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SYSTEM DESIGN AND MULTI-DISCIPLINARY OPTIMIZATION OF A NOVEL SPACE NESTED FLOATING ROBOT

Abstract

To achieve high quality microgravity environment, a novel nested floating robot is designed that can be operated inside the Space Station. The robot can offer the space sciences a high level of environment in the low frequency range. The floating device is composed of an exterior follow-up structure, inner system and experiment device. The experiment device is fixed on the inner system. The electromagnetic actuators between the exterior structure and the inner system are utilized to control the position and posture of the experiment device while the exterior structure is following the movement of the inner system. In order to keep the experiment device away from the disturbances caused by ventilation, machine noise, vibration of the platform, gravity gradient, etc., the sealed exterior cavity can be evacuated as a low vacuum chamber. In the previous work of the conceptual design, the parameters of the robot are set empirically and the preliminary optimizations of structure and actuator have been done. In these works some relationships between the different components and disciplines have been found.

The purpose of this work is to explore the possibility of using Multi-disciplinary Design and Optimization frameworks for complex system design of space experiment. Considering both launch environment and requirements of science experiments on orbit, the system design is described in details. The multi-disciplinary optimization of the floating robot for space science experiments is carried out by decreasing launch weight, frequency response, flux leakage, vacuum effect, tangent force, limit mounting space, heat rate on-orbit and etc. The structure optimization process model is built up by using Design Structure Matrix. Due to the complexity of structure parameters modification, the CAX software, the design model and analysis process are integrated based on ModelCenter framework. In this case, the geometry model is established by using MSC Software products (Patran). The structural analysis including mass estimation, linear static analysis and normal modes analysis are performed by using MSC Software products (Nastran). The electromagnetic analysis of actuators is performed by the magnetics postprocessing in ANSYS. The thermal model is built up in Matlab. The NSGA II, Gradient Optimization algorithm and surrogate based optimization algorithm for multi-objective optimization with constraints are utilized for validation mutually. In view of the optimization results, the entire performance of the floating robot is improved significantly.