BEA Comment on the Final Report of the Accident to the Boeing 737 ET-AVJ and operated by Ethiopian Airlines on 10 March 2023 [Investigation led by EAIB / Ethiopia]

Introduction

The observations on the Final report that the BEA asked the EAIB to append are as follows:

From the very start of the investigation, the BEA has, under the authority of the Ethiopian AIB and in cooperation with the NTSB and their technical advisers, actively participated in the understanding and the analysis of the aircraft systems, the operational aspects of the occurrence and the crew performance issues.

The BEA considers that the operational and crew performance aspects are insufficiently addressed in the EAIB final report, in particular with regard to the sequence of events that occurred before the activation of the 1st MCAS. Consequently this prevents the reader from having a precise and complete understanding of the event.

Shortcomings relating to the crew's actions, particularly in the first phase of the flight, is not accompanied by a thorough analysis of the reasons for the behaviours observed, in relation with their training, their experience and the company organization with regard to the training and knowledge acquisition principles.

The following comments represent important points that the BEA considers necessary to take into account in order to have a comprehensive and balanced report.
In accordance with paragraph 6.3 of ICAO Annex 13, the BEA requests that this document be appended to the Final Report.

Sequence of events

1. From Takeoff to the First MCAS

Shortly after take-off, as a result of the erroneous left AOA value, the left stick shaker was activated. On the activation of the stick shaker, the flight crew must apply the Approach to Stall or Stall recovery procedure, which is a memory item. As described in the FCOM/QRH, the first steps in the Approach to Stall or Stall Recovery procedure are to hold the control column firmly, disengage the autopilot and authrottle and then smoothly apply a nose down input. Only the nose down input was performed by the flight crew. The autothrottle remained engaged and the pilot later insisted on engaging the A/P.

Wind tunnel testing, modelling and AOA rupture mode analysis performed by the AOA sensor manufacturer concluded that the only possible scenario for the AOA sensor erroneous data was a foreign object impact, most likely a bird, causing separation of the vane at the hub and breaking of the vane heater wires. These results were presented to the EAIB in Addis Ababa in September 2019.

Five seconds after the activation of the stick shaker, an IAS DISAGREE message appeared on both PFDs. It was followed two seconds later by an ALT DISAGREE message. Although these messages were not recorded on the FDR, it has been established, by computations and later confirmed at the Boeing engineering simulator (eCAB), that they appeared on both PFDs.

In the case of the IAS DISAGREE, the flight crew has to apply the Airspeed Unreliable Non-Normal Checklist. This checklist states to first disengage the AP, then the Autothrottle and to put the F/D switches on OFF, before setting 10° pitch attitude and 80% N1 (when flaps are extended).

The Captain tried, in vain, to engage the AP. He did not disconnect the autothrottle. There were no crew exchanges on the CVR regarding the IAS DISAGREE or ALT DISAGREE

messages, which supports the conclusion that the IAS DISAGREE and ALT DISAGREE messages were most probably not seen by the crew throughout the flight.

At a height of approximately 350 feet radio altitude, the Captain again tried to engage the AP although the airline policy requests pilots to wait until they reach 500 feet radio altitude to engage the autopilot. This premature action, although not appropriate in stick shaker conditions, may be symptomatic of a state of stress that had been rapidly developing following the activation of the stick shaker and Master Caution immediately after takeoff.

A second attempt was made six seconds later, above 500 feet. The Captain's reaction after this second engagement attempt ("What's going on?") was probably related to the inability to engage the AP. The Captain's question remained unanswered and did not trigger any process of information acquisition, cross-check or crew decision making.

Passing 1000 feet radio altitude, at the third attempt, the AP was successfully engaged. MCP speed was set to 238 knots. However, the AP airspeed target was not the MCP speed but that of the erroneous LH minimum operational speed, which was above V_{MO} (340 knots). The AP therefore commanded a nose down to accelerate towards the erroneous minimum operational speed. The stabiliser trim value decreased from 5.6 to 4.6 units of trim. The aircraft descended at -1,400 fpm.

Thirty-three seconds after being engaged, the AP disconnected. The increase of speed beyond the target speed was not mentioned by the crew. Moreover, the autothrottle remained engaged and, due to the AOA foreign object impact resulting in partial vane separation, failed to change to N1 mode. It remained in ARM mode with takeoff thrust set. The ARM mode was never verbalised. It is highly probable that it was not identified by the crew.

