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CHAPTER 16
TAKE-OFF PERFORMANCE

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TAKE-OFF PERFORMANCE

INTRODUCTION

The minimum take-off distance is of primary interest in the operation of any aircraft because it defines the runway requirements. The minimum take-off distance is obtained by taking off at some minimum safe speed that allows sufficient margin above stall and provides satisfactory control and initial rate of climb.

Generally, the lift-off speed is some fixed percentage of the stall speed or minimum control speed for the aircraft in the take-off configuration. As such, the lift-off will be accomplished at some particular value of lift coefficient and angle of attack.

Depending on the aircraft characteristics, the lift-off speed will be anywhere from 1.05 to 1.25 times the stall speed or minimum control speed.

To obtain minimum take-off distance at the specific lift-off speed, the forces that act on the aircraft must provide the maximum acceleration during the take-off roll. The various forces acting on the aircraft may or may not be under the control of the pilot, and various procedures may be necessary in certain aircraft to maintain take-off acceleration at the highest value.

The power plant thrust is the principal force to provide the acceleration and, for minimum take-off distance, the output thrust should be at a maximum. Lift and drag are produced as soon as the aircraft has speed, and the values of lift and drag depend on the angle of attack and dynamic pressure.

In addition to the important factors of proper procedures, many other variables affect the take-off performance of an aircraft. Any item that alters the take-off speed or acceleration rate during the take-off roll will affect the take-off distance:

TAKE-OFF DISTANCE TABLE
Found in many Pilot operating Handbook

TAKE-OFF DISTANCE

PAVED, LEVEL, DRY RUNWAY, ZERO WIND, FLAPS UP

WEIGHT (LBS)	TAKE-OFF SPEED (KIAS) LIFT OFF	TAKE-OFF SPEED (KIAS) AT 50 FT	PRESSURE ALTITUDE (FT)	0°C GND RUN	0°C TOTAL TO CLEAR 50 FT	10°C GND RUN	10°C TOTAL TO CLEAR 50 FT	20°C GND RUN	20°C TOTAL TO CLEAR 50 FT	30°C GND RUN	30°C TOTAL TO CLEAR 50 FT
2300	60	65	SEA LEVEL	860	1500	900	1580	960	1670	1040	1770
			1000	920	1580	970	1670	1030	1750	1100	1860
			2000	1010	1700	1070	1800	1140	1940	1220	2060
			3000	1120	1840	1190	1950	1270	2040	1360	2270
			4000	1280	1980	1360	2100	1450	2230	1550	2490
			5000	1420	2200	1510	2330	1610	2470	1770	2720
			6000	1580	2420	1680	2560	1790	2710	1910	2960
			7000	1760	2680	1870	2830	1990	2990	2120	3210
			8000	1980	3020	2100	3180	2230	3350	----	----

NOTES: 1. For operation on a dry, grass runway, increase both distances, (i.e. "ground run" and "total to clear 50ft obstacle") by 5% of the "total to clear 50 ft obstacle figure".
2. Reduce take-off distances by 10% for each 10 kts headwind.
3. Increase take-off distances by 10% for each 5 kts tailwind, maximum tailwind component 10 kts.

The most critical conditions of take-off performance are the result of some combination of high gross weight, altitude, temperature, and unfavourable wind. In all cases, the pilot must make an accurate prediction of take-off distance from the performance data of the AFM/POH, regardless of the runway available, and strive for a polished, professional take-off procedure.

In the prediction of take-off distance from the AFM/POH data, the following primary considerations must be given:

- Pressure altitude and temperature - to define the effect of density altitude on distance.
- Gross weight - a large effect on distance.
- Wind - a large effect due to the wind or wind component along the runway.
- Runway slope and condition - the effect of an incline and the retarding effect of factors such as snow or ice.
-

