Incident

Aircraft Type and Registration:	Pilatus PC-24, D-CMSL
No & Type of Engines:	2 Williams International FJ44-4A turbofan engines
Year of Manufacture:	2022 (Serial no: 266)
Date & Time (UTC):	9 December 2022 at 1425 hrs
Location:	8 nm south-east of Liverpool Airport
Type of Flight:	Commercial Air Transport (Non-revenue)
Persons on Board:	Crew – 2 Passengers – None
Injuries:	Crew – None Passengers – N/A
Nature of Damage:	None
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	43 years
Commander's Flying Experience:	6,500 hours (of which 781 were on type) Last 90 days – 146 hours Last 28 days – 33 hours
Information Source:	AAIB Field Investigation

Synopsis

The aircraft's elevator controls became stiff as the aircraft approached its cruising altitude, resulting in an uncommanded descent of 800 ft. The flight crew successfully applied the Quick Reference Handbook (QRH) procedure for jammed elevator controls and full elevator control was regained during the descent. The investigation was unable to identify the cause of the stiff elevators and a detailed examination of the aircraft did not reveal any technical faults, so the likely cause was transitory.

History of the flight

D-CMSL flew into Liverpool Airport (Liverpool) during the afternoon of 8 December 2022 and was parked overnight on the main apron. The flight crew, having rested overnight, returned to the aircraft the next day for their planned afternoon departure; a non-revenue positioning flight to Birmingham Airport (Birmingham). While the air temperature had dropped below 0°C overnight, the pilots did not detect any evidence of airframe icing during their pre-flight external check and did not require the aircraft to be de-iced before departure.

In accordance with normal procedures for an OAT ≤10°C and visible moisture in the air, the crew selected engine nacelle anti-icing ON after engine start and carried out the engine ice-shedding procedure on the runway prior to takeoff. When the pre-takeoff flight control check was carried out, no restrictions or abnormalities were detected.

At 1417 hrs the aircraft took off from Runway 27, entered cloud shortly thereafter and climbed to FL90, where the aircraft was levelled and accelerated to 250 kt. Approximately two minutes later, the autopilot disengaged and the aircraft pitched nose-down. The co-pilot who was PF for the sector, pulled back on the yoke to counter the nose-down attitude change, but the yoke appeared to be "jammed" in pitch. Applying high force levels resulted in small corresponding movements of the yoke, but it remained very stiff. The PF followed the QRH procedure for a jammed elevator and used the pitch trimmer to help regain control of the aircraft's attitude, generating a climb back to FL90. During the uncommanded descent the maximum altitude deviation from the cleared flight level was approximately 700 ft.

Having resumed the cruise at FL90, the PF maintained manual flight while establishing the level of controllability available to him. Roll was unaffected but pitch control was severely restricted. The PF then re-engaged the autopilot but the aircraft started to climb so he disengaged it and resumed manual flight. He was able to re-establish FL90 using a combination of yoke input and pitch trim. Control was briefly handed over to the commander who confirmed he could also feel the restriction through the left yoke.

Weather conditions were better at Birmingham than Liverpool, so the crew elected to continue to their destination. At one point during the transit to Birmingham, the PF was applying significant pressure to the yoke when the restriction on its movement suddenly cleared. While pitch control remained excessively heavy, the PF had, what he described as "full authority" over the elevator. The autopilot was successfully re-engaged and behaved as expected, so the crew began their approach to Birmingham.

The commander took control for the latter stages of the descent and disconnected the autopilot at approximately 4,000 ft on base leg to assess controllability before starting the final approach. The pitch control forces were still slightly heavy, but less so than at FL90. During the approach the heaviness of the controls disappeared and the aircraft was landed manually without difficulty.

The controls reportedly felt "normal" during a post-shutdown flight control check. The pilots could not see any evidence of a control surface restriction when they later carried out a visual inspection of the airframe. They had not observed any airframe or canopy icing during the climb and the aircraft ice detectors had not alerted them to the presence of ice. Nonetheless, based on the initial nature of the problem and the subsequent heavy control forces which reduced during the descent into warmer air, the pilots considered that ice affecting the elevator and/or its control system was the most likely cause of the restriction.

