Vereniging van Nederlandse Verkeersvliegers

Dutch Air Line Pilots Association

Position Paper 08 / 1

Crosswind

Revision: 20th January 2009

This position paper represents the opinion of the Dutch Air Line Pilots Association based on IFALPA / ECA policy, legislation, scientific research and manufacturer guidelines and recommendations.

I·F·A·L·P·A
The Global Voice of Pilots
ECA

Issue

This position paper deals with the hazards in crosswind operation and stipulates the point of view of VNV in addressing these hazards.

Wind is in essence a stochastic phenomenon and can therefore not be described or dealt with in an exact manner.

Wind and all associated characteristics as crosswind and tailwind, shear, turbulence, vortices and gusts are of mere importance in our daily flight execution. Wind influences not only the aircraft's performance but also the aircraft handling characteristics and piloting task. Some specific operational hazards are introduced.

In order to conduct flight safely in windy conditions, one should assess these hazards very thoroughly and a profound safety study should be the basis of any crosswind policy. Because of all uncertainties a conservative approach should be assumed. As a result of all these variables a precise determination of airplane crosswind capability is impossible. Sufficient margins must be applied to cater for the inherent uncertain wind characteristics, to cater for all uncertainties in wind measurement and to cater for pitfalls in the certification and operational process.

Schiphol is recognized as a wind-critical airport due to its wind climate, the airport build-up and the runway orientation. Furthermore, wind has a substantial impact on its capacity.[12]

Background

Flight Safety Foundation (FSF) analysis of approach and landing accidents indicates that adverse wind conditions contribute to at least one third of the approach and landing accident rate for jets and almost half for turbo-props (1970-1997). Operation in higher crosswind and tailwind conditions imposes a greater risk. The accident rate increases exponentially with crosswind components over 20 kts.[8]

The problems encountered in crosswind conditions consist of unstabilized approaches, flight control saturation, pilot induced oscillations, loss of situational awareness, fatigue, overruns, short landings, hard landings, wingtip/pod strikes, tailstrikes, landing gear fatigue and localizer overshoots.[10]

Environmental concerns and a capacity drive have influenced runway allocation schemes in recent years and moved away from the operationally preferred options. The number of crosswind/tailwind takeoffs and landings has risen and will likely keep rising significantly in the near future.

Extensive recent research has provided qualitative and quantitative insight in the safety aspects of crosswind operations. Wind phenomena have been analysed to a larger detail by the advent of Computational Fluid Dynamics (CFD) modelling techniques and windtunnel testing and real life validation. Flight mechanical analysis and simulation have been improved and risk quantification has been extended.

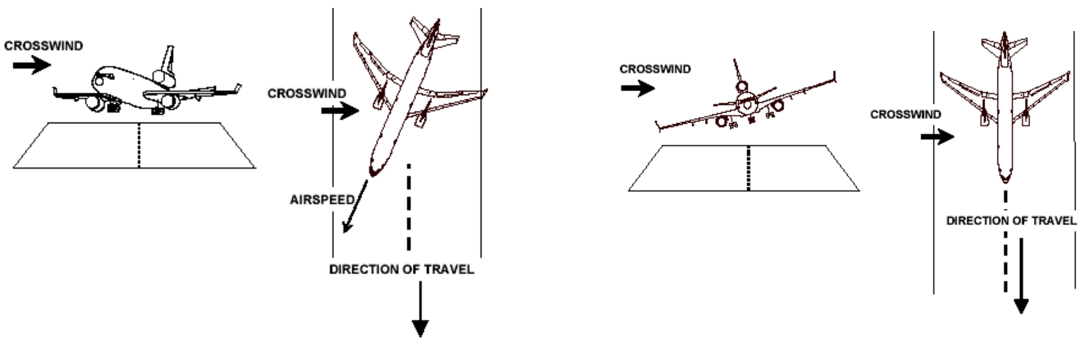
Flight operation in crosswind

In a crosswind landing, two different piloting techniques can be used: crabbed or (partially) decrabbed. The aircraft will remain on the extended centreline when equilibrium exists between the lateral forces originating from aerodynamic pressure, thrust, rudder and gravity (aircraft banked). On the ground the aircraft will remain on the centreline when an equilibrium exists between the lateral forces from wind, thrust, the rudder and tire friction.

