Final Report

B737-800, 9V-MGL

Tail Strike Event

Kathmandu Airport, Nepal

6 May 2022

TIB/AAI/CAS.205

Transport Safety Investigation Bureau
Ministry of Transport
Singapore

2 May 2023

The Transport Safety Investigation Bureau of Singapore

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ABBREVIATIONS

APU	Auxiliary Power Unit
ATC	Air Traffic Control
ATPL	Air Transport Pilot License
CAW	Cabin Altitude Warning
CVR	Cockpit Voice Recorder
ENG	Engine
ESN	Engine Serial Number
FC	Flight Cycles
FCOM	Flight Crew Operations Manual
FCTM	Flight Crew Training Manual
FDAP	Flight Data Analysis Programme
FDR	Flight Data Recorder
FH	Flight Hours
HIRM	Hazard Identification and Risk Management
HUD	Head-Up Display
KTM	Kathmandu, Nepal
LIP	Line Instructor Pilot
MSA	Minimum Safe Altitude
NNC	Non-Normal Checklist
OFP	Operational Flight Plan
OFV	Outflow Valve
OPT	Onboard Performance Tool
PIC	Pilot-in-command

PF	Pilot Flying
PM	Pilot Monitoring
RTOW	Regulated Take-off Weight
SID	Standard Instrument Departure
UTC	Universal Coordinated Time

SYNOPSIS

On 6 May 2022, after taking off from Kathmandu Airport, Nepal, the flight crew of a Boeing B737-800 suspected a tail strike event. As the departure out of Kathmandu required the aircraft to fly over high terrain, the flight crew continued climbing to above the Minimum Safe Altitude (MSA) of 14,400 feet before descending and depressurising the aircraft as per the tail strike non-normal checklist and diverting to land in Kolkata, India.

After the aircraft landed in Kolkata, an inspection confirmed that the skid shoe of the aircraft's tailskid assembly had contacted the runway in Kathmandu but there was no damage to the aircraft's aft fuselage structure.

The Transport Safety Investigation Bureau classified this occurrence as a serious incident.

AIRCRAFT DETAILS

Aircraft type	:	Boeing B737-800
Operator	:	Singapore Airlines
Aircraft registration	:	9V-MGL
Numbers and type of engines	:	Two engines / CFM56-7B27E
Engine hours/cycles since new	:	#1 ENG (ESN 862593): 1,200 FH / 462 FC Installed on 9V-MGL since 3 May 2021 #2 ENG (ESN 862354): 18,209 FH / 7,297 FC Installed on 9V-MGL since 21 July 2015
Date and time of incident	:	6 May 2022 at 09:13 UTC
Location of occurrence	:	Kathmandu, Nepal
Type of flight	:	Scheduled
Persons on board	:	8 Crews 165 Passengers

1 FACTUAL INFORMATION

All times used in this report are Singapore Local Time (LT) unless otherwise stated. Singapore Local Time is eight hours ahead of Coordinated Universal Time (UTC).

1.1 History of the flight

1.1.1 On 6 May 2022, a Boeing B737-800 operated a scheduled flight from Kathmandu (KTM), Nepal to Singapore. The aircraft took off from Runway 20 at about 0913 UTC. The flight crew comprised two captains, one of them was a Line Instructor Pilot (LIP). The LIP occupied the right seat and was the Pilot-in-command (PIC) for the flight. He was performing the Pilot Monitoring (PM) duty. The other captain occupied the left seat and was performing the Pilot Flying (PF) duty. The PF was undergoing a station check[1] by the LIP. This was the first flight out of KTM performed by the PF after more than 12 months from the PF's previous flight into KTM.

1.1.2 According to the PM, he felt a light thud when the aircraft rotated during the take-off. He immediately scanned the aircraft instruments and noted that there were no engine parameter anomalies. After the lift-off, from his monitoring of cabin interphone communications, the PM heard the aft cabin attendant reporting to the cabin attendant-in-charge about a thud and scraping sound just before the aircraft lifted off. This reinforced his thinking that the thud sound he had heard earlier during the rotation could be due to a tail strike.

1.1.3 The PM told[2] the PF about the thud sound and that there might have been a tail strike. The PF responded that no thud sound was heard during the rotation. This aircraft did not have a tail strike warning indication system in the cockpit. (Note: Such a tail strike warning indication is available on B737-800 aircraft installed with the Head-Up Display (HUD) option.) Data from the Flight Data Recorder (FDR) showed that the pitch angle reached 11.07° before the aircraft lifted off and that most of the time during the rotation the pitch rate was greater than 3° per second and, at times, greater than 5° per second.

1.1.4 The PF asked the PM if there was any cabin pressurisation problem. The PM

[1] Station Check – In order to maintain currency to operate as PIC into KTM, the operator requires captains to operate to KTM at least once every 12 months. Due to the COVID-19 situation, the PF had not been current, and this Station Check was for the PF to regain currency to operate into and out of KTM.
[2] The aircraft was then about 400 feet above ground.

replied that he was unable to determine at that moment as the cabin was only starting to pressurise[3]. The flight crew then carried out and completed the After Take-off Checklist. The flight crew did not review the Tail Strike Non-Normal Checklist (NNC) at this juncture[4]. They intended to address the Tail Strike NNC after the aircraft had cleared 14,400 feet, the Minimum Safe Altitude (MSA) along the departure route.

