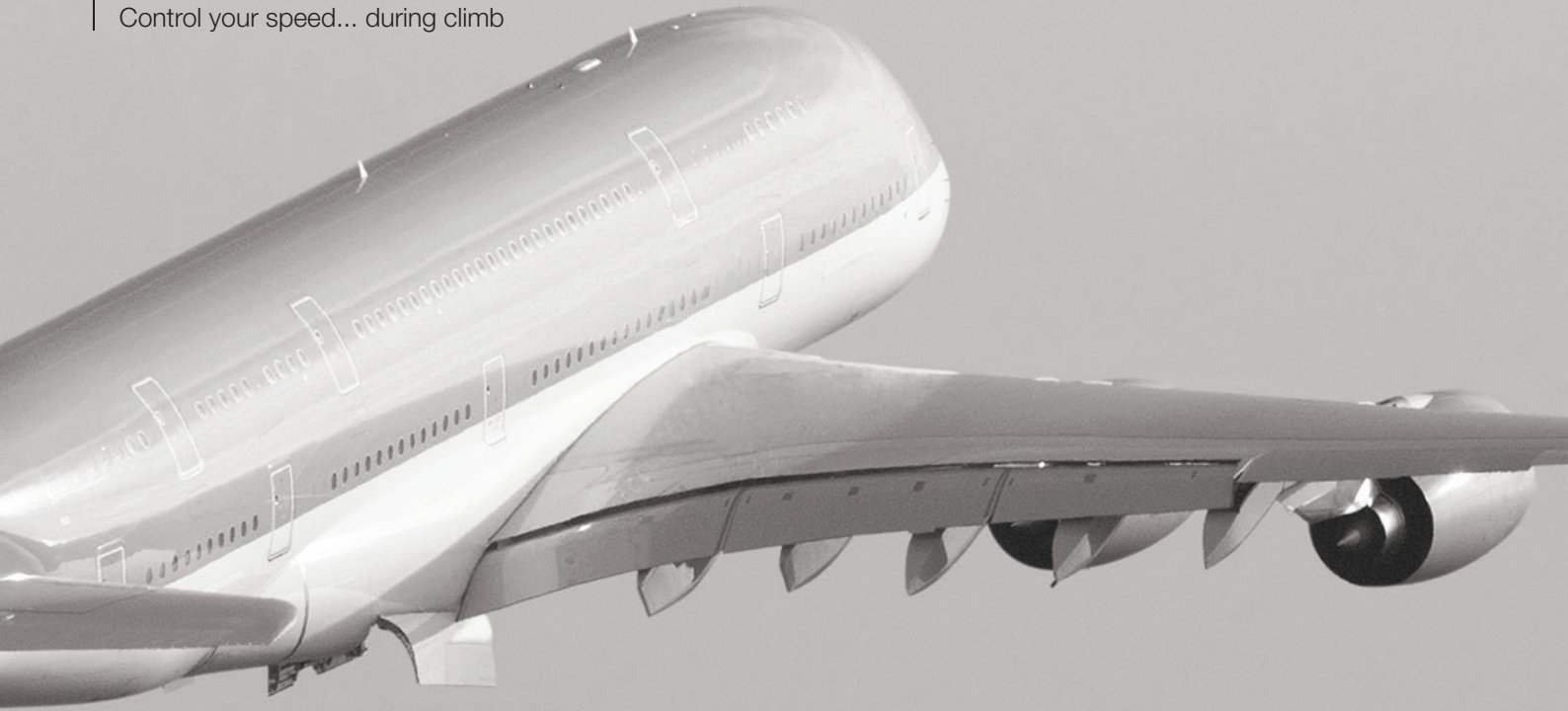




Control your speed... during climb

Second of a series of articles on the theme of speed control during a flight, which started in issue #18 of this magazine, we have just taken off and are now entering the climb phase. The main objective is to retract the slats / flaps at an adequate speed, while sustaining enough lift to accelerate and climb.



