 1 and "S" speed at or above 2 000 ft AGL.
- If the aircraft does not decelerate on the flight path or aircraft speed is significantly higher than "S" speed, extend the landing gear in order to slow down. The use of speedbrakes is possible. The flight crew should be aware that the use of speedbrakes causes an increase in VLS.




TCAS Mode selector.....TA or TA/RA

- FAA recommends to select TA only mode:
 - In case of known nearby traffic which is in visual contact
 - At particular airports and during particular procedures identified by an Operator as having a significant potential for unwanted or inappropriate resolution advisories (closely spaced parallel runways, converging runway, low terrain along the final approach, etc.).

AT 2 000 FT AGL MINIMUM

FLAPS 2..... ORDER

FLAPS 2.....SELECT

- Check deceleration toward "F" speed.
- For ILS / MLS  / GLS  and approaches using FLS , if the aircraft intercepts the flight path below 2 000 ft AGL, select FLAPS 2 at one dot below the flight path.
- If the aircraft speed is significantly higher than "F" speed on the flight path, or the aircraft does not decelerate on the flight path, extend the landing gear in order to slow down the aircraft. The use of speed brakes is not recommended.
- When the speed brakes are deployed, extending the flaps beyond FLAPS 1 may induce a slight roll movement, and in calm conditions a small lateral control asymmetry may remain until disturbed by a control input or by an atmospheric disturbance.

WHEN FLAPS ARE AT 2

L/G DOWNORDER

L/G lever.....SELECT DOWN

AUTO BRKCONFIRM

- If the runway conditions have changed from the approach briefing, consider another braking mode.

GROUND SPOILERSARM

EXTERIOR LIGHTS

NOSE sw.....T.O

RWY TURN OFF sw.....ON

WHEN LANDING GEAR IS DOWN

FLAPS 3.....ORDER

FLAPS 3.....SELECT

ECAM WHEEL SD page CHECK

- WHEEL SD page appears below 15 500 ft when landing gear is extended.
- Check for three green indications on the landing gear indicator panel. At least one green triangle on each landing gear strut on the WHEEL SD page is sufficient to indicate that the landing gear is downlocked. Rely also on the "LDG GEAR DN" green LDG MEMO message to confirm that the landing gear is downlocked.

● **If residual pressure is indicated on the triple indicator:**

RESIDUAL BRAKING PROC..... APPLY

FLAPS FULL..... ORDER

FLAPS FULL..... SELECT

- *Retract the speed brakes before selecting FLAPS FULL to prevent a pitch down when the speed brakes automatically retract.*
- *Check deceleration towards VAPP.*
- *Check correct TO waypoint on the ND.*

A/THR..... CHECK IN SPEED MODE OR OFF

WING ANTI-ICE pb-sw..... OFF

1.7 Meteorological Information

Relevant METARs reported were as given below:

VOBL 312300Z 29005KT 6000 Hz SCT012 SCT 080 20/20 Q1014 NOSIG=

VOBL 010030Z 27008KT SCT012 SCT080 20/20 Q1014 NOSIG=

VOBL 010100Z 28007KT SCT012 SCT080 20/20 Q1014 NOSIG=

VOBL 010130Z 28010KT SCT012 SCT080 20/20 Q1014 NOSIG=

The METAR valid at the time of incident indicated wind from 280° (headwind) at a speed of 7kts, with scattered clouds at 1200 ft and visibility of 6000 m in haze.

1.8 Aids to Navigation

All Navigational Aids on ground and of the aircraft were working satisfactorily.

