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LANDING PERFORMANCE OF LARGE TRANSPORT AEROPLANES

1 Introduction

1.1 An analysis of recent worldwide landing overrun incidents reveals that an overrun is likely to be characterised by a fast, high approach with a prolonged 'float' and long touchdown onto a wet runway. The same study also shows that these incidents were by no means confined to landings onto 'limiting' runways.

1.2 The purpose of this Circular therefore is to review some of the basic principles of aeroplane landing performance, to enable the factors affecting the stopping capabilities of the aeroplane to be understood and to appreciate the operational considerations inherent in the Flight Manual performance data.

1.3 It is important to remember however, that this document is intended as a guide only. It must not be taken as qualifying in any way the effect of the regulations themselves.

2 Landing Distance Certification and Field Length Factors

2.1 For large aeroplanes on the UK register, two methods have been available to establish the landing performance, the 'Arbitrary' and 'Reference' methods. In both cases, the scheduled landing distance in the Flight Manual may be regarded as consisting of two parts, an airborne distance from a specified screen height at the runway threshold to touchdown, and a ground roll from touchdown to a stop.

2.2 The majority of aeroplanes in the UK have been certificated using the 'Arbitrary' method. The gross landing distance is established with various parameters set at specific values. For example, the screen height at the runway threshold is 50 ft, the runway is dry, and the aeroplane flown at the reference landing approach speed, VREF, which provides a margin over the stall speed and the minimum control speed in the landing configuration. Maximum braking is applied after touchdown.

2.3 This gross distance should be regarded as a theoretical minimum, consistent achievement of which requires a high level of pilot skill under favourable conditions, and concluding in a level of deceleration that would normally be considered excessive from the passenger comfort point of view. Consequently, in order to provide an operationally realistic level of performance, this gross distance is multiplied by a 'field length factor' to obtain the Landing Distance Required.

2.4 This factor accounts for the normal operational variability that can be expected in day to day service such that the chances of a landing overrun are remote. It should be appreciated that the value of the factor is not the same for all aeroplane types. For example, propeller aeroplanes are not as sensitive to excessive approach speeds as are jet aeroplanes, consequently they are subject to a smaller factor.

2.5 The 'Reference' method was available for some older certifications and attempted to determine directly the effects of operational variations that could occur in everyday service. The gross distance from a screen height of 30 ft was measured from a fast approach (VREF+15) onto a wet runway, and the greater of the all engines and engine out distances was scheduled. Because these variables were addressed directly, a smaller field length factor was applied to the resulting gross distances to obtain the scheduled Flight Manual data. This method of landing distance certification is no longer used.

3 Operational Landing Distance Requirements

3.1 Article 44 of The Air Navigation Order 2005 requires aeroplanes flying for the purpose of public transport to comply with the performance requirements of JAR-OPS 1. The relevant requirements of JAR-OPS 1 require that the factored landing distance required (LDR) does not exceed the landing distance available (LDA), after taking into account the following:

(a) The landing weight;

(b) the altitude at the aerodrome;

(c) the runway surface condition;

(d) the slope of the runway if greater than ±2%;

(e) (i) still air conditions in the case of the most suitable runway for a landing in still air conditions;

(ii) not more than 50 per cent of the forecast wind component opposite to the direction of landing or not less than 150 per cent of the forecast wind component in the direction of landing in the case of the runway that may be required for landing because of the forecast wind conditions.

3.2 In the interests of simplicity and statistical probability, these dispatch rules were not designed to cater for all contingencies and they apply only before the flight commences. Nevertheless, they should allow the crew to conduct the flight without having to make a critical decision regarding the performance of their aeroplane, provided that the assumptions made at despatch remain valid. However, it is not uncommon for a flight to depart when it is known to be very probable that because of the need to use a particular approach aid, a landing will have to be made downwind and possibly downhill. In these circumstances, and where there is little margin between LDA and LDR, operators should give advice as to acceptable tailwinds for given landing weights, taking account of runway slope and using 150% of the reported tailwind component.

3.3 Landing Weight

3.3.1 The practice of 'tankering' extra fuel is a widespread procedure, which has the inevitable effect of moving the aeroplane's weight and performance closer to all the limits for a given flight. In the majority of cases this is not significant, but it is clearly inappropriate when dispatching to those airports at which a number of adverse factors (eg weather conditions) affecting landing performance are anticipated.