Meteorology

While D-CMSL was on the ground at Liverpool overnight temperatures dropped to -2°C at 0720 hrs but had risen to +4°C by 1150 hrs. There was no reported precipitation on the Liverpool METARs from 1720 hrs on 8 December until 1250 hrs the next day, although there were reports of showers in the vicinity of the airfield from 0950 hrs onwards. The reports showed that light rain showers and drizzle affected the airfield in the period 1250-1420 hrs.

When D-CMSL took off, the reported cloud base at Liverpool was 900 ft agl and the freezing level was approximately 1,300 ft amsl.

Aircraft information

Introduction

The Pilatus PC-24 is a twin-turbofan business jet with up to 10 passenger seats. It received an EASA CS-23 Type Certificate in December 2017 and is certified for flight into known icing conditions. More than 170 PC-24s are in service and the fleet has accumulated over 200,000 flying hours. Apart from D-CSML on 9 December 2022, the manufacturer has not received any other reports of stiff or jammed elevators from PC-24 operators.

Elevator control system

The aircraft's elevator control is a conventional, unpowered mechanical system comprising pilot and co-pilot control yokes connected via cables, pushrods, quadrants and levers to the elevator control surfaces (Figure 1).

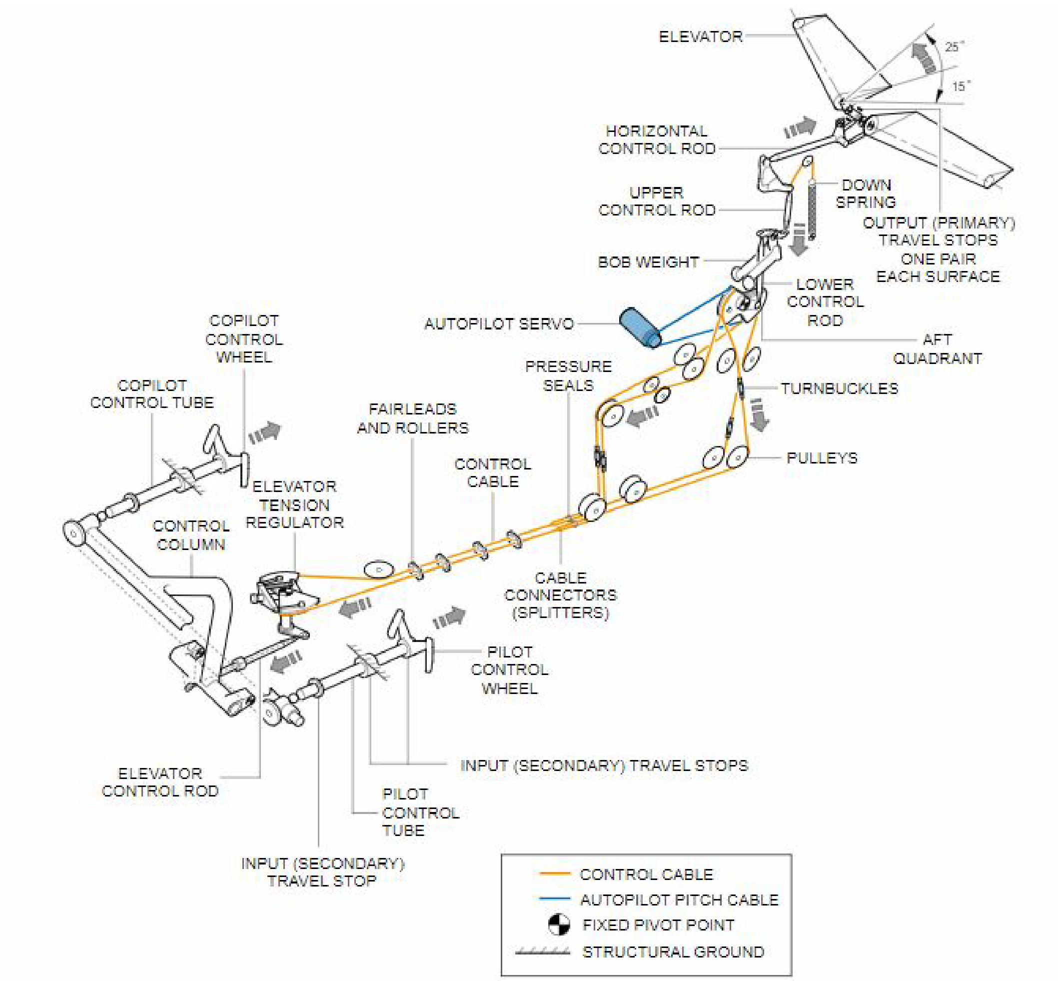

Figure 1

PC-24 elevator control system
(courtesy of manufacturer)

An elevator tension regulator, located under the right cockpit floor, maintains elevator cable tension throughout the operating temperature and cabin pressurisation ranges. The autopilot pitch servo is located behind the rear pressure bulkhead and is connected to the aft elevator quadrant via a bridle cable wrapped around a capstan on the servo output shaft. The capstan incorporates a friction clutch to allow the flight crew to move the elevators whilst the autopilot is engaged. The current drawn by each autopilot servo is monitored by the autopilot system. The autopilot (AP) directly controls the trim system in the pitch axis to off-load any steady state torque being held by the AP servos. In the case where steady state forces are being held by the AP servos for longer than a specified period, an AP HOLD NOSE UP /DOWN message will be generated. In the event that the AP servo does not have sufficient torque authority to maintain the flight director computed path/pitch targets, the AP will disconnect.