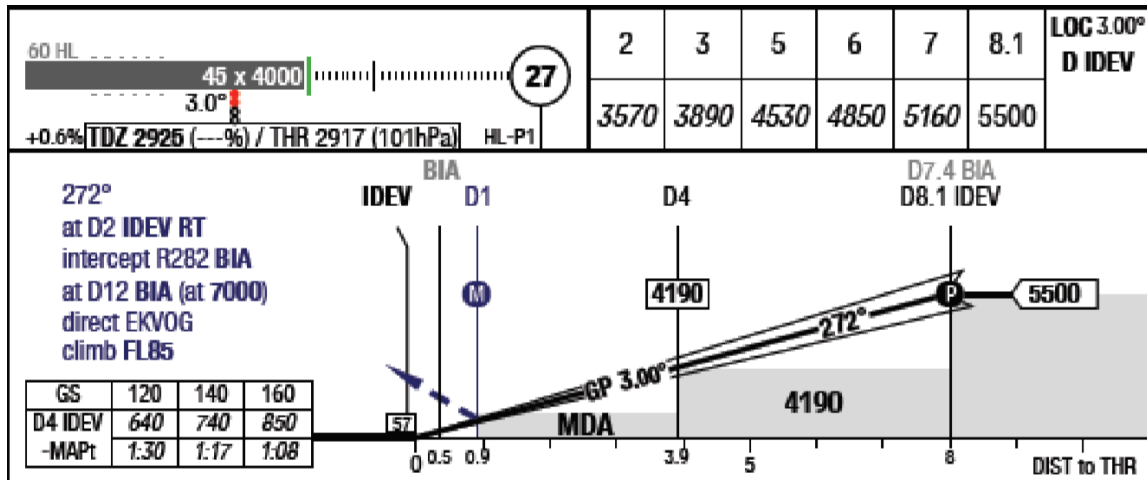
1.9 Communication

There was always two way communications between the ATC and the aircraft.

1.10 Aerodrome Information

The Runway orientation at BIAL international airport, Bengaluru is 09/27. Its elevation is 2925ft. The ILS is available for both approaches for runway 09/27.

PAPI is available for both sides of the runway. NDB is also available at BIAL for approach and landing.



The ATC is controlled and manned by Airport Authority of India. Met Office services are 24 Hrs. TAF, Trend Forecast and Briefing is available.

1.11 Flight Recorders

1.11.1 CVR

The relevant extract from CVR readout is as below:-

- During climb at about 4500 ft (1500 ft RA) Master Caution came on.
- The Master Caution of No 1 engine High Vibration was followed by QRH checklist.
- The aircraft climbed to FL140.
- The PAN PAN call was made by PF. He informed ATC that it was due to technical reasons.
- PF briefed the situation to Cabin crew that they were returning to Bangalore.
- The ATC vectored VT-WGJ for priority landing on Runway 27.
- The PF choose to disengage Auto thrust at approx. 12500 feet and disengaged Auto pilot at around 4000 feet.
- The PM gave speed check calls.
- Checklist and callouts were mostly standard.

- The PF switched off the glide slope mode switch on finals.
- The (low energy) speed speed speed warning came number of times.
- The PM gave repetitive inputs to PF to make necessary changes in the flight path.
- The PM didn't advise the PF to Go-around.

1.11.2 FDR

Following are the relevant extracts from FDR: (Aircraft touch down at 00:51:08 hours UTC)

Time (UTC)	
00:28:30	Start of Take Off roll
00:28:35	E1N2 VIB = 10 Units GND SPD = 20 Kts
00:29:08	Aircraft takes off, (EGT1/ EGT2) = 933/ 891
00:29:16	Autopilot engaged
00:29:24	Thrust reduced to CLIMB from FLEX-MCT
00:29:30	Speed target became 250 kts
00:29:45	Master Caution Comes ON for 6 secs
00:30:01 to 00:30:11	TLA 1 starts reducing to 20 and back to 24; no change in E1N2 VIB
00:30:14 to 00:31:42	Flaps retracted and TLA 1 starts reducing from 24.6 to 9.49
00:31:42	Aircraft crossing 8500 ft
00:32 :14	Subsequently Oil Pressure Eng1 starts reducing
00:32 :33	E1 N2 VIB starts reducing
00:33:27	Selected CAS increased to 276 kts
00:34:21	Master Caution triggered twice
00:34:41	E1 N1 increases to 10 Units for 3 secs
00:34:58	TLA ENG 1 brought back to zero, subsequently E1 N2 VIB reduced < 1 Unit. Master caution triggered every 5 seconds to alert the flight crew that one TLA is at idle and the other is not at MCT.

