Stan/Eval Newsletter
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Wake Turbulence – AIN Insights

Wake turbulence can be a threat on any flight. Every aircraft, both large and small, generate wake turbulence as a function of creating lift. Wake turbulence vortices can vary in strength, duration and direction. If encountered, these vortices can cause a loss of control inflight event or accident. The trick to surviving a wake turbulence encounter is to avoid it altogether.

Under IFR flying, wake turbulence avoidance is accomplished by air traffic controllers applying minimum separation standards based on each aircraft's class, as determined by size or aerodynamic characteristics. Separation may be accomplished by assigning specific speeds (distance and time) or altitudes to be flown. Pilots are expected to fly the speed and altitude assigned by controllers to maintain this minimum separation.

A pilot accepting a clearance to visually follow a preceding aircraft accepts the responsibility for traffic separation and wake turbulence avoidance. This is a common scenario for a wake turbulence encounter when pilots accept a clearance for a visual approach behind landing traffic. In this case, the pilot must maintain separation both vertically and horizontally from the preceding aircraft.

According to the Aeronautical Information Manual (AIM), the most common hazard of a wake turbulence encounter is associated with induced rolling moments that can exceed the roll control authority of an aircraft. In rare cases, the wake encounter can cause catastrophic in-flight structural damage.

An in-flight wake turbulence encounter close to the ground is almost always fatal. Wake turbulence encounters at higher altitudes can only be mitigated through proper and appropriate upset recovery training.

Caution: Helicopter Wake Turbulence (NAFI eMentor)

There is not a mock check ride, or a real check ride (covering private, commercial, instrument) or CFI that does not include some conversation around the topic of wake turbulence from fixed-wing aircraft. Land beyond, take off before, wait three minutes. The reminder we are given from ATC goes something like this, "Cleared to land, caution wake turbulence, departing 737". What is surprising is just how little is taught about helicopter down wash and virtually nothing about helicopter wake turbulence.

How many times have you heard, "Caution helicopter wake turbulence" or "Caution wake turbulence departing/landing helicopter"? Think hard. OK, stop wasting your time because it is rare or even nonexistent.

Notice, I have used the term *wake turbulence* not *rotor downwash*. That is because they are distinctly different. Beside the fact that the rotor blade produces them both, they have little in common.

Downwash is produced while at a hover or very slow hover taxi. Wake turbulence is produced with the helicopter in forward flight starting approximately at 20 knots. Downwash in ground effect hits the ground and moves out 360 degrees from the helicopter with hazardous winds in an area up to three times the diameter of the rotor disc. Wake turbulence from a helicopter is more like that from an airplane and moves behind the aircraft while it is in forward flight.

In 1996, the FAA published a report (based on tests with wake vortex hazards) with the objective of determining the need for rotorcraft separation standards of following aircraft. When you hear the term wake vortex, think wake turbulence.

The testing included four helicopters—S-76, UH-60, CH-53, and CH-47. They used a T-34 and a Decathlon as wake turbulence probe aircraft. What was learned was that within 3 nm behind the helicopter the probe aircraft experienced bank angle upsets that exceeded 30 degrees and, in some cases, more. Some resulted in a spin.

C182 Crash after encountering Helicopter wake turbulence

More recently, a C-172 pilot experienced helicopter wake turbulence flying behind a departing R-44 that resulted in full aileron deflection and rapid increase in VSI, followed by a rapid decrease in VSI. An SR-20 landing behind a departing UH-60 ended up cartwheeling down the runway with substantial damage to the aircraft and injury to the pilot.

A PC-12 fixed-wing airplane landing behind a departing UH-60 experienced more than 30-degree bank angles. Due to fast pilot maneuvering and powerful thrust, the aircraft did not crash. In September 2021, an experimental Vans 20 departed behind a landing S-76 EMS helicopter. The airplane reached approximately 50 to 60 feet, rolled left and then rolled right until inverted. The aircraft impacted the runway, resulting in a post-crash fire and one fatality.