The pilot has to perform a transition from a coordinated flight condition (the so-called crabbed approach) to a non-coordinated flight condition (side-slipping). If this transition is made earlier during the approach, the pilot has to hold the aircraft in the non-coordinated and therefore unstable condition for a longer period of time.

More decrab will increase the piloting effort, the roll angle on touchdown and the overall demands on the control capacity to the benefit of the side load impact on the undercarriage. Forward thrust will help a crabbed aircraft to remain on the centreline. A crabbed landing technique is therefore more suited for slippery runways up to the moment of thrust reverse selection.

Maximum bank angle and aileron/rudder effectivity together with the acceptable side slip determine the theoretical maximum crosswind component in the air; on the ground rudder/nose steering effectivity, tailplane dimensions, tire braking and slip angle, runway friction, and engine location in relation to the rudder do.



Crabbed approach (coordinated flight) Wing-down approach (non coordinated flight)

Figure 1 Crabbed vs. wing-down approach of aircraft during crosswind landing (illustrations from [NLR CR-98388])

Piloting task in crosswind operation

Operation in crosswind implies a demanding piloting task for a controlled take-off and especially landing. Especially in gusty wind, low visibility weather conditions or on wet or contaminated runways the piloting task is critical.

There is an increasing difficulty in the flare due to the heading change into the relative runway direction or due to the banked attitude of the aircraft.

Control authority diminishes in crosswind conditions. This can be especially important to counter the effects of gusts.

Effective symmetrical braking is more difficult with rudder application in a crosswind landing or during a rejected take-off (RTO). After selection of thrust reverse, misalignment with the runway centreline has an adverse effect on the lateral control.

The allowable crosswind during autoflight is generally lower than the allowable limit during manual flight. In some cases it is therefore necessary to transition from automatic flight to manual flight shortly before the landing (although normally at least at an altitude of 500ft).

The transition from instrument to visual flight mode is more difficult during a crosswind approach, even more so with a low ceiling.

Especially gusts increase the workload in crosswind conditions. The gusts lower the pilot's tracking performance and increase the risk of pilot induced oscillations (PIO).

Shortcomings

In many crosswind accident reports several contributing factors have been identified: the inaccuracy of wind measurement, unreliable runway braking action, runway assignment, the gustiness, the piloting techniques, aircraft flight dynamics, ground roll characteristics and nearing building developments.

Several shortcomings and critical factors have been identified, which create a typical hazard in the crosswind operation and require a closer look and a mitigating strategy or a conservative approach. Most of the relevant shortcomings will now be addressed accompanied by the relevant policies or points of view from VNV and IFALPA.

Wind Measurement

ICAO Annex 3 provides wind measurement and reporting recommendations. Wind measurement and presentation to a pilot are inherently liable to a lot of uncertainties and shortcomings: it's done neither at the right place, nor at the right time. A vertical wind profile is missing. The high frequency content of the wind disturbances is not represented in the wind measurement or reports.

Accuracy: the attainable accuracy of surface wind measurement is according to ICAO Annex 3 +/- 5 degrees and 1 kts (above 20 kts 5%). The reporting accuracy however is 10 kts and 60 degrees between the most backed and veered measured direction. Wind direction and speed can vary significantly without an updated wind report. A simple goniometric study indicates that especially variation of wind direction can significantly influence the crosswind component. VNV supports the general reporting accuracy of 5 kts and +/- 30 degrees.

Positioning: an anemometer is generally placed on a 6 to 10 m pole abeam the touchdown point and can therefore not cover the approach, landing and go-around area. The wind measurement should according to Annex 3 be representative for the touch down zone, but this can hardly be achieved in daily practise, let alone for the whole runway.

Unfortunately wind must be measured and may not be mathematically derived although this could produce more accurate and consistent wind data. VNV supports an addition to Annex 3 to allow mathematically derived wind data which has proven to be viable in experimental research.

Averaging: wind is stochastic. Its properties must therefore be described with statistical means. Deviation from the mean is a rule in statistics and there is in principle no maximum in a normal distribution. To handle wind data one is restricted to use moving averages based on the (near) past without any guarantees for the future. An 'actual or tower' wind report is in general averaged over 2 minutes. A METAR report consists of a 10 min averaged wind. Actual winds can therefore differ considerably from reported winds.

