



Engine Thrust Management - Thrust Setting at Takeoff

The FCOM Standard Operating Procedures (SOP) provide specific guidance to flight crews for thrust application at takeoff.

This article explains why 2-step thrust application is required at takeoff and why some extra steps should be taken in tailwind or significant crosswind conditions. It also provides recommendations to ensure optimum lateral control of the aircraft during takeoff roll and how to react if an asymmetric event is experienced at low speed.

ANALYSIS OF AN EVENT

Event Description

An A320 equipped with IAE engines was lined up for a static takeoff using Flex Thrust. It was 10:40pm local time, the runway was dry, the wind negligible and the outside air temperature had reached 33°C. There was a slight difference in the position of left and right thrust levers when the aircraft lined up on the runway that resulted in the following Engine Pressure Ratios (EPR) and N2 values:

- ENG 1: 1.01 EPR 61% N2
- ENG 2: 1.03 EPR 75% N2

The Pilot Flying (PF) then moved both thrust levers forward and paused for around 3 seconds near to the CLB detent where, the EPR and N2 increased to the the following values:

- ENG 1: 1.03 EPR 78% N2
- ENG 2: 1.24 EPR 91% N2

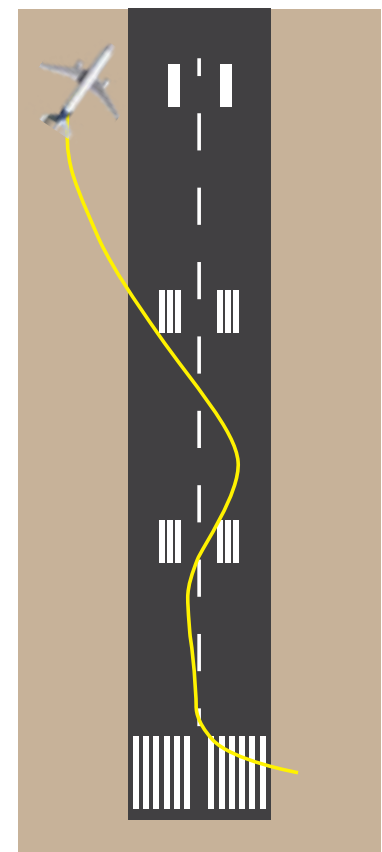
Eventually, the PF released the brakes and moved the thrust levers forward to the FLX detent. Engine 2 accelerated more rapidly than engine 1 and the resulting thrust asymmetry caused the aircraft to veer to the left. The PF tried to recover the trajectory by applying right rudder input and retarding the thrust levers to reduce thrust on both engines. Consequently, this caused the aircraft to sharply veer to the right. The PF applied differential thrust combined with left rudder pedals and tiller inputs. This caused the aircraft to veer sharply to its left while continuing to accelerate. The PF reacted again to apply full right rudder input combined with asymmetric braking and applied maximum thrust reversers in an attempt to stop the aircraft. The aircraft eventually came to rest to the left of the runway at 300 meters from the threshold **(fig.1)**. During this event, the ground speed did not exceed 31 kt.

Event Analysis

The root cause of this event was the initial difficulty to control the aircraft laterally due to the rapid asymmetric thrust increase at low speed. We will analyse this phenomenon in the following paragraphs and explain how the pilots can ensure a symmetric thrust increases to ease the lateral control of the aircraft in the early takeoff roll.

