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DESIGN ASSESSMENT OF GIMBAL BELLOWS USED IN A CRYOGENIC ROCKET STAGE USING EXPERIMENTS AND NUMERICAL METHODS

Abstract

The upper stage of most modern launch vehicles is powered using cryogenic propellants. The fuel and oxidiser from tanks are conveyed to the engine using fluid lines. The engine is capable of being gimballed so as to apply control forces in pitch and yaw directions. This movement of engine will induce deformations and consequently stresses on the feedlines. Gimbal ducts are used in cryogenic feedlines of launch vehicles in order to minimize the loads acting on the feed line due to gimbaling of the engine. The ducts consist of an axial bellow encased by a flexible system similar to a universal joint. The major loading on this bellow would be caused due to vibrations during vehicle operation. These vibrations induce lateral and torsional loads on the gimbal bellow unit in addition to internal pressure of the feedline. Design of the bellow is qualified by means of a test which involves replicating the loading in a lab level. The loads to be applied during test are computed based on integrated vibration analysis of liquid rocket stage fluid systems, where the bellow is used. This paper summarises the structural modelling, finite element analysis, results evaluation and development of methodology for acceptance testing and design qualification of a gimbal bellow used in a cryogenic rocket stage. The collapse pressure of the gimbal joint is also evaluated through finite element simulation in order to ensure sufficient margin on failure. The finite element predictions compared favourably with those from the test.