

SERIOUS INCIDENT

Aircraft Type and Registration:	Boeing 737-86N, G-DRTN	
No & Type of Engines:	2 CFM CFM56-7B26 turbofan engines	
Year of Manufacture:	2002 (Serial no: 32735)	
Date & Time (UTC):	9 February 2020 at 1122 hrs	
Location:	East Midlands Airport	
Type of Flight:	Commercial Air Transport (Passenger)	
Persons on Board:	Crew - 6	Passengers - 193
Injuries:	Crew - None	Passengers - None
Nature of Damage:	No 4 brake unit and wheel deformed due to brake heating	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	45 years	
Commander's Flying Experience:	12,300 hours (of which 893 were on type) Last 90 days – 75 hours Last 28 days – 13 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot and further enquiries by the AAIB	

Synopsis

In very gusty conditions, the aircraft experienced a significant loss of airspeed due to windshear as it approached V_1 on takeoff. The strong crosswind led to a loss of directional control so the takeoff was rejected after reaching V_1 . The aircraft stopped about 600 m from the end of the runway. The No 4 wheel and brake unit suffered heat damage from the high temperatures caused by full brake application during the rejected takeoff.

History of the flight

On the day of the event the weather at East Midlands Airport (EMA) was experiencing strong, gusty winds and squalls, resulting from Storm Ciara. The forecast indicated a wind of 200° at 32 kt with gusts to 45 kt. The crew arrived early for the briefing and the pilots discussed the weather situation at some length. The commander's initial decision was that he would conduct the takeoff from EMA due to the severe weather. The runway surface was wet, and the aircraft was therefore limited to a 25 kt crosswind component for departure. The co-pilot, during their discussions, informed the commander that as a Senior First Officer (SFO) he was permitted by the operator to use the same weather limits as the commander.

In addition to the weather considerations for the aircraft, the airport had stopped using high lift vehicles, which transport Persons of Reduced Mobility (PRM) and catering to the aircraft. The commander anticipated that there would be many difficulties that would consume

his attention in the lead up to departure and these were also discussed at the brief. On reflection, he decided that the co-pilot would prepare for and conduct the takeoff, allowing him to focus on the other matters.

Once at the aircraft the commander conducted the walkaround checks while the co-pilot prepared the cockpit for takeoff. As expected, the commander spent a considerable amount of time dealing with the airport ground staff and the operator's HQ as he tried to resolve several issues related to the strong winds.

During the cockpit brief the crew refreshed the actions for the Windshear Escape Manoeuvre and a Rejected Takeoff (RTO). The calculated performance figures for the departure were V_1 134 kt, V_R 149 kt, V_{RMAX} ¹ 158 kt and V_2 156 kt. Actions in the event of windshear at various stages of the takeoff were discussed along with the implications of windshear performance calculations. The aircraft had fuel loaded in excess of the planned requirement, so the crew decided to start and taxi to the departure end of the runway to await a suitable weather opportunity for takeoff. They had seen similar aircraft from other operators departing. The wind direction was relatively steady, and the pilots had calculated the maximum wind speed and direction that would give a crosswind component of 25 kt, which was 210° at 29 kt. They passed this figure to ATC.

As the aircraft approached the A1 holding point for Runway 27, the pilots were cleared for takeoff and were passed a wind of 220° at 32 kt. The pilots confirmed that this was in limit by referring to their Electronic Flight Bag (EFB). The aircraft lined up on the runway without stopping and takeoff thrust was selected.

At approximately 120 kt, the commander recalled a transitory reduction in airspeed of between 10 and 15 kt. He called this to the co-pilot but, as the acceleration resumed, decided to continue. The commander stated that approaching V_1 (134 kt) the aircraft deviated dramatically from the centreline to the right. He estimated the deviation was between 20° and 30° of heading. The commander saw a large downtrend on his airspeed indication and felt that the co-pilot's attempts to control the heading were ineffective. He stated to the investigation, "as PM, my instant snapshot was that indicated airspeed was reducing and we were below V_1 , so I called Stop." During this sequence of events both pilots recalled hearing the automated V_1 callout. The commander took control in accordance with Standard Operating Procedures (SOP), the RTO actions were carried out and the aircraft stopped on the runway centreline between M and H taxiways (Figure 1), with approximately 600 m remaining.