00:36:19	Auto Thrust was Disengaged, Master caution stopped. Alt 12872 ft and climbing
00:38:00	IFTB initiated
00:39:24	Master Caution – Eng1 Oil Filter Degraded & Eng 1 Oil Filter clogged
00:39 :47	TLA 2 also reduced to IDLE (18.6 deg)
00:40:09	EGT ENG 1 shoots up from 607°C to 945°C in 4 seconds (Most probably the ENG Failed at this juncture)
00:40:13	EGT ENG1I records ZERO. (possibly value> 999)
00:40:15	EGT ENG 1 Over limit warning triggers for 4 secs
00:40:17	Master Caution triggers for 4 secs., fuel flow drops to 67 kg/h from 256 kg/h
00:40:46.	ENG 1 Master Lever turned to OFF (Shut down)
00:47:00	Conf 1 + f Selected, ALT 5232 ft, IAS 207kts
00:49:27	Master Caution triggered – ‘Eng 1 OIL SYSTEM FAULT’
00:49:37	AP 1 & 2 disconnected by the flight crew
00:49:38 and 00:50:25	Manual Approach (1000ft to 400ft RA) Low energy aural warning “SPEED SPEED” triggered 4 times and aural warning “GLIDESLOPE” was triggered at 620ft RA for 14 seconds Alpha protection was activated 6 times
00:50:25	Manual Landing performed by the Captain (PF)
00:50:45	Aircraft was at 250ft RA Sidestick pitch up inputs increased the pitch to 10° by 125ft RA, activating the angle of attack protection. Further pitch up inputs were applied and continual full back stick was applied with Alpha Prot active from 25ft RA to touchdown.
00:51:08	Aircraft touched down hard on the runway threshold

1.12 Wreckage and Impact Information

The landing was classified as a severe hard landing and a loads analysis showed the main landing gears had experienced excessive loads and considered unserviceable.

1.13 Medical and Pathological Information

Both cockpit crew had undergone pre-flight medical examination prior to take-off from Bangalore including Breath Analyser Test. The pre flight medical was satisfactory.

1.14 Fire

There was no fire.

1.15 Survival Aspects

The incident was survivable.

1.16 Test and Research

NIL

1.17 Organisational and Management Information

The flight was operated by a scheduled Airlines having valid Scheduled Operator Permit (SOP) issued by DGCA. CEO is the Accountable Manager. The company has Director Operations and Director Training.

1.18 Additional Information

Flight Mode Annunciator display in case of Thrust Lever not at appropriate position is given below:

DISPLAY	COLOR	MEANING
LVR CLB (flashing)	White	Request to set the thrust levers in CL detent in the case not in position while the aircraft is above the altitude of thrust reduction with both engines running.
LVR MCT (flashing)	White	Request to set the live thrust lever in FLX/MCT detent in the case not in position after an engine failure (with speed above green dot).
LVR TOGA (flashing)	White	Request to set the thrust levers to the TOGA detent, if one of the following conditions is met: <ul style="list-style-type: none"> - Upon a go-around performed with one engine inoperative (engine failed or corresponding thrust lever set to idle): <ul style="list-style-type: none"> - The flight crew reduces the thrust lever of operative engine to FLX/MCT before reaching the thrust reduction altitude - Upon a soft go-around: <ul style="list-style-type: none"> - One engine fails, or - One thrust lever set to idle position, or - One engine is not in soft go-around thrust mode, or - The soft go-around function is lost.
LVR ASYM	Amber	(Two engines only). One thrust lever in CL or FLX/MCT detent and the other one is not in this detent.
THR LK (flashing)	Amber	After A/THR disconnection (action of the flight crew on FCU or failure) resulting in thrust being frozen. Both thrust levers being in CL detent or one in FLX/MCT (engine out) detent.

Note: The amber caution light flashes and a single chime sounds every 5 s, as long as the flight crew takes no appropriate action in the following cases:

- THR LK
- LVR CLB (if the thrust levers are below the CLB detent)
- LVR MCT (if the thrust levers are below the FLX/MCT detent)
- LVR TOGA (if the thrust levers are below the TOGA detent). For this case, single chime sounds every 3 s.