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Flight Operations
Standards and Safety
management



**PHILIPPE
CASTAIGNS**

Experimental Test Pilot

After take-off, the aircraft continues in the climb phase and flies away from the busy airspace. The objective for the crew is to accelerate to the en-route climb speed and at the same time, manage various aircraft configuration changes, usually consisting of gears, slats and flaps retraction, and a change from take-off power to climb power.

This article aims at shedding some light on the way the different maneuvering and limit speeds that are of use during climb are defined and determined, and how they can be implemented in daily operations.

MANAGING YOUR CLIMB: UNDERSTANDING SPEEDS

A climb is generally flown at an airspeed that is often initially limited by Air Traffic Control (ATC) instructions. To safely manage the climb phase within these restrictions, some characteristic speeds are useful tools, and they require a close monitoring. What speeds exactly should be monitored? What do these speeds mean and what happens if they are exceeded?

For every flight, characteristic speeds are computed automatically by the aircraft Auto Flight Systems (Flight Management System (FMS), Flight Guidance (FG) and Flight Envelope (FE)) and effectively displayed on the PFD airspeed scale. They are extremely useful as maneuvering speeds and limit speeds to safely guide the pilots configuration change decisions through the climb phase.

Our objective is to highlight the design and operational considerations underlying all recommendations Airbus has issued to flight crews regarding the monitoring of these speeds during climb.

Amongst other parameters, the maneuvering speeds Flaps (F), Slats (S) and Green Dot (GD) are a function of the Zero Fuel Weight (ZFW) inserted by the crew at FMS initialization. Therefore, any erroneous entry will impair these speeds.

Maneuvering speeds

In nominal conditions (all engines operative), the climb phase poses some challenges to the crew: accelerate the aircraft, maintain a satisfactory climb gradient and manage several configuration changes at the same time. To

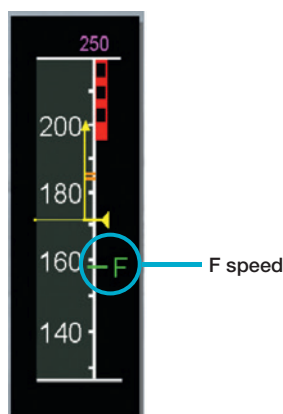
help pilots fly their aircraft safely through the different steps of this phase of flight, some characteristic speeds were defined as maneuvering speeds.

F, S and Green Dot speeds frame the aircraft climb performance limits.

“ F, S and Green Dot speeds frame the aircraft climb performance limits. ”

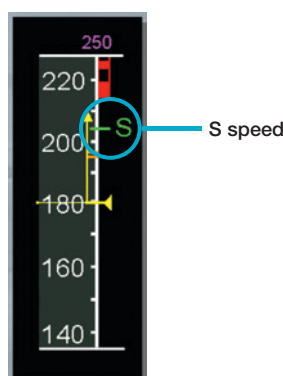
PROCEDURES

Control your speed... during climb



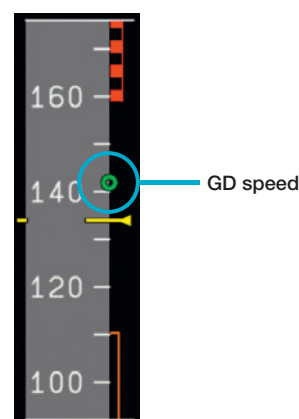
(fig.1)

F on the PFD speed scale



(fig.2)

S on the PFD speed scale



(fig.3)

GD on the PFD speed scale

F and S: Flaps and Slats minimum retraction speeds

» Definitions

F speed is the minimum speed at which flaps should be retracted from CONF 3 or 2 to CONF 1+F.

It is represented by a green “F” on the PFD speed scale and displayed only when the slats / flaps control lever is on position 3 or 2 (CONF 3 or 2) during the take-off phase, the initial climb and go-around (**fig.1**). It is no longer displayed when in configuration 1 or 1+F.

S speed is the minimum slats retraction speed, i.e. the minimum speed at which a clean configuration should be selected.

It is represented by a green “S” on the PFD speed scale and displayed only when the slats / flaps control lever is on position 1 (CONF 1 and 1+F) (**fig.2**).

» How are F and S determined during the take-off phase?