The 1996, an FAA study recommended that to avoid hazardous helicopter wake vortices and/or wake turbulence, fixed-wing aircraft in trail should remain 3 nm behind the helicopter. The report further shows that vortex decay time can take up to three minutes, depending on the size and speed of the helicopter.

It is imperative we teach our students about *both* the 3-rotor diameter rule when a helicopter is at a hover and to not cross with less than a three-mile separation behind a helicopter when it is in forward flight. CFIs and DPEs should include helicopters as part of the discussion about wake turbulence.

Wing and Power Loading Implications (Maj M. Banner FLWG)

Why can one airplane takeoff and land on short runways while another requires significantly longer takeoff and landing distances? Why does one airplane have better performance (rate of climb, airspeed) than another? Is the airplane you're about to fly underpowered or overpowered? The answers to these and similar questions lie in understanding aerodynamic concepts like Wing Loading and Power Loading.

Wing Loading, or the ratio of an airplane's weight to its surface area, is the average load each unit of the wing must carry. It's determined by dividing an airplane's current weight by its wing surface area (Equation 1). Power Loading, the ratio of airplane's weight to engine power output, is determined by dividing an airplane's current weight by the engine's generated horsepower (hp). (Equation 2).

$$\text{Wing Loading (lbs / ft}^2\text{)} = \frac{\text{Current weight (lbs)}}{\text{Wing surface area (ft}^2\text{)}}$$

(Equation 1)

$$\text{Power Loading (lbs / hp)} = \frac{\text{Current weight (lbs)}}{\text{Generated horsepower (hp)}}$$

(Equation 2)

Wing Loading	Power Loading
$14.7 \text{ lbs / ft}^2 = \frac{2{,}550 \text{ lbs}}{174 \text{ ft}^2}$	$14.2 \text{ lbs / hp} = \frac{2{,}550 \text{ lbs}}{180 \text{ hp}}$

(Equation 3)

For a jet-powered airplane, power loading may be determined as pounds of weight per pounds of jet thrust. For a propeller airplane like a Cessna 172S NAV III for example, at maximum ramp weight of 2,550 lbs, a 1G load imposed on the airframe and the engine operating optimally generating maximum 180 hp at normal barometric pressure and temperature has a wing loading of 14.7 lbs/ft^2 and power loading of 14.2 lbs/hp, respectively (Equation 3). So, exactly what do these numbers mean?

In general, airplanes with larger wing area and lower weight (low wing loading) can fly more slowly than an airplane with a higher wing loading. Airplanes with a smaller wing area and higher weight (high wing loading) must fly faster. As an example, compare a glider – low wing loading, say 5 lbs/ft^2 – to a military jet fighter and its much higher wing loading – say 100 lbs/ft^2. Power loading is used to determine if an airplane is underpowered, appropriately powered, or overly powered. Airplanes with relatively low horsepower and higher weight – i.e., with high power loading – say 16 lbs/hp – fly relatively slowly and may be considered as underpowered. Airplanes with more powerful engines and less weight – or with a very low power loading – say 5 lbs/hp – are capable of flying significantly faster and may be considered appropriately to overly powered. Obviously, appropriately and over-powered airplanes are capable of greater airspeed and climb performance than ones with low power loading.

Aircraft are designed to address specific needs, which, in turn, affect wing and power loading. For example, if an airplane is intended for short-field takeoff and landing (STOL) operations, where fast cruise speeds and high rates of climb are not priorities, a large wing surface area relative to the airplane's weight is used to minimize wing loading and maximize lift. The result is an airplane with short takeoff distance and low lift-off speed, as well as short landing distance and low landing reference speed (VREF). Although low wing loading is advantageous for STOL operations, there is a penalty; the greater the wing surface area, the greater is the drag, which limits cruise speed.