(fig.1)

View from above of the aircraft trajectory

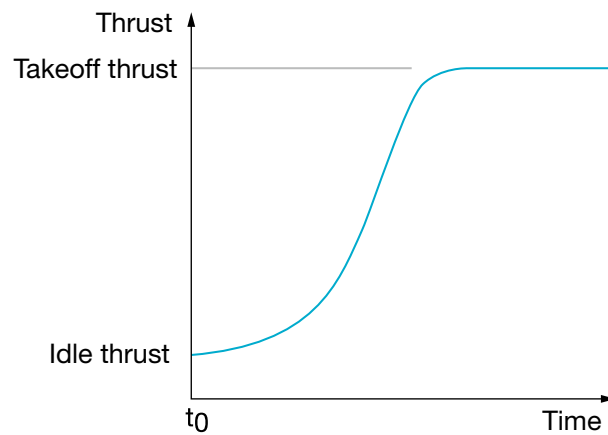


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Why could aircraft engines accelerate asymmetrically at takeoff?

On all jet engines, but particularly on high bypass ratio engines, the engine acceleration profile is not linear **(fig.2)**. It follows the engine control law that is defined to optimize the acceleration in a way that the risk of engine stall is reduced. It also takes into account the influence of the position of the engine installed on the aircraft and the effect on the airflow at the engine's inlet due to its proximity to the ground and the surrounding aircraft structure.

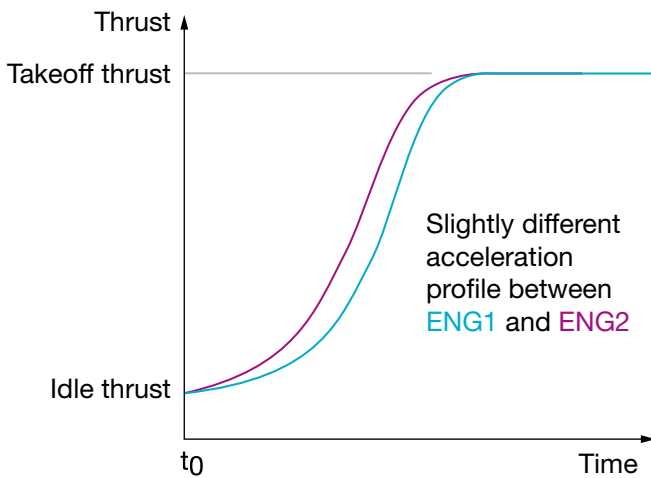


(fig.2)

Typical engine acceleration profile.

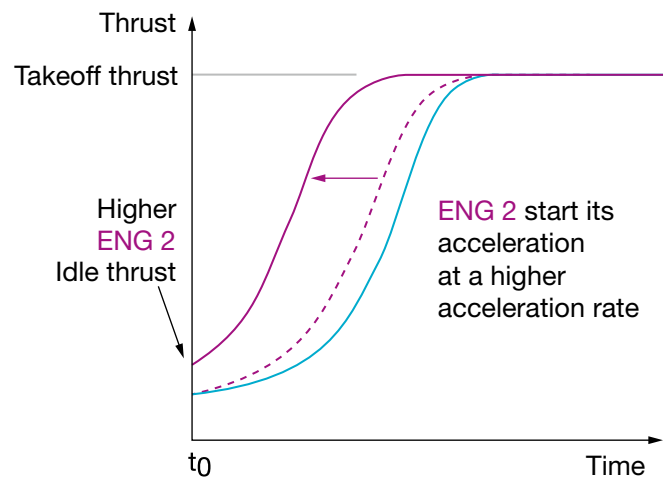
Every engine has its own performance level due to manufacturing tolerances. In addition, engine performance evolves with time due to wear and ageing. As a consequence, the acceleration profiles may slightly differ from one engine to another on an aircraft **(fig.3)**, even if fitted with new engines.

Similarly, the idle thrust can slightly differ from one engine to the other, moving the acceleration profile to the left on the graph **(fig.4)**.



