Paper ID: 62196
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Author: Mr. James E. McKevitt
University of Vienna, Austria, jamesm20@univie.ac.at

OPTIMISATION OF A HYDRODYNAMIC SPH-FEM MODEL FOR A BIOINSPIRED AERIAL-AQUATIC SPACECRAFT ON TITAN

Abstract

Titan, Saturn's largest moon, supports a dense atmosphere, numerous bodies of liquid on its surface, and as a richly organic world is a primary focus for understanding the processes that support the development of life. In-situ exploration of the body's equatorial regions begun by the Huygens descent probe is set to continue with the Dragonfly quadcopter, which will also act as a technology demonstrator for powered atmospheric flight on the moon. It will, therefore, be for future missions to build on this legacy and explore Titan's polar regions, performing in-situ measurements of the lakes and seas.

This work presents detailed refinements to the numerical models of a conceptualised bioinspired aerial-aquatic spacecraft, ASTrAEUS, diving into the lakes of Titan.

Previous work, limited by project time and computing power, provided a preliminary comparison between the spacecraft's performance in water and liquid nitrogen-ethane-methane. Now, with dedicated research time and use of the Vienna Scientific Cluster, much larger and more detailed simulations more accurately replicate impact forces and fluid responses during the 'plunge-dive' landing of ASTrAEUS.

Multiphysics simulations are performed in LS-DYNA using a coupled smoothed-particle hydrodynamic (SPH) finite element method (FEM) technique, well suited to the respective high surface liquid deformation and spacecraft rigidity. Various equations of state are demonstrated and numerous contact equations compared. Performance both with and without approximation of an infinite domain are also presented, allowing the effect of this fluid on these relatively new modelling techniques to be clearly seen.

Results are validated against performance predicted by hydrodynamic equations and experimental observations, with previous numerical work using SPH techniques in other studies also considered.

An understanding of this impact behaviour allows the simulation led optimisation of the spacecraft's design for the most challenging part of its mission profile, meaning regions of high stress in the fuselage and implications on wing folding mechanisms can be considered. The model with also later be used to predict the power needed for a successful escape from the liquid and a return to flight.