Mechanical Systems and Signal Processing 25 (2011) 112–122

Contents lists available at ScienceDirect

Mechanical Systems and Signal Processing

journal homepage: www.elsevier.com/locate/jnlabr/ymssp

Robust pole placement in structures by the method of receptances

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ARTICLE INFO

Article history:
Received 23 December 2009
Received in revised form
3 March 2010
Accepted 18 April 2010
Available online 24 April 2010

Keywords:
Robust pole placement
Receptance method
Structures

ABSTRACT

The problem of robust pole placement in structural vibration using receptance data is considered. Expressions are derived for the sensitivities of the eigenvalues to perturbations in the measurements and for robustness to measurement errors these sensitivity terms should be made as small as possible. A sequential multi-input state-feedback approach is described and by this procedure it is shown that a different eigenvalue may be assigned at each step without changing those eigenvalues assigned at previous steps. The columns of the force distribution matrix are chosen to excite easily the eigenvalue considered at the current step of the procedure. The sequential approach has the advantage of a characteristic equation that is linear in the control gains and is shown to be inherently more robust to measurement noise than the single-input method. The effects of sequential multi-input state feedback when combined with minimisation of eigenvalue sensitivity norms are investigated.

1. Introduction

The problem of eigenvalue assignment dates from the 1960s when Wonhan [1] showed that the controllability of an open-loop system was equivalent to assigning an arbitrary set of closed-loop poles. Porter and Crossley [2] developed a modal-control method whereby the gains were selected to satisfy orthogonality of the eigenvectors so that the unassigned eigenvalues remained unchanged. Kautsky et al. [3] showed that the assigned poles were as insensitive as possible to perturbation of the gains and system matrix terms when the closed-loop eigenvectors were made to be as close to orthogonal as possible. Juang et al. [4] used QR decomposition (equivalently singular value decomposition) to make the closed-loop eigenvalues as well conditioned as possible, thereby extending the work of Kautsky et al. [3]. Juang and Maghami [5] considered the second-order matrix pencil and assigned the poles of the system robustly, so the closed-loop eigenvectors were chosen to be as close as possible to a well-conditioned matrix. Chu [6] modified and re-interpreted the work of Kautsky et al. [3] and Juang and Maghami [5] for second-order systems by using results from the theory of matrix polynomials [7]. Datta et al. [8] developed three orthogonality equations for the second order pencil and went on to show how they could be applied in partial pole placement to assign certain selected poles while the other poles remained unchanged. Mottershead and Ram [9] carried out a survey of research on inverse eigenvalue problems in vibration absorption, including both passive and active methods for eigenvalue assignment.

A new approach to eigenvalue assignment in structural vibration problems was introduced by Ram and Mottershead [10] based on measured receptances and without the need to know or evaluate the **M**,**C**,**K** matrices. This work, mainly on single-input state feedback, has been further developed to include the assignment of eigenvalue sensitivities [11] and to

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0888-3270/$ - see front matter
doi:10.1016/j.ymssp.2010.04.005