1.1.5 The PF continued flying the aircraft on the IGRIS 1A Standard Instrument Departure (SID) and climbed the aircraft to maintain clearance from high terrain in the surrounding area[5]. During this time there was no indication of any pressurisation problem. KTM Air Traffic Control (ATC) cleared the aircraft to 27,000 feet. The bleed air source for the air conditioning packs was reconfigured from the Auxiliary Power Unit (APU) to the engine bleed source at 8,400 feet[6]. According to the flight crew, they retracted the flaps to achieve the appropriate configuration at 10,500 feet as required by the SID[7].

1.1.6 With the approval of KTM ATC, the flight crew levelled the aircraft at 15,000 feet. The PF noted and called out the cabin altitude of 4,000 feet and rate of climb zero[8]. The PF then sought and obtained the aft cabin attendant's confirmation that the latter had heard a thud sound during the take-off. In view of the suspected tail strike, the flight crew carried out aircraft systems check but found nothing abnormal.

1.1.7 While the aircraft was maintaining 15,000 feet, KTM ATC handed over control of the aircraft to Kolkata ATC in India. The PF then contacted Kolkata ATC and obtained a clearance to continue maintaining 15,000 feet.

1.1.8 The flight crew then reviewed the Tail Strike NNC and noted but did not execute at that juncture the action items required (including depressurising the aircraft and landing at the nearest suitable airport). Depressurising the aircraft would trigger the Cabin Altitude Warning (CAW) if this action was executed above

[3] According to the flight crew, they were aware that the absence of pressurisation problems did not necessarily mean that there was no structural damage.
[4] According to the PM, he looked at the Tail Strike NNC but did not discuss the checklist items with the PF as the tail strike was not confirmed.
[5] KTM airport is surrounded by high terrain and the SID is challenging and requires flight crew to adhere to speed and turning radius limits in order to avoid flying into terrain.
[6] The aircraft was operating close to its maximum take-off performance limit and the take-off configuration used was Flap 1 without using engine bleeds. APU bleed air was used for the operation of air conditioning packs during the take-off.
[7] The IGRIS 1A SID required aircraft to maintain a speed limit of 180 knots until the altitude of 10,500 feet, where the flight crew can start retracting the flaps to achieve the appropriate aircraft configuration.
[8] Zero cabin rate of climb means that the cabin altitude is stabilised, i.e. neither increasing nor decreasing.

10,000 feet[9]. The flight crew decided to descend the aircraft from 15,000 feet to 10,000 feet before performing the Tail Strike NNC to avoid triggering unnecessarily the CAW.

1.1.9 The fight crew were aware of the caution note in the Tail Strike NNC which stated that "*Continued pressurisation of the airplane can cause further structural damage*". The PF declared PAN[10] to Kolkata ATC and obtained permission to descend to 10,000 feet, which was the safe altitude for operating a depressurised aircraft without the need for supplementary oxygen.

1.1.10 As the aircraft was descending through about 12,000 feet, the PF called out the aircraft altitude and requested the PM to carry out the action items required by the Tail Strike NNC[11]. As regards the action to depressurise the aircraft, the PM rotated the cabin pressurisation mode selector on the cabin pressurisation control panel (see Figure 3 in paragraph 1.5.3.2) from AUTO to MANUAL and toggled the outflow valve (OFV)[12] switch to the OPEN position to open the OFV. According to the PM, after he had toggled the OFV switch to the OPEN position momentarily (approximately one second), the needle in the OFV position indicator (which shows the extent of valve opening) remained pointing at the same slightly open position even after some 20 seconds. So, he toggled the OFV switch to the OPEN position momentarily again but still did not observe any appreciable movement of the OFV position indicator needle. The PM told the investigation team that he recalled reading a cabin altitude of about 6,000 feet after attempting to open the OFV but he could not remember whether it was after the first or second time he toggled the OFV switch.

1.1.11 About 13 seconds after the PM first toggled the OFV switch, the cabin crew at the aft galley called the PF to report a loud wheezing sound. The PF believed that this was the sound of air rushing out through the OFV opening, which confirmed to the PF that the OFV was operating, and the PF mentioned this to the PM. However, the PM told the investigation team that he could not recall having heard the PF saying that the OFV was operating. Shortly after the cabin crew's call to the PF, when the aircraft was still above 10,000 feet, the CAW was triggered indicating that the cabin altitude had exceeded 10,000 feet.

[9] The pressure switches will close to trigger the CAW at cabin altitude between 9,000 and 11,000 feet.
[10] PAN call is used to declare that the flight is encountering an urgent situation which, for the time being, does not pose an immediate danger to anyone's life or to the aircraft itself.
[11] The flight crew's intention was to slowly depressurise the aircraft so that, when the aircraft levelled off at 10,000 feet, the cabin altitude would have increased to 10,000 feet (thereby avoiding triggering the CAW unnecessarily).
[12] To manually open or close the OFV, the flight crew would need to toggle the OFV control switch.