1.19 Useful or Effective Investigation Technique

NIL

2. ANALYSIS

2.1 GENERAL

- ✚ Both operating flight crew were appropriately licensed and qualified to operate the flight. Their preflight Medical was valid. They had undergone all refresher trainings and nothing was wanting as per the requirements.
- ✚ The aircraft had valid Certificate of Airworthiness/ Airworthiness Review Certificate at the time of incident. The aircraft held valid Certificate of Release to Service. The mandatory Modifications and SBs were complied with.
- ✚ The weather at the airport at the time of incident was fine and is not a contributory factor to the incident.

2.2. ENGINEERING (LOAD) ANALYSIS

The reason for engine parameters going beyond limits during flight and resultant “In Flight Shut Down” was because of No. 3 Bearing Failure. This is a known problem with Neo Engines. The initial review of the DFDR data plots indicated a max vertical acceleration of 2.68 g. ‘g’ values is sampled 8 times a second. Vertical ‘g’ is sampled 8 times per second in the DFDR readout and the peak value may not have been captured if it occurred between 2 recorded values. .

DFDR raw data was shared with Airbus who, carried out loads computation, in order to assess the severity of the event. The feedback was received wherein it was indicated that though the touchdown ‘g’ was 2.68, but computation of landing ‘g’, based on parameters, (i.e. Landing g, landing weight of the aircraft 64.45T and Rate of Descent at Touch down 13.1 feet/sec) gave a value of 3.25, classifying the event as a ‘Severe Hard Landing’.

Airbus has introduced new FDIMU software incorporating a new load 15 report which analyses additional parameters to the ones used in the existing software. With the application of the new software, the load 15 report will directly classify similar events as a ‘Severe Hard Landing’.

As far as severe hard landing is concerned, the aircraft or maintenance aspects have not contributed to the incident.

2.3 DFDR Analysis

The aircraft returned to Bangalore due to high vibrations followed by In-flight Engine Shut Down (IFSD) in Flight. The aircraft is fitted with P & W Neo engines and the engine vibration is a known issue. A DFDR analysis report was received from Airbus and has been used while analyzing the operational aspects of this occurrence.

2.3.1 High Engine Vibrations & ATB

During take-off roll, at a ground speed of 20 knots, Eng # 1 N2 Vibrations reached 10.0 Units. The other engine was operating normal with all parameters stable. Auto pilot was engaged in SRS/ NAV mode, when the aircraft was at 200 ft radio altitude with CAS as 164 knots. The N2 vibrations of 10.0 Units continued. The engine SD page got displayed and N2 vibrations flashed number of times during the above period.

Though ENG 1 HIGH VIB ECAM caution was recorded (as per ACARS), the caution is inhibited until 1500 ft RA. At that time, EGT on engine # 1 was 940°C and on engine # 2 it was 890° C. The caution was displayed above 1500ft RA

The aircraft continued to climb and while crossing 5000 ft with AP1 and A/THR engaged, vibrations were still 10.0 Units. Eng # 1 thrust lever was moved back but the Eng # 1 N2 vibrations continued to be 10.0 Units.

The crew continued the flight with CAS of 225 knots. After crossing 5500 feet, altitude was selected to 14000 feet. Both thrust levers remained in CL detent with auto thrust active. Engine # 1 N2 Vibrations continued at 10.0 UNITS.

While crossing 8500 feet with AP1 and auto thrust still engaged, Eng # 1 thrust lever was reduced to 9 degrees. Eng #1 N2 vibrations dropped from 10.0 Units to 5.0 Units. When the aircraft was climbing through 10000 feet, Eng # 1 thrust lever was moved from 9 degrees to 11 degrees. Correspondingly N2 vibrations

also started increasing and went beyond 5.0 Units. Auto Pilot 1 and Auto thrust were still engaged.

Eng # 1 N2 vibrations further increased to 6.8 Units which triggered the master caution warning twice. The Eng # 1 N2 vibrations reached 10.0 Units with engine stall. This caused the master caution second time.