The lack of thrust reduction aggravated the difficulties encountered by the crew to control the aircraft throughout the remainder of the flight. During this phase, besides the destabilising cockpit environment linked to the activation of the stick shaker and a Master Caution immediately after take-off, coordination and communication between the Captain and the F/O were very limited and insufficient. There was no discussion or diagnosis with respect to the nature of the events on board. The situational awareness, problem solving and decision making were therefore deeply impacted. The FO's lack of proactivity, which comes out from the CVR transcripts, seems to show that he was overwhelmed by the events on board from the moment the stick shaker triggered. His low flight experience (300 hours total) may have accounted for this situation.

The BEA regrets that the parts of the CVR transcript which show the difficulties encountered by the FO have been removed from the extracts of the CVR transcript published in the report.

It is regrettable that the report does not include a thorough analysis of the reasons for the behaviours observed, in relation with their training, their experience and the company organization with regard to the training and knowledge acquisition principles.

2. <u>From the First MCAS until the end of the flight</u>

As the flaps reached the retracted position, the MCAS was activated and the stabiliser trim position decreased from 4.6 to 2.1 units. Although the Captain was applying an increasing nose up force (between 100 and 125 lbs), only a brief electric trim up input of 2 seconds was recorded, which was insufficient to trim out the MCAS inputs and to relieve the aerodynamic loads. The stabilizer remained at 2.1 units of trim.

The force applied by the Captain on the control column during this phase only kept the airplane almost level. During the ECAB simulator sessions, the simulator crews felt it was

instinctive to use as much electric trim as needed to reduce the column forces in response to MCAS inputs while recognising that it was not very common in a normal flight.

During the second MCAS activation, the Captain applied a 9-second electric trim-up input. This interrupted the MCAS two seconds before its expected end. The effect of this second trim input fully countered the 2nd MCAS. However the aircraft was not returned to a fully trimmed condition as the first MCAS input had never been trimmed out.

During the 9 seconds of electric trimming, the stab trim cut-out switches were put in the cut-out position. At that moment, the stabilizer was at 2.3 units of trim and the Captain was pulling on the control column with a force of 80 Lbs. The altitude was 9,100ft, IAS 332 knots, pitch 2.5°, and vertical speed + 350 fpm.

When the speed exceeded V_{MO} 340 knots (varying between 360 and 375 knots), the overspeed warning triggered. The crew expressed their surprise. This may indicate that after retracting the flaps, the crew lost track of the IAS values. No thrust reduction was however performed.

During this phase, the physical efforts applied by the crew on the column probably impacted their situational awareness and their cognitive resources and did not allow them to undertake the proper actions.

Probable Cause (paragraph 3.2 of the report)
The BEA notes that the only probable cause retained in the EAIB report is related to the activation of the MCAS system.

The BEA believes that the crew's inadequate actions and the insufficient Cockpit Resource Management (CRM) played a role in the chain of events that led to the accident, in particular during the first phase of the flight, before the first MCAS activation.

Contributing Factors (paragraph 3.3 of the report)
The BEA notes that the contributing factors identified by the EAIB are only related to the MCAS system. The following contributing factors that come out of the analysis of the event, should also be stated in the report:

- The flight crew's failure to apply, immediately after take-off and before the first MCAS activation, the Approach to Stall or Stall Recovery Manoeuvre and the Airspeed Unreliable Non-Normal Check-list;
- The Captain's insistence on engaging the AP, contrary to the Approach to Stall or Stall Recovery manoeuvre procedure;
- Insufficient use of the electric trim to relieve the high control column forces after the MCAS nose down orders;
- The Captain's lack of thrust reduction when the speed became excessive, which in combination with insufficient trim, caused an increase of the forces which became unmanageable on both the control column and the manual trim wheel.
- The use of the Logipad system by the airline as the sole means to disseminate information on new systems and/or procedures, which doesn't allow the evaluation the crews' understanding and knowledge acquisition on new systems and procedures. This system was used to disseminate the information related to the MCAS system issued following the previous 737 Max accident and did not allow the airline to ensure that the crews had read and correctly understood this information.