The aircraft has a trimmable horizontal stabiliser with left and right elevators attached at hinges from the stabiliser rear spar. Each elevator has a balance tab, geared to the deflection of the elevator, to reduce the force required to move the elevator against air loads. The position of the horizontal stabiliser is controlled by a pitch trim actuator attached to the stabiliser front spar. When the autopilot is engaged, the stabiliser position is moved to reduce the load on the pitch servo to achieve a desired aircraft pitch attitude.

Ice detection system

The aircraft is equipped with two ice detectors, one mounted on either side of the fuselage near the nose. The provision of two independent detectors provides redundancy, as the system will still function if one detector should fail.

Each detector has a controller and a sensing element that vibrates at a fixed frequency, controlled by an oscillator circuit. The sensing elements are exposed to airflow across the detector. When ice accumulates on them the sensing element mass increases, changing the frequency of vibration which causes the detector to send the ICE signal to the utility management system. This causes a white ICE caption to be displayed on the MFD.

The ice detectors are automatically controlled and self-monitoring. If a failure occurs, a FAIL caption appears on the ice protection system synoptic page on the MFD, and an ICE DETECTOR FAIL advisory CAS message is displayed.

Jammed elevator QRH procedure

The aircraft's trimmable horizontal stabiliser is sufficiently powerful to overcome the effects of a jammed elevator and the manufacturer provides pilots with a QRH procedure to follow in such an eventuality (Figure 2). The pilots had practised landing with a jammed elevator during their type rating course flight simulator sessions.

Flight Controls: Landing No Elevator Control **3-NAE-11**

Landing in the event of a jammed or partially available elevator control.

WARNING

WITH JAMMED ELEVATOR CONTROLS, THE STICK PUSHER MAY NOT OPERATE EFFECTIVELY. STALLS MUST BE AVOIDED.

