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Low Speed Rejected Take-Off upon Engine Failure

1. Introduction

Rejected Take-Off's (RTO) are often considered in the context of V_1, the Decision Speed, otherwise called the Critical Engine Failure Speed. However, there are situations, at speeds much lower than V_1, when RTO's can be quite challenging. These are sudden engine failures at speeds when the rudder has not yet become effective for maintaining directional control. Consequently, establishing safe lateral control relies on the following: immediate cancellation of the forward thrust asymmetry, selecting both thrust reversers so as to take advantage of the "live" engine reverse thrust, steering with rudder pedals and asymmetric braking as appropriate.

In order to review the operational challenges, this article describes an in-service event when an engine failure at about 60 kt resulted in a lateral runway excursion.

This article reviews the pertinent Flight Crew Operating Manual (FCOM) Standard Operating procedures (SOPs) and Flight Crew Training Manual (FCTM) recommendations, and also reflects on the documentation relevant to other Airbus models.

2. In-Service Event

2.1 Engine Failure at low Speed

The daylight incident involved an A300-600 taking off from a uniformly wet runway, with patches of ice.

As the aircraft was being aligned, the go-levers were triggered and the Auto-Throttle was engaged in Take-Off mode. Both engines spooled up symmetrically.

Within 12 seconds, engine one stalled. The thrust asymmetry caused the aircraft to deviate to the left of the runway. Ground speed was less than 60 kt (fig. 1).

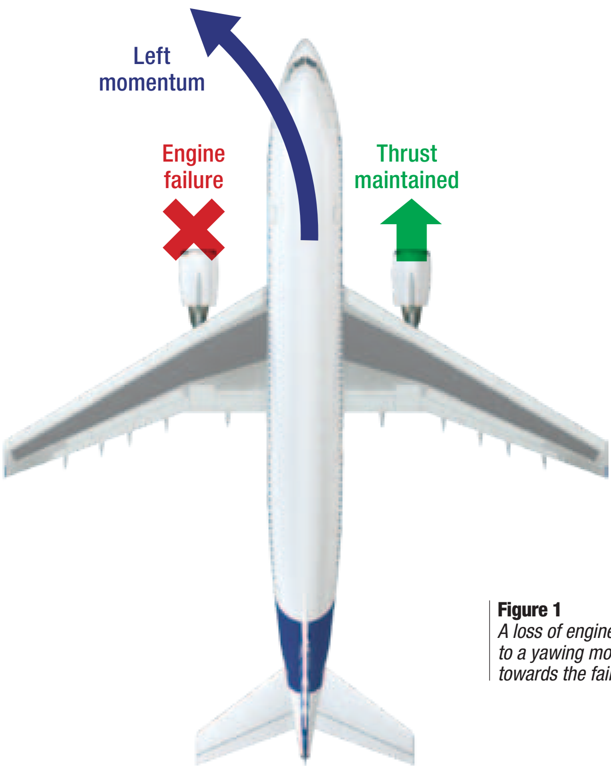

Figure 1
A loss of engine leads to a yawing moment towards the failed engine

2.2 Runway Excursion Sequence

The crew aborted the take-off within one second by simultaneously:

► Setting both thrust levers to IDLE, without applying reverse thrust.

► Applying right rudder pedals, thus counteracting the thrust asymmetry.

- The rudder pedal inputs acted both on the nose wheel steering and the rudder deflection. On the A300-600, the maximum achievable nose wheel steering angle, when using rudder pedals, is 6°. This does not depend on the air speed. The rudder deflected fully, but had limited aerodynamic effect at that speed.

► Applying manual brake inputs as follows: nearly full left and limited right pedal braking.

- This resulted in a significant asymmetric braking in the wrong direction.

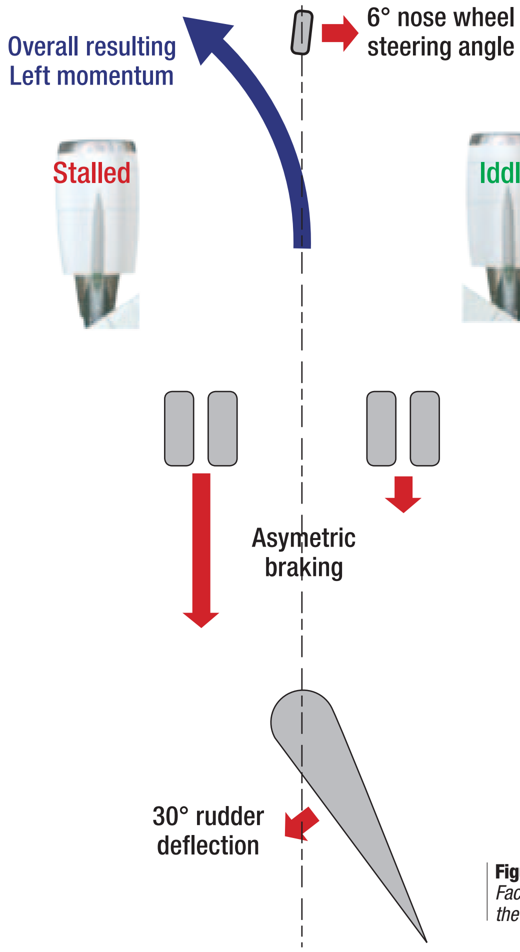

Figure 2
Factors leading to the runway excursion

(fig. 2) illustrates the individual effects and the overall resulting momentum. The directional balance was still to the left, so the aircraft continued deviating towards the edge of the runway.

