MPM-DDA simulation for soil cutting using a strain-rate dependent constitutive model

In recent years, the construction industry has promoted the application of ICT technologies to the construction process to improve productivity and safety. Research on the automated operation of construction machinery has become important in this context. For hydraulic excavators, understanding the soil-machine interaction behaviors, especially the resistance characteristics of soil, is key to the reasonable control of the machines. In this study, experimental and numerical studies were conducted to establish an excavation simulator using a coupled Material Point Method and Discontinuous Deformation Analysis (MPM-DDA).

The MPM-DDA models soil behaviors in the large deformation regime with the implicit MPM, and structures such as the excavator bucket with the DDA, which is an implicit type numerical method for discontinua. By considering the contact between soil (MPM) and structure (DDA) using the penalty method, soil-machine interaction analysis is enabled. To simulate the high-speed soil cutting process by a machine, the strain-rate dependency on the soil strength should be considered. Therefore, an elasto-viscoplastic constitutive model based on von Mises' failure criterion was newly introduced to the MPM-DDA.

For the validation of MPM-DDA, a soil cutting experiment using a dozer blade of an actual hydraulic excavator was performed and simulated using the strain-rate independent and dependent models, respectively. When the strain-rate independent von Mises model with soil parameters from the standard laboratory test was used, the soil movement was generally reproduced. However, the resistive force was significantly smaller than the measured value. On the other hand, the simulation using the elasto-viscoplastic model with parameter sets calibrated from laboratory tests under several strain-rate conditions estimated a more reasonable resistive force value close to the experimental results. Though further study on an appropriate parameter identification methodology is needed, the present study demonstrated the potential of the MPM-DDA with the elasto-viscoplastic model as an excavation simulator.

Keywords
MPM-DDA, Hydraulic excavators , Soil cutting simulation, Elasto-viscoplastic model