1.1.12 In response to the CAW, the flight crew completed the following actions as per the memory items[13] in the CAW Checklist:

(a) Donning oxygen masks and setting oxygen flow regulators to 100%

(b) Establishing crew communications

(c) Ensuring that the cabin pressurisation mode selector was selected to the manual mode[14]

(d) Assessing that the cabin altitude was controllable

The flight crew did not carry out the closing of the OFV as per the CAW Checklist. This was because the flight crew's intention was to open the OFV as required by the Tail Strike NNC.

1.1.13 The PM also manually deployed the passenger oxygen masks as a precautionary measure[15] but he did not inform the PF. The PF only became aware that the passenger oxygen masks were deployed after being informed by the cabin crew subsequently.

1.1.14 When the aircraft had levelled off at 10,000 feet and arising from the CAW, the PF requested the PM to obtain further clearance from Kolkata ATC to descend to 5,000 feet. The CAW ceased when the aircraft had descended to below 6,000 feet.

1.1.15 On reaching 5,000 feet, the PF and the PM removed their oxygen masks. The PF then asked the cabin attendants via the Passenger Address system to perform their decompression checks in the cabin. The cabin attendant-in-charge subsequently updated the PF that other than a child who appeared to be very sleepy and a passenger who complained of an ear blockage, there were no passenger injuries.

1.1.16 The flight crew experienced some radio communication difficulties with Kolkata ATC when flying at 5,000 feet. Their communications with Kolkata ATC were

[13] Memory items are actions that must be carried out by a flight crew quickly in response to a non-routine event, without having to refer to a checklist. The flight crew are required to memorise these actions.
[14] This step was already taken under the Tail Strike NNC.
[15] Passenger oxygen masks will only be deployed automatically when the cabin altitude exceeds 14,000 feet. The aircraft was below 12,000 at the time. According to the CAW Checklist, there is actually no need to deploy passenger oxygen masks if the cabin altitude is controllable. The flight crew will just need to maintain the appropriate cabin altitude.

relayed by other aircraft flying in the vicinity. The flight crew subsequently obtained, through such relays, Kolkata ATC's clearance to climb to 7,000 feet where their communications with Kolkata ATC improved. The PF informed Kolkata ATC of the suspected tail strike and of their intention to divert to Kolkata, India. The flight crew then commenced the diversion and performed an overweight landing in Kolkata[16].

1.1.17 After the aircraft landed in Kolkata, an inspection confirmed that the skid shoe of the aircraft's tailskid assembly had contacted the runway in Kathmandu but there was no damage to the aircraft's aft fuselage structure.

1.2 Injuries to persons

1.2.1 There was no injury to any person.

1.3 Damage to aircraft

1.3.1 There were signs of abrasion on the skid shoe of the aircraft's tailskid assembly (see **Figure 1**), indicating that there had been a tail strike in KTM. However, the drag lever had not been compressed[17], indicating that there was no damage to the aft fuselage structure.

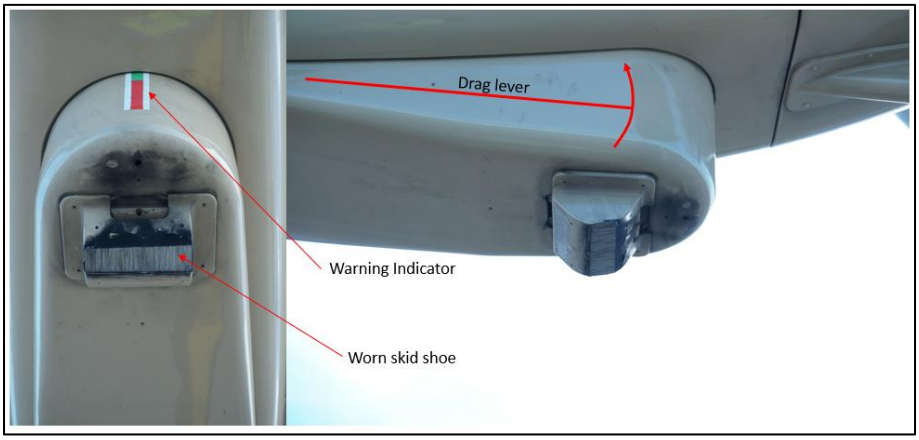

Figure 1: Tail Skid Assembly

1.3.2 The contacting of the skid shoe with the runway means that the pitch angle of

[16] The operator's flight planning policy, for departures out of KTM, is to have an alternate airport where the flight crew can divert to if necessary.
[17] The green band of the warning indicator was still visible, as can be seen in Figure 1.

the aircraft exceeded the pitch angle limit of 11° for the aircraft.