F speed varies according to the aircraft weight and altitude. It is tabulated in the Flight Envelope as a function of $V_{S1g CONF 1+F}$, which is the reference stall speed demonstrated by flight tests and agreed by the Airworthiness Authorities.

In this respect, F speed allows a margin above the stall speed in the configuration 1+F.

$$F \text{ speed} = k \times V_{S1g CONF 1+F}, \text{ with } k \text{ equal to about } 1.18 \text{ to } 1.26$$
$$V_{MCL} + 5 \text{ kts} \leq F \leq V_{FE CONF FULL} - 2 \text{ kts}$$

S speed varies according to the aircraft weight and altitude. It is tabulated in the Flight Envelope as a function of $V_{S1g CLEAN CONF}$.

In this respect, S speed allows a margin above the stall speed in the clean configuration.

$$S = k \times V_{S1g CLEAN CONF}, \text{ with } k \text{ equal to about } 1.21 \text{ to } 1.25$$

Green Dot (GD): best lift-to-drag ratio

» Definition

GD speed is the engine-out operating speed in clean configuration. In other words, it corresponds to the speed that allows the highest climb gradient with one engine inoperative in clean configuration.

In all cases (all engines operative), the GD speed gives an estimate of the speed for best lift-to-drag ratio. It is also the final take-off speed and it

represents the operational speed of the clean configuration and the recommended speed in holding in clean configuration.

It is represented by a green dot on the PFD speed scale and displayed only when the slats / flaps control lever is in the '0' (CLEAN) position and landing gears are not compressed (**fig.3**).

» How is GD determined?

GD speed is computed by the Auto-flight systems and is based on the aircraft weight. The GD formula has been set up so that the resulting air-speed provides the best lift-to-drag ratio for a given altitude, air tempera-

ture and aircraft weight, in clean configuration with one engine out.

In some phases of flight, GD is computed to minimize drag and thus, the fuel consumption (for example during the HOLD phase).

Limit speed

We have seen that deviations from the maneuvering speeds F , S and GD during climb can have an impact on the aircraft's aerodynamic performance. We will now focus on the limit speed V_{FE} .

V_{FE} : Maximum speed with Flaps Extended

With the A/THR engaged and active (CLB / OP CLB / SPEED green on FMA), the aircraft remains below V_{FE} .

When the A/THR is not active, V_{FE} exceedance may occur (for example during a go-around).

» Definition

V_{FE} is the maximum speed with flaps extended. It has a specific value for each flap setting.

Generally speaking, the maximum speed defining the aircraft's flight envelope is called V_{MAX} . V_{MAX} is equal to V_{LE} (maximum speed with landing

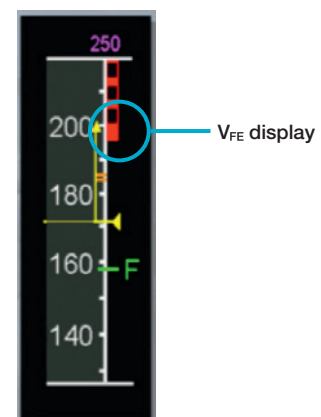
gears extended) or V_{FE} according to the aircraft configuration. V_{MAX} is equal to V_{MO} (or speed corresponding to MMO) only in the clean configuration. On the PFD speed scale, it corresponds to the lower end of the red and black strip **(fig.4)**.

» How is V_{FE} determined?

V_{FE} is the maximum speed for high lift configurations, i.e. with slats / flaps extended: it is related to the structural limitation of the slats / flaps. A V_{FE} is computed for each slats / flaps configuration, based on either the slats / flaps control lever position or the actual aircraft configuration (slats / flaps con-

trol surfaces position), depending on the aircraft type.

In order to keep a sufficient margin between the $V_{FE CONF 3}$ and the speed at which the next configuration is selected, the following inequality is met: $V_{FE CONF 3} \geq F + 10$ kts.



(fig.4)

V_{FE} on the PFD speed scale



MANAGING YOUR CLIMB: OPERATIONAL RECOMMENDATIONS

Flying a safe and steady climb requires pilots' attention to carefully manage the different configuration changes, while accelerating to the en-route climb speed and eventually, cruise speed.

