Flight Operations Briefing Notes

Takeoff and Departure Operations

Understanding Takeoff Speeds

I Introduction

Pilots are used to calculating takeoff speeds and, therefore, understand the operational significance of V_1, V_R, and V_2. However, they are slightly less familiar with the definitions of V_{MU}, V_{MCG}, and V_{MCA}.

Takeoff speeds are a safety key element for takeoff, and enable pilot situational awareness and decision-making in this very dynamic situation. The use of erroneous takeoff speeds can lead to tail strikes, high-speed rejected takeoffs or initial climb with degraded performance.

The objective of the following Flight Operations Briefing Notes is to provide, from an operational perspective, an overall review of takeoff speeds, and of the factors that affect the calculation and use of V speeds.

II Background Information

This section is provided as a takeoff speeds refresher. However, additional information is also available in the Airbus "Getting to Grips with Aircraft Performance" brochure.

II.1 Control Speeds and associated Takeoff Speeds

The efficiency of such aerodynamic surfaces as the wings (for lift), the rudder, the ailerons, and the elevators, depends on adequate airflow speed. This airflow speed determines the minimum takeoff speeds.

V_{MCG} (Velocity of Minimum Control on Ground)

During the takeoff roll, it is of utmost importance to know the minimum speed at which the aircraft will remain controllable, in the event of an engine failure on ground. This is because, in such a case, and if the takeoff is continued, only the rudder will be able to counteract the yaw moment that is generated by asymmetric engine(s) thrust.

Per regulations, the minimum speed at which an aircraft is defined to be "controllable" (lateral excursion lower than 30 feet) after an engine failure on ground, is referred to as V_{MCG} (Velocity of Minimum Control on Ground).

V_{MCG} mainly depends on:

- Engine(s) thrust
- Pressure altitude.

If a failure occurs before reaching V_{MCG}, the takeoff must be interrupted to maintain control of the aircraft.

Note: *Steering is not used during certification flight tests. However, in real life operations, steering would be helpful in controlling the aircraft.*

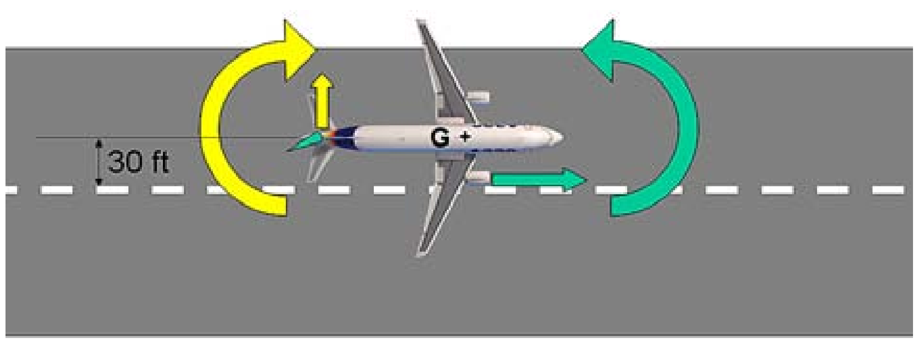

Figure 1

Ground Control after Engine Failure

V_1: Decision Speed

V_1 is the maximum speed at which a rejected takeoff can be initiated, in the event of an emergency. Additional information on this "Go/No-Go" decision can be found in the Flight Operations Briefing Note entitled: "**Revisiting the Stop or Go Decision**".

V_1 is also the minimum speed at which a pilot can continue a takeoff after an engine failure.

If an engine failure is detected after V_1, the takeoff must be continued. This implies that the aircraft must be controllable on ground. Therefore, V_1 is always greater than V_{MCG}.

V_{MU} (Velocity of Minimum Unstick)

V_{MU} is achieved by pitching the aircraft up to the maximum (tail on the runway, for aircraft that are are geometrically-limited) during the takeoff roll (Refer to Figure 2 below). The speed at which the aircraft first lifts off is V_{MU}. Therefore, lift-off is not possible prior to V_{MU}.

Note: *All Airbus aircraft types, with the exception of the A318, are geometrically-limited.*

Figure 2

V_{MU} Flight Test on an A330

V_R : Rotation Speed

The rotation speed ensures that, in the case of an engine failure, lift-off is possible and V_2 is reached at 35 feet at the latest.

