Load limit

Paul Phelan

You might think that a bit more weight will be OK, still within safety margins. But those extra kilos could push your aircraft to its breaking point.

THE B747-400 HAD completed loading at Singapore for its 14-plus hour flight to London, its final load figures indicating it would be 1.5 tonnes below its maximum take-off weight (MTOW) at brakes release.

However, noting that London Heathrow's forecast terminal weather was inhospitable and that the flight was carrying minimum fuel, the captain asked the first officer to have the refueller add the available 1.5 tonnes as extra fuel, warning him to be sure not to overfill. As the crew was receiving its airways clearance, the crew noticed the refueller had already added two tonnes, taking the aircraft 500kg over its MTOW.

What's half a tonne in almost 400? "There may be airlines that would carry the extra half a tonne for the sake of an on-time departure, but we're not one of them", said the skipper firmly. "I'll make sure it's burnt off before brakes release. Believe me, it doesn't take long."

It is that sort of uncompromising approach to safety that passengers expect, but don't always receive on a global basis.

Overloading is a common misdeed in general aviation, asserts a former GA chief pilot now flying with a major airline: "I was constantly astounded at the attitude of some of the people around me. In a single-

DAMIEN HEFFERNAN

"...the data suggest that even if the aircraft and its engines and propellers are in perfect condition and the pilot demonstrates test pilot quality handling, a rate of climb of marginally over zero feet per minute might be achieved at gross weight with gear and flaps retracted and cowl flaps open."

DAMIEN HEFFERNAN

engined aeroplane, you are told it doesn't make much difference to the engine-out glide angle. In a twin, they'll say you're in trouble anyway if an engine quits, so what's an extra couple of hundred kilos?"

Overloading is usually relatively easy to conceal, and in some cases there are commercial and personal pressures to overload.

You should understand the very real operational, structural, and legal implications.

The certification process establishes a series of weights for light aeroplanes where they meet various limiting structural, performance, or aerodynamic requirements. Typically these may include:

- A structural load limit, beyond which "permanent structural deformation" – failure – of critical components will occur.
- Weights according to certification category beyond which the aircraft cannot achieve minimum performance specifications.
- In some cases there may even be a weight which brings the aircraft to a maximum allowable stall speed for the certification category, or a weight beyond which spin recovery will be unsatisfactorily slow, or may not even be achievable.

The lowest of these limiting weights defines the aircraft's certified maximum take-off weight, which may then be further reduced, for a particular flight, by ambient conditions such as density, altitude and/or limiting take-off distance available.

Performance: Take the structural load limit. Normally GA aircraft are designed to 3.8G plus 50 per cent for the "ultimate load factor", to which they're tested by loading the wing up with sandbags, or with mechanical devices. At 3.9G the aeroplane is not allowed to suffer "structural deformation" (to bend permanently). At the ultimate load, (5.7G), it is allowed to bend, buckle and crumble, but if it stays in one piece and the controls can still operate, that's as far as the testing goes, and the structure will be certified.

If an aircraft is operated at a higher weight than its MTOW, failure will occur at a lesser "G" load. How much less, nobody knows, because the testing has not established that – and it may not be a simple linear relationship, it could be an accelerated one. Safety investigations have produced records of numerous structural failures which occurred within a particular type's fatigue life. There are even instances in which aircraft wings have been permanently deformed, usually during recovery from a high speed spiral dive, but the aircraft have remained flyable; which gives some confidence in the safety buffers provided by the certification process.

In Australia, CAO 20.7.4 requires GA twins in commercial operations under the IFR to be capable of a one per cent minimum climb gradient at 5,000ft in ISA (international standard atmosphere) conditions, with the critical engine shut down. For GA twins in other operations, the maximum weight is the one demonstrated to maintain height at 5,000ft. For VFR, the applicant has only to demonstrate a positive cleaned-up single-engine climb after take-off in ISA conditions. And remember, those trials were conducted in as-new aircraft, by an experienced test pilot, and usually in calm air.

Remember also that ISA conditions are defined as 15°C at sea level with a QNH of 1013.2KPa, and that in most of Australia for most of the year, temperature and pressure conditions are far more inhibiting than ISA.

If you are interested in understanding the realities of performance expectation, you should examine a type's certified engine-out flight manual performance following an engine failure after take-off on a summer day, where temperatures of 45°C are common.

The limited pilot operating handbook data for one well-known light twin does not provide figures for temperatures above 100°F (37.7°C). However, the data suggest that even if the aircraft and its engines and propellers are in perfect condition and the pilot demonstrates test pilot quality handling, a rate of climb of marginally over zero feet per minute might be achieved at gross weight with gear and flaps retracted and cowl flaps open. And that's before the effects of local turbulence and wind shear are taken into account.

Graph interpolation shows that with a 400lb (181kg) overload, the best engine-out performance you could hope for would be about a 100fpm rate of descent. If you hoped to achieve anything like a 150fpm rate of

DAMIEN HEFFERNAN

Faced with a choice of leaving behind fuel or payload, the latter is a safer option.

climb under those circumstances, you would need to be about 600lb (three passengers plus baggage) below MTOW.