The aircraft still continued to climb with Eng # 1 thrust lever moved to idle and Eng # 2 thrust lever in CL detent. This triggered the master caution every 5 seconds to alert the crew that autothrust is limited and to move the thrust levers. Auto thrust was disengaged when the aircraft was crossing 12900 feet which stopped the master caution. Auto pilot 1 remained engaged.

The crew decided to return and auto pilot was changed to OP DES mode when the aircraft was at 14000 feet. The selected altitude was reduced to 12000 feet and selected CAS was increased to 250 knots from 214 knots. There was no change in thrust lever positions, engine #1 TL remained at idle and engine #2 TL remained in CL detent, delivering climb power.

After about 84 seconds of initiation of turn back, Engine #1 oil filter degraded and filter clog messages were recorded on the ACARS report. (The ENG page was displayed on the SD.)

As engine #2 was at climb power and engine #1 was at idle, the aircraft energy was too high. The Autopilot was unable to maintain the 250 kts selected speed, even in level flight since Auto thrust was OFF and speed increased beyond 260 kts.

By reducing the thrust on engine #2, the AP was able to meet the selected CAS (target) and increase the aircraft descent rate towards the selected altitude.

After 30 seconds of reducing thrust on Eng # 2, engine fail ECAM caution got triggered with Eng # 1 EGT increasing from 610 degree C to 1095 degree C. The flight crew shut down Eng #1 by taking Engine #1 lever to OFF. The thrust levers were not moved as required in the FCOM. Engine #1 TL remained at idle

and engine #2 TL remained at 16° (intermediate position between idle and CL) for a minute.

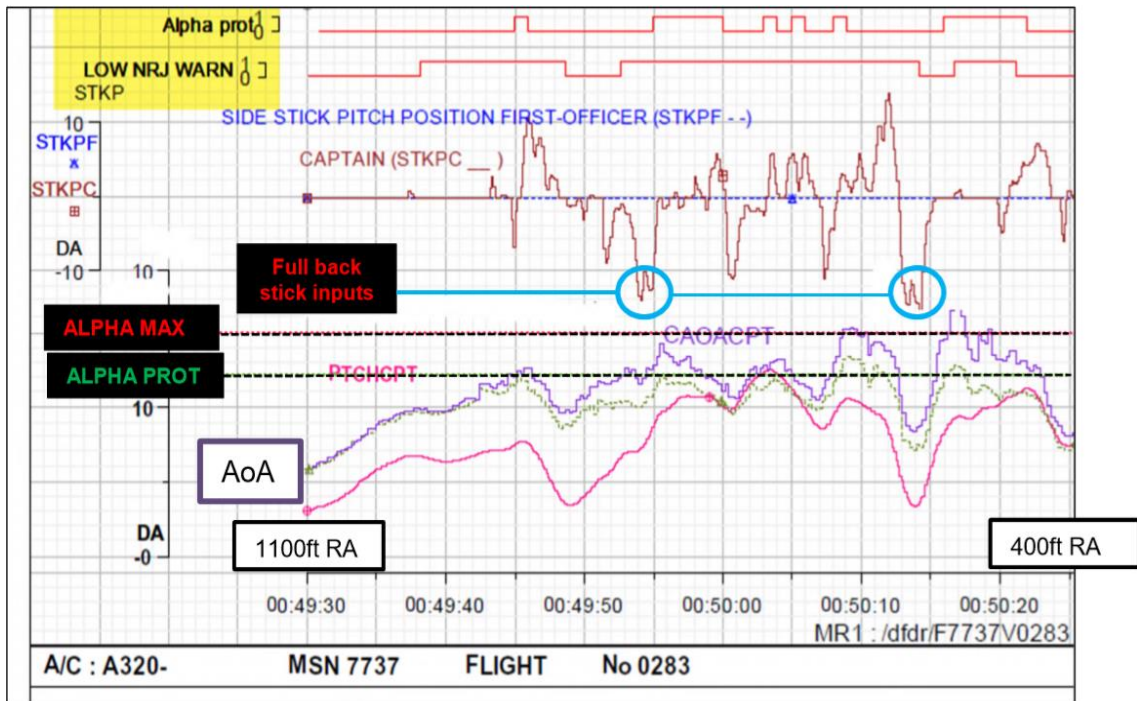
When the aircraft was at 6700 ft and descending to selected altitude of 5500 ft, speed was at selected CAS of 220 kts. A/THR remained OFF. Both TLs were at idle. With both APs engaged, LOC capture mode got engaged. LOC TRK mode got engaged a minute later, indicating that LOC is captured and was tracked. During this period, Glideslope mode was engaged and captured.

