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New electric powered drill rig to meet sustainable geotechnique

Nouvelle sondeuse électrique pour atteindre une géotechnique soutenable

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ABSTRACT: Drilling boreholes for geotechnical purposes such as sampling, in-situ tests and permeability testing are usually performed with the aid of drilling machines. These machines generally use internal combustion motors to provide energy to hydraulic pumps feeding the different actuators needed to push, rotate and hammer the drill bit into the ground. This results in a very noisy and polluted environment for the workers and the surrounding area. With the popularisation of electric vehicles, it’s time drilling machines also make the switch to electric power. This paper presents one such prototype machine developed by Fondasol company, with the initially proposed technical specifications and the realised equipment. An autonomy up to one week has been observed on real sites, depending on the project’s drilling objective. The use of electric motors allows for a new type of measuring while drilling, as the measurement of electric current and voltage is much more reliable than hydraulic pressure and flow rates. With this electric-based design, additional external sensors are no longer necessary. A first insight into this new type of measurements and its physical meaning is also given and discussed within this paper.

RÉSUMÉ: Les forages à des fins géotechniques comme le carottage, des essais pressiométriques et des essais de perméabilité sont habituellement exécutés à l’aide de machines de forage. Ces machines sont assez lourdes, généralement utilisent des moteurs thermiques pour fournir l’énergie aux pompes hydrauliques qui alimentent les différents vérins nécessaires pour pousser, tourner et marteler l’outil de forage dans le sol. Il en résulte un environnement très bruyant et pollué pour les travailleurs et les alentours. Avec la popularisation des véhicules électriques, il est temps pour les sondeuses de passer à l’énergie électrique aussi. Cette communication présente un prototype d’une telle machine, avec les spécifications proposées initialement et l’équipement réalisé. Une autonomie de plusieurs jours a été observée sur chantiers, selon l’enjeu du projet. L’utilisation de moteurs électriques permet une nouvelle forme d’enregistrement de paramètres instantanés, étant donné que la mesure du courant et de la tension électriques sont beaucoup plus fiables que les mesures de pression hydraulique et débit. Avec cette nouvelle conception, des capteurs externes additionnels ne sont pas nécessaires. Cet article montre un exemple de sondage faite avec cette sondeuse et discute de l’utilisation de ce nouveau type de mesure sa signification physique.

Keywords: Measuring while drilling; electrical drilling machine; sustainable development.

1 CONTEXT

Historically used in the energy resource fields but gaining popularity in the field of geotechnical engineering in the last decades, the method of measuring while drilling (MWD) involves monitoring and recording drilling parameters during the drilling process (Rodgers et al, 2020). In this method, a drill bit destroys the terrain as it advances downward, pushed and spun by hydraulic motors while a fluid cools down the equipment and removes loose debris from the hole (Reiffsteck, 2010).

The drilling may have multiple objectives: creating holes for sampling, in-situ tests like pressuremeter tests, installing piezometers, verifying the efficacy of soil treatments or simply gaining knowledge about the subsoil. It has the advantage of being a rapid essay giving continuous information, much like the cone penetration test, while allowing an identification of the soil (Fortunati & Pellegrino, 1998; Cardu et al, 2013).

The drill rigs used in creating these holes may vary in size and overall power but share similar architecture: they all have a mast on which translate the drilling head. The length of the mast and the characteristics of the drilling head may differ according to the project’s objectives (Reiffsteck, 2010).

In addition to the translation motor, the drilling head is equipped with a rotation motor and eventually a hammer that transmit rotating forces to the drill bit underground through the drill string. Both elements are usually hydraulic. The mast has the functions of guiding and driving the drilling head vertically, pushing the drill bit into the soil. This movement is also achieved by a hydraulic system (Reiffsteck, 2010).

There are other hydraulic systems in the rig as well, such as the stabilizing cylinders, the mandible and the cylinder that folds down the mast to put the machine in displacement mode. All these systems, as well as the pump for drilling fluid, are typically powered by a hydraulic motor (ICE) (Nishi et al., 1998; Reiffsteck, 2010).

According to Reiffsteck (2010), one of the risks associated with this method is the accidental release of hydrocarbons (oils or fuel) into the soil from the various hydraulic systems or the motor, which could contaminate the water table. The combustion motor also produces polluting gases and a lot of noise which can be detrimental to the workers' health and the surrounding area, even more so when used in closed environments.

