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Preliminary Study of Aircraft Dynamics and Performance: High Gust Condition Aspect

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Abstract

The performance capabilities of a certain model of airplane are always related to standard atmosphere (29.92 inches of mercury at 15° C at sea level). However, only rarely will the airplane actually operate under conditions that approximate standard atmosphere. Any increase in temperature or altitude means a decrease in the aircraft's optimum performance. Air density decreases with altitude. At high elevation airports, an airplane requires more runway to take off. Its rate of climb will be less, its approach will be faster, because the true air speed [TAS] will be faster than the indicated air speed [IAS] and the landing roll will be longer. Air density also decreases with temperature. Warm air is less dense than cold air because there are fewer air molecules in a given volume of warm air than in the same volume of cooler air. As a result, on a hot day, an airplane will require more runway to take off, will have a poor rate of climb and a faster approach and will experience a longer landing roll. In combination, high and hot, a situation exists that can well be disastrous for an unsuspecting, or more accurately, an uninformed pilot. The combination of high temperature and high elevation produces a situation that aerodynamically reduces drastically the performance of the airplane. The horsepower out-put of the engines decrease because its fuel-air mixture is reduced. The propeller develops less thrust because the blades, as airfoils, are less efficient in the thin air. The wings develop less lift because the thin air

exerts less force on the airfoils. As a result, the take-off distance is substantially increased, climb performance is substantially reduced and may, in extreme situations, be non-existent. Humidity also plays a part in this scenario. Although it is not a major factor in computing density altitude, high humidity has an effect on engine power. The high level of water vapor in the air reduces the amount of air available for combustion and results in an enriched mixture and reduced power. A gust or bump increases the load on the wings. The speed of the airplane should therefore be reduced when flying in gusty air. In approaching to land, on the other hand, a little higher speed should be maintained to assure positive control.
A number of important aspects related to the problem of flight through turbulent air will be discussed herein. The first aspect to be considered is the sensitivity of a particular aircraft to turbulence. Performance requirements of the aircraft (speed and range, etc.) govern the aspect ratio and wing loading which directly influence the sensitivity of the aircraft to gust disturbances. A second aspect considered is the probability of encountering turbulence of various intensities during low level flight operations. The third aspect is the effect of turbulence-induced vibrations on the comfort and task performance capabilities of the crew. The fourth aspect is the alleviation of turbulence-induced vibrations and loads.

Keywords: Flight Performance, Dynamics, Gust condition, inversion model.

1. Introduction

Weather is an important factor that influences aircraft performance and flying safety. It is the state of the atmosphere at a given time and place, with respect to variables such as temperature (heat or cold), moisture (wetness or dryness), wind velocity (calm or storm), visibility (clearness or cloudiness), and barometric pressure (high or low). The term weather can also apply to adverse or destructive atmospheric conditions, such as high winds, gust conditions, etc. Air flows from areas of high pressure into areas of low pressure because air always seeks out lower pressure. Air pressure, temperature changes, and the Coriolis force work in combination to create two kinds of motion in the atmosphere—vertical movement of ascending and descending currents, and horizontal movement in the form of wind. Currents and winds are important as they affect takeoff, landing, and cruise flight operations. Most importantly, currents and winds or atmospheric circulation cause weather changes. The stability of the atmosphere depends on its ability to resist vertical motion. A stable atmosphere makes vertical movement difficult, and small vertical disturbances dampen out and disappear. In an unstable atmosphere, small vertical air movements tend to become larger, resulting in turbulent airflow and convective activity. Instability can lead to significant turbulence, extensive vertical clouds, and severe weather. Be it a local flight or a long cross-country flight, decisions based on weather can dramatically affect the safety of the flight.

2. Defining Gust

Adverse weather (other than low visibility and runway condition) is a circumstantial factor in nearly 40 percent of approach-and-landing accidents.

Adverse wind conditions (i.e., strong cross winds, tailwind and Gust) are involved in more than 30 percent of approach-and-landing accidents and in 15 percent of events involving CFIT.

Gust is the primary causal factor in 4 percent of approach-and-landing accidents and is the ninth cause of fatalities.

Table 1: Weather factors in Approach-and-landing Accidents.

Factor	% of Events
Adverse weather	40 %
Adverse wind (all conditions)	33 %
Gust	4 %

Gust is defined as a sudden change of wind velocity and/or direction.

