OUTSIDE THE LIMITS

The flight envelope defines the safe operating range of an aircraft. We look at how a pilot can stay within the envelope, and the consequences of not doing so.

Beyond the specified G-force and airspeed limits – the flight envelope – damage or deformation of an aircraft *can be expected*.

Overloading the structure of an aircraft through wind shear, turbulence, or extreme manoeuvres can be disastrous.

Structural overloading

In general, aircraft strength is measured by the total load the wings are capable of supporting without permanent damage.

Aircraft are built to allow for 'ultimate load' factors generally 50 percent greater than the normal limit loads. Deformation might occur beyond the limit load, but breakage can occur beyond the ultimate load.

Under normal operation, an aircraft should stay within limit load levels, but factors such as extreme control inputs, sudden gusts, or excessive airspeed, can push the airframe closer to the ultimate load, and closer to breakage.

Structural fatigue

Every airframe is subjected to a range of stressors during its operating life, all of which could eventually lead to fatigue and failure. This is where proper maintenance and careful flight habits make all the difference.

Fatigue will develop over time, leading to cracks that grow rapidly until reaching complete failure. Weather, loading, speed, and G-force all contribute to this process.

Flying a plane at high speed in turbulent conditions will not only increase stress, but also increase the number of fatigue cycles in a given time period.

Similarly, a pilot who frequently pulls high G will contribute to fatigue damage at a greater rate than a pilot who is gentle with their aircraft.

Flutter

Flutter occurs when a part of the aircraft vibrates due to aerodynamic, inertial, and elastic forces, giving the same effect as a flag in the wind.

Ailerons are most susceptible to this effect, and gliders are particularly at risk due to their structural elasticity and propensity for high altitude operation.

An aircraft is designed to be 'flutter-free' within its flight envelope.

When encountering flutter, a quick reduction in airspeed and raising the nose may damp it out. Without taking action, the flutter could continue amplifying to the point of tearing the control surface or airframe apart. In the wrong circumstances this can happen in seconds.

Weight and balance

Weight and balance have a direct impact on the stress experienced by an aircraft.

Additional weight reduces angle and rate of climb, reduces ceiling and range, and increases landing speed and landing roll. It will also increase structural stress, and must be taken into account when considering the envelope.

Flying within the envelope

To remain within the flight envelope, a pilot must maintain input levels and speed appropriate for the conditions.

A gust while flying too slowly in turbulence can result in a stall condition, while flying too quickly can overstress the airframe.

The greatest safety margin can be found at manoeuvring speed, which is specified by the aircraft manufacturer. Overload damage is still possible at or below this speed, but is extremely unlikely in normal flight conditions.

Even at manoeuvring speed, excessive control inputs can result in damage. Rolling and pulling at the same time can also increase structural loads by one third.

In summary, stay within your flight envelope by keeping within published G and airspeed limits, fly appropriately in turbulence, and be particularly cautious about control inputs when at speed or under high G.

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