1.	Aircraft...	Use pitch trim to control aircraft pitch attitude. Make small pitch trim inputs and allow trim change to take effect before making additional inputs or aircraft configuration changes Consider using ≤15° angle of bank
2.	L/G..	Recommend extending L/G at safe altitude and <150 KIAS to minimize pitch change due to gear extension
3.	FLAP lever...	Extend in increments to Flaps 15°
4.	Airspeed..	Decelerate slowly to Flaps 15° V_{REF} Consider using AIRBRAKE for approach
5.	Landing Performance........................	Recalculate landing distance
6.	THRUST levers..................................	Adjust as required to maintain between 300 and 500 FPM rate of descent

At 50 feet AGL:

7.	Aircraft...	Consider slowly reducing thrust and using pitch attitude to reduce rate of descent for touchdown

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Figure 2

PC-24 QRH procedure for landing with a jammed elevator
(courtesy of manufacturer)

Recorded information

Flight recorders

D-CMSL was fitted with both a CVR and an FDR. The aircraft remained in service for nine days following the event, prior to the AAIB being notified, during which the CVR was overwritten. The following significant points from the FDR data are highlighted in Figure 3:

- D-CMSL was initially level at FL90 and 245 kt, with the autopilot (AP), autothrottle (A/T) and yaw damper (YD) engaged. The OAT was -13°C. The aircraft's dual ice detectors did not record the presence of ice at any point during the flight.

- At point A, a nose-up movement of the stabiliser is recorded and D-CMSL pitched up; no stabiliser trim changes were commanded by the crew. Simultaneously and, despite no force (measured at the base of the control column) being applied, the data shows a nose-down movement of the elevator, following which the position of the elevator remained static for several seconds.

- At point B, the horizontal stabiliser also moved nose-down and D-CMSL pitched down to -8°, entering a descent during which 800 ft of altitude was lost and the airspeed increased to 264 kt.

- Eight seconds later, with an increasing rearwards force applied to the control column the AP disconnected, at point C, which was recorded in the data as an 'abnormal disconnect[1]'. This was followed by the disconnection of the A/T and YD. As the pull force applied to the control column increased, the elevator moved nose-up. However, the FDR data showed that large column forces were needed for even small deflections of the elevator and, at times, the elevator position was recorded as static despite a force being applied to the control column.

- The crew had recovered the aircraft to FL90, by point D, using stabiliser trim inputs and column movements. The A/T, A/P and YD were also re-engaged.

- After a few seconds, D-CMSL pitched up again (point E) with a nose-up movement of the stabiliser recorded before the aircraft pitched down. The AP disengaged, which was recorded as an 'abnormal disconnect,' followed by the A/T and YD. Other than an initial movement of the elevator, in response to a pull on the column of 407.5 lbf[2] (the largest recorded force – point F) and slight movements in response to other large inputs, the elevator trace now appeared static.

- The AP and YD remained disengaged, although the crew re-engaged the A/T for periods, and the aircraft was manoeuvred using the stabiliser trim until the elevator once again responded to crew input approximately seven minutes later at point G.

- Prior to landing, a further 'abnormal disconnect' was recorded, although this is not shown in Figure 1, at approximately 3,000 ft when the OAT was -2° C.

Footnote

[1] The AP's operation is continuously monitored and an 'abnormal disconnect' is triggered if one of the AP monitors senses that the aircraft's flightpath is not closing, as expected, with the target flightpath. This is considered by the aircraft's manufacturer to be the most likely cause for the series of 'abnormal disconnects' recorded during the flight. Other causes for an 'abnormal disconnect' include an elevator or aileron servo failure, or a stick shaker activation.

[2] A load of -407.5 lbf in the elevator control rod, which is where the force transducer that is recorded by the FDR is located, equates to a rearward pull on the control yoke of 92 lbf.

