Drill bug: Developing bio-inspired drilling methods in extreme environments

Dr T. Mishra, Assistant Professor, Chair of Surface Technology and Tribology, Faculty of Engineering Technology, University of Twente. Contact: t.mishra@utwente.nl

Based on the reciprocating drilling mechanism found in the ovipositor of wood wasp, a drilling setup was designed and manufactured in the *Drill bug* project funded by the Crazy research call by the Engineering Technology (ET) faculty at University of Twente. The project was managed by Dr Tanmaya Mishra of the Surface technology and Tribology (STT) chair in the ET faculty. The drilling assembly was manufactured at Techno Centrum voor Onderwijs en Onderzoek (TCO).

The drilling assembly consists of 2 main parts: (1) The actuation mechanism and (2) the drill bit (tool). The design of the drill bit (Figure 1b) was made consisting of two separate conical parts consisting of convex serrations, to be able to drill through granular materials. The drill bit was 3D printed from polymer composite named Onyx. The actuation of the reciprocating mechanism is obtained from rotary motion of the motor shaft by using rods connected to rollers over elliptic cam (Figure 1c). A counterweight is attached to the loading system to allow for penetration of the drill bit into the granular specimen (Figure 1a and 2b). A climate chamber is designed and mounted around the specimen and connected to a modular humidifier to control humidity in the granular sample (to replicate environments). The drilling system is powered using a Brushless Geared, 80 W motor. The drilling setup along with the motor has been successfully mounted and connected with the PLC board (Figure 1b).

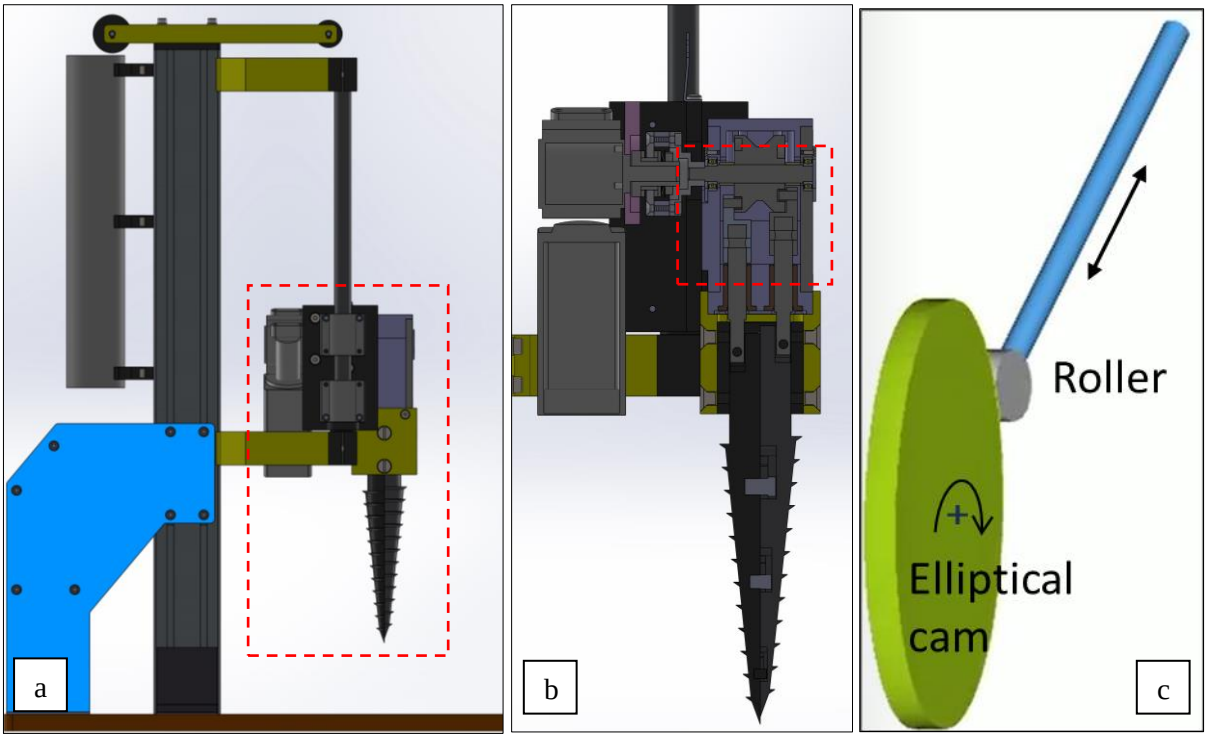

Figure 1. Design of the (a) drilling setup, (b) the drill bit assembly and (c) the actuation mechanism.

The drilling setup has been run without any major issues as shown in the demo video. Initially the drilling setup is used to drill though homogeneous glass beads of size 200 µm in a confined container (Figure 2b). As of now the drilling setup is not connected with any measurement devices such as load or displacement sensors which can help measure the load vs penetration performance of the drilling mechanism. Following initial test runs, certain points of improvement and analysis have been identified:

1. The internal friction in the drilling setup is quite high, following the dynamic loading in the cam-roller contact. Further design improvements aim to minimize friction in the actuation

mechanism by applying lubricant and bushing in contacts. Additionally actuation mechanisms such as crank-shaft, eccentric cam rollers will be designed and tested for comparison.