A wind report should be regarded as one momentary (averaged) appearance of the wind field. The wind and gust report should resemble a reliable and timely mean and variance and should describe the stochastic nature of the current wind. VNV opposes to the endless number of wind reports on final approach as this will give a false appearance of accuracy and safety.

VNV supports the introduction of derived wind reports instead of sole measurements in order to improve the quality and the validity of the report.

VNV opposes nearing construction developments that obstruct airflow around the anemometer and prevent reliable wind readout.

Gusts

Gusts are considered to be the short-term variances of the average wind pattern, resulting from the turbulent behaviour of the wind mass. This variance is stochastic and originates from a complicated process of superpositioned whirls. These whirls and their corresponding energy originate from windshear and convection in the atmospheric boundary and near the earth surface from large scale orographic features, terrain roughness and specific small scale terrain features, such as natural or man-made obstacles. Wind variation and turbulence will be most severe where windshear reaches a maximum: near the earth surface with strong winds.

In the surface layer (lower tens of meters) the vertical exchange of energy and the convective part of the turbulence can be disregarded, except near thunderstorms and local downbursts. This explains the fact that at very low altitude the wind does not necessarily veer with strength above the equator.

As mentioned before, the gustiness of the wind is the main contributing factor of crosswind related accidents and is the single most important cause for crosswind hazards. But gusts cannot be described in an absolute manner. The variance of the wind in strength and direction cannot be predicted, solely expected.

The measurement of wind is essential for a good description of the stochastic properties of this wind. The sampling rate defines the cut-off frequency of the gust measurement: high frequency components above 0.33 Hz (causing the turbulent "feel" of a wind field) are filtered because of the sampling rate (once per 3 seconds). Although gusts with duration of 2 seconds can influence the aircraft attitude, these wind fluctuations are generally not measured.

Higher frequency fluctuations are encountered in real-life and translated in turbulent behaviour, not influencing the aircraft performance or flight path, but they have an effect on the pilot working environment and workload.

The measurement time window will also influence the measured maximum wind and the gust factor. The so-called peak factor and the resulting gust factor will increase with a longer observation period simply through statistics. In other words, a short measurement will generate smaller deviations from an average wind. Furthermore, an extended observation period will diminish the chance of an exceedance from the measured maximum.

VNV believes wind and aircraft modelling should be realistic. They should encompass all relevant frequency components of the wind pattern for crosswind research, higher frequency components for aircraft handling and a realistic turbulence “feel” and lower frequency components for a realistic windshear environment affecting aircraft path and performance. These findings should be related to scientific study and real-world validation.

Certification

Most aircraft are certified (JAR/FAR/CS 25) with a maximum demonstrated crosswind/tailwind instead of a hard limitation. If the demonstrated crosswind is considered to imply a maximum limiting value for safe aircraft operation, this value will appear as limit in the certified Aircraft Flight Manual (AFM).

Guidelines for crosswind demonstration flight tests have been published in an FAA advisory circular, but are not obligatory. In general, gusts are not considered.

Runway conditions during crosswind demonstration flights are dry with excellent friction. The flights are conducted under ideal circumstances such as a steady crosswind, experienced pilots with short daytime working shifts and a perfect aircraft condition.

Crosswind guidelines for wet and contaminated runways are derived from piloted simulations and engineering analysis, not from flight tests. Care should be exercised in using these data as current simulators are not a good tool to explore the ground part of a landing or takeoff. According to [8] pilot evaluations in a simulator tend to be optimistic in most cases.

Autoland certification uses a mild wind model (JAR ACJ AWO 131) which is not representative for windy airports like Amsterdam or Cape Town.

To account for these differences VNV insists on using margins on artificially derived crosswind demonstrated values. It should not be allowed to advice operational crosswind limitations in excess of the demonstrated capability.

IFALPA proposes to incorporate hard crosswind limits in the aircraft flight manual.

Simulator training and wind modelling

In [4] (Crosswind Working Group Phase 1) it is stated: “It is generally recognised that the quality of wind modelling of the simulator software is insufficient.” According to [8] the quality of the mathematical ground model in combination with the motion and visual ques of a simulator is usually not high enough to allow sufficient confidence in the crosswind evaluation results.