1.4 Personnel information

1.4.1 Pilot-in-command

Occupying LH/RH Seat	RH (Performing PM Duty)
Age	59
Licence Type	Air Transport Pilot Licence (ATPL)
Issuing authority	Civil Aviation Authority of Singapore
Licence validity date	30 Sep 2022
Medical certificate	Class One
Medical certificate date	Valid till 30 Sep 2022
Medical operational proviso	Holder shall wear corrective lenses that correct for both distant and near vision and shall have available a second pair of spectacles whilst exercising the privileges of the licence.
Last base check	11 Jun 2021
Last line check	14 Oct 2021
Total flying time	10069 hr 38 min
Aircraft types flown	Airbus A320, Boeing B737-800[18]
Total flying on the B737 type	4030hr
Flying in last 90 days	108 hr 06 min
Flying in last 7 days	15 hr 34 min
Flying in the last 24 hours	6 hr 58 min
Duty time last 48 hours	08 hr 33 min
Rest period in last 48 hours	39 hr 27 min

1.4.2 Co-pilot

Occupying LH/RH Seat	LH (Performing PF duty)
Age	48
Licence type	Air Transport Pilot Licence (ATPL)
Issuing authority	Civil Aviation Authority of Singapore
License validity date	Valid till 30 Apr 2023
Medical certificate	Class 1
Medical certificate validity	30 Apr 2023
Medical operational proviso	Holder shall wear corrective lenses that correct for both distant and near vision and shall have available a second pair of spectacles whilst exercising the privileges of the licence.
Last base check date	5 Apr 2022
Last line check date	18 Oct 2021

[18] The PIC/PM obtained his captaincy on A320 in 2014 and was converted to the B737-800 fleet as a captain in 2015.

Total flying time	12088 hr 49 min
Aircraft type flown	Beechcraft B58, Airbus A320, Boeing B737-800
Total hour on type (B737)	5200 hr
Flying in last 90 days	95 hr 29 min
Flying in last 7 days	11 hr 09 min
Flying in the last 24 hours	6 hr 58 min
Duty time last 48 hours	8 hr 33 min
Rest period in last 48 hours	39 hr 27 min

1.5 Aircraft information

1.5.1 Aircraft take-off weight

1.5.1.1 The take-off weight of the aircraft was 75,477kg which was within the Regulated Take-Off Weight (RTOW)[19] of 76,100kg for this flight.

1.5.1.2 The flight crew used Flap 1 configuration for the take-off, as recommended by the Onboard Performance Tool (OPT)[20] in view of the environmental conditions, airport elevation and the aircraft's take-off weight.

1.5.2 Tail strike pitch angle limit

1.5.2.1 For B737-800, the aircraft manufacturer recommends in its Flight Crew Training Manual (FCTM), a rotation pitch rate of 2° to 3° per second. With such a pitch rate, the pitch angle at lift-off will normally be between 7° and 9°. The nominal lift-off pitch angle for an aircraft taking off with a Flap 1 setting is around 8.5°, with a tail clearance from the ground of about 13 inches (33cm). Tail strike will occur when the lift-off pitch angle exceeded 11°, assuming that the main landing gear wheels are on the runway and landing gear struts extended.

[19] Regulated Take-Off Weight is the maximum weight in which an aircraft can take off from a particular runway under specific condition (wind, weather, specific aircraft configuration, etc.)
[20] OPT is a take-off performance calculation application in the tablet issued to flight crew.

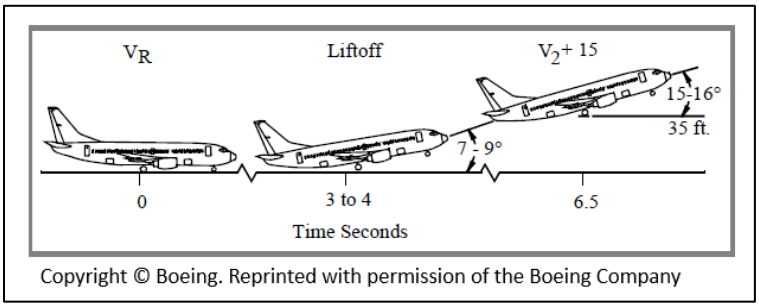

Figure 2: Typical take-off clearance for B737-800

1.5.3 Manual control of cabin pressurisation[21]

1.5.3.1 The aircraft cabin is pressurised so that the air pressure in the cabin corresponds to a lower altitude as compared to the actual aircraft altitude. Through the pressurisation, the cabin altitude is maintained at about 8,000 feet and flights above 10,000 feet require the carriage of supplementary oxygen.

1.5.3.2 Cabin pressurisation is controlled by the OFV. For the manual operation of the OFV, the cabin pressurisation mode selector on the cabin pressurisation control panel (see **Figure 3**) is selected to MANUAL[22]. To open the OFV (i.e. selecting a higher cabin altitude)[23], the OFV switch is toggled momentarily to the OPEN position and the flight crew should verify that the needle in the OFV position indicator moves to the right and also verify, on separate indicators (see **Figure 4**), that the cabin altitude climbs at the desired rate and that the differential pressure (between the cabin and ambient air) decreases. This step should be repeated as necessary to achieve the desired cabin altitude.

[21] Cabin pressurisation is a process in which conditioned air is pumped into the cabin of an aircraft when flying at high altitudes in order to create a safe and comfortable environment for passenger and crew.
[22] On selection to MANUAL, the green MANUAL light will be illuminated to indicate that cabin pressurisation is in manual mode.
[23] Increasing cabin pressurisation would mean that the cabin is maintained at a lower altitude and vise-versa.