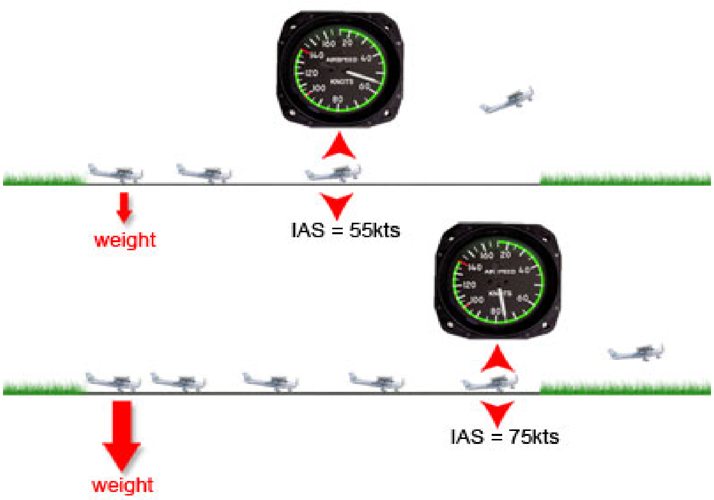
FACTORS AFFECTING TAKE OFF PERFORMANCE

Effect of Gross Weight

The effect of gross weight on take-off distance is significant and proper consideration of this item must be made in predicting the aircraft's take-off distance. Increased gross weight can be considered to produce a threefold effect on take-off performance:

- There is an increase in lift-off speed which is a function of stall speed.
- A heavier aircraft accelerates slowly so more runway length is required to achieve a given speed.
- It is more difficult to stop the aircraft if the take-off has to be aborted.

As a result of these factors, an increase in 10% of the take-off weight of a typical light aircraft will result in at least a 25% increase in take-off run. The increased weight will also reduce the rate of climb.



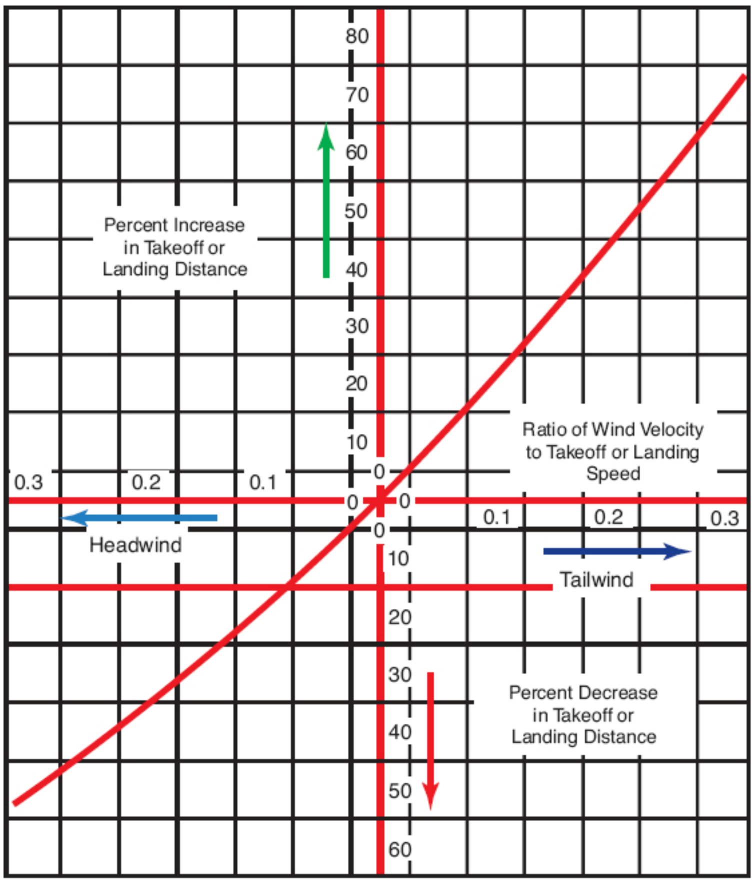
It is important to remember that maximum structural take off weight is a limitation that is imposed by the manufacture and must not be exceeded under any circumstances, otherwise structural damage may occur, another issue can arise from an overloaded aircraft, where that load factors may also be exceeded, for example in steep turn. A properly executed 60° angle of bank turn will result 2g load factor (twice the actual weight) so if you are 150kg over max take off weight, this in turn will require the wings to try and support an extra 300kg of apparent weight, exceeding the limitations imposed.