Indeed, not respecting the maneuvering and limit speeds leads to adverse consequences that we will review. Avoiding an overspeed situation during the slats / flaps retraction - with its potential structural damage conse-

quences - is important. It is therefore worth understanding the different V_{FE} display logics implemented in each aircraft family, and the resulting overspeed aural warning behaviour during the climb.

What are the operational implications of not respecting the maneuvering or limit speeds?

F and S: Flaps and Slats minimum retraction speeds

F speed (resp. S) is defined as the recommended minimum flaps (resp. slats) retraction speed. Retracting the flaps (resp. slats) at a speed significantly lower than F (resp. S) would reduce the margin against the high Angle-Of-Attack (AOA) protection. This could lead the aircraft to reach a speed below the lowest selectable speed VLS CONF 1 (or 0), and possibly low enough to break through the high AOA protection threshold.

Retracting the flaps (resp. slats) at a speed significantly higher than F speed (resp. S) would reduce the climb performance and thus, possibly compromise the aircraft ability to clear any obstacles (this is more likely if one engine is inoperative).

If flaps need to be maintained for a turn before acceleration altitude for instance, F speed (resp. S) can be used safely to perform a turn while climbing.

GD: Green Dot

At a given weight and engine rating, the potential climb gradient is maximum when (Thrust - Drag) is at a maximum - i.e. when the lift-to-drag ratio is maximum.

Deviating below GD involves an increase in the drag on the aircraft and would eventually undermine the aircraft's ability to continue a climb. Indeed, if the aircraft speed goes significantly below GD, with the maximum available thrust already in use (assuming that thrust levers have just

been set to CLIMB / MCT), then the only way for the crew to recover a satisfactory climb gradient is to decrease the rate of climb (even enter a descent if necessary) in order to accelerate to or above GD. This maneuver is obviously counteractive to the objectives of the climb phase.

Therefore in the clean configuration, the crew should not fly below GD in order to avoid degrading climb performance.

GD IN A NUTSHELL
Avoid flying below
GD during climb.

V_{FE}: Maximum speed with flaps extended

In case of take-off with A/THR not active, flying with slats / flaps extended, or extending slats / flaps well above V_{FE} directly poses a risk of structural damage through the slats / flaps track mechanisms. This may result in distortion of the flaps and slats or the extension mechanism or even the aircraft structure upstream. In case V_{FE} is exceeded, an overspeed aural warning is triggered in the cockpit in order to alert the crew.

The flight crew will have to reduce the speed or to retract the slats / flaps accordingly.

Exceeding V_{FE} may subsequently trigger inspections of the slats/ flaps mechanism and/or the aircraft structure.

Specific trouble shooting procedures exist to inspect and repair an aircraft after flight above V_{FE}. These procedures are available in the Aircraft Maintenance Manual (AMM).

V_{FE} IN A NUTSHELL

Do not fly with slats / flaps extended above V_{FE}.

How to avoid an overspeed during slats / flaps retraction?

Avoiding an overspeed during slats / flaps retraction relies on a variety of complementary aspects. Procedures, pilots' attention and coordination, anticipation of configuration

changes, understanding of the limit speed and of the different V_{FE} display logics and overspeed aural warning behaviour implemented in each aircraft family.

The common approach

Slats and flaps retraction during climb can be managed safely by following SOP, and observing the visual F and S indications on the PFD. Incidentally, doing so allows the crew to respect the V_{FE} indication displayed on the PFD and thus, avoid triggering an aural overspeed warning (with potential structural damage).

The use of A/THR also enables the crew to avoid an overspeed condition during slats / flaps retraction.

While the PF is expected to manage these configuration changes, the PM plays a key role in facilitating his/her

task by anticipating them. During the initial climb phase, the PM needs to be vigilant to speed trends and alert the PF in case the margin that is left against the applicable limit speed V_{FE} becomes too tight.

This is valid at all time, for all aircraft families.

