Nationaal Lucht- en Ruimtevaartlaboratorium

National Aerospace Laboratory NLR

Executive summary

Crosswind Certification - How does it affect you?

Problem area
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Description of work
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Summary

Many pilots will have encountered the situation in which the actual crosswind conditions at a destination were close to the company's limits. Not many pilots are actually aware of how crosswind limits are determined for an aircraft. This article will discuss the crosswind certification process and how it is translated to the normal day-to-day flight operation.

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1 Introduction

On June 1, 1999, an American Airlines McDonnell Douglas MD-82, crashed after it overran the end of runway during landing at Little Rock National Airport in Arkansas. The captain and 10 passengers were killed; the first officer, the flight attendants, and 105 passengers received serious or minor injuries; and 24 passengers were not injured. The aircraft was destroyed by impact forces and a post-crash fire. The controller of Little Rock Air Traffic Control advised the flight crew that a thunderstorm located northwest of the airport was moving through the area and that the wind was 280-degree at 28 knots gusting to 44 knots. The Cockpit Voice Recorder indicated that the captain and first officer discussed American Airlines' crosswind limitation for landing. The captain indicated that 30 knots was the crosswind limitation but realized that he had provided the limitation for a dry runway. The captain then stated that the wet runway crosswind limitation was 20 knots, but the first officer stated that the limitation was 25 knots. In the testimony at the National Transportation Safety Board's public hearing on this accident, the first officer stated that neither he nor the captain checked the actual crosswind limitation in the flight manual. The first officer testified that he had taken the manual out but that the captain had signalled him to put the manual away because the captain was confident that the crosswind limitation was 20 knots. During the accident investigation, it was determined that the Flight Manual crosswind limit was actually 10 knots, considering the wet runway and the fact that the RVR as less than 1800 ft. After touchdown directional control was lost due a combination of high crosswind, wet runway, and use of reverse thrust greater than 1.3 engine pressure ratio, which decreased the rudder effectiveness on this aircraft type.

The Safety Board determined that contributing to the accident was, amongst others, the flight crew’s continuation of the approach to a landing when the company’s maximum crosswind component was exceeded.

The above accident is an illustration of an event in which crosswind limits were exceeded with serious consequences. Many pilots will have encountered the situation in which the actual crosswind conditions at a destination were close to the company’s limits. Not many pilots are actually aware of how crosswind limits are determined for an aircraft. This article will discuss the crosswind certification process and how it is translated to the normal day-to-day flight operation.

2 Crosswind Certification Process

Aircraft with a maximum takeoff mass of 5,700 kg or higher are certified according to the US Federal Aviation Regulation FAR 25 and the European equivalent JAR/CS 25. Both JAR/CS 25 as FAR 25 state the following regarding crosswind:

§25.233 Directional stability and control.
(a) There may be no uncontrollable ground-looping tendency in 90-degree crosswinds, up to a wind velocity of 20 knots or 0.2 V_{S0}, whichever is greater, except that the wind velocity need not exceed 25 knots at any speed at which the aircraft may be expected to be operated on the ground. This may be shown while establishing the 90-degree cross component of wind velocity required by §25.237.
(b) Landplanes must be satisfactorily controllable, without exceptional piloting skill or alertness, in power-off landings at normal landing speed, without using brakes or engine power to maintain a straight path. This may be shown during power-off landings made in conjunction with other tests.

§25.237 Wind velocities.
For landplanes and amphibians, a 90-degree cross component of wind velocity, demonstrated to be safe for takeoff and landing, must be established for dry runways and must be at least 20 knots or 0.2 V_{S0}, whichever is greater, except that it need not exceed 25 knots.

Note that V_{SO} means the stall speed or the minimum steady flight speed in the landing configuration. The wind velocity must be measured at a height of 10 meters above the surface, or corrected for the difference between the height at which the wind velocity is measured and the 10-meter height.

When these rules are carefully examined, the following can be noticed:

- Only dry runways have to be considered,
- It is not clear if the wind velocity includes gusts or not,
- No crosswind limits have to be established, only demonstrated values.

