PZT layout optimization in semi-active vibration control systems of large space truss structures based on ground structure approach

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Abstract

Vibration suppression is one of the most important subjects in space structures design or operation. Due to the launch limit of the rocket, such structure might have extremely light weight and it could lead to the small stiffness which is easily vibrated. Moreover, different from the earth, vibration energies are hard to be scattered in the space vacuum environment. These problems could be overcome by vibration control methodologies. According to the case on the earth, the active vibration controls are the most effective one. However, it is very difficult to be operated accurately because they contain the fundamental instability. Another way is the passive vibration controls. Although they are free from the problem of the instability, the effect of vibration suppression is not high. Integrating these methodologies, the semi-active vibration methodologies were proposed as the novel methodology for the vibration suppression in space. Especially, the effectiveness of the energy-recycling type semi-active vibration control method was well studied. In designing control systems, such as the layout of actuators, the optimization approach can be utilized. Some methodologies were proposed for designing active or passive control systems. However, the optimization methodology for the energy-recycling type semi-active vibration control systems has not been studied yet.

In this research, we construct the optimization methodology of the energy-recycling type semi-active vibration control system for a space structure composed of trusses. Based on approximation techniques and numerical optimization techniques, we intend to generate optimal location of PZTs under the constraint for the total length of PZTs within a reasonable analysis time. Moreover, using this methodology, the optimal location of PZTs for the vibration suppression for multi-modal vibration is studied, which can be benchmark results of further study in the context of

the energy-recycling type semi-active vibration control systems. First, the design variables are set as the length of the piezoelectric actuator on each truss element based on the concept of ground structure approach. Physical properties of the actuator are formulated as the function of the design variables. Then, the vibration analysis problem of the truss structure is formulated based on the transient response analysis using the modal method and the Runge-Kutta method. The objective function is set as the integration of the total displacement over the whole analysis time domain. The sensitivity of the objective function is derived based on the adjoint variable method. Based on these formulations, an optimization algorithm is constructed using MMA. Finally, we provide numerical examples to illustrate the validity and utility of the proposed methodology.