3.4 Runway Slope

3.4.1 The landing distance operational factors specified in JAR-OPS 1 already account for uniform runway slopes up to ±2%, so no further adjustment is necessary. However, it has proved very difficult to find a general solution to the problem of the equivalence of a domed or dished profile to a uniformly sloping runway. Whilst the normal slope changes permitted on runways should prevent extreme cases from occurring, operators are advised to consider the profile, particularly when operating close to limiting landing performance conditions.

3.5 Runway Surface Condition

3.5.1 Under the Air Navigation (General) Regulations the customary method of calculating the landing performance required was, with very few exceptions, the consideration of a wet runway. JAR-OPS 1 however allows the landing distance to be predicated upon dry runway conditions provided that the runway is forecast to be dry at the estimated time of landing. Clearly, this provision carries with it the need to confirm, shortly before landing, that the runway has remained dry. Consequently, JAR-OPS 1 also requires an in-flight recheck of landing conditions to be performed as part of normal operational procedures.

4 In Service Landing Performance

4.1 Landing distances achieved operationally are affected by the variation in the values of various parameters from those assumed at certification. These include: Threshold speed; height over threshold; time from threshold to touchdown (float); delays in initiating stopping procedures; level of braking applied; runway friction.

4.2 Threshold Speed

4.2.1 As previously mentioned, either directly or indirectly, certification procedures consider an overspeed at the threshold of up to 15 kt. This upper limit has been chosen on the assumption that at any speed greater than this the pilot will discontinue the attempt to land.

4.2.2 Excess speed carried onto the runway will increase the possibility of an extended flare and increase the minimum stopping distance. It also reduces the margins available and promotes the likelihood of dynamic hydroplaning if the runway is covered with standing water.

4.2.3 Most operations manuals recommend the addition of a wind correction factor to the basic reference approach speed, VREF. The purpose of this is to provide protection against the reduction in wind speed close to the ground. In calm conditions, an increment of 5 kt is sometimes added. It should be remembered that the wind correction factor should be added to VREF and not to the calm conditions approach speed, VREF+5.

4.3 Location of the touchdown point

4.3.1 Another common factor in landing overrun incidents is a deep touchdown, which is most usually caused by excessive height at the threshold. An additional 200 ft of runway is needed for every 10 ft of excess height at the threshold.

4.3.2 An extended flare, concluding an otherwise accurate approach, might result in a smoother touchdown, but will use up valuable runway in the process. Aeroplanes can decelerate far more quickly on the ground than by floating along just above it. This merely reduces the available runway length in which the stopping procedures can have effect.

4.3.3 An additional factor to consider is that for a given threshold height and glideslope angle, a downhill runway will tend to yield an increased distance from threshold to touchdown compared with a level runway, if allowance is not made in the flare manoeuvre. Runways with a significant amount of downslope at the beginning of the landing run are most likely to cause problems in this area, and those in the UK are now highlighted in the AIP.

4.3.4 The conditions that create optical illusions which give misleading indications of height relative to the glidepath, created by, for example, sloped runways or by particularly narrow or wide runways are well known and should be anticipated when such characteristics are encountered. To help compensate in conditions where the visual perception of the flight path during a visual approach may be affected, all available runway approach aids should be utilised.

4.4 Ground Roll

4.4.1 Once on the ground, wheel braking is the most effective method of stopping the aeroplane. Hence it is important to commence braking as soon as possible. Reverse thrust and aerodynamic drag are more effective at higher speeds (and they are not affected by runway surface condition).

4.4.2 The effectiveness of the braking system is dependant upon tyre to ground friction, which the pilot can optimise by promptly lowering the nosewheel thereby ensuring the effective transfer of weight on to the main wheels.

4.4.3 Many aeroplanes are now fitted with automatic braking and ground spoilers (lift dump) systems. These usually depend upon wheel spin up and oleo compression signals to be activated before they can operate, so this is an additional justification for a prompt and positive touchdown.

4.5 Level of applied braking

4.5.1 Passenger comfort and brake wear considerations generally induce a reluctance to utilise the aeroplane's full braking potential. This is acceptable where other factors affecting stopping performance are favourable, for example when the braking action is good, and when the landing distance available is clearly not limiting. However, reduced braking will result in the erosion of the factors built into the scheduled landing distances and is not appropriate where the margin has been eroded for other reasons.

