MATERIALS AND STRUCTURES SYMPOSIUM (C2)
Space Structures I - Development and Verification (Space Vehicles and Components) (1)

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CHARACTERIZATION OF SPRING STIFFNESS VARIATION OF SOLID ROCKET MOTOR FLEX SEALS DUE TO COMBUSTION CHAMBER PRESSURE

Abstract

State of the art solid rocket motors employ flex seals/flex bearings for thrust vector control. Flex seals typically are made of spherical or conical shaped alternate layers of low modulus elastomer and metallic/composite materials bonded to each other. Such a construction yields low shear stiffness accorded by the elastomer, facilitating nozzle vectoring whilst providing compressive stiffness orders of magnitude higher than the shear stiffness, making it ideal as a pressure sealing flexible joint between the movable and non-movable parts of the nozzle. Spring stiffness of the flex seal is the major contributor to flex nozzle vectoring torque. Even with the low shear modulus elastomer formulations used in flex seals, the torque required to overcome the spring stiffness of the joint can be substantial, especially for large solid rocket motors, necessitating heavy actuation systems for nozzle vectoring. Spring stiffness of flex seals is found to be a function of the axial compression of the seal, which in turn, is governed by the combustion chamber pressure. Characterization of spring stiffness is carried out by vectoring tests of the flex seal at various chamber pressures which shows reduction in spring stiffness with seal compression. Data from large number of flex seals tested so far show that the behaviour is generic and repeatable. Theoretical backing for the reduction in spring stiffness is provided based on the theory of incremental elastic deformation of rubber and parallels with elastic instability of columns are drawn. Theory predicts reduction in shear stiffness of elastomeric slabs with increasing amounts of normal compression eventually leading to vanishing of the shear stiffness when subjected to a critical amount of compression. This property opens up new avenues in developing 'low torque flex seals' which, when operated near the low shear stiffness regime of the elastomer, can drastically bring down spring stiffness. Such low torque flex seals can be gainfully utilized in neutral burning motors operating at relatively high chamber pressure facilitating the use of highly optimized actuation systems resulting in significant inert mass reduction.