In an ultimate attempt to remain on the runway, an additional nose wheel steering demand was applied with the tiller. The aircraft went off the runway and stopped on uneven ground. Seven seconds elapsed between the engine failure and the runway excursion. There were no injuries and the aircraft sustained only limited damage.

3. Review of relevant Procedures

3.1 Seating/Pedal Position Adjustments

The final report documents that the likely key to the asymmetric braking in the wrong direction was the pilot's seating and pedal position adjustments.

The pilot was probably in a position where he could apply full rudder, but not full braking.

The A300-600 FCTM, Normal Operations, Pre-Start recommends to first adjust the seat by means of the eye-indicator, then the arm-rest, and finally the rudder pedals such as to be in a position to simultaneously apply full rudder and full brakes on the same side (fig. 4). Similar recommendation is reflected in other Airbus FCTM.

Figure 3
A300-600 cockpit

3.2 Directional Control during Take-Off

Use rudder pedals for directional control during take-off. As written earlier, the tiller was ultimately used to try and counteract the lateral deviation by increasing the nose wheel deflection. This was not effective. As ground speed builds up, the nose wheel skids if too much deflection is applied. When using the tiller, the nose wheel was deflected beyond its operational limit and skidded without directional effectiveness.

All Airbus FCOM SOP's applicable to take-off read:

DIRECTIONAL CONTROL_____

________________USE RUDDER

Additional information is available in the A300-600 FCTM (fig. 5). The same information is also reflected in the documentation relevant to other Airbus models.

3.3 Use Manual Braking at low Speeds

The Auto-Brake activation is associated to the automatic deployment of the ground spoilers, which occurs when the ground speed is above 85 kt on the A300/A310 (fig. 6) and 72 kt on other Airbus models.

As a result, the Auto-Brake may not activate in case of low speed RTO and braking must be performed manually.

3.4 Lessons learnt from Simulator Sessions

An A300-600 simulator session was run in order to experiment with different scenarios of engine failure at low speed during the take-off roll and determine the most appropriate course of actions. These involved different runway status (dry, wet and patchy icy).

Upon an engine failure at 60 kt ground speed, the crew would immediately select IDLE thrust on both engines. The session showed that:

A300-600 FLIGHT CREW OPERATING MANUAL	FCTM – NORMAL OPERATIONS PRE START		2.32.20
		PAGE 13	
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MISCELLANEOUS

SEATING POSITION

To achieve the correct seating position, the aircraft is fitted with an eye-position indicator on the centre windscreen post. The eye-position indicator has two balls on it. When the balls are superimposed on each other, they indicate that the pilot's eyes are in the correct position.

The flight crew should not sit too low, to avoid decreasing the cockpit out-off angle, therefore reducing the visual segment. During Low Visibility Procedures (LVP), it is important that the pilot's eyes are positioned correctly, in order to maximize the visual segment, and consequently, increase the possibility of achieving the appropriate visual reference for landing as early as possible.

After adjusting the seat, each pilot should adjust the arm-rests, so that his forearms rest comfortably on them.

The rudder pedals must then be adjusted to ensure that each pilot can achieve both full rudder pedal displacement, and full braking simultaneously on the same side.

Figure 4
A300-600 FCTM rudder pedals adjustment recommendation

A300-600 FLIGHT CREW OPERATING MANUAL	FCTM – NORMAL OPERATIONS TAKEOFF		2.32.30
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TAKEOFF ROLL

- PF applies sufficient forward input (approx half of full deflection) on control column until 80 kt, then progressively releases to neutral by 100 kt. This counteracts pitch-up during thrust application and improves nose-wheel adhesion. In the case of an aft C.G and/or strong crosswind it may be necessary to increase the forward pressure on the control column. If nose-wheel vibration or shimmy occurs, the forward pressure should be reduced.
- PF should use rudder-pedal steering for directional control. The use of the nose-wheel steering would cause over-correction and should be avoided.

Figure 5
A300-600 FCTM on rudder pedal steering during take-off

A300-600 FLIGHT CREW OPERATING MANUAL	LANDING GEAR BRAKES – ANTI SKID DESCRIPTION		1.14.40
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AUTO BRAKE *System activation :*

Braking is initiated by the ground spoiler extension command. Consequently, in the event of an acceleration-stop, if the deceleration is initiated with the speed below 85 Kts, the automatic braking will not be operative because the ground spoilers will not be extended.