2.3.2 Approach & Landing

(The aircraft had touched down at 00:51:08 hrs. UTC.)

During approach, at 00:49:31 hrs. UTC, aircraft was in CONF FULL (Slats/Flaps 27°/40°), Landing gear was selected down, Ground spoilers were armed, Auto brake was not armed and AP1 & 2 were engaged. At 1120 ft RA, the aircraft was tracking the GS and LOC. A/THR was disengaged with both TLs at idle. CAS was 135 kts. reducing. Aircraft pitch was 3.5° increasing.

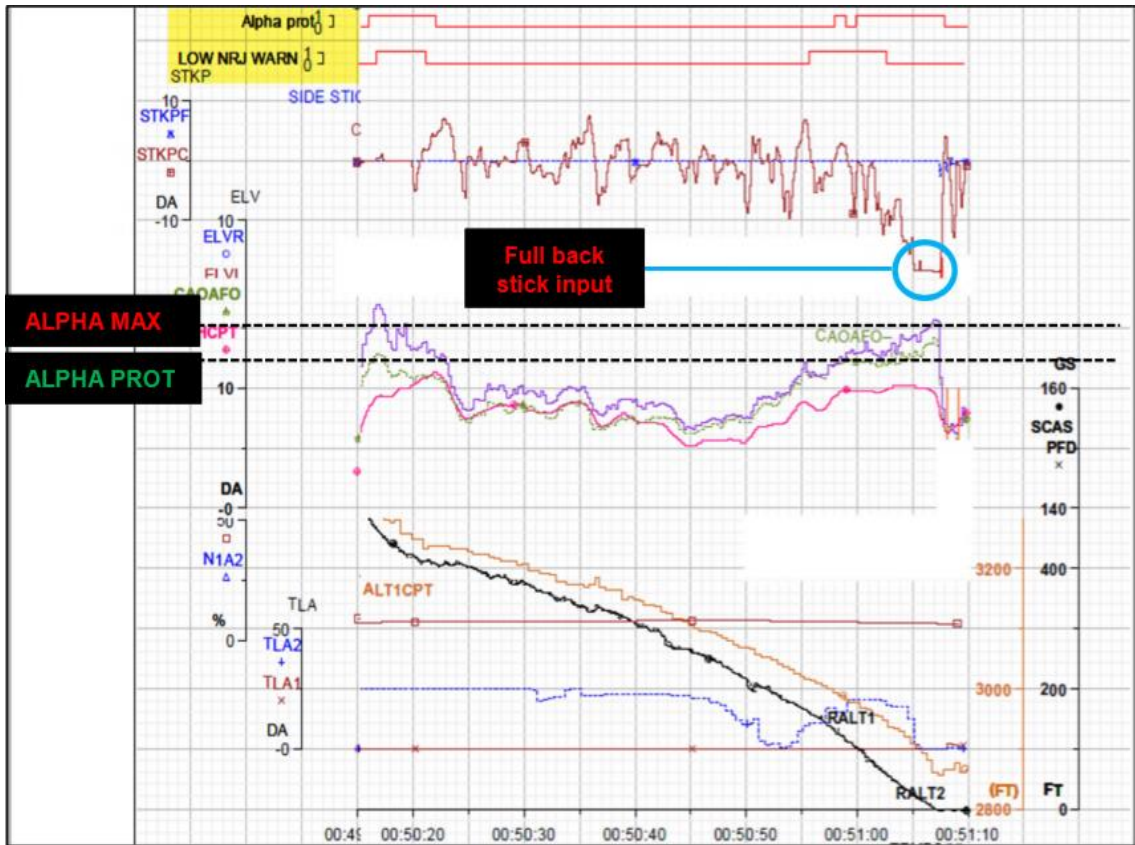
At 00:49:37, when the aircraft was at 1000 ft RA (decreasing), AP 1 & 2 was disconnected by the flight crew. CAS was 125 kts. Both FDs were engaged in GS/ LOC modes and the aircraft was aligned to the glide slope and localiser.



