STRUCTURAL/CONTROL OPTIMIZATION OF A LARGE SPACE STRUCTURES

Ijar M. Fonseca
Intituto Nacional de Pesquisas Espaciais - INPE
P.O. Box 515, S.J.Campos, SP, Brasil

Peter M. Bainum
Department of Mechanical Engineering
Howard University, Washington DC 20059, USA

Wagner Sessin and Paulo T. M. Lourenção
ITA
S. J. Campos, Brasil

Abstract

This paper focuses on the simultaneous approach for structural/control optimizatiom of a Large Space Structures with articulations, subject to the gravity-gradient. The finite element method has been used in conjunction with the Lagrangian formulation to derive the attitude dynamic equations of motion. The attitude is constrained to the orbital plane (pitch) and the orbit is assumed to be circular. The optimization problem formulation consists of defining a composed function given by the structural objective function plus the classic control cost function associated to the Linear Quadratic Regulator problem. The integrated approach links the structural and the control optimization together through the common constraints imposed on the system. The constraints taken into account for this study were placed on the structural weight, the first natural frequency of free vibration and on the control damping. The Search for Unconstrained Minimization Techniques, SUMT, were used to solve the optimization problem for the structure. By this approach the constrained problem is transformed into a sequence of unconstrained problems. The problem were solved by using the NEWSUMT-A and the ORACLS software package. The main features of the NEWSUMT-A includes: a) Newton's method with approximate second derivatives, used in the direction finding part of the unconstrained minimization; b) an extended interior penalty function formulation, used for inequality constraints; c) equality constraints are handled using exterior penalty functions; d) constraint approximations with an optional move-limit strategy. The MatLab software package has been also used to simulate the transient phase considering the optimal integrated system obtained by the integrated structure and control optimization. The control concept here consists of keeping the attitude close to a nominal configuration and of damping elastic vibrations. The paper facuses also: on the sensitivity analysis of the control system to small modifications in the structural parameters, and; b) on the software integration problems to solve the integrated structural and control optimization. The main steps involved in the integrated optimization process are: a) for given values of the cross sectional areas of the elements the eigenvalue problem is solved to yield the frequencies of free vibration and its associated eigenvectors; b) the plant matrix and the input matrix in the state-space input equations are calculated; c) the linear optimum regulator control problem is solved and the closed-loop eigenvalues, eigenvectors, and damping factors are determined by using the ORACLS package; d) the NEWSUMT-A optimizer generates a new set of design variables; and e) with these new design variables steps a-e are repeated until the optimum solution satisfying all the specified constraints is obtained.