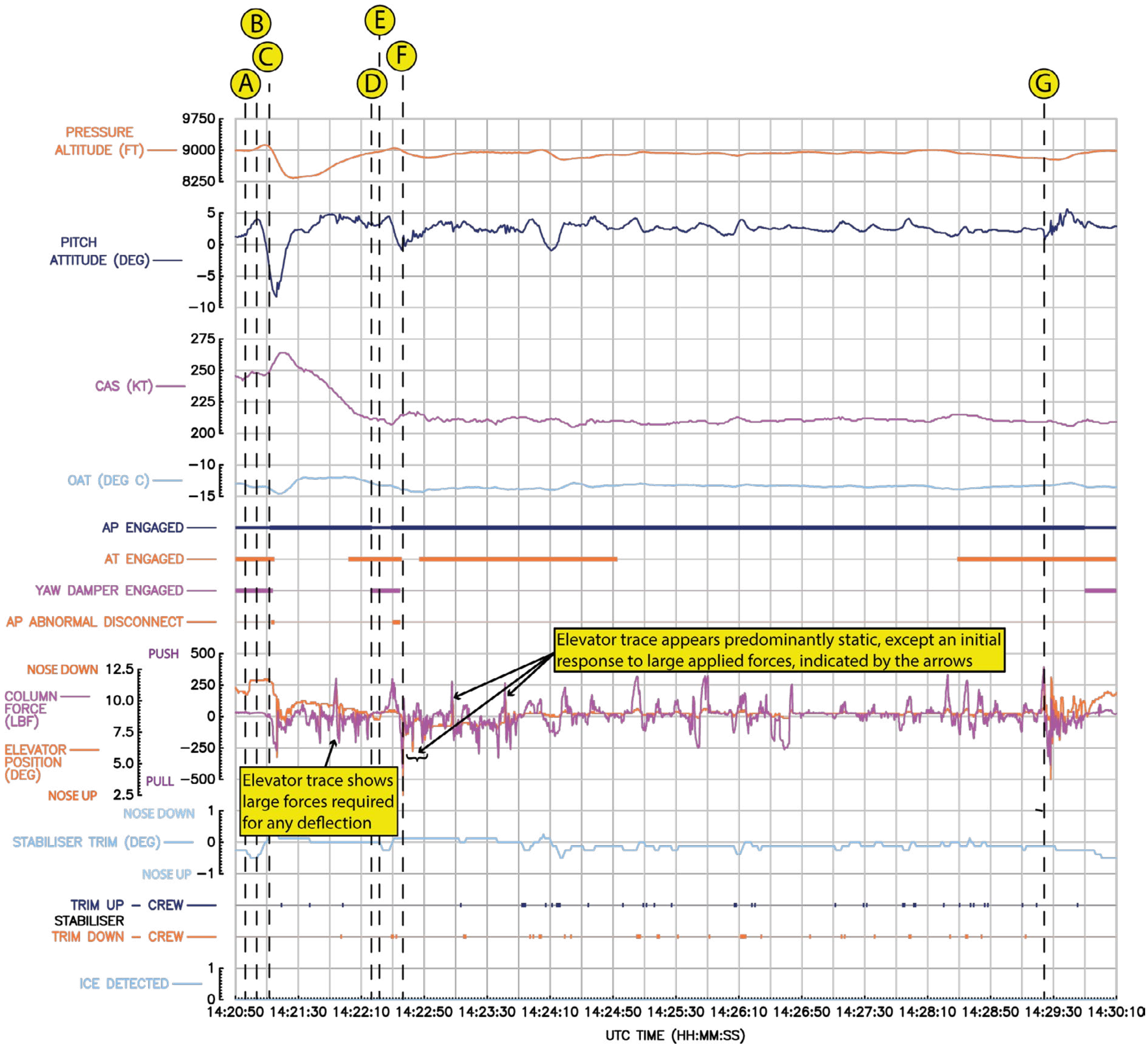

Figure 3

FDR data for the cruise portion of the incident flight

A plot of elevator position against column position[3] (Figure 4) shows data from the event flight in colour, and from 74 other flights recorded on the FDR in grey. The data shows that during the event flight, several clusters of points have a markedly flatter slope indicating where the movement of the elevator was severely restricted. Whilst the elevator's movement was restricted, the control column was still able to move over a substantial range of travel, although high control forces (indicated by the orange/red shading) were experienced during these periods.

Footnote

3 Both elevator and control column position were recorded by the FDR at a sample rate of 8 Hz. The elevator position is measured by a transducer at the top of the aircraft's tail, the column position by a transducer at the base of the column.

