CUTTING OF HIGHLY PLASTIC CLAY: ANALYSIS OF LARGE RAPID DEFORMATION PROCESSES

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Fig. 1. Example of a clogged cutter head.

Background

Dredging is the activity of removing submerged sediment and depositing it to a designated area. A Cutter Suction Dredge has a rotating cutter head with teeth for excavation of the sediment. Clay is a notoriously challenging material to dredge, as it may clog the suction head (fig. 1.). This will raise difficulties in estimating the production, the required power and increase the risk of downtime.
Important topics for the cutting process are the interaction between the clay sliding over the blade and the resulting macro deformation of the chip. Various cutting regimes can be distinguished, including the: Flow regime, Tear regime, Curling regime.
The objective of the CHiPS project is to study cutting regime transitions for dimensionless parameter groups of soil properties and operating conditions. Transitions range from static traction problems on soft mud to grinding action on stiff clay.

Goal

For investigating the cutting process and its associated problems, we designed a testing rig with the following objectives for allowing to conduct the experiments:

- Identifying the main parameters influencing the cutting forces and the cutting regime (fig.2.)
- Designing general arrangement for testing linear cutting models
- Capture the signals for force and deformation

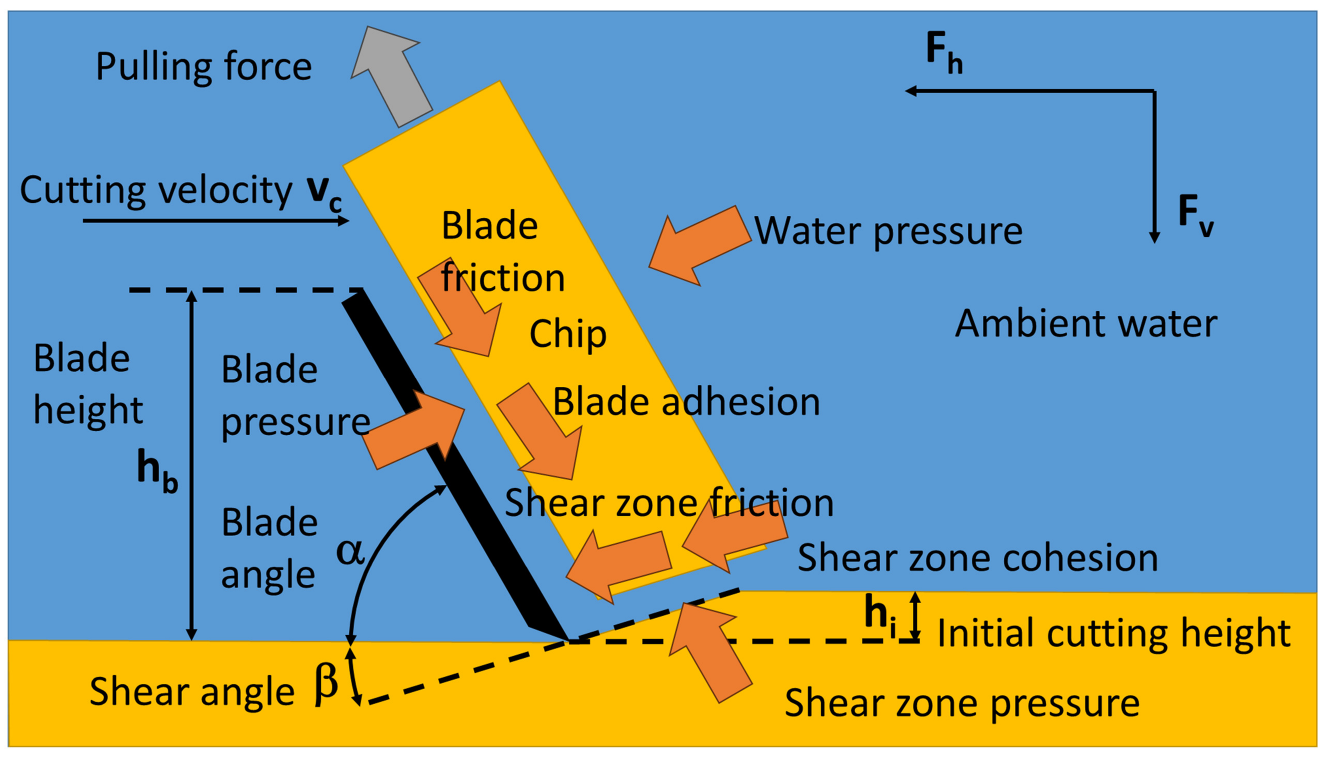

Fig. 2. Overview of the forces involved in the cutting of clay.

