Robust Control for Offshore Steel Jacket Platforms under Wave-Induced Forces

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Declaration

The work contained in this thesis has not been previously submitted either in whole or in part for a degree at Central Queensland University or any other tertiary institution. To the best of my knowledge and belief, the material presented in this thesis is original except where due reference is made in text.

Dongsheng Han

20 July, 2007

Abstract

This thesis is concerned with robust control of an offshore steel jacket platform subject to nonlinear wave-induced forces. Since time delay and uncertainty are inevitably encountered for an offshore structure and their existence may induce instability, oscillation and poor performance, it is very significant to study on how the delay and uncertainty affect the offshore structure. In this thesis, a memory robust control strategy is, for the first time, proposed to reduce the internal oscillations of the offshore structure under wave-induced forces, so as to ensure the safety and comfort of the offshore structure.

Firstly, when the system's states are adopted as feedback, memory state feedback controllers are introduced for the offshore structure. By using Lyapunov-Krasovskii stability theory, some delay-dependent stability criteria have been established, based on which, and by combining with some linearization techniques, memory state feedback controllers are designed to control the offshore structure. The simulation results show that such controllers can effectively reduce the internal oscillations of the offshore structure subject to nonlinear wave-induced forces and uncertainties. On the other hand, a new Lyapunov-Krasovskii functional is introduced to derive a less conservative delay-dependent stability criterion. When this criterion is applied to the offshore structure, an improved memory state feedback controller with a small gain is obtained to control the system more effectively, which is sufficiently shown by the simulation.

Secondly, when the system's outputs are adopted as feedback, memory dynamic

output feedback controllers are considered for the offshore structure. By employing a projection theorem and a cone complementary linearization approach, memory dynamic output feedback controllers are derived by solving some nonlinear minimization problem subject to some linear matrix inequalities. The simulation results show that the internal oscillations of the offshore structure subject to nonlinear wave-induced forces are well attenuated.

Finally, robust H_∞ control is fully investigated for the offshore structure. By employing Lyapunov-Krasovskii stability theory, some delay-dependent bounded real lemmas have been obtained, under which, via a memory state feedback controller or a dynamic output feedback controller, the resulting closed-loop system is not only asymptotically stable but also with a prescribed disturbance attenuation level. The simulation results illustrate the validity of the proposed method.

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List of Symbols

$\mathbb{R}^n$	n-dimension real space
$\mathbb{R}^{m\times n}$	set of all real m by n matrices
$\mathcal{L}_2[0,+\infty)$	space of square integrable functions on $[0,\ +\infty)$
A^T (resp. x^T)	transpose of matrix A (resp. vector x)
$\|x\|$	Euclidean norm of vector x
$\|A\|$	norm of matrix A
$A \leq B$	$B - A$ is a symmetric positive semi-definite matrix
$P > 0$	P is a symmetric positive definite matrix
$P < 0$	P is a symmetric negative definite matrix
I	identity matrix of appropriate dimensions
$*$	denotes a symmetric term in a symmetric, i.e. $\begin{bmatrix} P & W \\ * & Q \end{bmatrix} = \begin{bmatrix} P & W \\ W^T & Q \end{bmatrix}$
diag{...}	denotes a block-diagonal matrix