Wind models used on training simulators are simplified. In contrast with these models, real stochastic wind characteristics are time and position-variant, non-Gaussic and strength/direction correlated. Simulators lack sufficiently high response times, proper ground and aerodynamical models, high frequency turbulence and terrain induced wind effects.

Two-dimensional wind modelling (empirical, wind tunnel or mathematical) has limited validity for predicting unsafe wind situations. A given complex surface situation requires three-dimensional modelling and advanced fluid dynamics.

VNV believes that the current training and simulator quality is sufficient for the current crosswind practise embedded in a proper runway assignment scheme and a proper runway orientation according to the ICAO Annexes and PANS-OPS. Frequent crosswind landings with crosswind components higher than 15/20 kts will be rare. A more liberal runway assignment means additional requirements for training and simulating techniques.

Extra attention should be given to the effect of gusts and terrain induced wind effects.

Structural

The undercarriage is subject to a complex combination of loads and torques during a traversing crosswind landing. Neither FAR 25 nor JAR/CS 25 contains specific requirements for consideration of a crosswind landing impact on the undercarriage design.

The manufacturer carries out life-cycle load testing for each design. These tests however do not reflect real, dynamic multi-directional landing impact loads, but merely test the gear in normal, longitudinal and lateral direction separately.

IFALPA stresses the need to assess the dynamic impact load and structural fatigue in the undercarriage, resulting from more frequent crosswind landings.

Runway friction

Runway friction is a critical element in the crosswind takeoff and landing performance and controllability. Lack of friction has been recognized as a major contributing factor in wind related accidents. Runway friction is dependent on aircraft velocity, aircraft type and piloting techniques.

Runway friction is determined by the tire, the runway geometry and the surface micro- and macro-texture. Water disposal rate is mainly a function of the runway geometry and surface macro-texture. The friction provides the stopping and cornering forces which are important to avoid runway overruns and veer-offs.

Wet conditions or contaminants such as snow, ice, salt, rubber or poor surface maintenance could cause a degradation of the runway friction.

There is no worldwide uniform standard for measuring and quantifying runway braking action. There are numerous measuring techniques each generating a different outcome.

The published aircraft stopping distances are based on flight tests on a runway with excellent (dry) braking action. For runways with less friction these distances have been derived mathematically where the anti-skid efficiency can be based on limited flight test data.

The effect of the dynamic friction coefficient (i.e. the factual braking capability) is a complex phenomenon and is not known exactly for a specific aircraft on a specific runway. Therefore one cannot know exactly what the effect of the runway condition could be for the rollout and rejected take-off.

An antiskid system will not prevent tires from skidding sideways.

IFALPA supports the advent of uniform friction measurement and reporting that provides a direct relationship with the braking performance of an aircraft.

Operational procedures

Lack of proper crosswind procedures in the cockpit can undermine the safety level of the crosswind landing and take-off.

In general, aircraft manufacturers do not publish crosswind limitations but guidelines and maximum demonstrated values; there is no legal restriction on exceeding them. This leaves the final judgment up to the pilot. Generally, there is little knowledge of the database used, the assumptions made, or the validation processes involved to generate the certified data, whereas the manoeuvre can approach the limiting capability of the airplane.

A proper cockpit decision methodology with respect to crosswind is lacking. Crosswind limitations must account for visibility, runway condition, runway width, specific aircraft characteristics such as rudder blanking and pod/wingtip geometry and pilot experience. These aspects should be positively assessed before each landing.

Uncertainties in wind information and the operational impact warrant safety margins with respect to theoretical, demonstrated or derived wind limits as provided by the aircraft manufacturers.

Other considerations should be included as well: asymmetric braking will increase the landing distance and the FMS underestimates the actual crosswind component because of an inbuilt averaging filter and heading (instead of track) related wind conversion. Low altitude autopilot disconnect behaviour can provide insufficient time for a stabilised flight path, especially after the autoflight align mode engagement.

IFALPA supports the inclusion of crosswind limitations in the AFM.

Runway orientation and allocation

It is clear that the runway orientation scheme and the runway allocation have a direct impact on the encountered crosswind.

According to the ICAO Annex 14 recommendation runways should be directed in the prevailing wind direction. The runway layout at several airports does not comply with this.

ICAO PANS-OPS is clear in the runway assignment criteria for noise abatement: “Noise abatement should not be the determining factor in runway nomination when the crosswind component, including gusts exceeds 15 kts.” This criterion can be extended to 20 kts under certain conditions.

