Lunar, Mars, Near-Earth Asteroids, Deep Space Exploration (2)
Lunar, Mars, Near-Earth Asteroids, Deep Space Exploration - IP Session (IP)

Author: Prof. Rakesh Kumar
Indian Institute of Technology Kanpur, India

Mr. Aasheesh Bajpai
Indian Institute of Technology Kanpur, India
Prof. Ashish Bhateja
India

INVESTIGATION OF CRATER FORMATION DUE TO PLUME-SURFACE INTERACTION DURING LUNAR LANDING USING CFD-DEM APPROACH

Abstract

The phenomenon of jet induced cratering in granular beds has garnered significant interest due to its relevance in both natural and industrial settings. Craters form when jet exhaust interacts with a granular bed, a phenomenon critical for ensuring safe planetary landings and unlocking other benefits, such as the discovery of water ice during the Mars Phoenix landing. Crater formation and growth depends upon the impinging jet properties as well as that of granular bed. As crater erosion progresses, the crater profile changes over time, tending to saturate to a limiting profile. The existing literature on crater formation lacks sufficient details to fully understand the underlying physical processes and develop predictive models for plume impacts. Furthermore, there are significant challenges in the experimental study of this phenomenon, considering vacuum and low gravity requirements. The present study aims to enhance existing models and establish mitigation strategies to ensure the safety of future lunar missions by implementing computational simulation capability for a reliable prediction of surface erosion and crater formation due to plume surface interaction (PSI) during lunar landing. The key objective of this study is to utilize simulations to explore the morphological features of the crater and their temporal evolution. Numerical analysis is performed employing a novel model integrating computational fluid dynamics (CFD) for the gas phase, and the discrete element method (DEM) for the solid phase. Utilizing data from Apollo descent recordings, terrain photos, and ascent footage, this research investigates various phenomena such as regolith erosion, crater formation and characterization of ejecta properties. The study presents a comprehensive, axisymmetric simulation of plume-induced erosion and crater formation caused by a lunar lander at different nozzle conditions and at varying plume impingement heights above the lunar surface, under near-vacuum conditions. The simulations enable us to obtain steady state crater shapes, as well as surface erosion rates and their dependency on plume and grain properties. Thus, the study provides crucial insights regarding the plume surface interaction associated with lunar landing.