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Author: Mr. Giuseppe Maurizio Gagliardi
Università degli Studi di Napoli “Federico II”, Italy

Ms. Francesca Samà
Scuola Superiore Sant'Anna, Italy
Mr. Alessandro Emendato
Università degli Studi di Napoli “Federico II”, Italy
Prof. Anna Mercaldo
Università degli Studi di Napoli “Federico II”, Italy
Prof. Mandar D. Kulkarni
Embry-Riddle Aeronautical University, United States
Prof. Francesco Marulo
Università degli Studi di Napoli “Federico II”, Italy

SPACECRAFT SHAPE OPTIMIZATION THEORETICAL GUIDELINES FOR FUNDAMENTAL FREQUENCY REGULATION

Abstract

In this paper, the possibility of efficiently optimizing the value of the first natural frequency of spacecraft structures is analysed. The mathematical problem of optimizing the fundamental frequency has been faced in the 19^{th} century and extensively studied by many authors. The value of such a sensitive parameter, under the requirement of specific constraints to be fulfilled, is indeed extremely important. This is particularly relevant for spacecraft structures, where the fundamental frequency must meet a minimum requirement to ensure the suitability for the launch. It is theoretically known via the Faber-Krahn theorem that, in R^N, the open ball has the lower value of its first eigenvalue with respect to the Laplacian operator. Later, the same problem was analysed for regular polygons, and the expected results were proven for triangles and quadrilaterals, while the problem is still open for N-gones ($N > 5$). The same investigation has been here extended to the bi-harmonic operator, for which very few is known up to our days. This operator is representative of the general structural free vibration problem. The results obtained for the bi-harmonic operator have been confirmed and corroborated by numerical and experimental studies. Starting from a purely mathematical approach, the obtained theoretical results were used to derive shape optimization guidelines to increase the fundamental frequency. The obtained mathematical tools are useful when optimizing the shape of a space structure as they allow to choose appropriate design velocities to consistently affect the fundamental frequency. Changing the shape in a smart and efficient way also allows the increase in the first natural frequency value while maintaining the weight unchanged. Therefore, this work is suitable for a practical application for real spacecraft. The design criteria were applied to case studies of real satellites demonstrating their efficiency in optimizing the shape of spacecraft or their subcomponents. The results show an alternative way to optimize the fundamental frequency, avoiding stiffening the structure.