(fig.3)

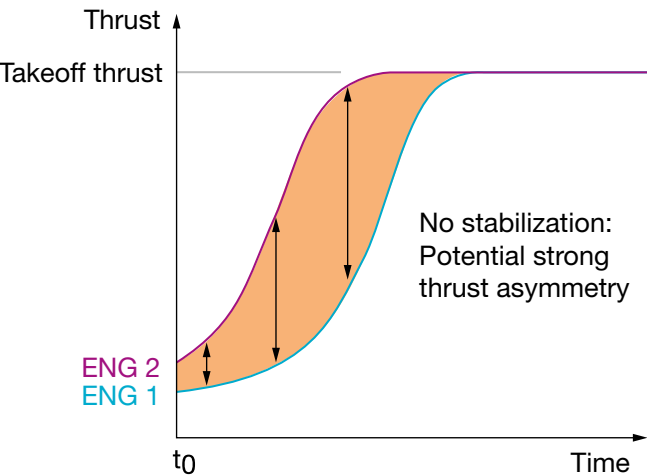
Difference between engines' acceleration profile.



(fig.4)

Difference between engines' idle thrust.

Taking into consideration both of these parameters, if the flight crew applies the takeoff thrust directly from idle thrust, without doing any stabilization step, the difference in engine acceleration performance could cause a strong asymmetric thrust condition **(fig.5)** that could be difficult to counteract with nose wheel steering only, due to limited effectivity of the rudder at low speed. ■

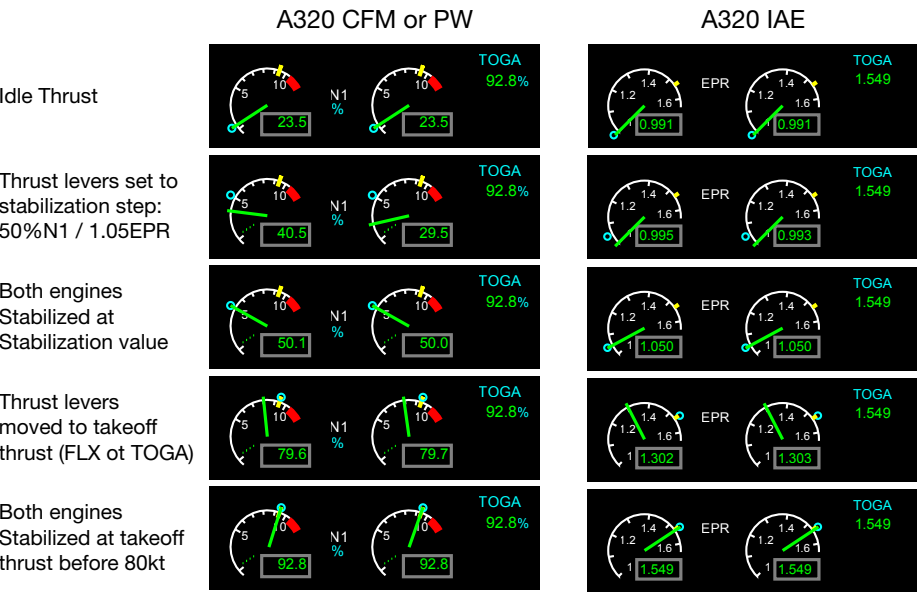


(fig.5)
Direct takeoff thrust application with no thrust stabilization step potentially creates a strong thrust asymmetry that may be difficult to counteract.

ENSURING A SYMMETRIC THRUST INCREASE AT TAKEOFF

FCOM Standard Operating Procedure

To avoid this potential strong thrust asymmetry, the FCOM SOP for takeoff provides a procedure that requests pilots to apply takeoff thrust in two distinct steps **(fig.6)** with some additional guidance for certain aircraft operating in the case of tailwind or significant crosswind conditions.



(fig.6)
Example of the standard thrust setting procedure at takeoff for an A320 aircraft depending on the engine type.