Once the aircraft stopped, the commander made a public address announcement to alert the cabin crew, and the pilots had a brief discussion regarding subsequent actions. They decided that they were able to vacate the runway and informed ATC of that decision, while also suggesting a runway inspection because the commander was concerned the aircraft may have struck runway edge lights. ATC did not deploy the airport fire service and the pilots did not ask for such assistance. The pilots decided to return to stand and were

Footnote

¹ See later section *Aircraft performance* for an explanation of V_{RMAX} .

cleared by ATC to do so. After the RTO, the commander was concerned about the co-pilot, who appeared to be preoccupied about what had happened during the takeoff. During the taxi in the commander believed that at least one brake was "binding" and that greater than normal thrust was required to taxi.

On the stand the aircraft was shut down as normal with the exception that, as soon as a tug and towbar were connected, the commander released the parking brake. He liaised with the cabin crew, company operations and the duty Pilot Base Manager, and the decision was taken to disembark the passengers because company engineering advised it would require a wait of one hour before they could commence work on the wheels. An engineering investigation revealed damage to the No 4 wheel and brake unit. The damaged brake unit was replaced, as were all wheels and tyres in accordance with the operator's maintenance manual.



Figure 1
East Midlands Airport Diagram

Recorded information

No FDR or CVR information was recovered for the event, but the Quick Access Recorder (QAR) recorded information which was available to the investigation through the operator's Flight Data Monitoring (FDM) system. An extract of the data is at Figure 2.

A brief reduction in airspeed before V_1 , as described by the commander, is shown in the trace. The indicated airspeed reduced briefly from 131 kt to 118 kt before recovering. V_1 and the initiation of the V_1 auto callout are highlighted by the second dashed line on the chart. Almost immediately after this point there was a reduction in airspeed from 142 kt to 129 kt over approximately 1.5 seconds and the aircraft heading changed to the right. There was a significant left pedal input and, between five and six seconds after V_1 , both brake pressures increased to 3,000 psi indicating autobrake RTO action. This is indicated by the third dashed line in Figure 2. The autobrake RTO mode is triggered by retardation of the thrust levers to idle. The RTO was initiated at an airspeed of approximately 149 kt but, because no CVR information was recovered, it was not possible to ascertain when the commander called "Stop" in this sequence of events.

Between V_1 and the start of the RTO the aircraft turned right by approximately 8° . Once the RTO was initiated, the aircraft responded to the left pedal input and turned rapidly left through approximately 14° before recovering to the centreline of the runway. Around the start of the RTO there were substantial changes in lateral g commensurate with the rapid changes in heading.