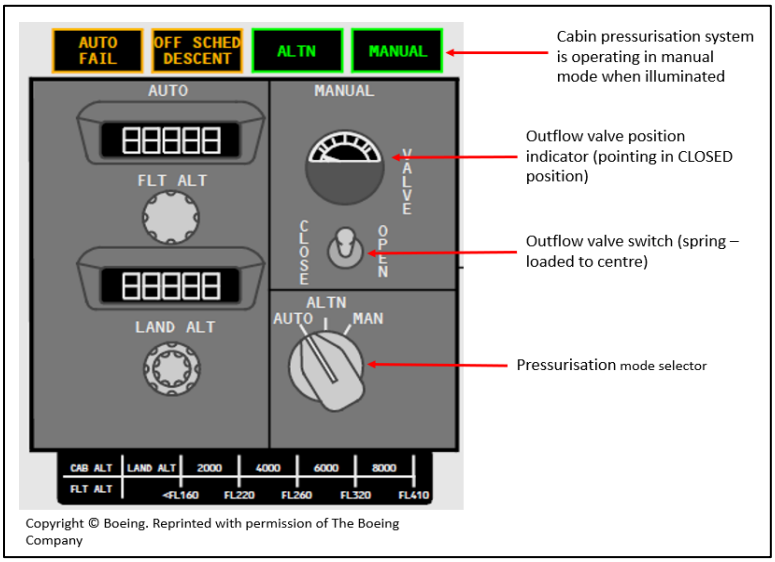

Figure 3: Cabin Pressurisation Control Panel

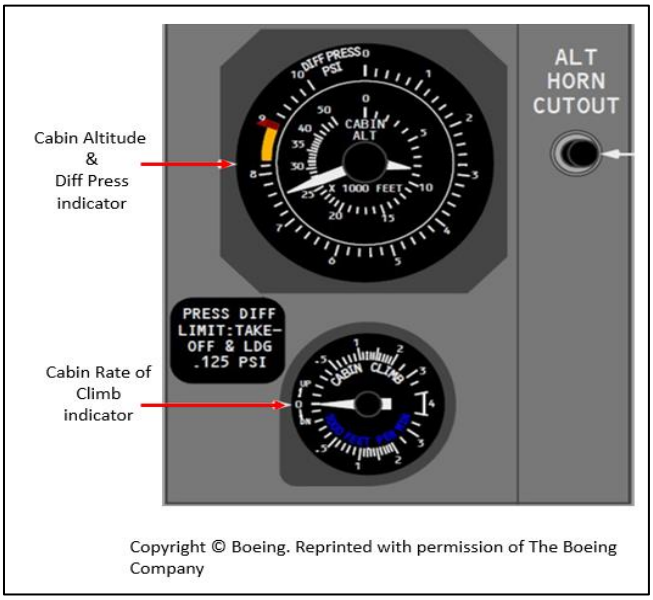

Figure 4: Cabin Pressure Indicators

1.5.3.3 The Tail Strike NNC calls for the aircraft to be depressurised by toggling the OFV switch, to avoid further damage to the aircraft structure in case the structural integrity of the fuselage has been compromised by the tail strike. The instruction in the B737 Flight Crew Operations Manual (FCOM) on manual control of depressurisation contained a caution note stating: *"Switch actuation to the manual mode causes an immediate response by the outflow valve. Full*

range of motion of the outflow valve can take up to 20 seconds".

1.6 Meteorological Information

1.6.1 The aerodrome observed weather report at 0850 UTC indicated an eight-knot wind from 220°, varying between 190° and 250°, which was predominately headwind for take-off on runway 20.

1.6.2 From an analysis of the FDR data by the aircraft manufacturer, the investigation team noticed a difference of about 10 knots between the aircraft's ground speed and airspeed during the aircraft's take-off roll up to the point of rotation. This difference suggests a tailwind with a component along the runway of about 10 knots.

1.7 Aerodrome information

1.7.1 KTM airport's elevation is 4,400 feet. Runway 20 has a length of 3,074 metres.

1.8 Flight recorders

1.8.1 The flight data recorder (FDR) and cockpit voice recorder (CVR) were read out by the investigation team.

1.8.2 The cabin altitude, cabin rate of climb, OFV position and the differential pressure (between the cabin and ambient) are not parameters recorded by the FDR.

1.9 Tests and Research

1.9.1 The investigation team carried out a ground test on the manual operation of the OFV on the incident aircraft. The OFV movement was responding instantaneously to the manual input. No anomalies were found. The problems described by the PM in paragraph 1.1.10 could not be replicated during the ground test.

1.10 Additional information

1.10.1 Flight crew training

1.10.1.1 According to the operator, the flight crew had been trained to execute the

proper rotation technique, including strategies based on the guidance in the aircraft manufacturer's FCTM Chapter on Take-off and Initial Climb for taking off in gusty conditions to prevent tail strike.

1.10.1.2 The investigation team reviewed the PM's and PF's recurrent training records and noted that the training on the topic of manual pressurisation control which they underwent was only a discussion-based training and computer-based training. The training did not involve the LIPs physically manipulating the manual pressurisation control and monitoring the OFV position indicator and cabin altitude/cabin differential pressure and cabin rate of climb indicators.

