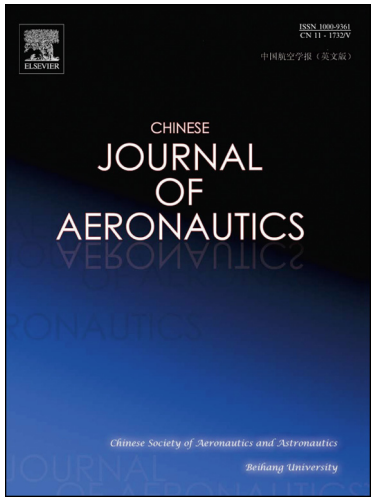

Full length article

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Active fault tolerant control for vertical tail damaged aircraft with dissimilar redundant actuation system

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Abstract

This paper proposes an active fault-tolerant control strategy for an aircraft with dissimilar redundant actuation system (DRAS) that has suffered from vertical tail damage. A damage degree coefficient based on the effective vertical tail area is introduced to parameterize the damaged flight dynamic model. The nonlinear relationship between the damage degree coefficient and the corresponding stability derivatives is considered. Furthermore, the performance degradation of new input channel with electro-hydrostatic actuator (EHA) is also taken into account in the damaged flight dynamic model. Based on the accurate damaged flight dynamic model, a composite method of linear quadratic regulator (LQR) integrating model reference adaptive control (MRAC) is proposed to reconfigure the fault-tolerant control law. The numerical simulation results validate the effectiveness of the proposed fault-tolerant control strategy with accurate flight dynamic model. The results also indicate that aircraft with DRAS has better fault-tolerant control ability than the traditional ones when the vertical tail suffers from serious damage.

Keywords: Fault-tolerant control; Model reference adaptive control; Linear quadratic regulator; Vertical tail loss; Nonlinear aircraft model; Electro-hydrostatic actuator; Dissimilar redundant actuation system

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1. Introduction

Structural damage to an aircraft, like the damage/loss of a vertical tail, can lead to loss of controllability, which would create a challenging situation for the pilots.[1-3] An example of such a situation, is the disaster that involved the Boeing 747 freighter aircraft that crashed in Mount Osutaka in 1985, with no one survived (520 fatalities). In this particular case, the aircraft lost the vertical tail and the hydraulic pipelines were pulled apart. This damage caused significant loss of controllability and, next to that, structural changes, which led to the crash. Another such similar example was 2001-A300, vertical tail loss, 265 fatalities. Such failures were likely to be survivable, if given correct control input and a wise trajectory. However, there were no effective measures for these aircraft with traditional centralized hydraulic actuation system (HAS) in such extreme situations, since the vertical tail loss would pull apart the hydraulic pipelines and lead the aircraft to lose pressures to actuate. Fortunately, the modern civil aircraft are developing towards the trend of being powered electrically more and more. Electro-hydrostatic actuators (EHA) have been applied in aircraft together with traditional centralized HAS, which produces dissimilar redundant actuation system (DRAS). [4,5] Consequently, there has been a growing interest in new-type aircraft with this kind of new actuation system. The commercial aircraft, A380, A350 and A400M of Airbus Company have adopted