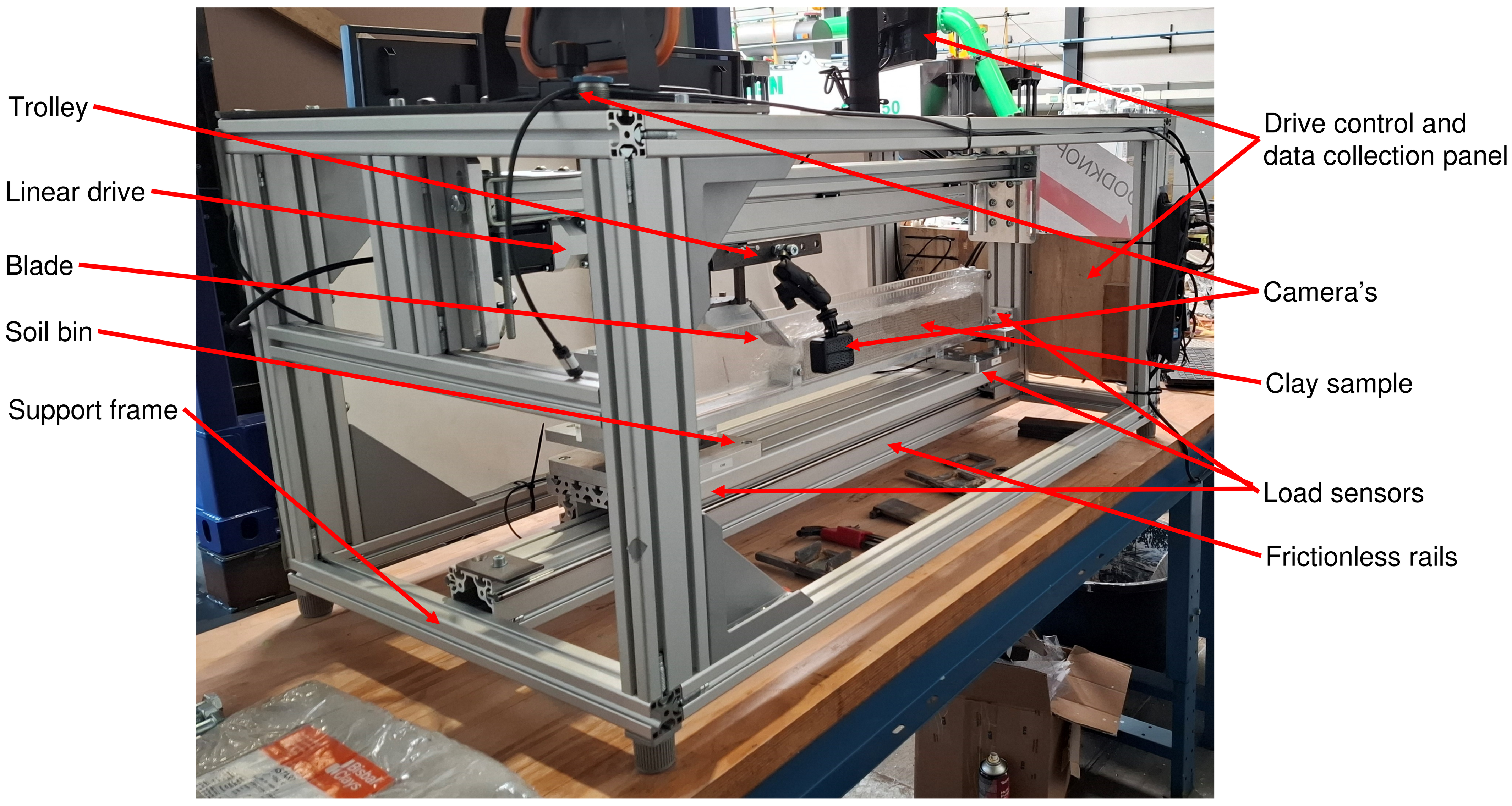

Fig. 3. General arrangement of the linear cutting test rig.

Method

The test rig is similar as used in previous experiments by others (fig. 3.). The blade is attached to a linear moving trolley, cutting through a block of clay mounted in a frictionless soil bin. The reaction forces on the box are measured. Images