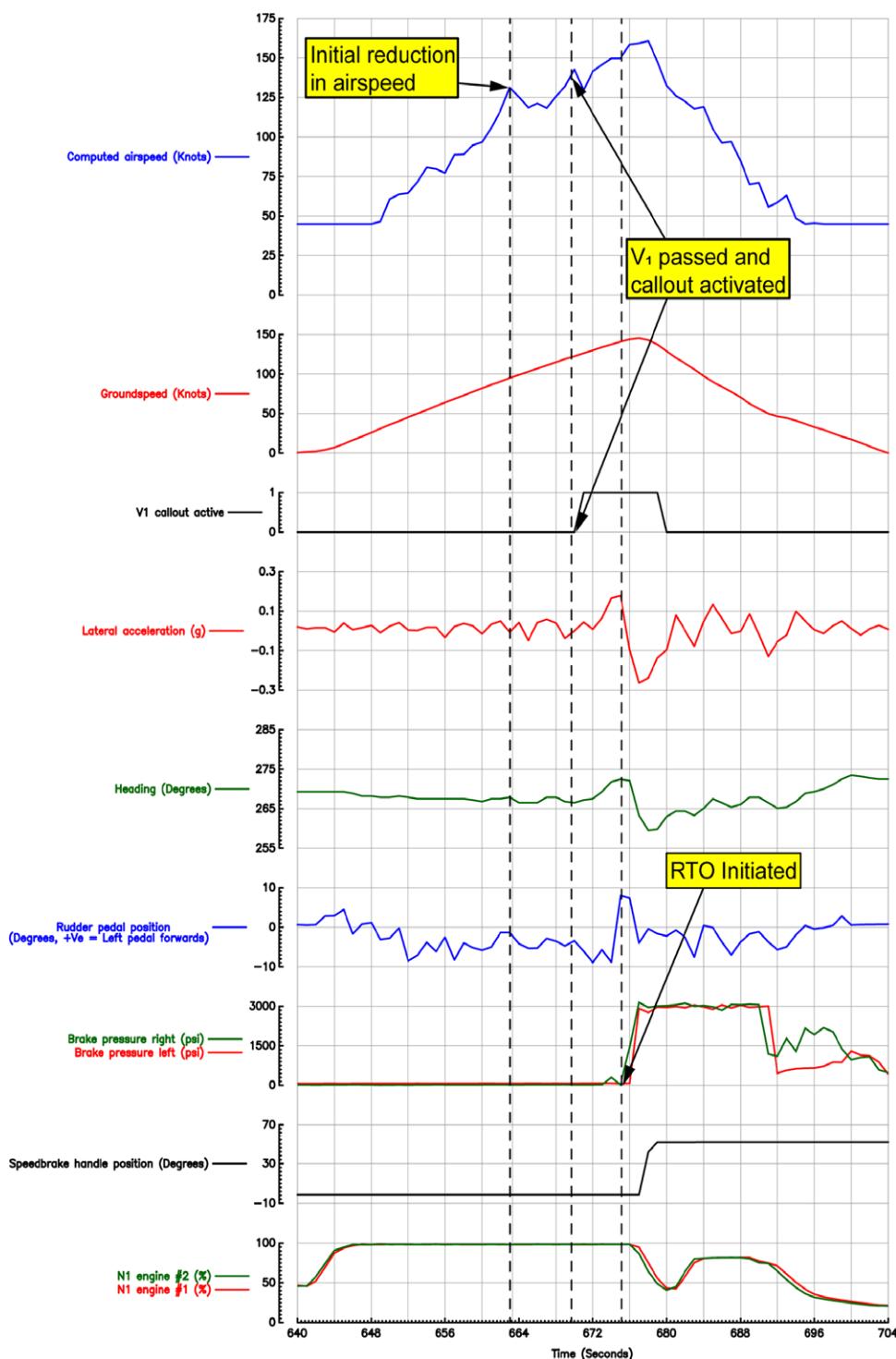


Figure 2
Flight Data Monitoring Extract

Commander's workload issues

The restrictions on the high lift vehicles meant that the aircraft galley carts could not be loaded. The planned sector to Tenerife was long and the commander was trying to ensure there would be as much customer service as possible. He reported that dealing with these ground handling issues was time consuming and was a factor in his decision to allow the co-pilot to operate.

Aircraft performance

The pilot's briefing covered the crosswind limitations for the takeoff, the prospect of windshear and the use of windshear performance calculations from the operator's EFB.

The windshear calculation for takeoff uses full thrust and, in addition to the usual calculated speeds of V_1 , V_R and V_2 , it also generates a V_{RMAX} . This is defined as the lowest of: the rotate speed for the maximum allowable weight for the runway and weather conditions; and the rotate speed for the actual weight plus 20 kt. The operator's Company Operating Procedures give the following advice for use of V_{RMAX} :

'When using Maximum Vr'

- *Set calculated V speeds for the 'Windshear' solution.*
- *Call 'rotate' at the V_{RMAX} speed.*
- *Clearly brief and agree the call that will be made by PM.*
- *If windshear is encountered at or beyond the actual gross weight Vr, rotate immediately, do not accelerate to V_{RMAX} speed but rotate without hesitation.'*

Meteorology

The airfield was affected by Storm Ciara and so the wind conditions were severe, with strong gusts. Actual weather reports from EMA are below:

09 Feb 2020 11:20	21037G48KT 9999 -RA BKN016 12/10 Q0980
09 Feb 2020 10:50	21040G56KT 9000 -RA BKN016 13/10 Q0981

Personnel

The commander had 12,300 hours total flying time of which 890 hours were on the Boeing 737 (B737). He began flying with the operator in March 2019 and had flown six departures from EMA in B737 aircraft. The co-pilot had 3,200 hours total time, of which 2,500 hours were on type, and had been with the operator for several years. He had been promoted to SFO in April 2019. The pilots had not met prior to this event.

Organisational information

The operator's Operations Manual advice on crosswind limits is shown in Figure 3.

