Optimal Control of Supersonic Inlet/Engine Combination

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This paper applies the techniques of modem optimal control theory to the design of a contol system for a two-input, two-output inlet/engine combination. The mathematical model of the integrated combination is formulated using an idea of flow matching of the inlet and the engine. The control problem is approached as a stochastic linear quadratic regulator problem. The state estimator is designed by a recursive eigenvalue-eigenvector method for a linear time-invariant state equation. The results of a digital simulation for a NASA 48 cm inlet/J85 engine combination show that this design method is satisfactory.

Introduction

THE integrated two-variable control of a supersonic inlet/engine combination is one of the important problems in the development of high-performance supersonic propulsion systems. Cole et al.,[1] Paulovich et al.,[2] and Baumbick et al.[3] have studied this problem by analog simulation with stiff differential equations composed of a first-order lag element for the medium-frequency inlet shock dynamics and a first-order lag element of low-frequency engine dynamics. Actually, the medium-frequency transient behavior of the inlet shock dynamics has been greatly simplified and the transient behavior of many other important parameters (such as engine turbine inlet temperature, compressor outlet pressure, etc.) ignored. Lehtinen et al.,[4] Zeller et al.,[5] and Seidel et al.[6] have studied the linear stochastic optimal control of a supersonic inlet with a single input and a single output, both analytically and experimentally. Zeller[7] has given a comprehensive survey on the application of modern control theory to engine control. DeHoff and Hall[8] and Skira et al.[9] have presented their valuable works on the application of optimal control to the acceleration of aircraft turbine engines. Lee and Guan[10] have presented a paper on the optimal control of the change of state in an aircraft turbine engine. But the optimal control problem for a two-variable system has not yet been solved.

This paper is devoted to presenting an analytical design method for such an optimal control problem (see Fig. 1). The two-variable control consists of a constant shock position X_s control, and a constant engine speed N control. The weighted summation of variances in increments of the controlled variables (X_s and N) and of the control variables (inlet bypass door control U_{BP} and fuel flow rate W_F) is selected as the performance index.

Formulation of the Integrated Control Object

Figure 2 is a block diagram of this system. The integrated control system consists of two main components (inlet and engine) and three accessories (bypass door, actuator, and main fuel pump). Downstream stochastic airflow disturbance ΔW_w, shock position and rotor speed measurement stochastic disturbances ΔV_{XS} and ΔV_N, are taken into consideration.

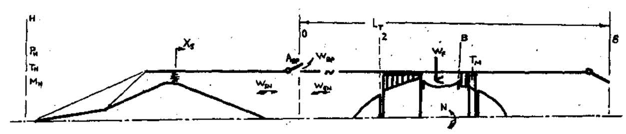

Fig. 1 Schematic diagram of the inlet/engine combination.

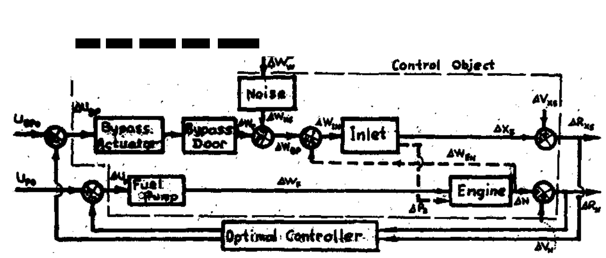

Fig. 2 Block diagram of the optimal control system of the inlet/engine combination.

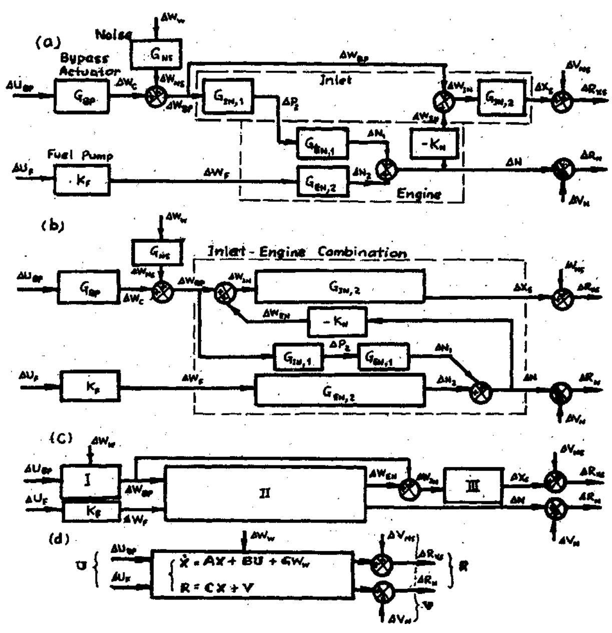

Fig. 3 Transformation of block diagram of the inlet/engine combination.

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