Note: *Therefore, at 35 feet, the actual speed is usually greater than V_2.*

The rotation of the aircraft begins at V_R, which makes lift-off possible, at the end of the maneuver.

The V_R must be such that the lift-off speed is greater than V_{MU}.

V_{MCA} (Velocity of Minimum Control in the Air)

The rudder is used to compensate for the yaw moment caused by thrust asymmetry. There is a minimum speed at which full rudder will be necessary, in order to fly a constant heading with level wings.

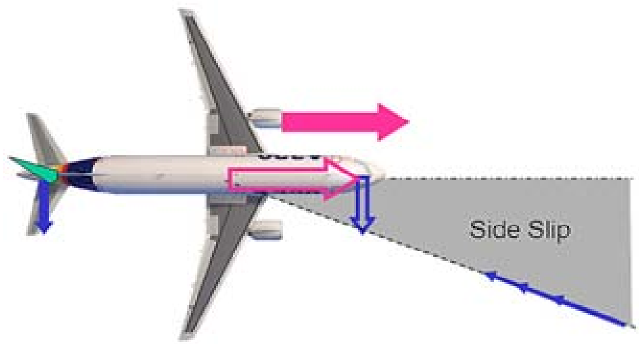

Figure 3

Sideslip Angle in a One Engine-out Condition

To reduce sideslip, this speed can be reduced even more, if the aircraft is banked on the live engine's side.

The lower the speed, the greater the necessary bank angle. The speed that corresponds to a 5-degree bank angle is defined, by regulations, as the minimum control speed and is referred to as V_{MCA} (Velocity of Minimum Control in the Air).

Figure 4

Roll Angle at VMCA

V_2: Takeoff Safety Speed

V_2 is the minimum speed that needs to be maintained up to acceleration altitude, in the event of an engine failure after V_1. Flight at V_2 ensures that the minimum required climb gradient is achieved, and that the aircraft is controllable. V_2 speed is always greater than V_{MCA}, and facilitates control of the aircraft in flight.

In an all-engines operative takeoff, V_2+10 provides a better climb performance than V_2 (Refer to Figure 5 below).

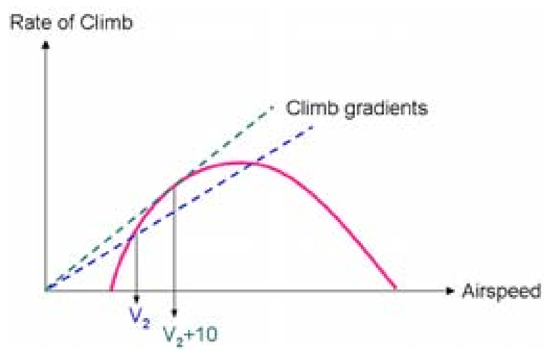

Figure 5

Climb Gradient Relative to Speed in a Specific Flaps' Configuration

If one engine is lost before reaching V_2, then the initial climb is flown at V_2.

If thrust is lost at a speed between V_2 and V_2+10, then the current speed is maintained, to ensure the most efficient climb speed.

It is not necessary to increase pitch, in order to reduce the speed to V_2, when a higher speed has already been reached.

II.2 Minimum Control Speeds with Derated Thrust

"JAR/FAR: AMJ 25-13 / AC 25-13

(4)(b) Derated takeoff thrust, for an aeroplane, is a takeoff thrust less than the maximum takeoff thrust, for which exists in the AFM a set of separate and independent takeoff limitations and performance data that complies with all requirements of Part 25."

A specific derate level corresponds to the basic maximum thrust that is reduced by a corresponding percentage value. New minimum control speeds (V_{MCG}, V_{MCA}) can then be established.

Reducing the minimum control speeds sometimes improves takeoff performance (higher MTOW), when taking off on a short runway. Indeed, the V_1 decision speed is the maximum speed at which it is still possible to reject the takeoff and stop the aircraft within the runway limits. Nevertheless, V_1 must be greater than V_{MCG}, and the "Accelerate-Stop Distance" is often the most constraining limitation on a short runway. A reduction in V_{MCG} then permits a reduction in the ASD for a specific takeoff weight, and can improve takeoff performance when the MTOW (without derate) is ASD/V_{MCG}-limited.

