BEA
Bureau d'Enquêtes et d'Analyses
pour la sécurité de l'aviation civile

Le Bourget 29 July 2011

Safety Investigation into the accident on 1 June 2009 to the Airbus A330-203, flight AF447

On Sunday 31 May 2009, the Airbus A330-203 registered F-GZCP operated by Air France took off at 22 h 29 to perform scheduled flight AF447 between Rio de Janeiro Galeão and Paris Charles de Gaulle. Twelve crew members (3 flight crew, 9 cabin crew) and 216 passengers were on board.

Introduction

Interim Report n°3 has been made possible by the complete readout of the flight recorders, which were recovered at the beginning of May 2011 after several campaigns of sea searches.

Up to that time, the information that was available did not give us any hope of a complete understanding of the circumstances of the accident. Despite this, based on the available information, it was possible for the BEA to make several safety recommendations, which are included in Interim Report n°2.

Over the past few weeks, analysis of the data recovered from the Flight Data Recorder (FDR) and the Cockpit Voice Recorder (CVR) has made a decisive contribution to the investigation. This has made it possible to determine the precise circumstances of the accident, to establish new facts and to issue some new safety recommendations, which are included in this report.

The investigation is continuing in order to develop the analysis to determine the causes of the accident, which will be included in the BEA's Final Report.

History of Flight and New Findings

The flight can be broken down into three phases:

- Phase 1: from the beginning of the CVR recording until the disconnection of the autopilot
- Phase 2: from the disconnection of the autopilot to the triggering of the stall warning
- Phase 3: from the triggering of the stall warning to the end of the flight

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▶ Phase 1 : from the beginning of the CVR recording until the disconnection of the autopilot

At the beginning of the CVR, shortly after midnight, the airplane was in cruise at flight level 350. Autopilot 2 and autothrust were engaged. The flight was calm. The crew was in VHF contact with the Recife ATC centre.

The crew mentioned the high temperature (normal plus eleven) and noted that the meteorological conditions did not pose any problems.

The Captain proposed that the copilot take a rest due to the length of his shift. The latter answered that he didn't feel like sleeping.

At 1 h 35 min 15, the crew informed the ATLANTICO controller that they had passed the INTOL point then announced the following estimates: SALPU at 1 h 48 then ORARO at 2 h 00. He also transmitted his SELCAL code and a test was undertaken, successfully.

At 1 h 35 min 46, the controller asked him to maintain FL350 and to give him his estimate for TASIL point.

Between 1 h 35 min 53 and 1 h 36 min 14, the controller asked again for the estimated time at TASIL with no response from the crew. There was no more contact between the crew and the ATC organisations.

A 1 h 55, the Captain woke the second copilot and announced "[…] he's going to take my place".

Between 1 h 59 min 32 and 2 h 01 min 46, the Captain attended the briefing between the two copilots, during which the PF said, in particular "the little bit of turbulence that you just saw […] we should find the same ahead […] we're in the cloud layer unfortunately we can't climb much for the moment because the temperature is falling more slowly than forecast" and that "the logon with Dakar failed". The Captain left the cockpit.

Findings:

- The Captain's departure occurred without clear operational instructions
- The crew composition was in accordance with the operator's procedures
- There was no explicit task-sharing between the two copilots

The airplane approached the ORARO point. It was flying at flight level 350 and at Mach 0.82 and the pitch attitude was about 2.5 degrees. The weight and balance of the airplane were around 205 tonnes and 29% respectively. Autopilot 2 and auto-thrust were engaged.

- The weight and balance of the airplane were within operational limits

At 2 h 06 min 04, the PF called the cabin crew, telling them that "in two minutes we should enter an area where it'll move about a bit more than at the moment, you should watch out" and he added "I'll call you back as soon as we're out of it".

At 2 h 08 min 07, the PNF said "you can maybe go a little to the left […]". The airplane began a slight turn to the left, the change in relation to the initial route being about 12 degrees. The level of turbulence increased slightly and the crew decided to reduce the speed to about Mach 0.8.

- The crew had noticed returns on the weather radar
- The crew made a heading change of 12° to the left of its route

▶ Phase 2: from the disconnection of the autopilot to the triggering of the stall warning

At 2 h 10 min 05, the autopilot then auto-thrust disengaged and the PF said "I have the controls". The airplane began to roll to the right and the PF made a left nose-up input. The stall warning sounded twice in a row. The recorded parameters show a sharp fall from about 275 kt to 60 kt in the speed displayed on the left primary flight display (PFD), then a few moments later in the speed displayed on the integrated standby instrument system (ISIS).