Remember that for US-certified light twin-engined aircraft, there is no spin recovery certification requirement; stalls are carried out in a 30° banked turn at only one degree per second deceleration; no tests are carried out above MTOW; and none at CofG positions beyond the maximum.

This means that the behaviour of the aircraft in those configurations is literally unknown, and you are well advised not to explore it. It's also worth remembering that test pilots exploring the aerodynamics of high-weight and extreme CofG carry parachutes, and on a number of occasions have used them! A small number of fatal accidents in Australia have been attributed in part to the pilot's inability to recover from an unintentional stall/spin, and weight and its distribution have been recurrent factors.

Fatigue: Another issue that has received little attention in US light aircraft certification is fatigue, as a structural fatigue expert points out:

"Aluminium structures will always fatigue – it's not a question of whether they will or not; it's a question of when. And it can easily be accelerated. If you regularly fly at only three per cent overloaded, the chance of having a wing come off is roughly doubled. At 10 per cent overload the safe life of the airframe may be reduced by 40 per cent."

Since the release of amendment 7 to FAR 23 (which became effective in 1969), the design standard for light aircraft, has included a requirement for consideration of structural fatigue "unless it is shown that the structure, operating stress level, materials and expected uses are comparable, from a fatigue standpoint, to a similar design that has had extensive satisfactory service experience." This exclusion clause applies to the majority of GA aeroplanes.

Even some aircraft in current production have their certification basis set at FAR 23 amendment 6 so they avoid the current structural fatigue requirements.

However Australia has applied its own fatigue requirements down through the decades, which is why some aeroplanes here have a retirement life on one or more of the critical highly stressed structural components such as lower spar caps.

Overloading scenarios: Consider a couple of credible Australian flight situations:

You're flying a six-seat twin on a bad-weather departure from a country aerodrome where there's no precision approach. You're 150kg above MTOW, most of which is in the aft locker because there was nowhere else to load it. You've just cleaned up for the climb, and you begin to throttle back when

> **"...test pilots exploring the aerodynamics of high-weight and extreme CofG carry parachutes, and on a number of occasions have used them!"**

one engine loses all power; fortunately you are able to feather the propeller. You "fly the aircraft" at exactly the best rate-of-climb speed, carefully trimming out while holding your heading. Already in cloud, you focus on not wasting a foot of altitude or a knot of airspeed. No problem, because this aeroplane has proved it can maintain a one per cent positive climb gradient at 5,000ft, OK?

Not really, because an experienced test pilot did that with a new airframe 30 years ago in calm conditions at ISA, and not overloaded. Today, it's ISA +12 and turbulent. Nevertheless, the aerodrome field elevation is only 1,000ft, and there should be enough margin if you keep the speed pinned.

But are you holding the right speed? Best-performance speed is related to weight, is calculated from the chart, and the chart stops 200kg short of your actual weight. You lower the nose to pick up a couple more knots. Then through a momentary cloud break you get a glimpse of a hill a bit too close. Instinctively you raise the nose a little.

The speed drops further than you'd like. At the reduced speed you find you're almost out of rudder authority to keep the aircraft straight because the aft CofG has eroded your stability. Nose down again, but the heavily loaded aircraft doesn't recover its speed as briskly as it otherwise would, nor does the rudder authority seem to improve as you hoped. The instability causes extra drag and costs you energy. This time, let's say you get a cloud break, find a good airstrip straight ahead, and get away with it.

Another scenario: Your aircraft suffered an unreported heavy landing two years ago, which started a minuscule crack in a bolt hole used to attach an undercarriage fitting to the main spar. The crack is concealed by the undercarriage attachment casting. You're loaded with supplies for a mining camp close by, so you're not carrying much fuel, but lots of payload, all in the fuselage.

The small crack has caused normal wing flexing and landing loads to place extra stress on the surviving structure, which has in turn caused the crack to grow. The last major inspection didn't require a look at the area. The crack was so small it probably wouldn't have been found anyway. Your zero fuel weight overload is located to maximise wing-bending moment. You're now outside the original safety margins in terms of maximum weight, fore-and-aft load distribution, and wing-bending moments. One flight, very soon, something will go SNAP.

Turbulence: Now let's assume ahead of you is an area of severe turbulence generated by outflows from a nearby thunderstorm. A sudden updraught seizes your aeroplane, followed by an equally sudden and violent downdraught. You decide conditions ahead may be even worse and that it's time to take emergency avoidance action. You're pulling 2.5G in a tight pull-up turn when the next updraught arrives, instantly doubling the 2.5G structural load.

Properly loaded, your aeroplane might have sustained 3.8 x 1.5 = 5.7G. Now, with MZFW exceeded by 12 per cent, at 5G, even for a second, the weakened wing simply fails.

If you do survive an accident and it's found that you were overloaded, you've voided your company's insurance unless the owner can prove he or she didn't know about the overload. Most operators are likely to try very hard to prove that. Is overloading really worth it?

Paul Phelan is a freelance aviation journalist and former regional airline pilot.