Maximum Crosswind Components		
General		
The quoted crosswind limits are based on steady wind (no gust) conditions and include all engines operating. These are Company limits based on demonstrated information and Boeing guidelines. Gust effects were evaluated and tend to increase pilot workload without significantly affecting the stated limits.		
The crosswind limits are valid for runway widths of 30 m and greater.		
In operations approaching the crosswind limits the Captain must take account of experience on type, experience of airfield characteristics, wind/gust behaviour, runway width and runway surface conditions when establishing whether to commence an approach or which crew member should operate as Pilot Flying.		
Second or First Officers (when not flying with a Training Captain) are limited to:		
Second and First Officer Crosswind Limit	Dry Runway	Wet Runway
	20 Knots	15 Knots
Take Off Limits		
Runway Surface Category	DS Runway Surface Condition	Crosswind Limit (kts) Non-winglet/Winglet
Dry	Dry	36/33
Wet	Wet	25

Figure 3
Operator's Crosswind Guidance

The runway at EMA is 45 m so these limits were valid for the airfield. To upgrade to SFO, co-pilots required in excess of 2,000 hours and six months of service with the operator post completion of training and to be assessed as suitable by the operator's training department. The operator stated that the intention of allowing SFOs to operate to the same limits as commanders is to give them relevant operational experience in challenging conditions before upgrading to command.

Quick Reference Handbook (QRH)

Rejected Takeoff

The aircraft manufacturer lists within the QRH the events for which a pilot should consider rejecting the takeoff. The list provides clear guidance to crews to assist them making what may have to be a very rapid assessment of an event during the takeoff roll. The takeoff is divided into low and high speed regimes for the purposes of the RTO, with the high speed regime defined as above 80 kt. The manufacturer states that, above 80 kt, a takeoff should be rejected only for:

- *fire or fire warning*
- *engine failure*
- *predictive windshear warning*
- *if the airplane is unsafe or unable to fly.*

Windshear information

Windshear is a large change in wind speed or direction over a relatively small distance (where the distance can be vertical or horizontal) and is considered a serious threat.

G-DRTN is fitted with a predictive windshear detection system, which is active whenever the aircraft is below 2,300 ft agl. The system can generate warnings and cautions which are displayed to the pilots and trigger an aural alert in the flight deck. Predictive windshear warnings are enabled during the takeoff until the aircraft reaches 100 kt, when they are disabled until the aircraft reaches 50 ft agl. Cautions are enabled from 0 kt to 80 kt, at which point they are inhibited until the aircraft reaches 400 ft agl. The crew did not receive a predictive windshear warning or caution during the takeoff at EMA.

G-DRTN is also fitted with a reactive windshear system, which only becomes active when the aircraft rotates to lift off.

The Non-Normal Manoeuvres section of the B737-800 QRH contains the following guidance for pilots who encounter windshear during the takeoff roll:

'If windshear is encountered before V_1 , there may not be sufficient runway remaining to stop if an RTO is initiated at V_1 . At V_R , rotate at a normal rate toward a 15 degree pitch attitude. Once airborne, perform the Windshear Escape Maneuver. If windshear is encountered near the normal rotation speed and airspeed suddenly decreases, there may not be sufficient runway left to accelerate back to normal takeoff speed. If there is insufficient runway left to stop, initiate a normal rotation at least 2,000 feet before the end of the runway, even if airspeed is low. Higher than normal attitudes may be needed to lift off in the remaining runway. Ensure maximum thrust is set.'

The manufacturer was asked for comment in relation to the text above and stated:

'The ... text ... does not imply that stopping could be initiated after V_1 . On the contrary, a windshear during takeoff roll can result in groundspeed greater than indicated airspeed due to the tailwind effect of the windshear. Because of the higher ground speed, performance data for stopping on a field length limited runway (a short runway) may not be accurate, resulting in a runway excursion even though the airspeed indicates V_1 or less at the start of the RTO.'

'If windshear is encountered before V_1 , takeoff performance may be degraded and the planned runway stopping distance may not be available. If the Captain determines that a safe rejected takeoff (RTO) cannot be made, the flight crew should continue accelerating to V_R and rotate normally. When airborne, perform the Windshear Escape Maneuver.'

[The] guidance [is] based on industry consensus and event data. Successful outcomes of windshear and other emergency events during takeoff have been more likely if takeoff is continued than if takeoff is rejected late or without sufficient stopping distance. However, guidance cannot be given for every possible set of

takeoff and windshear conditions. The Captain must assess each situation to determine the safest course of action.'

'The commander has the sole responsibility for the decision to reject or continue a takeoff in a windshear emergency. The commander must determine the safest course of action based on airspeed, airspeed trend, runway remaining, braking capability, and other indications of airplane performance.'

After an RTO event, the QRH directs pilots to consider the need for remote parking and to release the parking brake unless passenger evacuation is necessary.

