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DETAILED DESIGN AND VERIFICATION OF A WAVE SPRING SELF-PRESSURIZED TANK FOR A MICRO-RESISTOJET THRUSTER

Abstract

Although the benefits of compliant mechanisms have long been recognised in the medical and transportation industries, the application of such devices in miniaturized spacecraft has only recently started soaring as a consequence of enhanced mechanical precision, reduced need for maintenance, lower manufacturing costs and shorter production times. To this respect, the Delfi-PQ1 - a triple-unit PocketQube launched on 13/01/2022 - represents the cornerstone for future demonstration of miniaturized compliant mechanisms applied to the propellant storage system (PSS) of micro-resistojet thrusters. This paper aims to present a detailed design and verification of a self-pressurised tank for the TU Delft Vaporizing Liquid Micro-resistojet, based on a distributed compliant mechanism. A crest-to-crest wave spring is chosen as the most suitable option due to its compact configuration and efficiency in applying restoring force. Since it is not possible to simply down-scale existing concepts, it is necessary to develop and qualify new components and analytical methods. The customised design of the device builds upon an analytical model for the mechanical behaviour that grounds its roots on Castigliano's theorem. The methodology implemented for the crest-to-crest mechanism takes into account the torsional rotation of the circular rings about contact points being precluded by the presence of subsequent turns, as opposed to single-turn wave spring washers, largely affecting the spring response. An optimization study is thus conducted with the objective of maximising the propellant expelled whilst minimising the spring mass, where the following parameters constitute the design space: wave angle, number of turns and waves, spring mean diameter, radial width, spring cross-section and wire thickness. Furthermore, the analysis is constrained by the heating chamber operating pressure, the PSS footprint volume and the safety factors on the UTS and yield strength of the wave spring material. Although steel and titan have been considered, the resulting design showed a significant dependency of the expelled propellant mass on the modulus of resilience of the material chosen, denoting the need for further investigation on the available material options. The compliance of the PSS structure with the requirements is verified by means of a preliminary analysis based on the Euler-Bernoulli beam theory and buckling for thin plates. Nevertheless, additional work will be conducted on the development of a coupled model for the fluid-structure interaction to validate the overall system behaviour. The novel optimization study outlined in this paper provides insightful considerations on the performance and operations of compliant mechanisms in miniaturized spacecraft applications.