論文題目要旨

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論文題目：Modeling Penetration Resistive Force in Non-Cohesive and Cohesive Granular Layers Considering Failure and Flow Mechanisms

論文要旨：

This thesis aims to develop the predictive model for the penetration resistive force into non-cohesive and cohesive granular layers. First, the author extends a previously proposed model for non-cohesive granular materials by incorporating a cohesion term into its underlying constitutive law. Subsequently, using the Discrete Element Method (DEM), the author performs numerical simulations under various conditions of granular and intruder properties. Comparing the extended model with the numerical simulation results reveals discrepancies under certain conditions. To resolve these discrepancies, the author investigates the penetration mechanisms through particle behavior analysis in granular layers. Detailed analysis of shear strain rates in granular layers indicates that differences in penetration resistive force arise between the model and simulations when no shear band forms. Thus, depending on the shear band formations, the author introduces the effect of failure modes to the model by modifying the failure range in granular layers and the model cohesion parameter. Particle velocity field analysis in granular layers revealed that penetration resistive forces differ between the model and simulation when the stagnant zone forms in front of the intruder. The range of the stagnant zone primarily depends on intruder properties. Based on these results, the author introduces the effect of the stagnant zone, predicted from the intruder properties, into the model. The model incorporating these penetration mechanisms can quantitatively explain simulation results under various granular and intruder property conditions. Furthermore, the author considers the geotechnical application of the extended model. Specifically, through an inverse analysis of measured penetration resistive forces using the model, the author estimates geotechnical parameters of lunar regolith and simulant. The estimated parameters show generally good agreement with literature values. Numerical simulations using these estimated parameters also are consistent with the experimental data. Therefore, the inverse analysis of penetration resistive force using the extended model can be utilized to estimate the geotechnical parameters of regolith on the extraterrestrial surface.