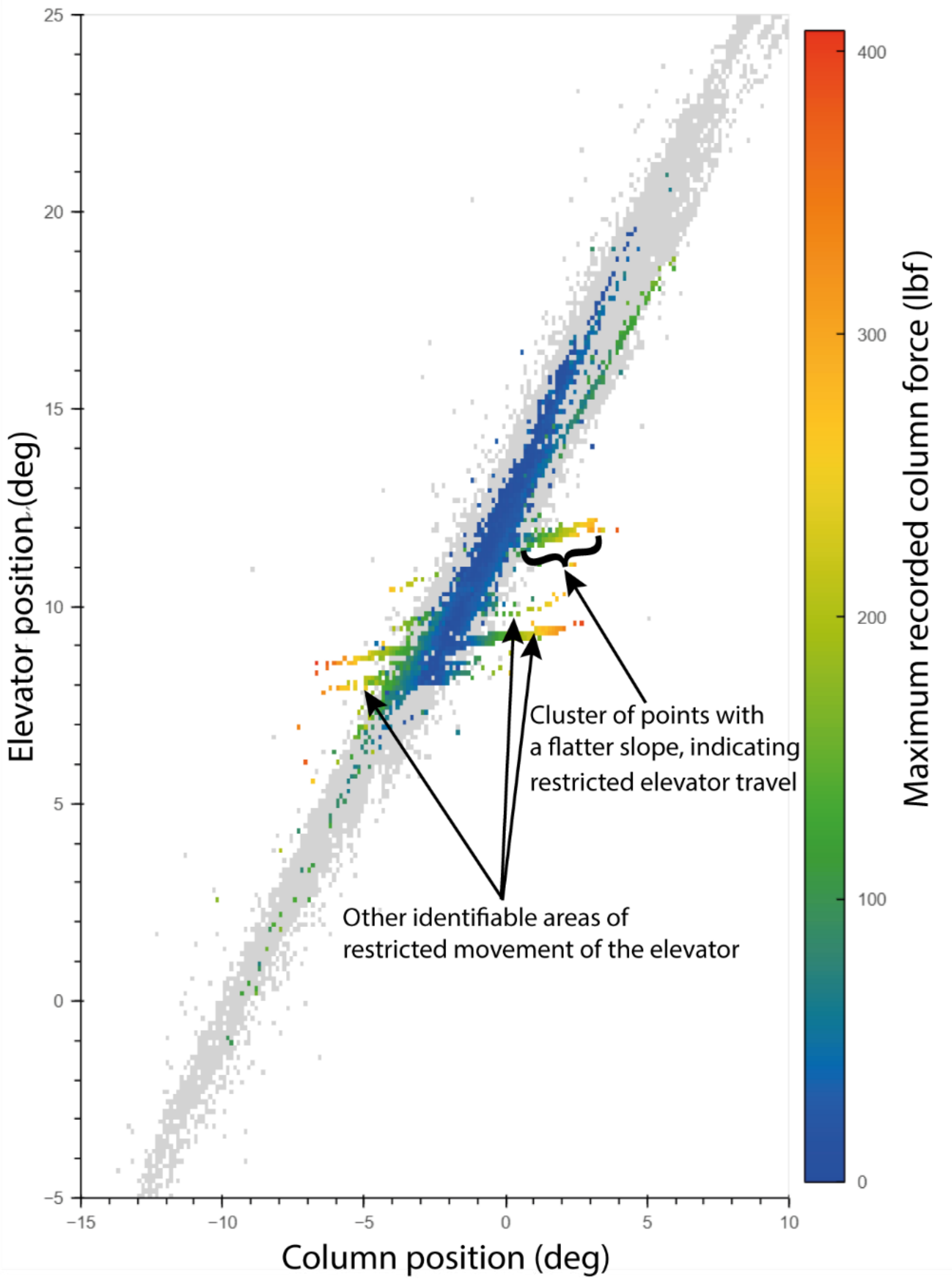

Figure 4

Elevator position vs column position data for the event flight

On board aircraft condition monitoring systems

The Pilatus PC-24 is fitted with an Aircraft Condition Monitoring Function (ACMF), which is an integral part of the Central Maintenance Computer (CMC), that analyses data on the aircraft's databuses and logs data when certain trigger conditions are met. The CMC also has a Fault History Database (FHDB) function that stores faults.

