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Thesis Abstract

Methodologies for Using Satellite-Based Positioning Systems in Determining Vibration Parameters of Aircraft Structure

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This thesis looks into applications of GPS other than navigation that would improve the performance, reduce the cost and enhance the safety of aircraft. General Aviation (GA) category of aircraft is the one that benefited least from technological improvements, despite the fact that GA pilots are, in general, in greatest need of maximum technological support. The emphasis of this work is on GPS applications for light aircraft, however, most of the conclusions, are equally applicable to other categories of flying vehicles as well.

Most GPS receivers perform very accurate position and velocity measurements and an appropriate placement of antennas at the extreme points of an aircraft's structure enables the attitude of the aircraft to be easily determined and consequently controlled without using any other sensors. However, the fact that the aircraft is not a rigid structure results in a reduced accuracy of this approach.

A proposed solution to this problem is the addition of a centrally located antenna used as a reference point, which makes the peripheral antennas capable of measuring both the periodic and non-periodic wing flexure. The accuracy of the wingtip displacement is thus significantly improved using the relative GPS positioning. Oscillatory wing motion can be measured only to an extent determined by the positioning frequency of the given GPS receiver. A method developed here takes into account low-frequency natural modes of the wing and monitors whether the frequency of the actual wing motion approaches a natural frequency established earlier. This will not only improve the safety by providing a warning against flutter, but also provide a long-term fatigue indication.

The varying amount of fuel in the wing tanks throughout the flight is also considered in this thesis. The relationship of the fuel status and frequency domain parameters of the wing is established both analytically and experimentally.

Based on this work, two practical applications are examined. One is the use of the experimental modal analysis for detecting structural deterioration; the other one is a GPS-based Flight Management System for light aircraft named AWIMI. The former proposes two novel methods of ground vibrations tests used for determining modal frequencies to be monitored in flight. The latter uses the GPS data and fuel data, compares the distance to the destination with the rate of fuel flow and warns the pilot when the remaining fuel is insufficient to complete the flight.

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