For a derated takeoff, the limitations, the procedures, and the performance data must be included in the Aircraft Flight Manual (AFM). For each derate level, a specific RTOW chart can be defined for a each runway, in order to take into account such new limitations as minimum control speeds.

Note:

The objective of flexible thrust differs from that of derated thrust. Both types of thrust cannot be used interchangeably.

Flexible Thrust is a thrust reduction, designed to save engine life. This thrust is reduced to take advantage of the available runway length, when full thrust is not necessary (from a performance perspective), but takeoff speeds with full thrust still apply.

III Operational and Human Factors Affecting Takeoff Speed Computation and Utilization

The following factors are often observed when analyzing takeoffs in which takeoff speeds were not respected. Two cases can be observed:

III.1 Error in Takeoff Speed Computation:

- Data, issued from a computerized system, is rarely challenged. However, incorrect inputs may occur, and could result in inadequate takeoff speeds values.
- In takeoff speed calculations, Zero Fuel Weight (ZFW) is sometimes mistaken for Gross Weight (GW). This is particularly true when a last minute change occurs in cargo loading, or when time pressure and workload are high. Therefore, calculated speeds will be much lower than expected, and will lead to: Tailstrikes, “heavy aircraft” sensation, and high-speed rejected takeoffs.
- Takeoff speeds calculations are based on specific configurations. Any change in the parameters of these configurations will invalidate takeoff speeds. Examples of such parameters include a runway change, a wet runway that becomes contaminated, or a takeoff from an intersection.

III.2 Error in Takeoff Speed Utilization:

- When a last minute-change occurs, takeoff speeds are sometimes modified and crosschecked during pushback or taxi. During such phases of flight, the PF workload is high. As a result the PF may not have sufficient time or resources to perform efficient crosschecks.
- If an incident occurs before V_1, the PNF’s attention may be focused on trying to assess the situation and may forget the V_1 announcement.

- In the event of an engine failure after takeoff, and in an attempt to climb faster, there may be a tendency to set a pitch attitude too high, if FD bars are not followed. The aircraft is then flown below V_2, and climb performance cannot be ensured, as illustrated in Figure 5.

IV Prevention Strategies and Lines of Defense

The following strategies help to prevent takeoff speed errors. Airlines should:

- Define and use good CRM practices for takeoff speed computation and crosscheck.
- Conduct a takeoff briefing that highlights takeoff speeds, slats/flaps configurations, and weight, depending on the daily weather conditions. Attention should be paid to takeoff speeds, particularly if they were changed during taxi, in order to detect possible keystroke errors.
- For aircraft that are not equipped with a V_1 auto-callout: close attention to the V_1 standard callout should be paid.
- Emphasize that, once airborne, pilots should always follow the Flight Director's pitch guidance bar and should consider using the autopilot in the event of an engine failure. This will considerably reduce the flight crew's workload during demanding flight phase situations.

V Summary of Keypoints

Takeoff speed calculation errors are often due to a combination of two factors:

- Error in parameter entry
- Poor crosschecks by other crewmember.

Prevention strategies should be developed to ensure efficient crosschecks, particularly after last-minute changes (runway change, loadsheet modification…).

VI Associated Flight Operations Briefing Notes

The following Flight Operations Briefing Notes should be reviewed along with the above information:

- **Conducting Effective Briefings**
- **Preventing Tailstrike at Takeoff**
- **Revisiting the "Stop or Go" Decision**
- **Preventing Runway Excursions and Overruns at Takeoff**

VII Regulatory References

- JAR/FAR 25.107 Subpart B – Takeoff Speeds

VIII Airbus References

The following Airbus brochure provides more performance-oriented information concerning takeoff speeds:

- "Getting To Grips with Aircraft Performance"

IX Additional Reading Material

Example of events linked to takeoff speeds are available in the following documents:

- Transportation Safety Board of Canada – 2002 Air Investigation Reports – 14 June 2002 (**www.tsb.gc.ca/en/reports/air/2002**)
- National Transportation Safety Board – NTSB accident number: NYC91FA086 (**http://www.ntsb.gov/**)
- Flight Safety Foundation – Accident prevention – May 1995
- Flight Safety Foundation – Accident prevention – May 1996

Note:

These documents can be found on the Flight Safety Foundation website: **http://www.flightsafety.org/home.html.**

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