Like with almost any rule given in JAR/CS/FAR 25 the aircraft manufacturer needs additional guidelines to actual know how the comply to these rules. The FAA has published a flight test guide for the certification of transport category aircraft in the form of an Advisory Circular (AC 25-7A) known as the Flight Test Guide. This Advisory Circular contains guidelines about the crosswind demonstration flight tests. The important parts of the FAA Flight Test Guide are as follows.

25.237 - Wind Velocities.

Explanation.

- There must be a 90-degree crosswind component established that is shown to be safe for takeoff and landing on dry runways.
- The aircraft must exhibit satisfactory controllability and handling characteristics in 90-degree crosswinds at any ground speed at which the aircraft is expected to operate.

Crosswind Demonstration.

A 90-degree crosswind component at 10 meters of at least 20 knots or 0.2 V_{S0}, whichever is greater, except that it need not exceed 25 knots, must be demonstrated during type certification tests.

There are two results possible:

- A crosswind component value may be established which meets the minimum requirements but is not considered to be a limiting value for aircraft handling characteristics. This "demonstrated" value should be included as information in the Aircraft Flight Manual.
- A crosswind component value may be established which is considered to be a maximum limiting value up to which it is safe to operate for takeoff and landing. This "limiting" value should be shown in the Operating Limitations section of the AFM.

Procedures.

(i) Configuration. These tests should be conducted in the following configurations:

- At light weight and aft CG (this is desirable; however, flexibility should be permitted).
- Normal takeoff and landing flap configurations using the recommended procedures.
- Normal usage of thrust reversers. Particular attention should be paid to any degradation of rudder effectiveness due to thrust reverser airflow effects.
- Yaw dampers/turn co-ordinator On, or Off, whichever is applicable.

(ii) Test Procedure and Required Data. Three takeoffs and three landings, with at least one landing to a full stop, should be conducted in a 90-degree crosswind component of at least 20 knots or 0.2 V_{S0}, whichever is greater, except that it need not exceed 25 knots. For each test condition, a qualitative evaluation by the pilot of aircraft control capability, forces, aircraft dynamic reaction in gusty crosswinds (if available), and general handling characteristics should be conducted. The aircraft must be satisfactorily controllable without requiring exceptional piloting skill or strength. Wind data from the INS systems, tower, or portable ground recording stations should be corrected to a 90-degree crosswind component and to a height of 10 meters.

These guidelines give a lot more information than the rules themselves. However, these guidelines still leave plenty of room for different interpretations by its users. Let us have a closer look at what the text in the Flight Test Guide really means for crosswind certification. A distinction is made between manual landings and autolands.

3 Manual landing

According to the Flight Test Guide there are two possibilities on how to note crosswinds in the Aircraft Flight Manual AFM.[1] If the demonstrated crosswind is not considered to be a limiting value for aircraft handling characteristics, this demonstrated value can be placed as information in the AFM. Higher crosswinds are then allowed when the applicable operational requirements and the airline specification allow it. For instance, the AFM of the B737-400 states the following on crosswind "*The maximum demonstrated crosswind component for takeoff and landing is 35 knots reported wind at 10 meter height. This component is not considered to be limiting on a dry runway with all engines operating*". Does this mean that there is no limit for this aircraft? The simple answer is NO, this aircraft will have a limit but it was not found during certification. Other manufacturers make very similar statements for their aircraft. Interesting is the fact that nothing is said about gusts. It remains unclear whether in the example of the B737-400 the crosswind of 35 knots includes or excludes gusts. This fact is important when the operator is using the demonstrated crosswind in their Aircraft Operating Manual AOM. Up to this moment only Airbus gives a gust value in the certified crosswind. An overview of maximum demonstrated crosswinds of a number of aircraft is shown in Figure 1. It is clear from this figure that the demonstrated crosswind capabilities have not shown a significant trend during the last forty years of aircraft certification. The average demonstrated crosswind is 30 knots. Amongst the different aircraft significant variation in the demonstrated crosswinds exists. One of the reasons of this variation is due to Mother Nature. An aircraft manufacturer has no influence on the weather. In a certification flight test program of new aircraft, every test is carefully planned and scheduled. For crosswind certification a location and week are selected for which it is most likely to have strong wind conditions. When the moment of truth is there the actual wind maybe far less than hoped for. Usually there is no time available up to the certification date of the aircraft to conduct additional crosswind test flights. It is not uncommon that after the aircraft was certified additional test flights are made by the manufacturer to demonstrate higher crosswind capabilities.