EFFECT OF WIND

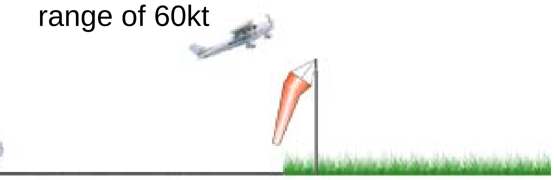
Of all the many factors affecting the performance of the aircraft during take-off by far the most significant is the wind. A headwind allows the aircraft to reach its take-off airspeed at a lower groundspeed so reducing its ground run. For example a headwind component of 20% of the lift-off speed will reduce the ground run by approximately 35% whereas a similar tailwind component will result in a 45% longer run than in still air.

The gradient of climb following lift-off will be steeper when taking off with the benefit of a headwind so improving obstacle clearance.

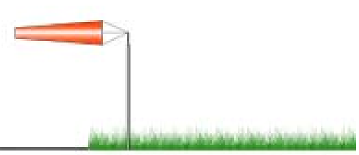
The effect of wind on landing distance is identical to the effect on take-off distance. The graph illustrates the general effect of wind by the percentage change in take-off or landing distance as a function of the ratio of wind velocity to take-off or landing speed.



Taking off in a NILL wind situation would mean that the aircraft will need to accelerate from an airspeed of zero to lift off speed, say 60kt. A speed range of 60kt



Taking off in a 40kt head wind situation would mean that the aircraft will need to accelerate from an airspeed of 40kt to lift off speed, say 60kt, A speed range of 20kts (shorter ground run)



Taking off in a 40kt Tail wind situation would mean that the aircraft will need to accelerate from an airspeed of minus -40kt to lift off speed, say 60kt, A speed range of 100kts (very long ground run)

Remember : <u>INDCATED</u> airspeed for each of the above examples at liftoff would be the <u>SAME</u>

GROUND EFFECT

Aircraft may be affected by a number of **ground effects**, or aerodynamic effects due to a flying body's proximity to the ground.

The most significant of these effects is known as the wing in ground effect, which refers to the reduction in <u>drag</u> experienced by an <u>aircraft</u> as it approaches a <u>height</u> approximately equal to the aircraft's <u>wingspan</u> above ground or other level surface, such as the sea.

The effect increases as the wing descends closer to the ground, with the most significant effects occurring at an altitude of one half the wingspan. It can present a hazard for inexperienced pilots who are not accustomed to correcting for it on their approach to landing, but it has also been used to effectively enhance the performance of certain kinds of aircraft.

EFFECT OF FROST, ICE OR SNOW

Even a small amount of ice, snow of frost on a wing can significantly reduce lift by up to 30 % in some cases, increase drag by up to 40 % in some cases, and increases aircraft weight.

It alters the performance characteristics of the wing and may significantly increase the speed associated with an aerodynamic stall.

It is essential that all ice, frost and snow is removed from the wings and if possible, the tailplane before flight. Many accidents involving large and small aircraft have crashed as a direct result of ice, frost and or snow accumulation.

EFFECT OF TAKE-OFF SPEED

The effect of proper take-off speed is especially important when runway lengths and take-off distances are critical. The take-off speeds specified in the AFM/POH are generally the minimum safe speeds at which the aircraft can become airborne.

Any attempt to take-off below the recommended speed could mean that the aircraft may stall, be difficult to control, or have a very low initial rate of climb. In some cases, an excessive angle of attack may not allow the aircraft to climb out of ground effect.