Gust occurs in all directions, but for convenience, it is measured along vertical and horizontal axis, thus becoming vertical and horizontal Gust:

2.1 Vertical Gust:

The variations of the horizontal wind component along the vertical axis, resulting in turbulence that may affect the aircraft airspeed when climbing or descending through the Gust layer. The variations of the wind component of 20 kt per 1000 ft to 30 kt per 1000 ft are typical values, but a vertical Gust may reach up to 10 kt per 100 ft.

2.2 Horizontal Gust:

The variations of the wind component along the horizontal axis (e.g., decreasing headwind or increasing tailwind, or a shift from a headwind to a tailwind).These variations of wind component may reach up to 100 kt per nautical mile.

Gust conditions usually are associated with the weather situations such as Jet streams, Mountain waves, Frontal surfaces, Thunderstorms and convective clouds, Micro bursts, etc. Gusts associated to jet streams, mountain waves and frontal surfaces usually occur at altitudes that do not present the same risk than micro bursts, which occur closer to the ground.

3. Influence of Gust Conditions on Aircraft Performance

The flight performance is affected as the Headwind gust instantaneously increases the aircraft speed and thus tends to make the aircraft fly above intended path and/or accelerate (Figure 1, item 1). Also, a downdraft affects both the aircraft Angle-Of-Attack (AOA), that increases and the aircraft path since it makes the aircraft sink (see Figure 1, item 2). Apart from this, Tailwind gust instantaneously decreases the aircraft speed and thus tends to make the aircraft fly below intended path and/or decelerate (see Figure 1, item 3).

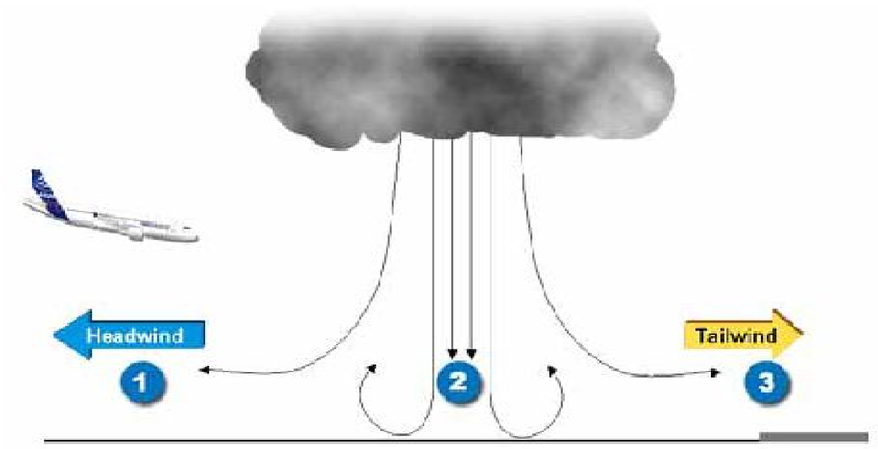

Figure 1: Gust effects on flight performance.

4. Recognition of Gust Conditions

Timely recognition of Gust conditions is vital for the successful implementation of the gust recovery/escape procedure. Some of the deviations which may be considered as indications of a possible gust include variation of Indicated airspeed in excess of 15 kt; Ground speed variations; Analog wind indication variations: direction and velocity; Vertical speed excursions of 500 ft/mn; Pitch attitude excursions of 5 degrees; Glide slope deviation of 1 dot and Heading variations of 10 degrees.

Also, an optional Gust warning is available on most aircraft models. The gust warning is based on the assessment of current aircraft performance (flight parameters and accelerations).The gust warning is generated whenever the energy level of the aircraft falls below a predetermined threshold. The wind shear warning system associated to the Speed Reference System (SRS) mode of the flight guidance constitute the Reactive Wind shear Systems (RWS), since both components react instantaneously to the current variations of aircraft parameters. To complement the reactive wind shear system and provide an early warning of potential gust activity, some weather radars feature the capability to detect gusty areas ahead of the aircraft. This equipment is referred to as a Predictive Wind shear System (PWS).

5. Conclusion

Knowledge of the atmosphere and the forces acting within it to create weather is essential to understand how weather affects a flight. By understanding basic weather theories, a pilot can make sound decisions during flight planning after receiving weather briefings. Also, the crew should remain alert to recognize a potential or existing gust conditions, based on all the available weather data, on-board equipment and on the monitoring of the aircraft flight parameters and flight path, and timely measures should be taken to enhance instruments scan, whenever conditions for potential gust exist.

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