

LONGITUDINAL STABILITY AUGMENTATION DESIGN WITH TWO DEGREE OF FREEDOM CONTROL STRUCTURE AND HANDLING QUALITIES REQUIREMENTS

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Abstract

This paper presents the design of longitudinal stability augmentation system (SAS) using a two degree of freedom control structure based on the LQR¹ technique in the frequency domain, which is robust to plant uncertainties, sensor noise and external disturbances. The design incorporates various handling quality requirements involving modal and bandwidth domain criteria. The design is done looking its use in the possible alternative mode in fly-by-wire aircraft with relaxed stability. The approach is applied throughout the flight envelope of a commercial aircraft and the first results obtained are presented.

1 Introduction

An aircraft model, characterized by its weight, center of gravity (x_{cg}) position, airspeed, altitude, flight path angle, flaps configuration, and landing gear position among others, is subject to a wide range of parameters variation. These characteristics change its dynamics and for this reason a dynamic mode that is stable and adequately damped in one flight condition may become unstable or at least inadequately damped in another flight condition. In commercial aircraft a lightly damped oscillatory mode may cause a great deal of discomfort for passengers or make it difficult for the pilot to control the aircraft. For a combat aircraft this condition may lead to a more critical

situation because the aircraft is already inherently unstable due to the maneuverability requirements and capability of attack.

These problems are overcome by using feedback control to modify the aircraft dynamics. Also aircraft's manufactures are currently developing improvements in terms of weight diminution, aerodynamic efficiency and optimization of fuel consumption. These changes are naturally leading to design of new airplanes with relaxed stability, increasing the use of feedback control laws [1]. Either a Stability Augmentation System (SAS) to increase and to change the natural frequencies of aircraft modes or a Control Augmentation System (CAS) to control the modes and to provide the pilot with a particular type of response are used as control laws. In this sense a Two Degree of Freedom (TDOF) controller [2] is normally used to project a Stability Augmentation System.

The TDOF is a robust control strategy that guarantees a better performance against uncertainties, sensor noise and external disturbances when compared with some classical techniques [3]. The structure was successfully implemented for control position problem in a SCARA manipulator robot [4] and at the present moment, a technique extension, applicable to commercial and military aircrafts, is being developed.

The project focuses on finding optimal gains to shown robustness at different flight conditions using fixed gains instead of traditional gain scheduling. The gains are calculate using a LQR

¹Linear Quadratic Regulator

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Aeronautical Engineering ,1971 A selection of annotated references to unclassified reports and journal articles that were introduced into the NASA scientific and technical information system and announced in Scientific and technical aerospace reports STAR and International aerospace abstracts IAA *Design of a Flight Director/configuration Management System for Piloted STOL Approaches* ,1973 ICAS Proceedings, 1986 International Council of the Aeronautical Sciences. Congress, International Council of the Aeronautical Sciences, 1986 **International Aerospace Abstracts** ,1998 OSTIV Publication , **Fundamentals of High Lift for Future Civil Aircraft** Rolf Radespiel, Richard Semaan, 2020-10-17 This book reports on the latest numerical and experimental findings in the field of high lift technologies. It covers interdisciplinary research subjects relating to scientific computing aerodynamics aeroacoustics material sciences aircraft structures and flight mechanics. The respective chapters are based on papers presented at the Final Symposium of the Collaborative Research Center CRC 880 which was held on December 17-18 2019 in Braunschweig Germany. The conference and the research presented here were partly supported by the CRC 880 on Fundamentals of High Lift for Future Civil Aircraft funded by the DFG German Research Foundation. The papers offer timely insights into high lift technologies for short take off and landing aircraft with a special focus on aeroacoustics efficient high lift flight dynamics and aircraft design Proceedings International Council of the Aeronautical Sciences, 1984 **NASA SP.** ,1993 **Aeronautical Engineering - A Special Bibliography with Indexes /supplement 1/** ,1971 *Proceedings of the ... Congress of the International Council of the Aeronautical Sciences* International Council of the Aeronautical Sciences. Congress, 1994 **The Aeronautical Journal** ,1971 Vertica ,1981 Effects of Forebody Strakes and Mach Number on Overall Aerodynamic Characteristics of Configuration with 55 Deg Cropped Delta Wing Gary E. Erickson, 1992 *Government Reports Announcements* ,1975-02-07 **Government Reports Announcements & Index** ,1975 **UTIAS Report** University of Toronto. Institute for Aerospace Studies, 1971 **Rotorcraft Design** North Atlantic Treaty Organization. Advisory Group for Aerospace Research and Development, 1978 *Scientific and Technical Aerospace Reports* ,1987 Lists citations with abstracts for aerospace related reports obtained from world wide sources and announces documents that have recently been entered into the NASA Scientific and Technical Information Database *Fifty Years of Flight Research* David F. Fisher, 1999 A bibliography of Technical Reports from Dryden Research Center 1946-1996. Dryden was a National Advisory Committee for Aeronautics (NACA) facility from 1946-1958 when NACA became NASA National Aeronautics and Space Administration. This bibliography encompasses both NACA and NASA publications. Illustrated with diagrams and photos. Black and white version. *Synergistic Airframe-propulsion Interactions and Integrations* Steven F. Yaros, 1998 This white paper addresses the subject of Synergistic Airframe Propulsion interactions and integrations. **SnAPII** The benefits of **SnAPII** have not been as extensively explored. This is due primarily to the separateness of design process for airframes and propulsion.

systems with only unfavorable interactions addressed The question How to design these two systems in such a way that the airframe needs the propulsion and the propulsion needs the airframe is the fundamental issue addressed in this paper Successful solutions to this issue depend on appropriate technology ideas This paper first details some ten technologies that have yet to make it to commercial products with limited exceptions and that could be utilized in a synergistic manner Then these technologies either alone or in combination are applied to both a conventional two engine transonic transport and to an unconventional transport the Blended Wing Body Lastly combinations of these technologies are applied to configuration concepts to assess the possibilities of success relative to five of the ten NASA aeronautics goals These assessments are subjective but they point the way in which the applied technologies could work together for some break through benefits

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