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PREDICTING EROSIVE WEAR BY EXHAUST-BLOWN LUNAR DUST THROUGH EXPERIMENTALLY-VALIDATED COMPUTATIONAL MODELING

Abstract

NASA's Apollo 12 mission provided evidence that lunar dust, accelerated by the exhaust plumes of landing spacecraft, is capable of causing erosive wear damage to nearby lunar structures. During Apollo 12, the Surveyor III lunar probe was "sandblasted" by lunar dust particles advected by the exhaust plume of the Lunar Lander. The Moon's low gravitational field and the negligible atmospheric drag allow lunar dust to travel unimpeded for long distances. As a result, lunar structures located far from the spacecraft's landing site are susceptible to erosive wear damage. In particular, optical instruments, such as lenses and mirrors, and thermal devices, such as radiators, can be severely affected by particle impingement. Though the particles may not remove much material, their impacts change the object's surface characteristics which the authors have previously proven can lead to significant optical changes. The experimental investigations the authors have reported previously with the JSC-1AF lunar dust simulant are used to validate the computational model in the current work. The model uses the discrete element method (DEM) and computational fluid dynamics (CFD) to predict the motion and impingement of the dust particles. In this study, erosive wear of steel, aluminum, and acrylic surfaces by JSC-1AF, and the effect of 30 degree and 90 degree impact angles are computationally simulated. A Hertzian contact formulation is used to predict the indentation of the particles into the surface. It was found that this modeling approach is well-suited to quantitatively predict the erosive wear on the materials simulated as the modeling results agree with the experiments in the volume of material removed and the shape of the particle impact region. Such physics-based, quantitative modeling approaches for this phenomenon are important as they help to identify methods and materials which will prove useful in mitigating the effects of lunar dust erosive wear. Modeling is also helpful for obtaining information about low gravity, thermally-extreme environments which are challenging to access experimentally. Finally, the Moon is poised to see an unprecedented level of landings in the next few years. With a recent landing in late 2013 and several more planned by various countries and companies before the end of the decade, the dust blown by the exhaust from these spacecraft will become a significant factor affecting the ability for these missions to succeed and in preserving historic lunar landing sites.