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Space Structures II - Development and Verification (Deployable and Dimensionally Stable Structures) (2)

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INITIAL VALIDATION OF A CLOSED LOOP FILTER AND CONTROLLER APPROACH FOR ACTIVE STABILIZATION OF THERMOMECHANICAL DISTORTIONS

Abstract

Increasing technological progress in space technology is accompanied by an increased demand for accuracy. The alignment of optical instruments or antennas on the satellite platform requires structural stability that can no longer be achieved with traditional, passive methods, such as the use of materials with high stiffness or low coefficient of thermal expansion. Within the Infrared Astronomy Satellie Swarm Interferometry (IRASSI) project, an approach to actively stabilize structures against low-frequency periodic heat induced deformations has been developed and simulated. In this study, the basic functionality of that thermomechanical FEM model is demonstrated by means of the thermal transfer functions between the changes in the applied heat and the resulting temperature changes, as well as a closed loop filter and controller approach consisting of a linear quadratic regulator (LQR) and a Kalman filter. For this purpose, an experimental setup consisting of an aluminum plate with 14 temperature sensors, four heating elements for controlling the structure and one heating element for simulating the perturbation is used. The evaluation of the thermal transfer functions in the model compared to the experimental setup shows a deviation of the phase shift of less than 0.6 % and an amplitude shift of less than 3.5 % on average. A Kalman filter processes the temperature measurement in order to obtain an optimal estimate for the LQR controller, which then calculates the necessary change in the heating power of the four control heating elements to minimize the displacements at the desired two positions in x- and y-direction. The verification is performed by a camera system as an external validation tool, which is able to resolve micron-scale displacements by measuring the spatial displacement of a speckle pattern applied to the structure using sub-pixel accurate image correlation algorithms. While the range of values of the amplitudes of the displacements is 9.44 μm in the uncontrolled case, an improvement of more than 4.1 dB could be achieved by applying the filter and controller system. Thus, it is demonstrated that this method has the potential to further improve already highly stable structures or to make lighter and cheaper materials with poorer passive stability values usable through active structural stabilization.