Investigation of the soil-tool interaction by SPH (Smooth Particle Hydrodynamics) based simulation

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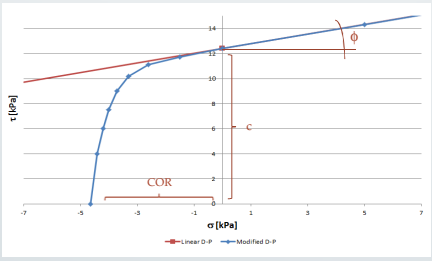
Introduction

We have investigated the interaction between soil and various agricultural tools by computer simulations. Only particle based simulation methods seemed to be able to handle the high level of distortion and forces during the process. There are already some researches with mesh-free methods in the field of soil-tool interaction (e.g.: with Discrete Element Method (DEM)), but we do not know about anybody who have tried the SPH solver for this problem. Our main goal was to explore the capabilities of SPH according to DEM through simple simulations in ANSYS AUTODYN 13.

Material model

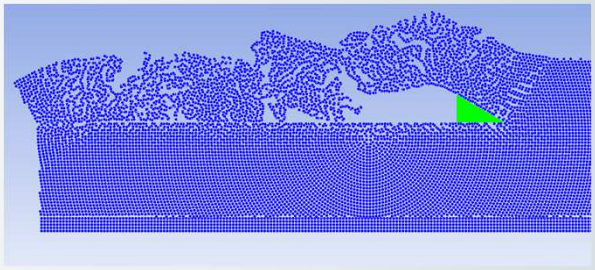
For the modelling of soil we have choosen the wide known Drucker-Prager material model, which was implemented in the material library of AUTODYN. Since we have experienced in our first simulations too much cohesive behaviour (Because of the inaccuracy of the D-P model at low tensile stress values.), we have decided to develop a D-P based own material model. We modified the genuine D-P model so, that we have limited the maximal tensile stress at a value equals to a certain percent (COR, cut off ratio) of the cohesion coefficient.



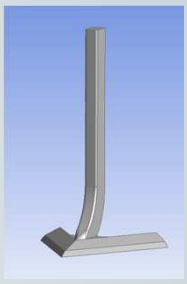
Modified D-P model of cultivator sweep (c=12,4 kPa; ϕ=21°; μ=0,5ϕ; COR=37,5%)

Flat wide blade – 2D

As first step we have decided to analyse a 2D model of a flat blade, because of time efficiency and its simplicity. We did detected the clod generation and crack surfaces in the soil body, and compared the results with the theoretical model of McKyes. Based on theese early model 37,5% was choosen for further simulations as the value of COR. One simulation took about 10 hours. (1 core 2,6 GHz, 600 MB RAM)



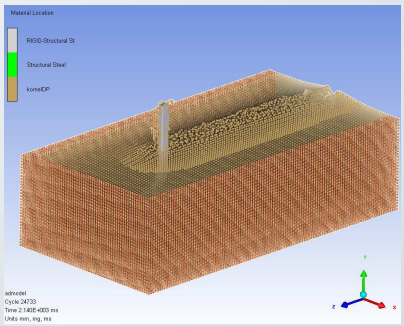
Flat wide blade (α=15° (rake angle); c=20.4 kPa; ϕ=34°; COR=50%, v=0.6 m/s)



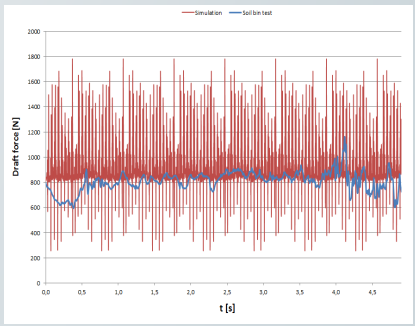
Cultivator sweep geometry

Cultivator sweep – 3D

As the first 3D model we have choosen a cultivator sweep. The input paramteres of the material model was determined through a laboratory shear test of Tamás and Jóri (2010). The results were compared also with their soil bin tests and DEM simulations. We could fairly good predict the draft force with only 1-200 N failure. To run an analysis we needed about 24 hours. (1 core 2,6 GHz, 1GB RAM)



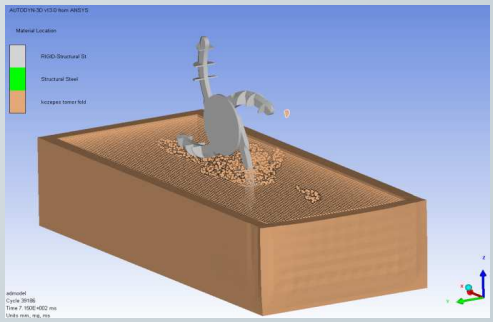
Cultivator sweep simulation



Cultivator sweep calculated and soil bin test results

Forest cultivator tool – 3D

As a pure experiment we have decided to investigate an active, forest cultivator tool too. We would have liked to see, whether the solver is able to handel such a complex geometry and high level of deformation. With some solver limitations and cutt offs we could run succesfull simulations and we are working on the validation of our results with real mesaurements also now.



Forest cultivator simulation

Summary

We had only 20-30% failure to measurement results what is quite good considered the inhomogeneus structure of soil. On the basis of the work of Tamás and Jóri (2010) we were only with 5-10% less accurate than DEM, but we needed with orders of magnitude less computational resource and time. (2D model – 1 week to 10 hours) ANSYS AUTODYN's interface is also much more user-friendlier than any other DEM programs. Further validated simulations are needed to investigate the implementation of D-P model and some known instability problems of SPH solvers.

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