Concept: AIRCRAFT STABILITY

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1. Definition

A condition is said to be stable if the response to a small perturbation is to negate the effect of the perturbation. Aircraft Stability is defined [1] as the property of an aircraft to maintain its attitude or to resist displacement, and if displaced, to develop forces and moments tending to restore the original condition.

2. Introduction

When a child launches a paper airplane, the most frequent cause of an unsuccessful flight is that the airplane flips out of control to an extreme attitude and loses lift. This is usually because the airplane is not statically stable. With small adjustments to the weight distribution, or by deflecting a control surface, the flight characteristics of the paper airplane can be greatly improved. Flight vehicles are usually designed so that small perturbations to the flight condition, such as those due to gusts or unintended movements of the controls, result in a response that reduces and cancels out the perturbation. An airplane flying along a generally horizontal path is said to have positive longitudinal static stability if an increase in lift results in a pitching moment that reduces the angle of attack and thus reduces the lift coefficient. This occurs if the center of gravity of the vehicle is ahead of the center of pressure. This is a strong reason why small single engine airplanes have the engine located at the front, putting this large weight far forward from the center of gravity. To counter the nose-down pitching moment about the center of gravity, a horizontal tail or canard is used. The tail may have to exert a small downward lift under some conditions to maintain stability. If the opposite were true, that is, the center of pressure were ahead of the center of gravity, then an increase of lift would cause the airplane to pitch up, further increasing the angle of attack and thus the lift. This is an unstable condition. Similar considerations apply for yaw and roll stability. In the case of roll, the speed of the roll reduces the angle of attack of the upward-moving wing and increases that of the downward-moving wing, hence providing the restoring moment. In the case of yaw, the force on the vertical tail offers the stabilizing response to a yaw perturbation. The amount of restoring moment available, is measured by the tail volume, which is the product of the projected surface area of the tail and the moment arm from the

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aircrafts center of gravity to the centric of the tail area. For instance, one design criterion for the size and location of the vertical tail on a twin-engined aircraft is that the tail volume must be large enough so that the side force available by deflecting the rudder (without stalling it) at takeoff speed must be enough to counter the yawing moment due to failure of one engine while the other is at maximum thrust. The excess moment available beyond the most demanding anticipated condition is called the static margin. The price of having a large static margin, apart from increased structural weight, is that more control force is necessary to deliberately change the attitude of the aircraft.

3. Advanced

Although a vehicle may be statically stable and generate a restoring response to a perturbation, there may be a phase difference between the perturbation and the response. Thus the effect of a pitch-down moment, for instance, may be that the aircraft actually pitches down, but then pitches back up again. Dynamic stability refers to keeping perturbations from growing at any frequency. A statically stable vehicle might go into increasing dynamic oscillations, such as the phugoid mode of longitudinal instability where the aircraft pitches up and down in a sinusoidal oscillation. This is often a very slow movement with a period of several seconds. A severe example of a dynamic roll instability is the phenomenon of wing rock motion which may be very rapid.

4. Supersets

Statics, Dynamics, Weight and Balance.

5. Subsets

Static stability, static margin, dynamic stability, phugoid, wing rock, fishtail, resonance, divergence, tail volume, stick force.

6. Other fields

Spacecraft stability, propellant stability, combustion stability

7. Notes:

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8. Byline

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[2] NASA: 08 Aircraft Stability and Control. Scope and Subject Category Guide , Scientific and Technical Information, NASA http://www.sti.nasa.gov/sscg/08.html

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