1.10.1.3 The operator trained its flight crew based on the aircraft manufacturer's B737 NG/MAX FCTM's guidelines for non-normal situation as follows:

(a) Recognise the non-normal situation by calling out the malfunction clearly

(b) Maintain the aircraft control by the PF flying the aircraft while the PM maintaining situational awareness and supporting the PF to ensure obstacle clearance and aircraft control

(c) Analyse the situation

(d) Accomplish NNC after the desired flight path and appropriate configuration are correctly established

1.10.1.4 The B737 NG/MAX FCTM's Non-Normal Operation guidance for Tail Strike contained a note "Anytime fuselage contact is suspected or confirmed, accomplish the appropriate NNC without delay." According to the aircraft manufacturer, "without delay" means that, in the case of 1.10.1.3(d), the flight crew should begin the Tail Strike NNC when the desired flight path and appropriate configuration are correctly established, which in this event would be at about 10,500 feet.

1.10.2 Procedure for operating in high terrain regions

1.10.2.1 The aircraft manufacturer indicated in the Manoeuvring and Appendices sections of its B737NG[24]/MAX FCTM that:

- the operators should plan routes over mountainous terrain to include

[24] B737NG includes B737-600, B737-700, B737-800 and B737-900

carriage of additional oxygen, higher initial level off altitudes and emergency routes in the event a depressurisation is experienced; and

- the operator should document its guidance for flight planning for routes over mountainous terrain in an approved company route manual or any other document that contains any route specific considerations.

1.10.2.2 The operator has published Supplementary Procedures for operations in high terrain regions specifying oxygen and depressurisation requirements for routes in high terrain regions, including escape routes to avoid high terrain. The operator also provided customised Operational Flight Plans (OFP) for flights operating in high terrain regions that comply with these requirements. The Supplementary Procedures were not applicable to KTM as the aircraft was fitted with sufficient oxygen to meet the requirement for KTM operation.

1.10.2.3 The operator also published airport briefing notes for its flight crew containing information such as common hazards, operational restrictions and qualifications, geography, terrain and weather, aerodrome information, aircraft configuration and performance, special procedures, etc.

1.10.2.4 The operator did not see the need for specific or additional guidance for tail strike to be provided to the flight crew when operating to and out of airports that have surrounding high terrain on the grounds that the aircraft manufacturer had already provided a Tail Strike NNC and guidance in the FCTM.

1.10.3 Safety Management System

1.10.3.1 The operator's Hazard Identification and Risk Management (HIRM) programme had identified the hazards, risks and defences when operating into and out of KTM airport. However, the HIRM programme did not identify hazards and assess risks relating to the scenario of a tail strike occurrence during take-off from KTM airport. According to the operator, the hazard posed by a tail strike is already addressed in the aircraft manufacturer's Tail Strike NNC and flight crew training.

1.10.4 Flight Data Analysis Programme

1.10.4.1 The operator has a Flight Data Analysis Programme (FDAP) that collects and analyses flight data for flight operations quality control in support of its safety management system. Rotation pitch rate during take-off is a parameter being

monitored by the FDAP.

1.10.4.2 At the time of the incident flight, the rotation pitch rate detection threshold in the FDAP software was set at 4° per second while the aircraft manufacturer's FCTM states that, when the proper rotation technique is followed, the resultant rotation rate will be between 2° and 3° per second. With the rotation pitch rate detection threshold reduced to 4° per second, the FDAP still did not detect any high pitch rate events, thus giving the impression that all B737 take-offs had been carried out with a rotation pitch rate of less than 4° per second prior to, and including, the incident flight. This was despite that the FDR recorded a rotation pitch rate at times greater than 5° per second before lift-off during the take-off at KTM airport.

1.10.4.3 The operator subsequently reduced the rotation pitch rate detection threshold of the FDAP software to 3° per second but the FDAP still did not detect any high rotation pitch rate events. The operator then discovered that the FDAP software detection threshold for high rotation pitch rate would only register an event when the exceedance of rotation pitch rate was over two consecutive seconds and that an exceedance over just one second would not be registered. The operator subsequently adjusted the high rotation pitch rate detection threshold to 3° per second occurring for a duration of one second.

1.10.4.4 Following this adjustment of the detection threshold, the operator's B737-800 and B737-8 FDAP detected several rotation pitch rate events above 3° per second. Three of these events (including the incident flight), had a rotation pitch rate of more than 5° per second. Two of these three flights involved a pitch angle of more than 9°.

2 ANALYSIS

The tail strike occurred due to over-rotation of the aircraft by the PF during the take-off from KTM. The investigation team looked into the following:

(a) Rotation pitch rate

(b) Performing Tail Strike Non-Normal Checklist (NNC)

(c) Tail strike indication

(d) Operation of the outflow valve (OFV)

(e) Operator's Hazard identification and Risk Mitigation (HIRM) programme

(f) Standard callout for oxygen masks deployment

2.1 Rotation pitch rate

2.1.1 During rotation of an aircraft at take-off, a high pitch rate will increase the likelihood of a tail strike. According to the aircraft manufacturer's FCTM, when the proper rotation technique is followed, the resultant rotation rate will be between 2° and 3° per second. In this incident, the pitch rate was, at times, greater than 5° per second. As mentioned in paragraph 1.6.1 there was likely a tailwind with a component of about 10 knots along the runway during the aircraft take-off roll up to rotation. The high pitch rate together with the tailwind component during rotation probably eroded the tail-to-ground clearance margin and resulted in the tailskid contacting the runway.