PF carried out manual approach. Between 1000 ft to 400 ft RA, high activity was recorded on Pilot Flying side stick. Pitch varied between 3° and 12° nose up and Roll varied between 0° and 10° (right wing down). Vertical descent rate varied between 0 ft/ min and 1600 ft/ min. CAS varied between 125 kts and 113 kts (VLS was 127 kts).

During this period, low energy aural warning “SPEED SPEED SPEED” triggered 4 times. Thrust was manually increased on engine #2. Aircraft started to dip under the glide slope by 1.4 dots and EGPWS aural warning “GLIDESLOPE” was triggered at 620 ft RA for 14 seconds. Glideslope deviation reached 2.7 dots below glide slope at 400 ft RA. Alpha protection was activated 6 times. AoA reached 12° (Alpha Prot) and 15° (Alpha Max).

The approach was continued despite the aircraft being unstable in attitude, below the glideslope by 2.7 dots and its speed below VLS. In accordance with the FCOM stabilisation criteria a go-around should have been performed.



When the aircraft was at 400 ft RA, engine # 2 thrust was controlled manually between idle and CL detents. At 250 ft RA, engine # 2 TL was progressively reduced (reached to IDLE detent at 200 ft RA) then moved to the CL detent before being set at IDLE detent again at 40 ft RA. Pitch increased from 5° to 10° nose up. CAS reduced from 130 kts to 110 kts at landing (VLS -17kts). Roll varied between 6° right wing down and 2° left wing down. Flare was performed while full back stick order was applied. Alpha Prot was active. AoA increased from +12.8° to +15.7° (= AoA max). Alpha Prot limited the AoA from increasing further

At the time of touch down, CAS was 109 kts (VLS -18kts), vertical descent rate was -752 ft/ min, recorded VRTG was 2.68 g, pitch was 10° nose up and AoA was at Alpha Max (15°)

2.4 Circumstances leading to the incident

On application of take-off thrust, Eng # 1 N2 Vibrations increased to 10 Units. It is the maximum value that can be displayed on the engine SD page. Though ECAM is inhibited during take-off and till 1500 ft RA after take-off, N2 VIB would have been flashing during that period on the lower ECAM/ SD page.

During climb at about 4500 feet (1500 ft RA), ENG1 HIGH VIB ECAM caution displayed. Flight crew carried out QRH checklist as per the procedure. The flight was continued, though thrust on engine #1 was reduced sufficiently for the vibrations to reduce below the threshold of 5 Units. The crew kept climbing to FL 140 whereas they could have leveled off for trouble shooting.

As soon as Eng #1 thrust was increased, once again there was increase in the Eng N2 vibrations and stalling of Eng # 1. Engine #1 thrust lever was set to idle while engine #2 thrust lever was left at CL detent. In the event of one engine thrust lever at idle, other engine thrust lever should be set to MCT. The inaction of the crew induced an FMA display "LVR MCT" (flashing) caution, which repeated every 5 seconds. The flight crew at this stage should have moved the thrust levers to MCT, but instead they disconnected the auto thrust which remained so till end of the flight.

The flight crew after discussion among themselves decided to return to Bangalore. PAN PAN Call was given. The reason mentioned was due technical. Here, correct reason i.e. engine problem could have been mentioned.

During descent, engine #1 failed and was shutdown. Engine #2 was reduced to idle till reaching 1000 ft RA. Till that point, the flight was on auto pilot, with auto thrust OFF (engine #2 was controlled manually).

Aural low energy SPEED SPEED SPEED warnings were triggered from 1000 ft and GLIDESLOPE warnings were triggered from 620 ft RA. The aircraft was below the Glideslope by 1.4 dots. Successive side stick pitch up inputs resulted in the pitch increasing up to 12°, activating the Angle of Attack protection. The

approach was continued despite being unstable and significantly below the Glideslope (2.7 dots below the Glideslope). The unstable approach continued till touchdown. All checklists were carried out but PM did not advise PF to go around.

