Genetic Algorithm Frequency Domain Optimization of an Anti-Resonant Electromechanical Controller

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Abstract. The new standard for actuators in the aerospace industry is electromechanical actuators. This paper describes an approach whereby PID and DFF controllers are used in unison to effectively manipulate a thrust vectoring system.

1 Introduction and Background

Thrust vector control (TVC) is a prime example of an aerospace system in which electromechanical actuators (EMAs) can potentially be effective. Researchers at NASA's Marshall Space Flight Center are currently developing EMAs to replace the hydraulic servo actuators for use on space vehicles with TVC. The current paper focuses on the control of EMAs in TVC applications and on the optimization of such control systems with genetic algorithms (GAs).

2 Problem Environment

Thrust vector control involves the manipulation of engine thrust direction to achieve attitude adjustment of a vehicle. Figure (a) illustrates the placement and function of the actuators for TVC. The objective of the current effort is to develop an EMA controller that can provide accurate engine position control (high bandwidth) while at the same time rejecting the disturbance forces encountered during startup and shut down.

Scott and Karr [1] presented a control system for manipulating the TVC that incorporated the PID and DFF controller architectures. This control architecture is presented in Figure (b).

3 Results

In this problem, a GA is asked to determine values for five control gains used in the control system. Each parameter was represented with an eight-bit substring. A fitness function was defined that considered (1) the magnitude of the

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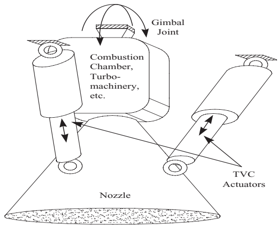
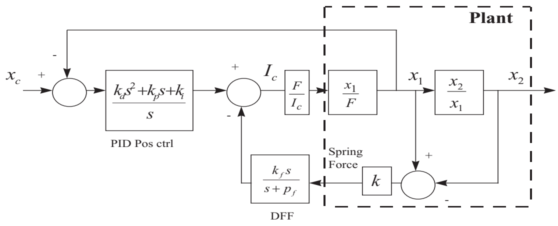


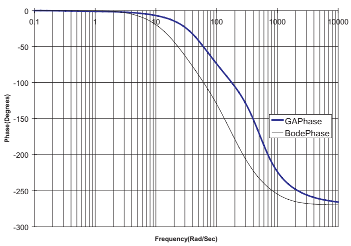
(a) TVC operation



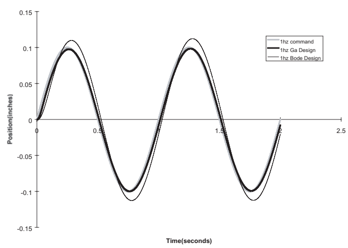
(b) Block Diagram representation of total system

frequency response, (2) the number of peaks in the frequency response, and (3) the rate at which the frequency response decreases.

Figures (c) and (d) compare the performance of the GA-designed controller to that of the previously best-known Bode controller. This figure shows that the GA controller produces a smaller phase lag in the engine closed loop frequency response for higher frequency ranges when compared closed loop system incorporating the Bode controller. This accentuates the tracking ability of the GA controller. The GA design produces a higher bandwidth than the Bode controller. Additionally, by reducing the resonant peak in the Bode controlled system, the GA controller provides a higher overall phase margin.



(c) Phase of the Engine frequency response



(d) Engine response due to a .1in 1hz sine input

References

1. Scott, D. A., Karr, C. L., & Schinstock, D. E. (2003). Genetic algorithm frequency domain optimization of an anti-resonant electromechanical controller. *Engineering Applications of Artificial Intelligence*, **12**, 201–211.