2.1.2 As mentioned in paragraph 1.10.4.4, there were several events involving pitch rate greater than 3° per second registered by the FDAP. Whether there was any likely tailwind component involved in these events, the high rotation pitch rate is of concern and the investigation team opined that the operator should re-emphasise to all its flight crew the proper rotation technique.

2.2 Performing Tail Strike Non-Normal Checklist (NNC)

2.2.1 A tail strike occurring when operating out of an aerodrome in high terrain areas, such as KTM airport, can be a major challenge to the flight crew. The aircraft manufacturer has a Tail Strike NNC and guidance in the FCTM. The Tail Strike

NNC contains the action items to be taken when a tail strike is confirmed or suspected and the FCTM states that the Tail Strike NNC should be carried out without delay.

2.2.2 As mentioned in paragraph 1.10.1.4, “without delay” means the flight crew should begin the Tail Strike NNC when the desired flight path and appropriate configuration are correctly established, which in this event would be at about 10,500 feet. The investigation team opined that the flight crew in this event could have considered beginning the Tail Strike NNC after reaching about 10,500 feet and while the aircraft was still climbing to the MSA of 14,400 feet. Doing so might result in the CAW triggering and automatic deployment of oxygen masks for the passengers (see Footnote 14 in paragraph 1.1.13), but the inconvenience of oxygen masks deployment should be manageable and acceptable, in view of the unknown risk of aircraft structural failure with the continued pressurisation of the aircraft.

2.3 Tail strike indication

2.3.1 The incident aircraft does not have a tail strike warning indication system. It is an option for operators who purchased the HUD system. The flight crew determined that the aircraft had probably experienced a tail strike basing on the cabin crew’s account. The investigation opined that if a tail strike warning indication was available in the flight deck, it would have helped the flight crew make better decision as to whether to perform the Tail Strike NNC urgently.

2.4 Operation of the outflow valve (OFV)

2.4.1 As mentioned in paragraph 1.1.10, the PF requested the PM to carry out the actions required by the Tail Strike NNC and one of the action items was to depressurise the aircraft. Accordingly, the PM toggled the OFV switch manually to open the OFV after selecting the cabin pressurisation mode selector to MANUAL. The PF noticed that the OFV was operating, and the PF mentioned this to the PM. However, the PM did not see any appreciable movement on the OFV position indicator despite having toggled the OFV switch twice and had apparently not heard what the PF said to him.

2.4.2 The investigation team could not think of a reason why the OFV position indicator could not show any appreciable movement in view of the following:

(a) The PF had been informed by the cabin crew that there was a wheezing sound which the PF interpreted as a sign that the OFV was operating.

(b) Post-incident test on the manual operation of the OFV on the incident aircraft did not reveal any anomaly, and the problems described by the PM in paragraph 1.1.110 could not be replicated.

The PM said that he was about to try a third time in toggling the OFV switch when the CAW was triggered. This was despite the PM noticing that the cabin altitude was at about 6,000 feet after having toggled the OFV switch. The fact that the cabin altitude had changed from the initial 4,000 feet to 6,000 feet clearly showed that the OFV had responded to his inputs and was opening. The investigation team suspected that the PM was too focused on checking the OFV position indicator and did not monitor the cabin altitude/differential pressure and cabin rate of climb indicators, and also did not register the PF saying that the OFV was opening.

2.4.3 The investigation team could only suspect that the PM might have been out of practice with the skills relating to manipulating cabin pressurisation. The investigation team noticed that since the PM's conversion training to the B737 fleet as a captain in 2015, he did not practise manipulating cabin pressurisation[25].

2.5 Operator's Hazard identification and Risk Mitigation (HIRM) programme

2.5.1 The operator stated that it is impossible for airport HIRM to address all non-normal events that may happen and did not identify tail strike out of KTM airport as a hazard that would require additional mitigation over and above the Tail Strike NNC and was satisfied that its flight crew had been trained to perform the Tail Strike NNC tasks. The investigation team opined that tail strike out of KTM airport would represent a very challenging situation due to the uniqueness of the operating environment, i.e. aerodrome in the vicinity of high terrain, when the flight crew needed to clear the MSA and the aircraft needed to be depressurised, as required by the Tail Strike NNC, to avoid any further structural damage.

2.5.2 It is understood that the aircraft manufacturer's FCTM and NNCs are developed

[25] The programme of the recurrent training for the PM as a Line Instructor Pilot/Instructor Pilot did not include actions on manipulating cabin pressurisation.

to cover the majority of airline operations and each operator has to consider its unique operational specificities and adopt appropriate control measures. The operator should have considered, as part of its HIRM programme, the complexity of a tail strike situation at aerodromes at high elevations surrounded by high terrain such as KTM airport, and developed targeted guidance and training that will:

(a) help the flight crew decide when would be the best time to execute the Tail Strike NNC;

(b) remind the flight crew of the potential risk of aircraft structural failure with the continued pressurisation of the aircraft; and

(c) remind the flight crew to expect that the CAW could be triggered when performing the Tail Strike NNC at around or above 10,000 feet.