[1] Most operators do not use the AFM as an operational manual, but are authorised to use the Aircraft Operations Manual (AOM) as a substitute for the AFM instead. The information in the AOM is based on and in agreement with limitations in the AFM. With respect to crosswind limitations as stated in the AOM, these are company limitations that are derived from information in the AFM.

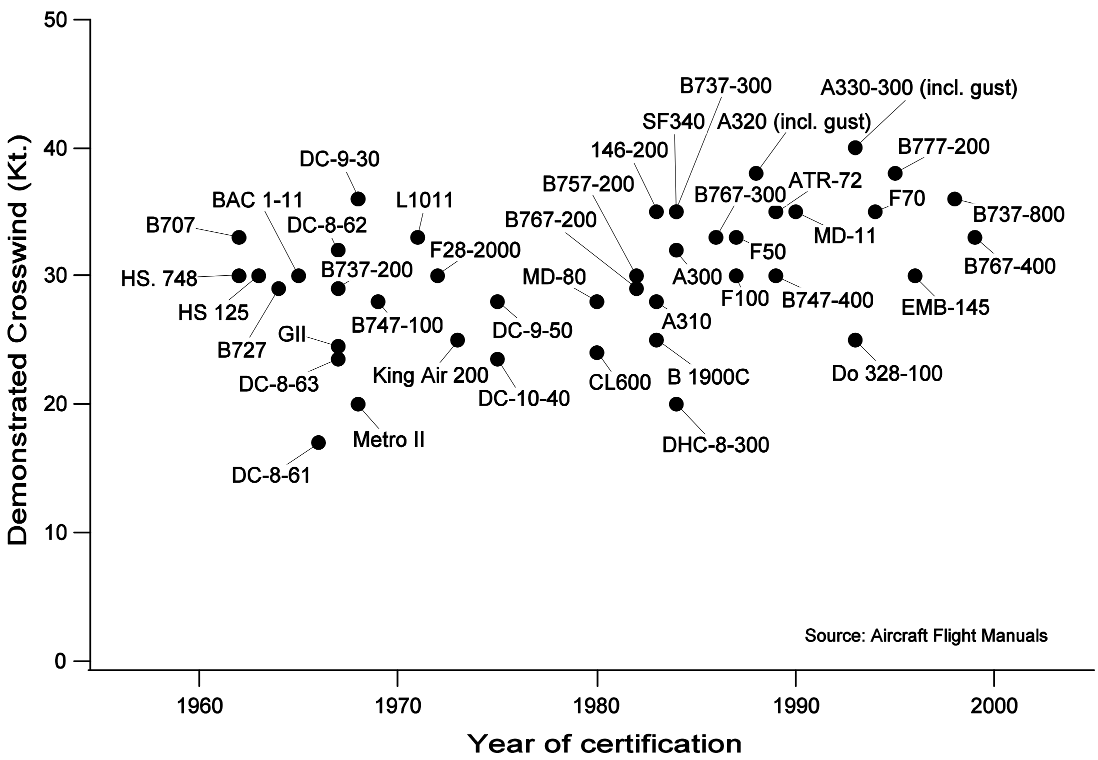

Figure 1: Overview of maximum demonstrated crosswinds.