The aircraft made a severe hard landing at the runway threshold while the PF was still commanding a full back stick. The aircraft pitch was 10° nose up, Alpha Prot was active and speed was 18 kts below VLS.

3 CONCLUSIONS

3.1 Findings

- 3.1.1 Both operating flight crew were appropriately licensed and qualified to operate the flight. Their preflight Medical was valid.
- 3.1.2 The aircraft had valid Certificate of Airworthiness/Airworthiness Review Certificate and Certificate of Release to Service at the time of incident.
- 3.1.3 The weather at the airport at the time of incident was fine and is not a contributory factor to the incident.
- 3.1.4 Shortly after take-off thrust was applied, engine # 1 vibrations increased to 10 UNITS, the maximum value that can be displayed on the engine SD page. The take-off roll and flight was continued. ENG1 HIGH VIB ECAM caution displayed at 1500 ft RA and approximately, one minute later, thrust on engine # 1 was reduced to keep the vibrations below the threshold of 5 Units.
- 3.1.5 Engine #1 thrust lever was set to idle while engine #2 thrust lever was left at CL detent. This induced an FMA display “LVR MCT” (flashing), repeated every 5 seconds. After about 88 seconds, the flight crew disconnected auto thrust, without making any changes to the thrust lever positions.
- 3.1.6 An in-flight turn back was initiated to the departure airport.
- 3.1.7 During descent as engine #1 failed, it was shutdown. Thrust of engine # 2 was reduced to idle.
- 3.1.8 A manual approach was performed by the PF. (No AP/ ATHR below 1000’ RA)

- 3.1.9 “SPEED SPEED SPEED” and “GLIDESLOPE” warnings were triggered. Successive side stick pitch up inputs resulted in the pitch increasing up to 12°, activating the Angle of Attack protection.
- 3.1.10 The approach was unstable. The aircraft went below the glidepath. The speed was too low. The aircraft was in a low energy state.
- 3.1.11 PF has not carried out Go Around, nor the PM advised PF to go around.
- 3.1.12 The aircraft envelope protections limited the Angle of Attack from exceeding Alpha Max during the final approach and landing.
- 3.1.13 The aircraft performed a severe hard landing (2.68 g) while the PF was still commanding a full back stick. Airbus subsequently computed the g value as 3.25 and incident was assessed as severe hard landing
- 3.1.14 At the time of touchdown, the aircraft pitch was 10° nose up, Alpha Prot was still active and the speed was 18 kts below VLS.
- 3.1.15 During rectification on ground, oil chip was detected in MCD No. 3 (AGB & MGB).
- 3.1.16 The involved engine was replaced and on the recommendation of the supplier, Safran, both main landing gears were also replaced.

3.2 CAUSE

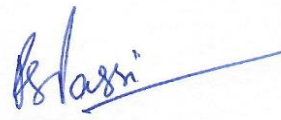
Unstabilised approach due to improper understanding of automation and thrust management after failure of one of the engines in flight resulted in severe hard landing and consequential damages.

4.0 RECOMMENDATIONS

For all Airlines flight crew

- 4.1 During simulator trainings (normal flying or with failures), emphasis should be laid on the use of appropriate levels of automation at all times. There should be clear understanding of automation, its appropriate level of selection and confirmation by assessing the aircraft response.

- 4.2 To maintain handling skills, adequate manual flying should be practiced on aircraft, whenever conditions are favorable. Prior appropriate briefing MUST be given to Pilot Monitoring for giving callouts of parameter deviations promptly so that smooth transition back to automation can be carried out if required.
- 4.3 There should be strict compliance of stabilized approach by the flight crew. PM should play an assertive role while calling out deviations and carry out a “Go Around”, if required.



(R S Passi)

Investigator-in-Charge

Aircraft Accident Investigation Bureau



(Capt. Sangita Bangar)

Investigator

Aircraft Accident Investigation Bureau



(Manoj Kumar)

Investigator

Aircraft Accident Investigation Bureau

Date: 04.02.2020
Place: New Delhi