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Optimized Fighter Aircraft Roll Stabilizer for Better Suppression of the Falling-Leaf *

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ABSTRACT

Appropriate structure and tuned controller for aircraft control surfaces is essential in achieving agile (desirable transient) and safe operation. Traditionally gain scheduling is employed for aircraft automatic control design which couplings among variables are usually undermined. This is adequate for conventional maneuvers; however, (fighter) planes which may undertake aerobatic or sharp maneuvers, due to the nonlinear nature of the aircraft dynamics, may be faced with nonlinear phenomena such as the falling leaf mode. In this paper, a modified structure for roll controller is suggested and its parameters are tuned using genetic algorithm which outperforms the one that has already been employed in the system. Comparative simulations are provided to support the idea.

Keywords: Flight control, Falling leaf, Lateral stabilization

I. INTRODUCTION

The main function of control loop of an aircraft is to ensure the desired lateral, longitudinal and directional command is followed perfectly in all intended flight maneuver over a wide range of working conditions, and unexpected disturbances. Although the flight control system constitutes a small part of the overall navigation, its role is essential in a safe aircraft operation. A correctly tuned feedback control guarantees exact pilot command tracking, suppression of external disturbances (e.g. wind gusts), and maintaining dynamical behavior in presence of variations of aircraft parameters (robustness against parametric uncertainties).

Design of such a control system for an aircraft, however, is challenging. The aircraft dynamic is highly nonlinear, due to the severe kinematics and inertial coupling of the variables, and its parameters are time variant, imprecise and heavily dependent on flight conditions (e.g. angle of attack, side slip angle) [1]. As a result, a lot of conventional and advanced control techniques, such as proportional-integral-derivative (PID), fuzzy logic (FL) [2], robust [3], sliding mode [4], $H\infty$, dynamic inversion [5], a combination of model inversion with an online adaptive neural network, a nonlinear adaptive design based on back stepping, neural networks [6], RBFNN based adaptive design [7] all have been tried with promising achievements.

However, traditionally aircraft controller is designed employing gain scheduling (GS) approach where the system dynamic for each axis about its operating point is linearized and PID controller is applied separately for each of them where the inertial cross-couplings among roll, pitch, and yaw dynamics are assumed negligible [8].

In case of highly maneuvering aircrafts, such as F/A-18, the proof of sufficiency of the technique comes under scrutiny, especially when an aircraft crash occurs. Severe roll rate coupling can destabilize the lateral autopilot and cause accident. Ignoring the nonlinear effects due to high angle of attack, sideslip and or high angular rates is no longer appropriate. The flight out of control falling-leaf is one of such a nonlinear phenomenon which cannot be portrayed by the aircraft linear model [9]. Therefore, in the case of F/A-18, the baseline controller was replaced by a revised one to suppress the falling leaf mode [1].

In this paper, a new structure for the roll controller is suggested in need for better falling leaf mode

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