If the demonstrated crosswind is considered to be a maximum limiting value up to which it is safe to operate the aircraft, the demonstrated crosswind value will appear as a limiting value in the AFM. It is not allowed to operate the aircraft beyond this crosswind. The demonstrated crosswind for practically all aircraft certified by the FAA and JAA was not considered as limiting by the test pilots during the last forty years. Rare examples of modern aircraft with a hard crosswind limit are the Fokker 70 and the SAAB 2000 (without aileron modification). These aircraft were found to be demanding on aileron capacity, in particular after decrabbing the aircraft just before touchdown. The test pilot makes a pure subjective assessment whether or not the crosswind is limiting. The test pilot must consider that the aircraft is satisfactorily controllable, without exceptional piloting skill or alertness, according to the rules of FAA and JAA. This means that an average pilot should be able to handle the aircraft in those crosswinds the test pilot did not consider limiting. During a crosswind certification flight, a pilot of the airworthiness authorities accompanies the aircraft manufacturer’s test pilot. The airworthiness authorities give the final subjective judgment regarding crosswind operations. When a test pilot does its thing, he/she is well rested and prepared. The normal line pilot (e.g. arriving after a long night flight) is not necessarily well rested and is not especially prepared to make landing in strong crosswind conditions. Of course, it comes with the job description that he/she can do it! The Flight Test Guide gives three methods of determining the crosswind during the test flight. Only one is representative for what a line pilot has to its disposal, the tower wind. Okay you also have the FMS wind on the Nav Display ND. Is that wind not like the INS wind mentioned in the Flight Test Guide? Unfortunately, the FMS wind is not what it appears to be, in particular during takeoff and landing. First, the FMS wind is not corrected to a height of 10 meters. At 500 ft. above ground level the wind is about 50% higher than at a height of 10 meters. Second, internal FMS calculation of especially the crosswind component during approach is filtered, delayed and very sensitive for small errors in track or heading measurement. Furthermore, the FMS wind is not corrected for sideslip. Therefore, when you decrab the aircraft the FMS will give you a completely wrong picture. To quote the chief test pilot of the former McDonnell Douglas Company, "*you can get any crosswind you like from the FMS by simply side slipping the aircraft*".

The same type of cup anemometers used to determine the tower wind, are generally used in the portable ground recording stations. The big difference is that the tower wind not necessarily reflects the actual wind you will encounter during the last part of the landing (just before touchdown). In general there can be several sources for uncertainty in the tower wind reports, as conveyed to the pilot. One of the main sources is obviously the stochastic character of the wind phenomenon, due to which the wind may change since the last report to the pilot. Other sources for uncertainty are the way the wind measurements are processed and the reporting procedures to the pilot (which by the way are all according to international standards and recommended practices for observing and reporting of surface wind characteristics!).

Depending on the way the data are analyzed crosswind derived from the INS system includes or excludes wind gusts. At least one large aircraft manufacturer uses the INS data to derive a crosswind by plotting the crosswind component as function of time. The crosswind at the time the aircraft is 10 meters above the ground is then read off the plot. Engineering judgment is used in fairing the data. Another manufacturer has a different approach in determining the crosswind value during flight tests. During the flight tests the pilots of this aircraft manufacture requested the tower wind when the aircraft was close to a height of 10 meters from the ground. The mean wind given was then used to compute the crosswind during the crosswind certification flights. If this last aircraft manufacturer had used the approach of fairing INS data as mentioned before, the demonstrated crosswind capability for one of their aircraft would have been at least 10 knots higher than presently mentioned in the AFM of this aircraft.

In summary, the Flight Test Guide leaves plenty of room for significant variations in the derived crosswind capabilities of an aircraft. The Flight Test Guide is still much under development. The latest draft of the revised Flight Test Guide (dated February 2002) gives some more clarification on certain points regarding crosswind certification, however the comments made here still apply.