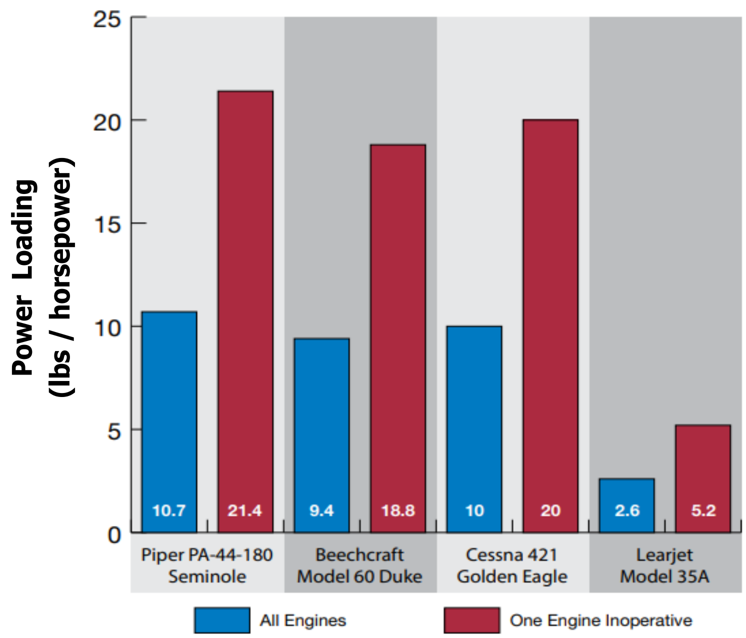
Airplanes designed with high wing loading – compared to those with relatively less wing loading – require longer takeoff and landing distances. For example, compare a Cirrus SR22 with wing loading of 23.5 lbs/ft^2, to a Citabria 7GCBC with a wing loading of 10.6 lbs/ft^2. That's 55% less than an SR22. Further, the SR22 has a sea level, standard day takeoff ground roll at maximum weight (3,400 pounds) of 1,058 feet; its landing ground roll is 1,161 feet. The 7GCBC has a sea level, standard day takeoff ground roll at maximum weight (1,800 pounds) of 231 feet. Its estimated landing distance under the same conditions is a mere 200 feet. When fast cruise airspeeds and high climb rates are intended—and STOL is not a priority – engineers design airplanes with high wing loading and low power loading. The lower the power loading, the greater will be its performance (airspeed and rate of climb) and vice versa. For example, the F104 "Starfighter" is characterized by very high wing loading and low power loading. It weighs 24,840 pounds and has a small wing surface area of 196 square feet. Consequently, wing loading is high at 126.7 lbs/ft^2. Its engine generates 14,800 pounds of thrust (afterburner on), resulting in very low power loading of 1.67 lbs/lb thrust, or a thrust-to-weight ratio 0.59. As one result of its low power loading, the F104 is capable of Mach 2 speeds and has a phenomenal rate of climb: 60,350 feet per minute.

A light sport aircraft (LSA), designed to meet a specific maximum weight of 1,320 pounds, typically has low wing loading, approximately 10 lbs/ft^2. Compared to aircraft with much higher wing loading, these aircraft are airborne at lower airspeeds and in shorter runway takeoff distances, tend to float on landing if speed is too great and are more affected by crosswinds at lower airspeeds. Additionally, they have reduced stability and a greater tendency to be bounced around by windy and turbulent conditions, wind gusts and thermals. They also may be harder to control and usually will have lower stalling speeds. An LSA's low wing loading can require greater effort to compensate for crosswinds and turbulence during landings.

