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Airbus Crosswind Development and Certification

1. Introduction

This article is one of a series in which we in Airbus try to create a bridge of information across the gap that exists between the manufacturers world of certification and the operators day to day environment.

At first glance, the issue of crosswind certification for a large transport aircraft may seem simple. The following is an extract from the EASA CS25.237(a) requirements:

A 90 deg cross component of wind velocity, demonstrated to be safe for take-off and landing must be established for dry runways and must be at least 20 kt or Vs MLW (1 g stall speed at Max Landing Weight) whichever is greater, except that it need not exceed 25 kt.

However, the subject is far more complicated than this short sentence may lead you to believe. So how do we deal with crosswinds during flight test and certification and what are the implications for operators?

2. History

Historically, there were two methods of computation. For early certifications, ATC tower winds were used to assess the level of crosswind experienced at take-off and landing by flight test crews. This was done with an old fashioned anemometric recording system, registering wind values at a nominal 10 metres above ground level. This method evolved into using aircraft generated cross wind data by calculating the 10 m high wind using the difference between the True Air Speed (TAS) vector and the IRS computed Ground Speed (GS) vector during a 20 second period (+_10 sec) around take-off and landing. However, as natural IRS drift creates inaccuracy, this had to be taken into account. The drift value had to be periodically measured in order to correct IRS Ground Speed. With the advent of Differential GPS (DGPS) and more recent on-board instrumentation systems, the GS vector is now calculated using highly accurate data and, therefore, this correction is no longer necessary.

In the early days of certification, when using tower winds, the average wind values were taken over the previous two minutes and the gust values over the previous 10 min period. Although ICAO considers wind gusts only if the peak value exceeds the two minute average by 10 kt, some airport weather services provide gust values lower than 10 kt. This method is still used for the broadcast of ATC tower winds. With the new flight test methodology, however, a much more representative assessment of the aircraft capability is achieved.

With the early Airbus certifications, we provided 'Average plus Gust' values in our FCOMs. However, it was felt by many that this format complicated the decision making process. Therefore, following a period of study beginning in 2004 we have now moved to a 'Single Value, Gust Included'. This effectively means that a direct comparison of the maximum demonstrated value (provided by us, the manufacturer) can be made against the maximum value communicated by the Tower or ATIS, including the gust if announced.

3. Maximum Demonstrated Crosswind Definition

Today, **maximum demonstrated crosswind** figuring in the FCOM is derived from the maximum crosswind that has been encountered during the complete certification process and recorded in a particular manner that has been agreed in conjunction with the authorities. It is **not necessarily the maximum aircraft crosswind capability** of the aircraft. It is purely based upon data recorded within the aircraft during the period of the certification process. Furthermore, it is often observed to be significantly different from the wind provided by ATC.

4. Flight Test Methodology

Firstly, wind data as experienced by the aircraft is collected for a period of +-10 sec either side of the take-off or landing. Then, we need to correlate this data to the established reference height of 10 metres. This is done with a mathematical correction to the data, which varies with height to compensate for the boundary layer type effect near the surface.

A conservative proportion of the gusts observed are then added to the maximum steady crosswind wind value obtained. With this (gust added) value, we check that we have sufficient control authority in an equivalent steady wind case, based upon empirical flight control response data. If this is validated, we propose the value to the authorities for certification and inclusion in the AFM, for take-off and for landing.

On take-off, however, there is another effect, which can have a big influence on crosswind limitation and/or take-off procedure: that of engine intake airflow distortion. This is covered in a separate analysis and many tests are carried out to ensure we provide a suitable operating envelope for our engines during take-off and landing. However, this may influence the final choice of demonstrated crosswind value provided and will almost certainly impact the procedure for applying take-off power. Manufacturers can choose to automatically limit engine regime for certain Ground Speeds if necessary, in much the same way that they sometimes automatically avoid certain rpm ranges to avoid fan blade flutter for example. However, there is always a slight compromise, in order to ensure that take-off performance is not significantly reduced as a result. Limitations are imposed for the A380 and A340 500/600, for example, where the engine limitations are more penalizing than the demonstrated crosswind limitation and this is published in the FCOM limitations section.