4.6 Approach profile

4.6.1 From the foregoing paragraphs it will be appreciated that achievement of the scheduled landing distances is optimised by the aeroplane being at the right speed at the right height at the beginning of the landing distance available. The importance of the contribution of an accurately flown, stabilised approach to this objective cannot be over emphasised. Crews should therefore not hesitate in carrying out a missed approach if it becomes apparent that the aeroplane will not cross the threshold at the correct height and speed and in the correct configuration.

5 Landing on Contaminated Runways

5.1 JAR-OPS 1 defines a contaminated runway as one which is covered with ice, snow, slush, or more than 3 mm of standing water.

5.2 Attempts to land on contaminated runways involve considerable risk and should be avoided whenever possible. Ideally, if the destination aerodrome is subject to these conditions the departure should be delayed until conditions improve, or an alternate used.

5.3 Advisory data in the Flight Manual or Operations Manual concerning landing weights and techniques on slippery or contaminated runways should be used to determine whether there is an adequate distance margin over and above the normal Landing Distance Required.

5.4 Operators should ensure that runways which are notified as being 'slippery when wet' are annotated as such in their operations manual and that appropriate guidance (such as landing technique, maximum weight, maximum crosswind, minimum headwind) is given to pilots having to land in these conditions.

5.5 Note that in conditions of heavy rain, depths of water exceeding approximately 3 mm can occur, and if present over a significant proportion of the length of the runway, will have an adverse effect on landing performance. Under these conditions, aquaplaning is likely to occur, with its attendant problems of negligible wheel braking and loss of directional control. For these reasons, crews should be familiar with the characteristics of aquaplaning, as its symptoms can be confused with braking failure.

6 Abnormal Configurations

6.1 Where dispatch is permitted in accordance with a Minimum Equipment List with unserviceabilities that affect the stopping performance of the aeroplane (eg thrust reversers, ground spoilers inoperative), performance corrections will be stated. These corrections are designed to account fully for the effects of the unserviceability and thus restore the normal safety factors in the scheduled performance data. However, this will reduce the usual margins between the landing distances available and required and pilots should therefore be mindful that judgements based on experience of operating onto a particular runway which is not normally limiting may no longer be valid.

6.2 Where a failure occurs in flight to other systems (eg restricted use of high lift devices) crews will normally be provided with advice on their effect on landing distance. Allowing for the low probability of such an occurrence, lower safety factors, if any, may have been applied compared to those used for the normal conditions. Therefore, even when such performance corrections are taken into account there may be a reduction in safety margins available to account for variations in, for example, touchdown accuracy or stopping technique. Other conditions, such as reduced wind limits, may also apply in such cases.

7 Inflight re-check of Landing Performance

7.1 As stated earlier, an aeroplane's suitability to land at the intended destination is predicted upon forecasts at the time of despatch. In order to ensure that the assumptions made at despatch remain valid, JAR-OPS 1.400 prescribes an inflight re-check requirement, and requires the commander to satisfy himself prior to commencing an approach to land, that a safe approach and landing can be made, taking into account the actual state of the aerodrome. This re-check is particularly important given that JAR-OPS 1 permits despatch on the basis of dry landing distances if the landing runway is forecast to be dry at the estimated time of landing.

7.2 Any significant departure from the flight plan, such as an unscheduled diversion, would clearly justify a review of the landing performance. If such a diversion was as a result of an emergency aeroplane condition which necessitated a prompt landing, then clearly this would be justification for contemplating a landing on a runway which, although nearby, could not fully accommodate the increase in the factored LDR due to the failure condition. Such a decision requires a sound knowledge of the principles involved to make an assessment of the conflicting considerations - the information given in this Circular should assist pilots in this task.

8 Summary

8.1 The certification procedures and operating requirements together address the reasonable variation of various parameters in day to day operations so that the probability of the Landing Distance Required exceeding the Landing Distance Available is remote.

8.2 However, the existence of these allowances should not be taken as an indication that there will always be adequate protection against an overrun if there is excessive threshold speed onto a limiting runway with questionable braking qualities. In arriving at the factor to cover residual variabilities such as height at the threshold, 'float' before touchdown, delays in commencing braking procedures, substandard wet runway braking action, their effect on landing distances are combined statistically, not arithmetically. It cannot be assumed that the scheduled landing distances can accommodate a landing in which all relevant parameters are at the limit of their tolerance in the adverse sense.

8.3 The highest degree of confidence in successfully achieving the scheduled landing distances is obtained by crossing the threshold at the correct height and at the target threshold speed, touching down firmly after a normal flare and applying maximum retardation without delay.

This Circular is issued for information, guidance and necessary action.

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