2.6 Standard callout for oxygen mask deployment

2.6.1 As mentioned in paragraph 1.1.13, the PM, in response to the CAW, manually deployed the passenger oxygen masks as a precautionary measure. However, the PF was not aware that the passenger oxygen masks were deployed as the PM did not inform the PF in any way of his oxygen masks deployment action.

2.6.2 Keeping each other in the cockpit informed of the flight operational situation is a common safety strategy practised by flight crew and is important for ensuring that flight crew members have the same operational picture. This will allow them to better manage any abnormal situation that pops up.

2.6.3 Oxygen masks deployment, an irreversible action, is a significant event in flight operation. It is desirable for the operator to consider including oxygen masks deployment in the list of standard callout items.

3 CONCLUSIONS

Findings are made from the information gathered. The findings should not be read as apportioning blame or liability to any particular organisation or individual.

3.1 The tail strike occurred during the take-off at KTM airport was due to over-rotation by the PF, coupled with a likely tailwind with a component of about 10 knots along the runway. The rotation pitch rate was, at times, greater than 5° per second as recorded by the FDR. The pitch angle of 11.07° recorded also exceeded the 7° – 9° normal pitch angle range.

3.2 The flight crew could have considered beginning the Tail Strike NNC after reaching about 10,500 feet and while the aircraft was still climbing to the MSA of 14,400 feet.

3.3 The incident aircraft did not have a tail strike warning indication system installed. If such a warning indication system was available in the flight deck, it would have helped the flight crew make better decision as to whether to perform the Tail Strike NNC urgently.

3.4 The operator's recurrent training programme for LIPs/Captains did not include practising the skills relating to manipulating cabin pressurisation. The investigation team suspects that the PM might have been out of practice with the skills relating to manipulating cabin pressurisation.

3.5 The operator did not consider, as part of its HIRM programme, the complexity of a tail strike situation at aerodromes at high elevations surrounded by high terrain and did not develop targeted guidance and training for its flight crew.

3.6 In response to the Cabin Altitude Warning (CAW), the PM manually deployed the passenger oxygen masks as a precautionary measure without informing the PF. The operator did not have a requirement for standard callout for oxygen masks deployment.

4 SAFETY ACTIONS

Safety actions taken by organisation(s) concerned arising from discussions with the investigation team.

4.1 The operator reviewed the event and Quick Access Recorder (QAR) data with the incident flight crew and conducted remedial simulator training for them which covered the following:

- Take-off briefing on application of Threat and Error Management and calculation of take-off data using the onboard performance terminal application in company issued iPad
- Take-off rotation techniques in various aircraft configurations and environmental conditions
- Tail Strike NNC
- Cabin Altitude Warning and Emergency Descent
- Go-around and Overweight landing consideration
- Error recognition and recovery

4.2 The operator issued a Preliminary Factual Bulletin (PFB) concerning the event. The PFB was shared during pilot dialogue for awareness. The operator has also incorporated the lessons learnt from the incident in the form of facilitated discussion during recurrent and initial crew training.

4.3 As mentioned in paragraph 1.10.4.3, the FDAP detection threshold for rotation pitch rate has been changed to 3° per second occurring for a duration of one second. In the event of an exceedance, the data will be further analysed with reference to the maximum pitch angle reached during take-off for comparison with the aircraft manufacturer's recommended take-off pitch angle range. When necessary, the operator will review with the flight crew concerned regarding the proper rotation technique.

5 SAFETY RECOMMENDATIONS

A safety recommendation is for the purpose of preventive action and shall in no case create a presumption of blame or liability.

5.1 It is recommended that the operator:

(a) Re-emphasise to all its flight crew the proper rotation technique to prevent tail strike. [TSIB RA-2023-001]

(b) Consider providing targeted guidance and training for aerodromes at high elevations surrounded by high terrain that will:

(1) help the flight crew decide when would be the best time to execute the Tail Strike NNC; [TSIB RA-2023-002]

(2) remind the flight crew of the potential risk of aircraft structural failure with the continued pressurisation of the aircraft; [TSIB RA-2023-003] and

(3) remind the flight crew that the CAW could be triggered after completing the Tail Strike NNC at around or above 10,000 feet. [TSIB RA-2023-004]

(c) Include the practising of the skills relating to manipulating cabin pressurisation in the recurrent training for Line Instructor Pilots/Captains. [TSIB RA-2023-005]

(d) Include oxygen masks deployment in the list of standard callout items. [TSIB RA-2023-006]

5.2 It is recommended that the aircraft manufacturer consider making the tail strike warning indication a standard feature on the flight deck to better help flight crew decide as to whether to perform urgently the Tail Strike NNC in the event of a confirmed or suspected tail strike situation. [TSIB RA-2023-007]