Postprint: Analysis of Dynamic Characteristics of Lunar Regolith Landslides under Microgravity

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Abstract

With the continuous advancement of lunar exploration, geological hazards such as landslides pose potential threats to lander deployment and human activities. However, under low-gravity and vacuum conditions, lunar regolith landslides exhibit dynamic characteristics distinct from those on Earth, and their mechanisms remain unclear, necessitating systematic investigation. This study employs numerical simulation methods to systematically explore the dynamic mechanisms of lunar landslides. First, a discrete element model for lunar regolith is constructed based on a contact model that simultaneously considers van der Waals forces and rotational resistance; subsequently, microscopic parameters are calibrated through triaxial compression tests using shear strength as the calibration criterion; finally, chute landslide simulations are conducted under microgravity conditions, with Earth gravity serving as a control. The results indicate: (I) van der Waals forces cause the landslide to exhibit obvious bulk sliding during the initial stage, and demonstrate trailing effects and scraping action throughout the sliding and accumulation processes; (II) compared to terrestrial conditions, lunar landslides feature longer duration, lower velocity, and smaller impact force, with these three parameters varying by a factor of approximately 2.45; (III) the proposed "energy-equivalent acceleration" framework can effectively characterize the landslide dynamic process, thereby dividing it into four stages: bulk sliding, collapse, granular flow, and impact-accumulation.

Full Text

Landslide Dynamics on the Moon under Microgravity Conditions

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Abstract

As lunar exploration continues to advance, geological hazards such as landslides pose a potential threat to lander deployment and human activities. However, under low-gravity and vacuum environments, lunar soil landslides exhibit dynamic characteristics distinct from those on Earth, and their mechanisms remain poorly understood, necessitating systematic investigation. This study employs a numerical simulation approach to systematically explore the dynamic mechanisms of lunar landslides. First, a discrete element model for lunar soil is constructed based on a contact model that simultaneously considers van der Waals forces and rotational resistance. Subsequently, micro-parameters are calibrated through triaxial compression tests using shear strength as the calibration criterion. Finally, chute landslide simulations are conducted under microgravity conditions, with Earth gravity serving as a control. The results indicate that: (I) van der Waals forces cause obvious overall sliding during the initial stage, as well as trailing effects and scraping actions during the sliding and accumulation processes; (II) compared with Earth environments, lunar landslides have longer durations, lower velocities, and smaller impact forces, with these three parameters showing approximately 2.45-fold differences; (III) the proposed "energy equivalent acceleration" framework can effectively characterize the landslide dynamic process, enabling it to be divided into four stages: overall sliding, collapse, granular flow, and impact-accumulation.

Keywords: lunar soil landslide; microgravity; dynamic mechanism; lunar soil contact model; chute test; discrete element method