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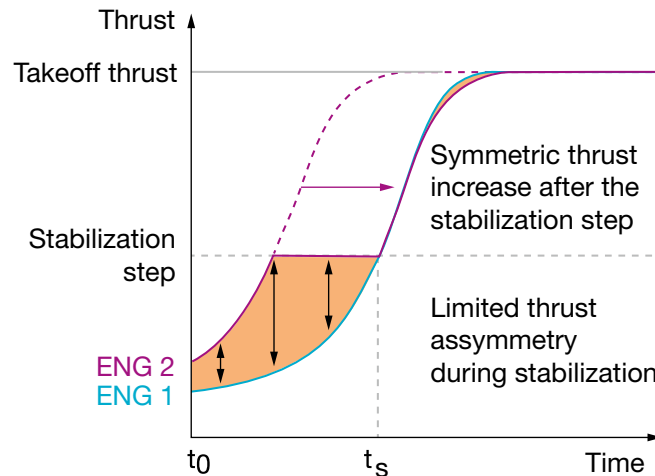
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Why pilots should set thrust in two steps for takeoff?

The stabilization step ensures that all engines reach a rotation speed value from where the increase of engine thrust will be almost identical to each other **(fig.7)**. The N1/EPR/THR stabilization value is defined during flight test campaign for every engine type with collaboration from engine manufacturers.

(fig.7)

Using a stabilization step, the potential thrust asymmetry remains limited before the stabilization and both engines accelerate almost simultaneously from t_s .



Specific use-case when differential thrust is used for the aircraft line-up

In some cases, differential thrust is used to line-up the aircraft on the runway. If the pilot commands takeoff power without first doing the engine thrust stabilization step, the resulting asymmetric thrust condition may be significant due the engines accelerating from an already very different rotation speed.

This is why a thrust stabilization step is important after using differential thrust to line-up the aircraft, to avoid causing a strong thrust asymmetry condition during the early stages of the takeoff roll.

Static takeoff or rolling takeoff?

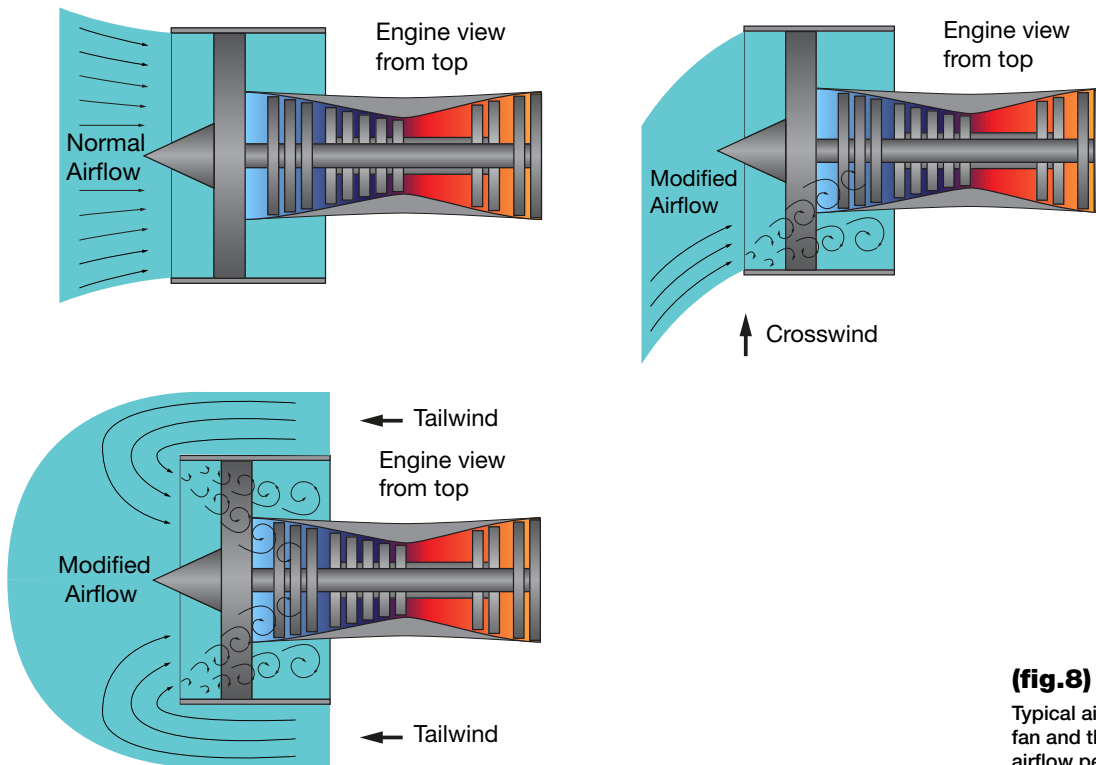
The FCOM describes procedures for a static takeoff, but a rolling takeoff is also permitted.