Examination of the ACMF logs showed that there were no logs stored for the event flight.

The FHDB showed that several faults were recorded during the flight, including multiple messages related to the loss of the AP, which were annunciated to the crew, and faults related to the functioning of the AP that were logged for maintenance purposes. The timings of these messages closely correlated with disengagements of the AP, as recorded on the FDR. In addition, the FHDB shows that at 14:21 hrs an AP HOLD NOSE-DOWN message was logged, indicating the AP servos applied a constant torque to maintain the aircraft's flightpath.

Closed-Circuit TV Recording and bystander's photograph

Closed-Circuit TV (CCTV) recordings from Liverpool showed the weather conditions, particularly the level of precipitation, in the hour prior to departure. It also showed how the pre-departure external checks were carried out by the crew. A screenshot from the recording (Figure 5) taken approximately one hour prior to departure shows rain and large areas of standing water on the apron.

Figure 5

Screenshot from the CCTV recording, an hour prior to departure of D-CMSL

Fleet data

During the investigation the aircraft manufacturer undertook a review of pre-delivery flight test data, gathered from several pre-delivery aircraft, and data taken from their own flight test aircraft to establish whether any previous occurrences of restricted elevator travel could be found. From this data, which covered 107 aircraft, plots of elevator position against column position were produced, and the data from 11 aircraft was selected for further examination.

This data was reviewed by the manufacturer using a web-based tool developed by the AAIB, which allowed the evolution of the data over time to be studied. Following the review, the manufacturer concluded:

'In summary, based on the above analysis and all other available information, we are not aware of any PC-24 restricted elevator event except on the incident aircraft.'

Maintenance history

The aircraft was delivered new to the operator in April 2022 and had accumulated 459 flying hours and 339 flight cycles prior to the event flight; no defects relating to the elevator flying controls had been experienced during this period. The aircraft had last been washed 52 flights before the event flight.

The aircraft had been de-iced only once, 20 flights before the event flight, with 'unthickened' Type 1 de-icing fluid. This fluid is a propylene glycol de-icing fluid and does not contain any thickening agents. De-icing is performed to remove frozen or semi-frozen moisture from the external surfaces of an aircraft prior to flight.

Aircraft examination

Examination by aircraft manufacturer

The aircraft was examined at Birmingham by the manufacturer on 13 December 2022. The examination included visual examination of the elevator control system and the autopilot pitch servo cables[4], elevator and autopilot pitch servo cable tension checks[5], and a functional test of the elevator control system[6]. In addition, an autopilot operational test[7] was carried out.

Visual examination of the elevator control system did not identify any faults with the elevator controls or the autopilot pitch servo cables. The elevator functional tests did not identify any anomalies with the elevator controls.

The tension check on the elevator control cables revealed that the tension regulator rigging gap was 10.0 mm, which was below the required range of 10.8 – 11.8 mm at the ambient temperature of 3°C when this check was carried out. Therefore, the elevator control cable tensions were marginally below the required tension range. The actual cable tension in the elevator cables was not measured or recorded prior to their adjustment.

The elevator control cable turnbuckles were adjusted to increase the tension regulator rigging gap to 11.7 mm. After this adjustment, the tensions in the left and right elevator cables were measured at 332 N and 317 N respectively.

Footnote

4 AMM task PC24-A-E27-30-0000-00A-310A-A.
5 AMM tasks PC24-A-E27-30-0000-00A-369A-A and PC24-A-E27-30-0000-00B-271A-A.
6 AMM task PC24-A-E27-30-0000-00A-340A-A, omitting those sub-tasks requiring the aircraft to be supported on jacks.
7 AMM task PC24-A-E22-10-0000-00A-320A-A, steps 16 to 19.

