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TRANSIENT RESPONSE ANALYSIS OF A WATER-LANDING SPACE CAPSULE SUBJECTED TO A PRESSURE FIELD WITH SPATIAL AND TEMPORAL VARIATION

Abstract

The descent phase of the Indian Human Spaceflight (GAGANYAAN) mission culminates with the Crew Module (CM), carrying the astronauts, touching down at a pre-determined site in Indian waters. An understanding of the dynamic responses of the Crew Module during this impact event is imperative to assess the structural integrity of the module and to ensure safety of the crew. One of the major factors governing dynamic responses at critical locations of the Crew Module during this event is the pressure field developed over the impacting surfaces during water impact. The nature of this pressure-field depends on impact conditions like the orientation of the CM during touchdown and its velocities along and perpendicular to the surface of water. This pressure-field, which acts over a local region during initial touchdown, gradually gets distributed over a wider surface area. Thus, for a given impact condition, this field varies with respect to (a) location on the impacting surface i.e. spatial variation, and (b) time i.e. temporal variation. In the current study, a two-step approach is adopted to characterize the dynamic responses of a simulated CM during water landing. In the first step, the spatial and temporal distribution of pressure-field over the CM are estimated for various impact conditions through numerical simulations using a Coupled Eulerian-Lagrangian (CEL) approach. The CM is considered as a rigid body and modelled using conventional Lagrangian elements while water is modelled using an Eulerian mesh. The numerical simulations are validated using results of scaled-model water-drop tests. In the second step, the pressure-field, obtained from step 1, is mapped onto a detailed structural dynamic finite element model of the simulated CM and transient response analyses are carried out to obtain the structural responses at critical locations. Results of this study are used to define the limits for design and qualification tests of individual sub-systems of the CM.