Operator's report into the RTO

The operator noted that the call of V_1 was omitted by the crew in what was an '*undoubtable increase in workload*'. The call of V_1 is the cue for pilots to remove their hand from the thrust levers, and the operator considered that, without that cue, the pilot's hand might have remained on the thrust levers, '*which lends itself to a rejection*'.

Other Information

The Takeoff Safety Training Aid², published by the Federal Aviation Administration in 1993, contains extensive information on RTO events, RTO decision making and analysis of RTO accidents and trends. Section 2, the Pilot Guide to Takeoff Safety was updated in 2004.

Analysis

The weather conditions during the event were severe and the aircraft was being operated to the limits in the operator's documentation. The operator's guidance states that the commander should take account of wind/gust conditions, pilot experience, runway width and surface conditions in deciding who should operate. In this case the co-pilot had three times more hours on type than the commander, was more familiar with EMA, and was permitted to operate to the same limits as the commander. The commander considered that allowing the co-pilot to operate the aircraft was within the operator's guidance and would allow him to focus more of his attention on managing the preparation for departure.

During the aircraft's takeoff roll, there was a 13 kt reduction in airspeed prior to V_1 . The commander noted the reduction and informed the co-pilot. It was short lived and as the acceleration in airspeed resumed the commander decided to continue. At this stage of the takeoff, windshear is not one of the manufacturer's RTO criteria and neither predictive nor reactive windshear warnings or cautions would be expected.

As the aircraft passed V_1 the automated callout sounded, but immediately thereafter the airspeed decayed, the aircraft yawed rapidly right away from the centreline and there was a noticeable change in the lateral g. The commander was concerned the aircraft could exit the runway and considered the situation to be unsafe. He had seen the reduced airspeed with the associated downward trend indication, which occurred approximately five seconds

Footnote

² https://www.skybrary.aero/index.php/FAA_Takeoff_Safety_Training_Aid [Accessed August 2020].

before V_1 , and called "Stop" to reject the takeoff. The RTO actions were promptly and correctly carried out along with rapid control inputs to return the aircraft to the centreline.

There are many factors to be considered by crews in deciding whether to continue or reject a takeoff in windshear conditions, but the manufacturer's comments show that successful outcomes are more likely when the takeoff is continued rather than rejected. Windshear causes the relationship between airspeed and distance travelled along the runway to be altered unpredictably leading to doubt about the continued validity of performance calculations.

In this case, in addition to windshear, the commander had to contend with the fact, and the startling effect, of the aircraft swinging off the centreline immediately after V_1 . Both pilots recalled hearing the V_1 auto callout, but they did not call it themselves, and the operator wondered whether the lack of a spoken cue might have meant the pilot's hand remained on the thrust levers. Removing the physical connection to the thrust levers at V_1 is intended to remove the possibility that pilots will instinctively or impulsively close the levers in response to an adverse event. If the pilot did keep his hand on the thrust levers, it might have made it more likely that he would take the option to reject the takeoff.

The manufacturer commented that the commander has sole responsibility for a decision to reject or continue a takeoff and must determine the safest course of action based on many factors. It was also stressed that guidance in the QRH was not intended to imply that '*stopping could be initiated above V_1* '. In this case, however, although the RTO commenced above V_1 , the commander brought the aircraft under control and stopped on the runway with 600 m remaining.

Following the RTO, the brakes would have been in the caution band for temperature. In these circumstances, the QRH Non-Normal Manoeuvres section contains guidance for pilots, such as to review the brake cooling schedule and consider whether there is a need for remote parking. In the event, however, this information was not considered, and the aircraft taxied to a normal stand despite there being slight binding in the brakes. It appeared likely that preoccupation with what had just happened and concerns for the co-pilot's wellbeing distracted the commander from considering the QRH guidance.

Conclusion

The commander had a high workload managing the departure and, to give himself time, decided that the co-pilot should fly the take off. In very gusty wind conditions, the aircraft encountered a windshear event near V_1 which caused a 13 kt reduction in airspeed. Additionally, the strength of the crosswind during takeoff caused the aircraft to veer right. Concerned that the aircraft might leave the runway, and considering the situation to be unsafe, the commander initiated an RTO five seconds after V_1 . The crew had not called V_1 , although the automatic callout had sounded. The SOP is to continue a takeoff when V_1 has been reached because, as the manufacturer commented, successful outcomes are more likely when a takeoff is continued rather than rejected. In this case, the aircraft stopped on the runway with 600 m of runway remaining.

The No 4 wheel and brake unit suffered heat damage from the full braking being applied during the RTO.