Wing and Power Loading – moving numbers and not constant

Like stall speed, wing and power loading values are not constant and change with flight conditions. For example, current weight, a common factor in the aforementioned equations, directly affects wing and power loading. The word "current" connotes that aircraft weight is a variable. For example, a Cessna 172S has a Utility-category maximum takeoff weight of 2,200 pounds. At the same airplane's Normal-category max takeoff weight of 2,550 pounds, wing and power loading decrease proportionately by approximately 14%. A situation having the opposite effect on wing and power loading is a steeply banked, constant altitude turn. For a Cessna 172S at 2,550 pounds in a 60-degree bank, constant-altitude turn, the load factor is 2G's, which has the effect of doubling the airplane's weight to 5,100 pounds. Under this condition, wing and power loading (assume constant horsepower) increase by nearly 100% compared to its 1G condition. It should come as no surprise wing loading also has a direct effect on stall speed, which also is a moving number affected by a variety of factors, stall speed increases in proportion to the square root of wing's loading. Quadrupling wing loading doubles stall speed.

In Equation 2, the word “generated” preceding horsepower implies engine horsepower is not constant. Instead, it varies with throttle settings and with altitude. In fact, engine power output decreases by approximately 3% per 1,000-foot increase in density altitude for an aircraft with a normally aspirated engine. For example, at 5,000 feet density altitude, a Cessna 172S engine which is capable of generating 180 hp at sea level, generates a maximum of only 153 hp, a 15% reduction. Assume a load factor of 2G while in a 60 degree bank, constant altitude turn. What happens to power loading? It increases to 33.3 lbs/hp, significantly worsening flight performance (2G X 2,550 lbs = 5,100 lbs ÷ 153 hp). The greater the power loading, the worse the acceleration and climb capability, and vice versa.



Wing and power loadings presume these values remain constant. Nothing could be further from reality. At a minimum, an airplane’s weight decreases as fuel is burned. Airplanes engaged in firefighting and parachute operations routinely see wide variations in wing and power loading during a single flight. For the typical general aviation pilot, the most glaring – and challenging – changes in power loading will come when flying a twin-engine airplane following failure of one engine. As the figure demonstrates, losing half of an airplane’s power also doubles its power loading which in turn worsens its climb and flight performance. From the above, it’s easy to understand the old saying that: “A twin has two engines because it needs two engines”. However, note the Learjet 35A, it is so overly powered (power loading 2.6 lbs/lb thrust) that loss of one engine increases power loading to only 5.2 lbs/lb thrust, i.e., relatively good flight performance on one engine.

Everyday application

Being a safe, competent pilot requires more than knowing how to fly an airplane under various flight conditions. It also includes a practical understanding and application of relevant aerodynamic concepts like wing and power loading. Airplane performance and handling characteristics are significantly affected by the magnitudes and interrelationships of these two variables, to include but not be limited to takeoff and landing distances, climb performance, cruise airspeeds, airplane stability and stall speed. Knowledge of wing and power loading concepts help pilots to better understand their airplane’s capabilities.

Rehearse for the Worst! (LtCol P. Holt TNWG)

In the most recent issue of the Air Combat Command's (ACC) safety magazine "Combat Edge", there is an article titled "Rehearse for the Worst". This article reminded me of my 27-year Air Force career flying various aircraft and how we prepared for our operational and training flights. In around the table mission preparation with the crew, we would review a selected emergency procedure for the aircraft. In single seat aircraft we would also review an emergency procedure for the aircraft with our formation mates. Prior to taking the runway for takeoff we would brief engine failure procedures with the crew and in single seat aircraft, each pilot would mentally review engine failure procedures.

In the CAP, best safety and operational practices suggest that a crew briefing during mission planning should include a selected emergency procedure for the aircraft with your Mission Observer or Instructor Pilot (MO, IP). Also prior to takeoff, you should brief the crew of Engine Failure Before Takeoff and Engine Failure After Takeoff and any questions that they might have. This is covered in CAPS 73-1/attachment 3. Crew Resource Management (CRM) is imperative, and your crew needs to know what you plan to do in case of an engine failure emergency.
As the "Combat Edge" article says: "the more you rehearse for the worst, the better able you are to fall back on training when things go wrong".

Articles for the National Stan Eval Newsletter:

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