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# A Mathematical Model for Studying Landing Dynamics of a Typical Lunar Soft Lander

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**Abstract :** Lunar landing is one of the most critical phases of lunar mission. The lander is provided with a soft landing system to prevent structural damage of lunar module by absorbing the landing shock and also assure stability during landing. Presently available software are not capable to simulate the rigid body dynamics coupled with contact simulation and elastic/plastic deformation analysis. Hence a separate mathematical model has been generated for studying the dynamics of a typical lunar soft lander. Parameters used in the analysis includes lunar surface slope, coefficient of friction, initial touchdown velocity (vertical and horizontal), mass and moment of inertia of lander, crushing force due to energy absorbing material in the legs, number of legs and geometry of lander. The mathematical model is capable to simulate plastic and elastic deformation of honey comb, frictional force between landing leg and lunar soil, surface contact simulation, lunar gravitational force, rigid body dynamics and linkage dynamics of inverted tripod landing gear. The non linear differential equations generated for studying the dynamics of lunar lander is solved by numerical method. Matlab programme has been used as a computer tool for solving the numerical equations. The position of each kinematic joint is defined by mathematical equations for the generation of equation of motion. All hinged locations are defined by position vectors with respect to body fixed coordinate. The vehicle rigid body rotations and motions about body coordinate are only due to the external forces and moments arise from footpad reaction force due to impact, footpad frictional force and weight of vehicle. All these force are mathematically simulated for the generation of equation of motion. The validation of mathematical model is done by two different phases. First phase is the validation of plastic deformation of crushable elements by employing conservation of energy principle. The second phase is the validation of rigid body dynamics of model by simulating a lander model in ADAMS software after replacing the crushable elements to elastic spring element. Simulation of plastic deformation along with rigid body dynamics and contact force cannot be modeled in ADAMS. Hence plastic element of primary strut is replaced with a spring element and analysis is carried out in ADAMS software. The same analysis is also carried out using the mathematical model where the simulation of honeycomb crushing is replaced by elastic spring deformation and compared the results with ADAMS analysis. The rotational motion of linkages and 6 degree of freedom motion of lunar Lander about its CG can be validated by ADAMS software by replacing crushing element to spring element. The model is also validated by the drop test results of 4 leg lunar lander. This paper presents the details of mathematical model generated and its validation.

**Keywords :** honeycomb, landing leg tripod, lunar lander, primary link, secondary link
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