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A hybrid control approach for pole assignment to second-order asymmetric systems

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ABSTRACT

Structural modification in the form of adding mass and stiffness (and sometime damping) as a means of passive control to assign desirable poles and zeros for symmetric systems has been extensively studied. Pole and zero assignment by means of active control has also attracted much research. Assignment of poles to stabilise second-order damped asymmetric dynamic systems using structural modifications and state-feedback control, respectively, was carried out recently. It was found that the former is often incapable of assigning complex poles with negative real parts for asymmetric systems while the latter is nearly always capable of doing that. However, the gains required to assign poles with negative real parts using active control can be high.

This paper presents a two-stage passive (structural modification) and active (state-feedback) combined control approach to assign complex poles with negative real parts to damped asymmetric dynamic systems to suppress flutter instability. This hybrid approach is motivated by possible restriction to gains of actuators and cost of sole active control. Simulated numerical examples show its effectiveness over the individual control strategies of passive control and active control.

1. Introduction

Vibration in engineering structures is often undesirable and should be reduced. There are many ways of suppressing vibration. One philosophy is to assign desirable poles (damping ratios and natural frequencies) to avoid resonances or reduce responses at resonances, or assign zeros to certain locations or assign a mode or modes to a structure. Pole assignment in the first-order state-space formulation has been studied for many years in the control community. Typical results can be found in [1]. Vibration of machines and structures are governed by second-order differential equations, which should be the natural home for structural vibration control. Inman [2] suggested that new and useful results in the future would be more likely to come from formulating problems in physical coordinate systems. Partial pole assignment and (full) pole assignment in the second-order formulation were described in [3,4]. Poles and eigenvectors can be assigned simultaneously [4]. These methods may be classified as model-based, where the system matrices (mass, stiffness and sometimes damping) are required; and as non-model based, where such information, though useful, is not required. Receptance-based methods belong to the latter category.

Assigning modal properties using receptances has clear advantages. Weissenburger [5] studied assignment of a single frequency by a unit-rank modification. Yee and Tsuei [6] studied how to shift a number of frequencies. He and Li [7] investigated assignment of zeros, and zero and pole cancelation. Mottershead studied zeros and their sensitivities [8] and zero assignment using measured receptances [9]. Kyprianou et al. [10] assigned frequencies to a frame structure by adding a beam.

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