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ABSTRACT

FACULTY OF ENGINEERING AND APPLIED SCIENCE

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FLIGHT DYNAMICS AND AUTOMATIC FLIGHT CONTROL SYSTEM OF AN HYPERSONIC TRANSPORT AIRCRAFT

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Since it is expected that an hypersonic transport aircraft (HST) could significantly affect the nature of future overseas travel, this thesis examined the problem of providing an automatic flight control system (AFCS) which would provide effective flying qualities in a variety of conditions.

No such HST has yet been designed, hence all the work carried out was based on a mathematical model of the HST flying at different hypersonic speeds and heights. It was found from a study of the uncontrolled aircraft's dynamic characteristics that the aircraft was both statically and dynamically unstable, and hence the principal requirement of the AFCS was to stabilise the aircraft. In preference to several alternative control theories, the theory of the Linear Quadratic Regulator (LQR) was used to obtain the design of the AFCS because it guaranteed closed-loop stability with considerable robustness. The commonly perceived disadvantage of using LQR theory viz. the arbitrary choice of the state-weighting matrix, was overcome by developing a new method of determining the state-weighting matrix based on desirable values of the eigenvalues of the closed-loop AFCS. These eigenvalues were chosen to result in the required flying qualities. To protect the aircraft in the event of control failure required that a reconfiguration control system be provided. The effects of noise on the feedback control law were also examined, and a study of minimising these effects by the use of an active filter was carried out. It is shown from an evaluation of the resulting covariances that the use of a deterministic Luenberger estimator provided results as good as those obtainable from a Kalman filter for which the noise uncertainties had to be assumed. Since thrust was used as one of the controls, a non-linear dynamic model of a probable propulsion system was simulated and included in the AFCS to establish the extent to which the non-linear dynamics affected the aircraft flying qualities, but no significant effects were observed. The use of an optimal tracking system to achieve optimal trajectory flight was also considered.

The work of this thesis shows that complete stable control of an HST in the presence of the control failure, changing flight conditions, non-linear engine dynamics, and feedback sensor noise contamination can be achieved by the AFCS design presented.