Abstract

In this thesis, we consider the problem of robust control of large flexible space structures (LFSS). Dynamic models of LFSS are characterized by their high order and their significant number of highly uncertain, lightly-damped, clustered low-frequency modes. We propose the use of a left-coprime factorization (LCF) of LFSS dynamics in modal coordinates for robust control design. The plant uncertainty is described as stable perturbations of the coprime factors. The structure of the LCF allows us to transform easily modal parameter uncertainty into an unstructured description of the uncertainty as stable norm-bounded perturbations in the factors. The resulting set of perturbed LCFs is guaranteed to include all perturbed plant models produced by variations in the modal parameters within their bounds. Uncertainty in the coprime factors can also represent unmodeled modes and actuator dynamics. Closed-loop robustness to perturbations of the modal parameters within a priori bounds is guaranteed provided that the ∞-norm of a certain closed-loop sensitivity matrix can be made less than one with a stabilizing controller. Two multivariable $\mathcal{H}_\infty$ designs and two μ-synthesis designs for an LFSS experimental testbed are presented together with simulation and experimental results to illustrate the technique.

Once a family of perturbed LCF models has been derived from the LFSS model in modal coordinates, it is often desirable to test if it is consistent with a set of experimental data obtained on the plant. The objective is to reduce plant model uncertainty. The model/data consistency problem for coprime factorizations considered here is this: Given some possibly noisy frequency-response data obtained by running open or closed-loop experiments on the system, show that these data are consistent with a given family of perturbed factor models and a noise model. The results given are applicable to a large class of systems admitting coprime factorizations in $\mathcal{RH}_\infty$. A theorem on boundary interpolation in $\mathcal{RH}_\infty$ is a building block that allows us to devise computationally simple necessary and sufficient tests to check if the perturbed coprime factorization is consistent with the data. The cases of noise-free and noisy open-loop and closed-loop frequency-response data are treated.