of the grid printed on the side of the clay block (fig. 4.) are captured with a GoPro camera of later evaluation with PIVlab®. A total of 30 experiments were conducted.

Fig. 4. Deformations visible with a grid printed on .side of the clay sample.

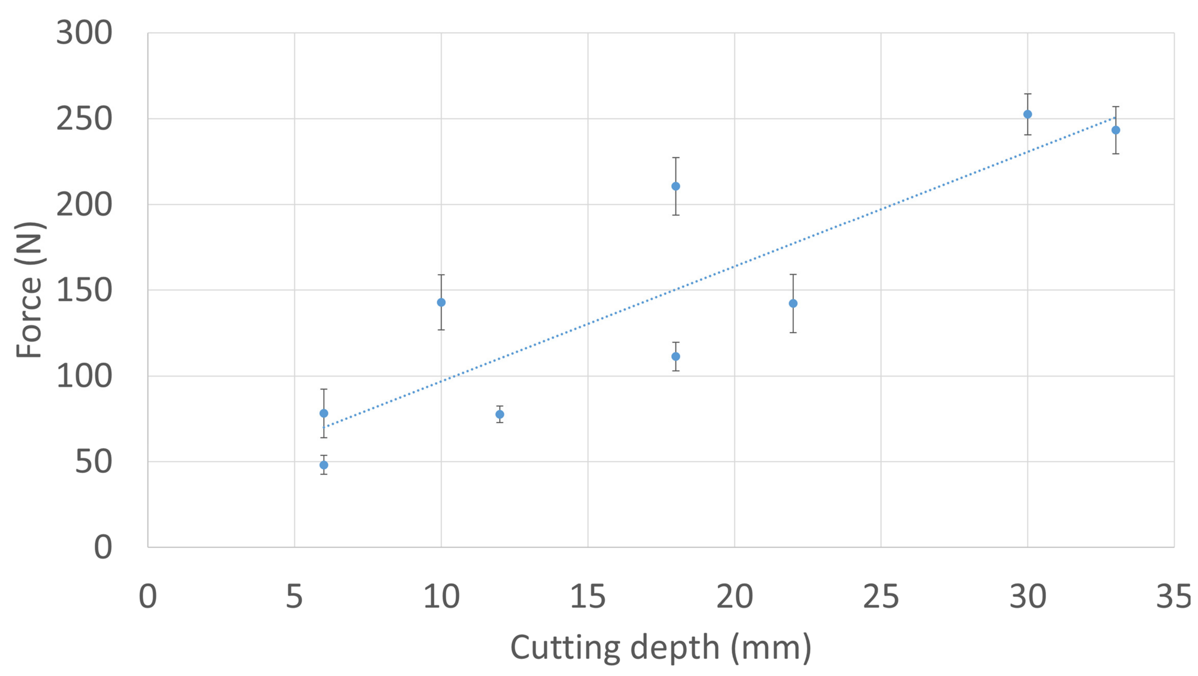

Fig. 5. Linear relation between main cutting force vs cutting depth.

