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Design and comparison of LQG/LTR and H_∞ controllers for a VSTOL flight control system

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Abstract

In this paper two robust controllers for a multivariable vertical short take-off and landing (VSTOL) aircraft system are designed and compared. The aim of these controllers is to achieve robust stability margins and good performance in step response of the system. LQG/LTR method is a systematic design approach based on shaping and recovering open-loop singular values while mixed-sensitivity H_∞ method is established by defining appropriate weighting functions to achieve good performance and robustness. Comparison of the two controllers show that LQG method requires rate feedback to increase damping of closed-loop system, while H_∞ controller by only proper choose the weighting functions, meets the same performance for step response. Output robustness of both controllers is good but H_∞ controller has poor input stability margin. The net controller order of H_∞ is higher than the LQG/LTR method and the control effort of them is in the acceptable range.

Keywords: VSTOL flight control; LQG/LTR design; Kalman filter; Robust control

1. Introduction

In recent years there has been considerable interest in the application of advanced control theories to the design of flight control systems for vertical short take-off and landing (VSTOL) aircrafts [1]. The trust vector propulsion actuation technology allows

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these types of aircrafts to have high agility and wide range of maneuverability, but made it a difficult system to operate and control. Several controller design methodologies have been proposed for such aircrafts in literatures. Eigenstructure assignment which is a well-suited method for multivariable control systems design has been used for VSTOL aircrafts in [2,3]. Because of high and complex nonlinearities of dynamic of VSTOL aircrafts, nonlinear control design techniques are one of the main candidates [4]. Linearization of nonlinear VSTOL plant made it possible to use linear control methodologies such as PID controllers with fuzzy supervisory [5]. Even in the case of high-order nonlinear plants robust control methods can be used to compensate for uncertain high frequency dynamics and neglected actuator effects [6–8].

In this paper we shall describe the application of LQG/LTR method, to design a VSTOL aircraft pitch plane dynamic control system and the results are compared with the controller designed based on H_∞ method. Through all of the design procedure a linearized operating point is considered and the performance and robustness are the main design objectives.

In this regard, the paper will appear as follows: after describing the model of VSTOL aircraft in Section 2, LQG/LTR method is briefly introduced, and a robust controller for VSTOL aircraft is designed based on it. In Section 5, H_∞ method and its application to design of VSTOL pitch plane is explained and the obtained controllers are compared from the performance and robustness points of view. Finally, Conclusions are presented in Section 5.

2. Aircraft problem description

The generic VSTOL aircraft model was developed by royal aerospace Establishment (RAE) provides a vectored thrust aircraft model for use in advanced vertical short take-off and landing (AVSTOL) studies and also for real-time piloted simulations. The model is highly comprehensive, taking in to account of such things as aerodynamic interference, effects from the vectored thrust as well as modeling the aerodynamic coefficients and nonlinear engine effects [9]. The flight case considered here is at 120 knots, in which the condition of aircraft is semi-jetborne as shown in Fig. 1. The linearized A, B and C matrices of the state space model which are given in appendix comprise a forth-order rigid body model, a third-order engine model, and actuators are modeled by first order lags [11]. The objective is to design a longitudinal control law to provide tracking of airspeed, flight path angle and pitch rate using the inputs tail-plane, throttle and nozzle. The symbols

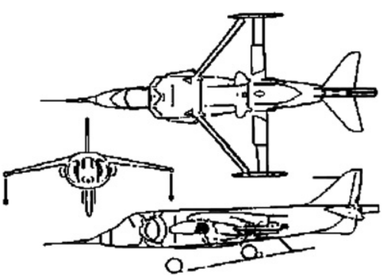

Fig. 1. A general semi-jetborne VSTOL aircraft.