

ABSTRACT

Maintaining survivability of asymmetrically wing-damaged civil aircraft has been a very important, fairly recent and not a very well researched problem in the aircraft flight mechanics and control domain. Moreover, for fighter aircraft, apart from structural wing damage, significantly asymmetric dynamics may also result from asymmetric firing of onboard stores. Inviting such asymmetry is, in deed, permissible as it allows for carrying nonidentical stores, non-paired firing, and getting rid of carrying dummies altogether. Moreover, asymmetric ejection of stores with a relative velocity not only gives rise to mass asymmetry, but also produces unwanted reaction impulses potentially affecting the intended motion of the aircraft. The situation further aggravates when, due to combat and safety demands, the aircraft is required to go in for some complex maneuvers under such asymmetric conditions. These issues have not been addressed in the literature and the present thesis is aimed at filling this gap.

First, the six degree-of-freedom dynamics of the laterally mass varying aircraft is derived from a variable mass system perspective. Two different approaches are considered to derive the model from the first principle. Thereafter, the global behavior of the asymmetric dynamics is studied using bifurcation analysis technique and a hitherto unknown modest spiral dive like mode is found to emerge in the asymmetric condition even in the low angle-of-attack regions. Moreover, this mode is observed to become significantly steeper as the centre of gravity shifts farther from the plane of symmetry. Also, a novel attempt is made to correlate the bifurcation diagrams with the static characteristics of the aircraft. Next, it is demonstrated that if the closed loop controllers are designed in the conventional way then the sudden lateral centre of gravity movement significantly deteriorates maneuver performance especially while performing some aggressive post stall maneuvers such as the cobra and the Herbst. To overcome the problem, four novel closed loop control formulations are proposed using the sliding mode technique. With their own advantages and disadvantages, they are shown to recover back the lost maneuver performance to great extents. Further, a novel single loop sliding mode control formulation is proposed to perform the cobra and aileron roll maneuvers under both normal and asymmetric conditions. This demonstrates that the conventional inner-outer loop control implementation based on the time scale separation of the aircraft dynamics may be completely removed in some flight control problems.