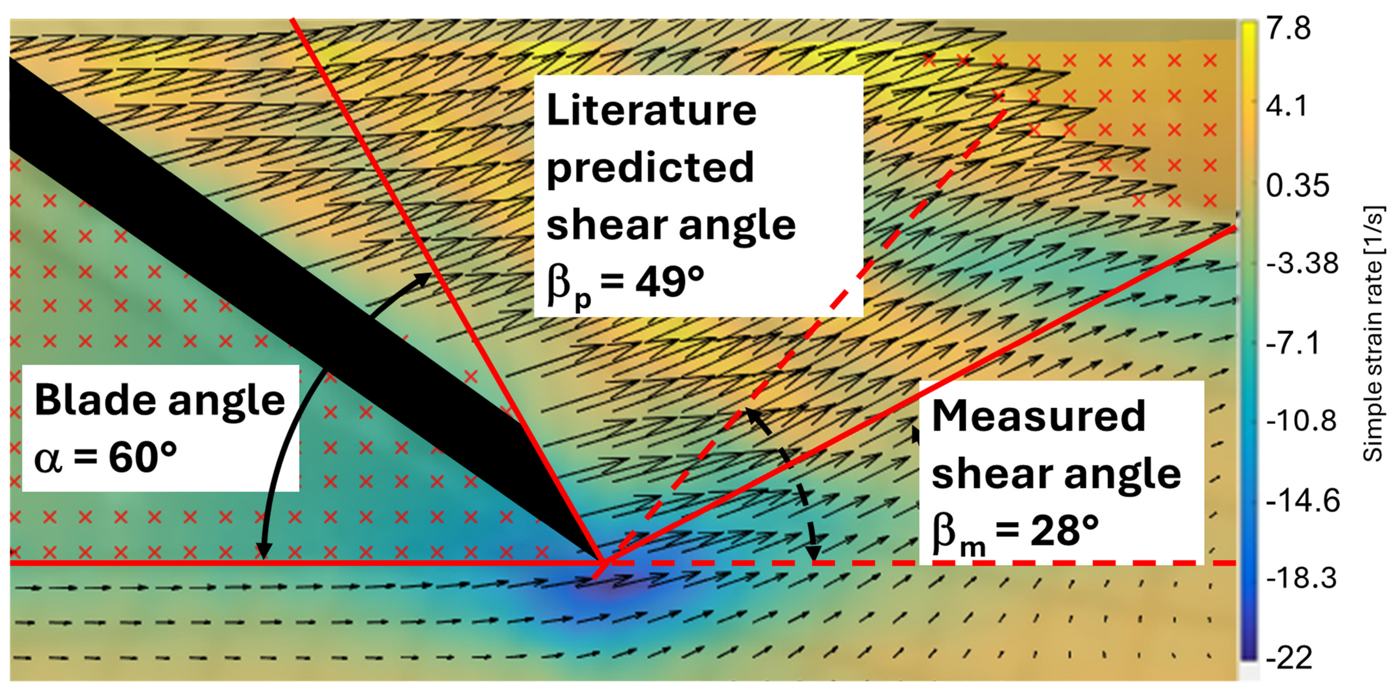

Fig. 6. Captured deformations in a vector field using PIVlab®.
Note the difference between predicted and measured shear angle.

Results

- The tests confirm a linear relation between cutting depth and cutting forces predicted by existing models (fig. 5.)
- Displacements can be accurately measured from the PIVlab® registrations.
- Measurements indicate that the external friction cannot be neglected (fig. 6.). This appeared in the measured shear angle, which was much lower than the calculated shear angle.

Conclusions

- The test rig is capable of testing and measuring the behaviour of clay during cutting.
- The collected data is low noise, reproducible and reliable for validation and improvement of strain rate models of clay cutting.
- Adhesion and external friction contribute to the cutting forces and cannot be neglected. The resulting shear angles are heavily influenced by this parameter.
- Tensile strength has to be checked/measured for consistent results and needs to be implemented in future models.
- The chip thickness, shear angle and strain rate are successfully captured by scanning a printed grid on the clay. PIVlab® can be used for creating the vector field.

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