Differences arise when we look more closely at the V_{FE} display logics for each family. In particular, we want to emphasize the possibility of a temporary, yet inconsequential, overspeed aural warning on A300/A310, A320 and A330/A340 Families.

The case of untimely temporary overspeed aural warning during slats / flaps retraction

» A300/A310, A320 and A330/A340 Families

On A300/A310, A320 and A330/A340 Families,

- The V_{FE} value displayed on the PFD is based on the slats / flaps control lever position and it moves by one step as soon as this lever is moved.
- The overspeed aural warning triggering threshold varies according to the actual aircraft configuration, i.e. the slats / flaps surfaces real time position.

Therefore, during slats / flaps transition, the dynamic acceleration of the airplane may lead to a temporary OVERSPEED WARNING even if the current speed is out of the red and black strip displayed on the PFD. In this situation, there are neither operational consequences nor safety issues.

This is due to the following logic:

- When the flap lever is moved from CONF 2 (or 3) to CONF 1+F, F speed could be very close to V_{FE} before flaps retraction. Once the flap retraction is initiated, $V_{FE \text{ CONF } (2 \text{ or } 3)}$ moves in one step to $V_{FE \text{ CONF } 1+F}$ before the flaps actually reach CONF 1+F. As a consequence, in acceleration towards S speed, the V_{FE} aural warning could activate although the actual surfaces speed is below the displayed V_{FE} .
- When the flap lever is moved from CONF 2 (or 3) to CONF 1+F, S speed could be greater than $V_{FE \text{ CONF } 1+F}$ before the surfaces retract. When automatic flap retraction occurs, the barber's pole does not move before the flaps fully retract.

» A350 and A380 Families

On A350 and A380 Families, a different logic was developed. The V_{FE} display on the PFD is directly based on the actual aircraft configuration, as is the overspeed aural warning trigger-

ing threshold. This means that the two signals are perfectly synchronized, thus the risk of an untimely temporary overspeed warning is eliminated.

The case of temporary overspeed aural warning during slats / flaps retraction after a heavy-weight take-off

In the particular case of a heavy-weight take-off, the risk of a temporary overspeed aural warning is increased. Indeed, in this configuration, S speed is quite close to $V_{FE \text{ CONF } 1+F}$ because the aircraft weight is higher and the lift needed to climb is higher too. Therefore the slats need to remain extended for longer. As a result, the crew will order flaps retraction at a speed that might be higher than the Flaps Auto-retraction speed. In that case, should the acceleration of the airplane be rapid, a V_{FE} aural warning may momentarily trigger. This logic is as per design and structural limits are not encountered.

For example, an A320 at a Take-Off Weight (TOW) of 76T, S speed of 205 kts, the pilot will order flaps retraction most probably at or slightly above 210 kts, which is precisely the Flaps Auto-retraction speed. Once the slats / flaps control lever is in the retracted position, the V_{FE} red and black strip is no longer displayed on the PFD speed scale. If the airplane accelerates rapidly, then the airspeed may catch up the actual instantaneous V_{FE} momentarily, which will trigger the V_{FE} aural warning.

Again, this logic is as per design and structural limits are not encountered. ■



BEST PRACTICE

After a heavy-weight take-off, do not delay slats / flaps 0 selection above S speed in order to prevent possible temporary V_{FE} overspeed aural warning.



During climb, in manual flight, the main risk is to experience an aural overspeed warning (with potential structural damage) as a result of a late slats / flaps retraction. Understanding the implications of climb speeds is paramount to enable pilots to sense instantly the available margin they have left to avoid exceeding the limit slats / flaps retraction speed.

In practice, once the aircraft is airborne, pilots must be fully cognisant of the airspeed as well as the speed trends at all time in flight.



DID YOU KNOW _____

To know more about speeds, read our brochure “Getting to grips with aircraft performance”, available on AirbusWorld.

A presentation was also made at the 11th Perf and Flight Ops Conference in Dubai in 2011.

Safety first

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Airbus
Product Safety department (GS)
1, rond point Maurice Bellonte
31707 Blagnac Cedex - France
safetycommunication@airbus.com
Fax: +33(0)5 61 93 44 29