During static takeoff, the brakes are released at t_s **(fig.7)** once all engines have reached the stabilization step value, therefore, the aircraft is not affected by any potential thrust asymmetry that can happen between t_0 and t_s .

If a rolling takeoff is performed, the pilot must also respect the stabilization step. The flight crew uses opposite rudder pedals inputs as the aircraft is rolling to counteract any thrust asymmetry experienced during the stabilization phase between t_0 and t_s . With the engines at a low rotation speed the potential thrust asymmetry remains limited up to the engine stabilization step value.

Why an additional thrust setting is necessary in tailwind or significant crosswind conditions?

In tailwind and significant crosswind conditions, the airflow entering into the engines is modified (**fig.8**). Some perturbations may appear downstream of the leading edge of the engine inlet and potentially cause an engine stall if the perturbed airflow enters the core of the engine.



(fig.8)

Typical airflow distortion affecting the fan and the engine core with associated airflow perturbations.

The FCOM thrust setting procedure in the case of tailwind or significant crosswind is in two steps:

- Step one is to ensure engines increase their thrust symmetrically by using the stabilization step.
- Step two is acceleration of the aircraft with the pilot progressively increasing thrust from the stabilization step value to reach takeoff thrust. As the aircraft accelerates the relative wind resulting from the forward momentum counters the disturbed airflow conditions caused by crosswind or tailwind, reducing the risk of engine stall and the risk of experiencing the associated thrust asymmetry.



NOTE

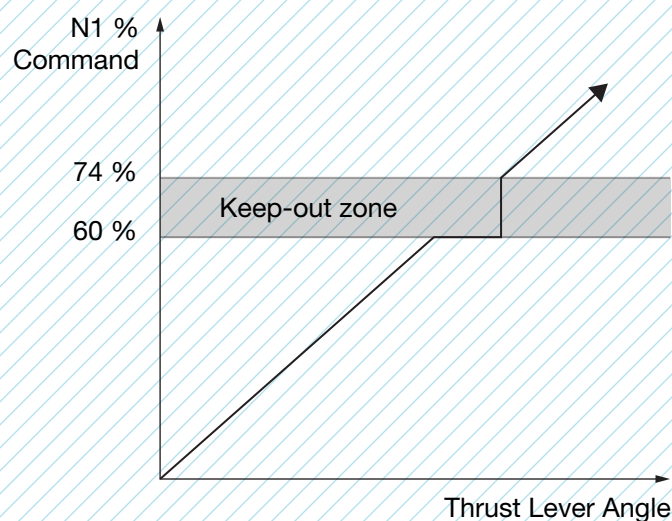
For A330 and A380 equipped with Rolls Royce TRENT engines, the FCOM procedure does not request the pilot to apply progressive thrust application between the engine stabilization step and the takeoff thrust in case of tailwind or significant crosswind. The engine control logic automatically manages the engine thrust during the takeoff roll on these aircraft.

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Specificity of aircraft equipped with Rolls Royce and IAE engines

On aircraft equipped with Rolls Royce or IAE engines, a “keep-out zone” prevents stabilized engine operation in a specific N1/EPR range, when on ground below a certain speed, to prevent fan instability. During the progressive application of the takeoff thrust after the stabilization step, the flight crew should ensure that the levers are advanced **continuously and simultaneously**. Moving the thrust levers too slowly may lead to asymmetric engine acceleration if one thrust lever is moved outside of the keep-out zone before the other.