- The AP disconnected while the airplane was flying at upper limit of a slightly turbulent cloud layer
- There was an inconsistency between the measured speeds, likely as a result of the obstruction of the Pitot probes in an ice crystal environment
- At the time of the autopilot disconnection, the Captain was resting

At 2 h 10 min 16, the PNF said "so, we've lost the speeds" then "alternate law protections […]"

The airplane's pitch attitude increased progressively beyond 10 degrees and the plane started to climb.

- Even though they identified and announced the loss of the speed indications, neither of the two copilots called the procedure "Unreliable IAS"
- The copilots had received no high altitude training for the "Unreliable IAS" procedure and manual aircraft handling
- No standard callouts regarding the differences in pitch attitude and vertical speed were made
- There is no CRM training for a crew made up of two copilots in a situation with a relief Captain

The PF made nose-down inputs alternately to the right and to the left. The climb speed, qui which had reached 7,000 ft/min, dropped to 700 ft/min and the roll varied between 12 degrees to the right and 10 degrees to the left. The speed indicated on the left side increased suddenly to 215 kt (Mach 0.68).

- The speed displayed on the left PFD remained invalid for 29 seconds

The airplane was then at an altitude of about 37,500 ft and the recorded angle of attack was around 4 degrees.

From 2 h 10 min 50, the PNF tried several times to call the Captain back.

▶ Phase 3: from the triggering of the stall warning to the end of the flight

At 2 h 10 min 51, the stall warning triggered again. The thrust levers were placed in the TO/GA detent and the PF maintained his nose-up input. The recorded angle of attack, of the order of 6 degrees at the triggering of the stall warning, continued to increase. The trimmable horizontal stabiliser (THS) began moving and passed from 3 to 13 degrees nose-up in about 1 minute; it remained in this position until the end of the flight.

- The approach to stall was characterised by the triggering of the warning, then the appearance of buffet
- A short time after the triggering of the stall warning, the PF applied TO/GA thrust and made a nose-up input
- In less than one minute after the disconnection of the autopilot, the airplane was outside its flight envelope following the manual inputs that were mainly nose-up
- Until the airplane was outside its flight envelope, the airplane's longitudinal movements were consistent with the position of the flight control surfaces
- Neither of the pilots made any reference to the stall warning
- Neither of the pilots formally identified the stall situation

About fifteen seconds later, the speed displayed on the ISIS increased suddenly towards 185 kt.

- The invalidity of the speed displayed on the ISIS lasted 54 seconds

It was then consistent with the other speed displayed. The PF continued to make nose-up inputs. The airplane's altitude reached its maximum of about 38,000 ft; its pitch attitude and its angle of attack were 16 degrees.

At 2 h 11 min 42, the Captain came back into the cockpit. In the following seconds, all of the recorded speeds became invalid and the stall warning stopped.

- The Captain came back into the cockpit about 1 min 30 after the autopilot disconnection
- The angle of attack is the parameter that enables the stall warning to be triggered; if the angle of attack values become invalid, the stall warning stops
- By design, when the speed measurements were lower than 60 kts, the 3 angle of attack values became invalid
- Each time the stall warning was triggered, the angle of attack exceeded its theoretical trigger value
- The stall warning was triggered continuously for 54seconds

The altitude was then around 35,000 ft, the angle of attack exceeded 40 degrees and the vertical speed was around -10 000 ft/min. The airplane's pitch attitude did not exceed 15 degrees and the engine N1 was close to 100%. The airplane was subject to roll oscillations that sometimes reached 40 degrees. The PF made a nose-up left input on the sidestick to the stop that lasted around 30 seconds.

- The airplane's angle of attack was not directly displayed to the pilots

At 2 h 12 min 02, the PF said "I don't have any more indications", and the PNF said "we have no valid indications". At that moment, the thrust levers were in the IDLE detent and the engines' N1's were at 55%. Around fifteen seconds later, the PF made pitch-down inputs. In the following moments, the angle of attack decreased, the speeds became valid again and the stall warning was triggered again.

At 2 h 13 min 32, the PF said "we're going to arrive at level one hundred". About fifteen seconds later, simultaneous inputs by both pilots on the sidesticks were recorded and the PF said "go ahead you have the controls".

The angle of attack, when it was valid, always remained above 35 degrees.

- Throughout the flight, the movements of the elevator and the THS were consistent with the pilot's inputs
- The engines were working and always responded to the crew's inputs,
- No announcement was made to the passengers

The recordings stopped at 2 h 14 min 28. The last recorded values were a vertical speed of -10,912 ft/min, a ground speed of 107 kt, pitch attitude of 16.2 degrees nose-up, roll angle of 5.3 degrees left and a magnetic heading of 270 degrees.

No emergency message was sent by the crew. The wreckage was found on the seabed at 3,900 m on 3 April 2011, 6.5 nautical miles north-north-east of the last position transmitted by the airplane.