Clearly is stated that these values include gusts. Some countries deviate from this ICAO recommendation.

In practise the above mentioned rule is difficult to apply. General rules for runway assignment are lacking and the runway selection process can depend on the expert knowledge of the individual air traffic controller. There are more factors than wind, visibility, cloud base and runway friction that influence the choice of a runway combination. The procedure for changing runways in use due to changing wind conditions is complex. A runway change can result in a temporary loss of capacity.

Furthermore Air Traffic Controllers can apply additional safety margins. Pilots have the final authority to accept the allocated runway or opt for another runway.

IFALPA supports the current runway assignment criteria for noise abatement and stresses that gusts should be included.

VNV believes that these criteria should equally apply for capacity enhancement or other non-operational considerations.

VNV believes that noise abatement runway assignment criteria apply for all landing and take-off runways in case of simultaneous runway use.

IFALPA stresses that the commander has the final authority to accept or request a runway for safety reasons and that this request shall be granted.

Runway environment

The runway environment and surrounding terrain roughness determine the turbulence intensity of the wind. Wind blanking and subsequent shear can originate from nearby constructions. Gustiness and wind blanking cause flight path instability, degraded aircraft performance and increased pilot workload in takeoff and landing. These wind effects originate mostly from the specific features of the runway environment.

The environment can be described in terms of terrain roughness and in terms of specific nearby constructions or natural masses. Obstacle clearance planes do not guarantee an unobstructed wind flow. Extra measures must be taken.

VNV believes that in the design of an airport and local building plans all effects on the wind climate should be addressed and assessed according to an objective criterion. Sufficient means and knowledge is currently available to assess these effects on the aircraft.

Conclusions

The inherent stochastic properties of wind warrant safety margins with respect to published demonstrated or derived wind limits.

Many shortcomings and uncertainties play a role in crosswind operation. Many factors have been identified in the field of wind measurement, (structural) certification, operations, runway condition measurement and reporting, piloting techniques, runway allocation and building induced turbulence, which have a (negative) impact on flight safety in crosswind conditions. Mitigating strategies have been proposed by VNV and IFALPA.

A conservative and comprehensive approach should be undertaken in any crosswind safety study.

The PANS-OPS recommendation for 15-20 kts maximum crosswind for runway allocation cannot be increased without significant reductions in operational safety margins in current day-to-day operation.

References

1. *ICAO Annex 3 "Meteorology".* International Civil Aviation Organization (ICAO) (Fourth Edition, July 2004)

2. *TR 2002.xx KNMI Gusto "Toepassing van vlaagtheorie op windmetingen en verwachtingen".* Wichers, Schreur en Geertsema.

3. *ICAO Annex 14 "Aerodromes".* International Civil Aviation Organization (ICAO) (Third Edition, July 1999)

4. *Report Phase 1 of the Crosswind Working Group, The Netherlands.* Crosswind Working Group (KLM/Schiphol Group/LVNL/Martinair/Transavia), 2001/2002

5. *Procedures for Air Navigation Services, Aircraft Operations.* International Civil Aviation Organization (ICAO) Document 8168 (PANS-OPS) Volume I Flight Procedures, Part IV Chapter 2.

6. *Federal Aviation Regulations Part 25: Airworthiness standards, Transport category airplanes.* Federal Aviation Administration, December 2003

7. *Joint Aviation Requirements Part 25, Large Aeroplanes, Section 1 – Requirements.* Joint Aviation Authorities (JAA), Change 14, 27 May 1994.

8. *Safety aspects of aircraft operations in crosswind.* G.W.H. van Es, P.J. van der Geest a.o. NLR Contract Report CR –98388 / NLR-TP-2001-217, December 1998 / May 2001

9. *Safety Aspects of Criteria Governing Cross- and Tailwind*. Final Report and Recommendations Committee on cross- and tailwind criteria (Rinnooy Kan Committee), March 17th, 2000

10. *A Study on the Safety Aspects of Criteria Governing Cross- and Tailwinds.* NLR-CR-2000-082

11. *Wind criteria due to obstacles at and around airports.* NLR-CR-2006-261, Sep 2005

12. *Reducing the impact of crosswind conditions on the capacity of Schiphol Airport.* Crosswind Working Group Phase 2, 2003.