The tension check on the elevator servo cables recorded a tension of 152 N, which was below the minimum required tension of 250 N (the allowable range being between 250 and 285 N). The elevator servo cable tension was adjusted to 272 N.

The autopilot functional check was carried out with no faults identified.

Following this examination, the aircraft was released back to service and no subsequent occurrences of stiff or jammed elevators were experienced.

Subsequent examination by the AAIB

The aircraft was examined by the AAIB on 28 February 2023, during a scheduled annual maintenance inspection. A detailed visual examination of the elevator controls did not identify any abnormalities or evidence of any foreign object contact or damage. The elevator controls were found to operate smoothly through the full range of control deflection, and no evidence of any de-icing fluid residue was present. All drain holes in the elevators and elevator balance tabs were free from obstruction and there were no witness marks visible on areas where the elevators rotate in close proximity to the horizontal stabiliser. The elevator balance tabs were in good condition, with no obstruction to their hinges or driving pushrods. A functional test of the autopilot was also carried out, with no abnormalities noted.

Manufacturer testing

The aircraft manufacturer conducted functional testing of a PC-24 aircraft with the autopilot pitch servo bridle cable tension initially set at the required tension of 310 N, before being reduced to 110 N and finally 50 N. The tests showed that for all tensions tested, the bridle cable did not slip or reduce the rate of elevator movement commanded by the autopilot. There was also no evidence of any chafing or abnormal contact between the cable and the pitch servo capstan and adjacent structure.

Analysis

Faced with an unexpected and uncommanded pitch down in IMC, the PF reacted instinctively by taking manual control of the aircraft and tried to raise the nose by pulling back on the yoke. On finding that the pitch control was severely restricted the PF followed the first stage of the QRH procedure for a loss of elevator control, which he had previously practised in the simulator. The QRH procedure worked as intended giving the PF sufficient manual flight control authority to regain and maintain the designated cruise level. After the initial severe restriction cleared the crew were able to re-establish automated flight. For additional reassurance the commander reverted to manual flight earlier than normal for an instrument approach and performed an uneventful landing.

Examination of the aircraft immediately after the incident flight and during the following annual maintenance inspection did not identify any evidence of a defect or foreign object damage to the elevator controls that could have restricted movement of the elevator. The cable tension in both the elevator and pitch servo bridle cables measured after the flight was below the Aircraft Maintenance Manual limits. The aircraft manufacturer stated that this is not an uncommon finding and would not restrict the movement of the elevator.

The possibility that the elevator restriction was caused by ice formation on the elevator control system could not be excluded, however it is unlikely that external ice accretion was a factor as both of the aircraft's dual ice detectors did not detect the presence of airframe icing. The manufacturer has stated that no other operator reports of stiff or jammed elevators had been received.

During this investigation the manufacturer reviewed flight data from a number of other PC-24 aircraft and confirmed that no other similar elevator restrictions were observed in the data, or have been reported by other PC-24 operators. However, data from the event flight clearly showed periods when an elevator control restriction was present on D-CMSL. The restrictions were most apparent in the data when it was plotted as a scatter plot against column position as the slope of neighbouring data points was markedly different when a restriction was present.

Conclusion

With the autopilot engaged, the aircraft did not capture the commanded cruise flight level but continued to climb before then pitching down and descending 800 ft below it. The uncommanded descent was halted by the intervention of the PF pulling the control column rearwards, which also caused the autopilot to disengage.

The PF found the elevators very stiff to move, requiring high force inputs on the control yoke for small elevator movements. The use of the QRH jammed elevator control procedure was successful and allowed the crew to maintain control of the aircraft and to descend, during which normal elevator control was regained.

The investigation could not identify the cause of the stiff elevators and the aircraft manufacturer is not aware of any similar stiff or jammed elevator events on the PC-24 fleet. The possibility that the elevator restriction was caused by ice formation on the elevator control system could not be excluded.

Published: 25 January 2024.