(fig.9)

Example of the keep-out zone on A320 aircraft equipped with IAE engines

What if asymmetric thrust happens at low speed during the takeoff roll?

In the case of an asymmetric thrust event at takeoff, the flight crew should reject the takeoff if the veering moment cannot be counteracted using nose wheel steering.

The technique described in the FCTM “engine failure at low speed” should be applied:

- Immediately reduce all thrust levers to IDLE
- Select all reversers
- Use rudder pedals for directional control, supplemented by symmetrical or differential braking if needed

Communication between Pilot Flying and Pilot Monitoring

During the takeoff roll, a key role of the Pilot Monitoring (PM) is to monitor engine thrust. The PM must monitor the N1/EPR below 80kt, and announce “THRUST SET” when the takeoff thrust is reached for all engines. Should any thrust asymmetry be observed, the PM must immediately inform the PF and may call for a rejected takeoff if needed. ■

ADDITIONAL RECOMMENDATIONS TO FLIGHT CREWS

The event described at the beginning of this article is also the opportunity to remind flight crews with some recommendations to facilitate the lateral control of the aircraft .

Forward sidestick input during the early stage of the takeoff roll

(Except on A380) - The FCOM also requests pilots apply a half-forward side stick input, or full forward input if there is tailwind or significant crosswind, up to 80kt IAS to counter the nose up effect of the thrust application and then release this input gradually to reach the side stick neutral position at 100kt. This will increase the load on the nose wheel to aid in directional control of the aircraft.

Seating position and pedals adjustment

Since the flight crew can only rely on the nose wheel steering and to the last extend differential braking to maintain the centerline during the low speed part of the takeoff roll, they must make sure that they are properly seated. The pilot should be able to move the rudder pedals to their maximum deflection and apply maximum manual braking at the same time, should a rejected takeoff be initiated.

An incorrect pedal adjustment can make it difficult for the pilot to apply differential braking when needed. It can even lead to an opposite differential braking if the pedals are too far from the pilot.

Refer to the FCTM and to the [“Are you properly seated?”](#) Safety first article published in January 2018 for more information on adjustments to achieve optimal pilot’s seating position. ■

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CONTRIBUTORS:

Norbert HIRTZ

Powerplant Expert
Design Office

Xavier BOUSQUET

Head of Engine Performance
Design Office

Capt. Xavier LESCEU

HO Operational & Training Policy
Flight Operations Support

Sourya KAHLOUL

Flight Operations
Support Engineer
Flight Operations Support
and Training Policy

Sundeep GUPTA

Accident Investigator
Product Safety

With thanks to:

**Xavier VILLAIN,
Olivier LAFFONT,
Marc LE-LOUER**
from the Flight
Operations Support

To ensure that an aircraft's engines simultaneously accelerate during the early stages of the takeoff roll, the flight crews must wait for all engines to reach the stabilization step before advancing the thrust levers to command takeoff thrust. If the pilot flying applies takeoff thrust directly from idle without observing the stabilization step, the engines may accelerate at different rates and this will cause an asymmetric thrust condition, which may be difficult to counteract and could lead to a lateral runway excursion event.

In the case of tailwind or significant crosswind, the progressive increase of engine thrust from the stabilization step up to takeoff will allow the gradual acceleration of the aircraft to counter the effects of the distorted airflow at the engine's inlet and avoid the airflow disturbances inside the engine that may cause an engine to stall.

If an asymmetrical thrust condition is experienced at a low speed during the takeoff roll, and the flight crew cannot counteract it through rudder pedals inputs, the takeoff must be rejected using all thrust reversers and by applying differential braking if needed to bring the aircraft to a safe stop.

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

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