4 Autoland

Many modern jet transport aircraft are certified and capable of performing autoland operations. These autolands are constrained with respect to crosswind. As opposed to the demonstrated crosswinds for manual landings, the autoland crosswind is always a limit. Autoland certification under crosswind conditions is established primarily through a large number of computer simulations of automatic landings of that particular aircraft. The simulations must show that under varying conditions the touch down performance complies with the criteria set by the FAR/JAR autoland requirements. By means of a specific set of flight tests, it must be demonstrated that the actual touch down performance falls within the footprint of the performed simulations. The maximum crosswind values for autoland operations are often less than the manually demonstrated crosswind landings. This is sometimes caused by system constraints. However, autoland certification is a time consuming process and therefore costly. Since autoland capabilities are mainly intended for low visibility operations (CATIII), the need for high crosswind limits is simply not there. This is the main reason for the lower crosswind limits. Many autoland systems should be able to handle higher crosswinds. For instance, the B767-400 has a maximum certified crosswind during autoland of 25 knots. Flight test with this aircraft showed that autolands in a 40 knots crosswind could be made. Similar the Fokker 100 has a limit of 25 knots, however flight tests showed that this aircraft could handle crosswinds up to 38 knots including gusts during an autoland.

5 Use of crosswind limits in practice

In the previous section it is explained how your aircraft has been certified for crosswind operations. The question remains how all this is translated into the numbers that you can find in your AOM. First of all, if hard crosswind limits have been established for an aircraft the AOM may never show higher values. However, as already noted most aircraft do not have hard crosswind limits. So, what happens then? A survey was taken of a number of operators worldwide. These operators were requested to send the crosswind limits for the aircraft they operated as published in their AOMs. The operators were also asked to provide information about any additional limitation posed on crosswind operations. From this survey the following interesting facts are identified for the operators surveyed:

- Most operators use crosswind limits that do not exceed the demonstrated crosswinds,
- Most of the operators include gusts in their crosswind limits,
- All operators adjust the crosswind limits for wet and contaminated runways,
- Some of the operators adjust the crosswind limits for visibility,

- Most of the operators have reduced crosswind limits for less experienced pilots. (Note that for instance FAR part 121.438 demands that first officers that have less than 100 hrs currency on type, are not allowed to make crosswind landings in excess of 15 knots),
- Most operators account for runway width.

Interesting is the fact that there are operators that use crosswind limits that exceed the demonstrated values. This is no problem as long as the aircraft does not have hard limits, at least seen from a legal point of view. Boeing has derived crosswind guidelines that exceed the demonstrated values, through piloted evaluations in an engineering simulator and engineering judgement without a having conducted a single flight test. These evaluations were made upon the request of some ETOPS operators who wanted to have more operational flexibility regarding the availability of alternate airports during an ETOPS flight. There has been criticism on this approach by certification authorities. Remarkable is the fact that these crosswind guidelines are based on steady wind (no gusts) conditions due to the difficulty in modelling gust in the flight simulator. However the acceptable gust value is still left to the operator. Interesting are the conclusions made by the Irish accident investigation board regarding a crosswind related accident with a B737-800: "*Lower crosswind limits aid the crews decision making process…in interests of flight safety*" and *"…it would seem prudent for the operator to review their crosswind limitations as a priority, in interests of flight safety"* (source: AAIU Report 2001-010). Increasing the limits as advised by Boeing, is fully contrary to these safety recommendations.

Adjustments for runway condition, runway width, and visibility are not considered during the crosswind certification. These adjustments are based on the advisory information provided by the manufacturer. Again a combination of piloted evaluations in simulators and engineering judgement are used to derive the numbers. However the quality of the mathematical ground model in a flight simulator in combination with the motion and visual ques of a simulator, is usually not high enough to allow sufficient confidence in the evaluation results. Therefore crosswind limits based on pilot evaluations in a simulator may prove significantly different (optimistic in most cases) from realistic values. Note again that flight tests are not conducted nor required by the civil aviation authorities.

The word "limit" does not apply to all operators. Some operators have no hard crosswind limits defined in their AOM. It is then left to the captain to decide whether he/she wants to land or not.

So how does crosswind certification affect you as pilot? A large part of the answer depends on who is the manufacturer of the aircraft you are flying. In addition, policy of the operator can be important. As a pilot, one should recall the description of the accident given at the beginning of this article.