5. Take-Off Technique

Engine manufacturers design choice plays a large part in the initial procedural approach to setting take-off thrust and, as mentioned above, may be crosswind limiting. Significant lateral control should be avoided during the take-off run in order to prevent extension of spoilers which will have a detrimental effect on performance and may induce some directional disturbance. With strong crosswinds there will be a natural tendency for the aircraft to roll away from the wind at lift-off and this can be compensated for by a smooth lateral input as the aircraft becomes airborne.

Figure 1
Take-off from Keflavik, Iceland. Note how the wind lifts the right wing.
Maximum reported crosswind at the time was 56 kt in gusts

Extract from A330/A340 FCTM information on take-off roll (all Airbus programs share the same philosophy):

For crosswind take-offs, routine use of into wind aileron is not recommended. In strong crosswind conditions, small amounts of lateral control may be used to maintain wings level, but the pilot should avoid using excessive amounts. This causes excessive spoiler deployment, which increases the aircraft's tendency to turn into wind, reduces lift, and increases drag. Spoiler deflection starts to become significant with more than half side stick deflection. As the aircraft lifts off, any lateral control applied will result in a roll rate demand. The objective is for the wings to be maintained level.

This philosophy applies to the entire Airbus fleet. Although the lateral stick displacement threshold for spoiler deployment varies a little between types, the objective of avoiding unnecessary spoiler deployment however remains valid.

6. Landing Technique

The wings level technique is recommended. In particularly strong crosswinds kicking off around two third drift as a minimum is normally sufficient to ensure that the lateral stresses are not excessive on the undercarriage at touchdown (max residual drift 5 deg at touchdown), whilst at the same time ensuring minimum risk of a downwind drift away from the runway centreline. This has been applied to all aircraft from the A300/310, where roll/yaw coupling during decrab is marked due to the wing-sweep/dihedral effect, through the single aisle and long range Fly By Wire (FBW) aircraft where lateral compensation is similarly required and to the A380 where flight control law compensation provides a pure yaw response to rudder pedal input.

Where small amounts of lateral control are eventually required, avoid excessive bank angles (max bank angle 5 deg). Aim for a positive touchdown and do not be tempted to finesse the touchdown or float for any considerable time. This will inevitably lead to a downwind drift away from the centreline.

For the A380, and in the near future for the A350 XWB, there is no apparent induced roll when kicking off drift in the flare due to flight control law compensation. The flare laws in these two types have been adapted to produce a pure yaw demand when applying rudder to reduce drift prior to touchdown. Of course, the flight control surfaces are providing the lateral input for you, behind the scenes, in order to prevent the natural lateral stability of the aircraft from producing the induced rolling effect. However, this is transparent to the pilot who is looking down the runway to ensure he lands his aircraft in the right place without excessive drift.

Figure 2
"Crabbed" final approach to Keflavik, Iceland. Picture taken from the south taxiway with the runway easily visible. Maximum reported crosswind at the time was 56 kt in gusts

Extract from A380 FCTM information on lateral and directional control (all Airbus programs share the same philosophy):

FINAL APPROACH
In crosswind conditions, the flight crew should fly a "crabbed" final approach wings level, with the aircraft (cockpit) positioned on the extended runway centerline until the flare.

FLARE
The objectives of the lateral and directional control of the aircraft during the flare are:
- To land on the centerline
- To minimize the loads on the main landing gear.

The recommended de-crab technique is to use the following:
- The rudder to align the aircraft with the runway heading during the flare
- The roll control, if needed, to maintain the aircraft on the runway centerline.

The flight crew should counteract any tendency to drift downwind by an appropriate lateral(roll) input on the sidestick.
In the case of strong crosswind during the de-crab phase, the PF should be prepared to add small bank angle into the wind to maintain the aircraft on the runway centerline. The flight crew can land the aircraft with a partial de-crab (i.e. a residual crab angle up to about 5 deg) to prevent an excessive bank. This technique prevents wing tip or engine nacelle strike caused by an excessive bank angle. Therefore it is wise to know what the maximum bank angle is during the flare phase for the type you are flying so as to ensure no such strikes.
As a consequence, this can result in touching down with some bank angle into the wind, therefore, with the upwind landing gear first.