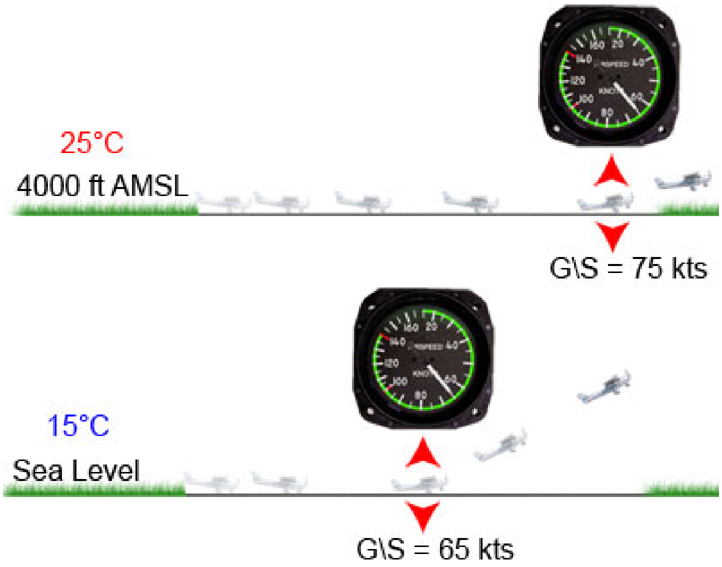
On the other hand, an excessive airspeed at take-off may improve the initial rate of climb and "feel" of the aircraft, but will produce an undesirable increase in take-off distance. Assuming that the acceleration is essentially unaffected, the take-off distance varies as the square of the take-off velocity.

Thus, 10 % excess airspeed would increase the take-off distance 21 %. In most critical take-off conditions, such an increase in take-off distance would be prohibitive, and the pilot must adhere to the recommended take-off speeds.

EFFECT OF PRESSURE ALTITUDE

Take-off on a day of low atmospheric pressure will also result in a longer take-off run, longer take-off distance and reduced rate of climb. We obtain mean sea level pressure as a QNH value and this must be taken into account in performance planning. We do so by calculating the airfield **pressure height,** which expresses atmospheric pressure in terms of its equivalent height in a standard atmosphere. Rather than enter performance charts with a hecto-pascal value, we find it more convenient to consider take-off in low atmospheric pressure the same as a take-off from an airfield at a higher elevation. Thus when QNH is low we add a correction to airfield elevation to obtain the airfield pressure height.

If an aircraft of given weight and configuration is operated at greater heights above standard sea level, the aircraft will still require the same dynamic pressure to become airborne at the take-off lift coefficient. Thus, the aircraft at altitude will take-off at the same indicated airspeed as at sea level, but because of the reduced air density, the true airspeed will be greater.



EFFECT OF AIR TEMPERATURE

Similarly high air temperatures result in lower air density and adversely affects take-off performance. We can combine our knowledge of temperature with the value we have found for airfield pressure height to find **density height.** This is an expression of atmospheric density in terms of its equivalent height in a standard atmosphere. Rather than to think of density as grams per cubic centimetre, it is much more convenient to talk of density height. Take-off in high air temperatures is like a take-off from an airfield at a higher elevation. So when temperature is high we add a correction to airfield pressure height to obtain the density height.

EFFECT OF RUNWAY SLOPE

An up-sloped runway will reduce acceleration and therefore increase the distance required for take off. Deceleration distance will be reduced in the event of an aborted take-off. The gradient of slope is given as a percentage, calculated by taking the elevations above mean sea level of both thresholds, finding the vertical difference and converting it to a percentage of the Take-off Run Available. A rule of thumb guide is that a 2% up-slope will increase the increase the take-off run by about 20%.

EFFECT OF RUNWAY SURFACE

Care should be taken to consider the effect of runway surface on take-off performance. A clean dry hard surface of concrete or bitumen will allow shorter runs than a surface of grass because of rolling resistance and braking effectiveness. Water will be a hazard as will snow or slush for the same reasons and will introduce additional hazards of slipperiness and aquaplaning. The load bearing strength of the surface material and construction is also of concern when operating heavy aircraft.

The following table indicates the effect of different surfaces on the length of the take-off run for a typical light aircraft :

RUNWAY SURFACE	*APPROXIMATE INCREASE IN TAKE-OFF RUN*
Short Grass	*10%*
Long Grass	*25%*
Soft Ground	*25% – 100%*

EFFECT OF FLAPS

The use of flaps for take-off will lower the stall speed and consequently lift-off will occur at a lower speed. Small amounts of flap will generally reduce the take-off run but may not significantly reduce the take-off distance which you will recall is the distance required to achieve the screen height of 35 or 50 feet. This is because in most aircraft the use of flaps reduces the lift-drag ratio and so reduces the rate of climb.