2. Currently the setup is operating at maximum (motor) torque capacity to overcome friction in the system. Applied torque by the motor will be increased by using gear boxes with higher gear ratio in combination with a more powerful motor.
3. The softer drill bit (made by 3D printed polymer) is wearing out due to entrapment of crushed granular (hard sand) particles within the drill tips. We aim to manufacture drill bits from tool steel to avoid wear and increase the lifetime. A gap slot between the halves of the drilling parts will be provided to allow for movement of granular (sand) material.
4. By coupling an oscillation along with reciprocating drilling to fluidize granular media drilling performance can be improved in sand and regolith over traditional percussion and rotary drilling methods. The oscillatory mechanism is inspired from the locomotion of reptiles and fishes in desert and aquatic environment respectively.

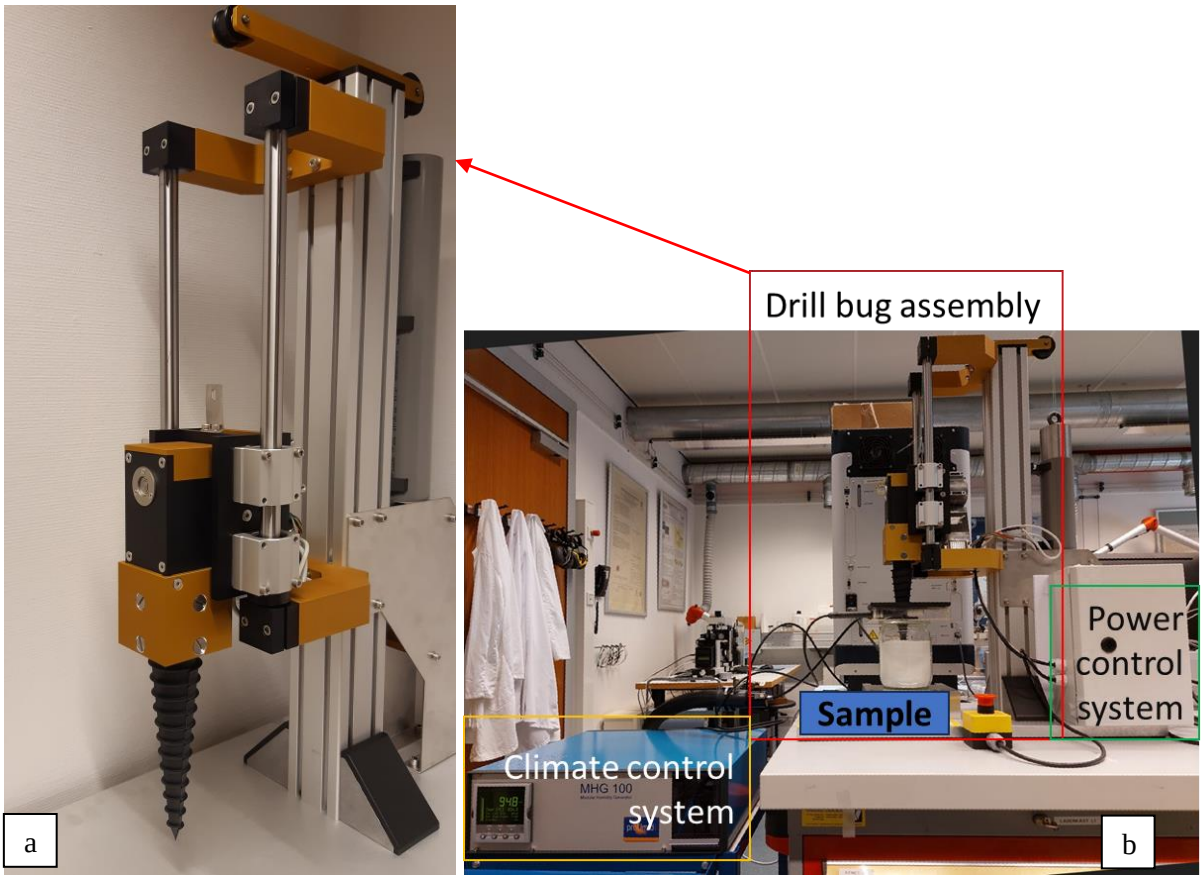

Figure: (a) Drill bug assembly and (b) mounting and running of the drill bug setup along with the power control and climate (humidity) control systems in the STT lab.

Going forward, the drilling set up is the topic of Masters and pre-Masters assignments and has been uploaded in the website of canvas for University of Twente (chosen topic for 3 pre-masters student assignment). The setup has also been used on a lecture on 'Engineering application of geomaterials: Inspired from Nature' in the Masters course on 'Nature inspired design and Engineering'. Through the new drilling setup, we aim to test and develop novel and robust drilling setups, relevant for efficient and sustainable drilling in extreme environments. The Drill bug project has set the stepping stone to initial research in Drilling engineering and Drilling tribology in University of Twente. Going further we plan to extend this research field through collaborations and proposals.