One further point is worth mentioning, because we see repeated cases in Flight Operational Quality Assurance (FOQA) data in which less than optimum crosswind touchdowns are made: the response to rudder pedal input at the decrab is positive for all our aircraft. However, due to pure aerodynamics and inertia it takes a reasonable time from the input being made to the aircraft reacting. If we were hand-flying in crosswinds every day, we would become very well tuned to the aircraft response and make a perfect crosswind landing every time (I wish!). However, there appears to be a tendency, borne out by operational Digital Flight Data Recorder (DFDR) data, towards a late initiation of the decrab. This is perhaps natural, since the risks associated with an early decrab are perhaps more severe. However, practice, as always, is the key. Any opportunity in the simulator, even if not truly representative of the flying the real aircraft is invaluable, as the response time to rudder input should be representative.

7. Effect of Thrust Reverse

Of course, touchdown is not the complete story, as the roll-out is an equally important phase of the crosswind landing. This is where ground based dynamics come into play, even though there are still varying degrees of aerodynamic controllability during the deceleration phase.

When selecting reverse thrust with a given crab angle, the reverse thrust results into two force components:

- A stopping force aligned along the aircraft direction of travel (runway centerline)
- A side force, perpendicular to the runway centerline, which further increases the tendency to skid sideways.

Unequal weight distribution on the main landing gear during touchdown and braking also produces a yawing moment. This can be destabilizing should the asymmetric wheel loading and braking be sufficiently high and this can be caused by the crosswind itself or by lateral stick input. Furthermore, autobrake systems do not always provide a useful aid in this regard, as they will apply braking regardless of whether one main-wheel bogie alone has released brake pressure due to antiskid operation.

In all cases, brakes and reverse should be applied smoothly. If there is any concern with directional controllability then reduce or cancel reverse as necessary and reduce braking until control is regained. Then smoothly re-apply brakes and reverse if necessary.

8. Operational Implications

With the FCOM provided maximum demonstrated crosswind value and the tower provided current wind value, the decision making process is not always easy for the pilot on approach in limiting wind conditions. Runway condition is also a factor critical to maintaining lateral control once on the ground and has to be considered. Companies may provide operation recommendations, but the topography around the touchdown zone can sometimes lead to significant variations of actual winds experienced. Local knowledge is very useful and often incorporated in specific airfield briefs. It is perhaps natural, therefore, that many pilots glance at the ND windspeed indication during approach to help them in their decision making process. There is a catch here, however. As ND wind on A320 Family/A330/A340 is derived from IRS data, indications may be significantly different from reality. This is due to the lack of correction for the IRS drift, mentioned earlier. On A380 (and in the future for A350 XWB), the use of GPS Ground Speed for the ND wind display provides a more reliable additional source of information. Ultimately, it is the Captain who is called upon to use his judgement and skill, based upon all the data and knowledge available to him.

Remember also that if your aircraft has a degraded flight control system through MEL clearance or in flight failure, then a more severe crosswind limitation may apply. Similarly, an engine out condition will imply a limited ability to correct for drift in one direction. Again a more restrictive limitation may exist.

9. Autoland Certification

Certification of autoland and its associated wind limitations is done based upon a statistical analysis of autolands carried out during flight test and certification. These values should be treated as hard limits for the autoland system. Although, in theory, if the tower winds indicate that you are within the autoland crosswind limit you can continue to make your autoland, common sense would indicate that you take care, as in reality the winds could be beyond the autoland system capability. As always, be ever ready to take over manually should the need occur.

10. Conclusion

The maximum demonstrated crosswind is just that: a demonstrated value that was observed during certification based upon the weather conditions that we were able to find during the flight test campaign. Companies may define their own limitations based upon their own experience. For the line Captain, asking himself whether he can land or take-off in the crosswind conditions of the day, he should take all information available to him in the decision making process. Tower wind may be the starting point, but it is not the whole story. Ultimately the responsibility rests with the Captain and if there is any doubt, discontinue the approach. As always, the anticipation of what is coming is the key to a successful outcome.

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