Figure 6
Auto-Brake is associated to the ground spoilers

A300-600 FLIGHT CREW OPERATING MANUAL	FCTM – ABNORMAL OPERATIONS OPERATING TECHNIQUES		2.33.20
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LOW SPEED ENGINE FAILURE

If an engine failure occurs at low speed, the resultant yaw may be significant, leading to rapid displacement from the runway centreline.
To regain or maintain directional control on the runway, it is necessary:
– To immediately reduce both thrust levers to IDLE, which will reduce the thrust asymmetry caused by the failed engine
– To select both Reversers irrespective of which engine has failed
– To use rudder pedal for directional control, supplemented by symmetrical or differential braking if needed. The steering hand-wheels may be used when taxi speed is reached.

Note : 1. If rudder pedal input and differential braking are needed, apply both on the same side
2. Below 85kts the ground spoilers will not deploy and the auto brake will not activate.

Figure 7
A300-600 FCTM on Low speed engine failure at take-off

► Keeping directional control with rudder pedals upon the initial trajectory deviation, as instructed by SOP's, was effective in all cases.

► When full symmetric braking was applied, both brake pedals on stops, no runway excursion was experienced. However, given the runway length available in such early RTO scenarios, it appeared that braking performance was much less an issue than directional control. Smoother recoveries were achieved with less pronounced braking inputs.

► Asymmetric braking may contribute to maintaining directional control, provided that it is applied towards the operative engine. When applied towards the failed engine during the simulator session, the aircraft unavoidably deviated towards the edges of the runway.

► When maximum reverse thrust is applied on the operative engine, the trajectory deviation is reduced by a small amount given the limited efficiency of reverse thrust at low speed but still in a helpful recovery sense.

3.5 Operational Advice

The observations made during this simulator session support the operational advice included in the FCTM, Operating Techniques, Low Speed Engine Failure on low speed RTO. (fig. 7).

These recommendations are reflected in the FCTM for the whole Airbus fleet.

4. Training Recommendations

4.1 Safety Recommendation by the final Investigation Report

In the operational summary, the final report highlights:

"...deficiencies in pilot training with regard to training for sudden losses of engine thrust in the speed range below VMCG."

The following safety recommendation is associated to this finding:

"EASA is recommended to ensure that initial and recurrent pilot training includes mandatory rejected take-off exercises that cover events of a sudden loss of engine thrust below VMCG."

VMCG Minimum Control Speed on the Ground

EASA CS 25.149 (e) definition of VMCG:

"VMCG, the minimum control speed on the ground, is the calibrated airspeed during the take-off run at which, when the critical engine is suddenly made inoperative, it is possible to maintain control of the aeroplane using the rudder control alone (without the use of nose-wheel steering), as limited by 667 N of force (150 lbf), and the lateral control to the extent of keeping the wings level to enable the take-off to be safely continued using nor-mal piloting skill. In the determination of VMCG, assuming that the path of the aeroplane accelerating with all engines operating is along the centreline of the runway, its path from the point at which the critical engine is made inoperative to the point at which recovery to a direction parallel to the centreline is completed, may not deviate more than 9.1 m (30 ft) laterally from the centreline at any point.

VMCG must be established, with –

(1) The aeroplane in each take-off configuration or, at the option of the applicant, in the most critical take-off configuration;
(2) Maximum available take-off power or thrust on the operating engines;
(3) The most unfavourable centre of gravity;
(4) The aeroplane trimmed for take-off; and
(5) The most unfavourable weight in the range of take-off weights."

For the A300-600, VMCG is documented in the Airbus FCOM within section Aircraft General - Operational Limitations, FCOM 2.01.20.

2 -SPEEDS

A - VMCA - VMCG

	kt CAS	kt IAS
VMCG	109.5	114 in 15/0 and 15/15 113 in 15/20

4.2 Airbus Position

Training plays a vital role in emphasising the importance of applying correct SOP and techniques.

Airbus encourages operators to include low speed RTO's in their recurrent training program if not already implemented. This should include unexpected RTO's well below V_1 to ensure both pilots are seated in a position where full rudder with full manual symmetric braking can be achieved.

Additionally, yearly line checks (or the equivalent of) should include an observation of the correct seating position for all relevant phases of flight by the Line-Check Captain.

5. Conclusion

This in-service incident illustrates the challenges associated with containing the sudden asymmetry resulting from engine failure during the first seconds of a take-off acceleration. However it is possible to maintain directional control by reacting immediately and in a coordinated manner:

► Thrust levers are closed

► All reversers are selected (even if designated as an MMEL item)

► Apply up to full opposite rudder pedals until directional control is regained

► Braking may be symmetrical or differential as needed to complement steering

► Steering hand-wheels may be used when taxi speed is reached.

Being in a position to effectively respond implies that both pilots have adjusted their seat such as to be in a position to simultaneously apply full rudder and full brakes on the same side if required.

Effective response also relies on crew training. Therefore Airbus supports Operators including RTO's scenarios in the recurrent training. The engine failure should be unexpected and introduced at speed well below V_1. Such scenarios would address simultaneously the seat adjustment and the coordinated response to the sudden asymmetry.

Safety First

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A350 XWB
First flight of A350 XWB at Toulouse-Blagnac Airport

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