To remedy these issues and improve on the method's energy efficiency, Fondasol has developed an electric drill rig that is presented in this paper. The use of electric motors also allows a different way of measuring drilling parameters, which is also discussed in the article.

2 OBJECTIVES OF THE CLEA PROTOTYPE

The new CLEA drill rig proposes to change soil investigations by using electric motors instead of mechanic/hydraulic actuators fed by an internal combustion engine.

This allows more efficient drilling, as electric motors are more energy efficient than hydraulic systems, while producing less noise and air pollution. The drilling parameters can also be measured more reliably, as it is easier to continuously monitor electrical currents and voltages than fluid pressure or flow rate.

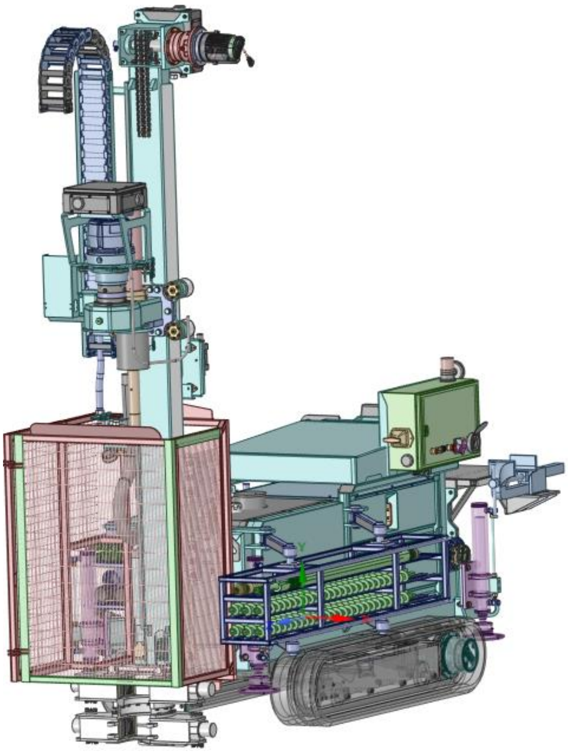

Figure 1. Electric drill rig prototype by Fondasol.

3 DRILL RIG SPECIFICATIONS

The prototype can achieve vertical speed of 900 m/h or 1500 mm/min with a maximum force of 21 kN. This movement is powered by an electric motor. The electric rotation motor allows a rotation speed of 350 rpm and a torque of 1500 Nm.

These specifications were chosen to approximate those of a conventional 32 kW hydraulic drill rig: vertical speed of 900 m/h, down force of 20 kN, rotation speed of 300 rpm and 1500 Nm of torque.

The battery bank used for the prototype is in the form of a detachable wagon and an autonomy of well over a week has been observed in the field (8 to 12% of battery used per day).

However, at this stage of development the prototype is not completely electric, it was built on the chassis of a conventional rig and still uses ICE powered hydraulic systems to operate the stabilizing cylinders and to unfold the mast. The engine is also used to power the continuous tracks while in displacement mode. A new 100% electric prototype is being built at the moment on a custom chassis with integrated power banks.

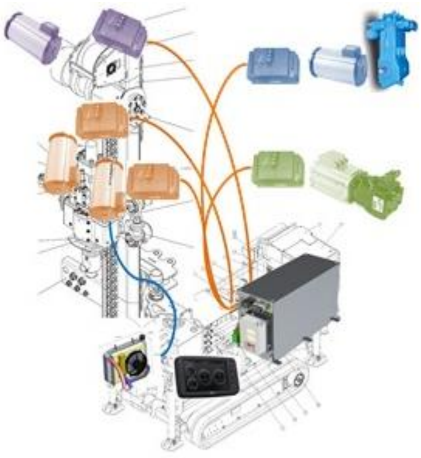

Figure 2. Scheme of all electric motors in the prototype.

4 ELECTRICAL MWD MEASUREMENT

The use of electric motors allows the monitoring of drilling parameters through the current and voltage. These electrical parameters are directly proportional to torque and rotation speed, respectively. This advantageously replaces the pressure transducers and the optical/magnetic sensors used to measure rotation speed typically used in conventional hydraulic rigs that only indirectly measure each parameter. The pressure transducers also have the disadvantage of not measuring the forces truly delivered to the drill bit as they are placed beside the pumps and cannot account for energy losses in the system (Peronne et al., 2021).

Unlike the typical measurements, the CLEA directly measures the current delivered to each motor, which is directly proportional to the torque applied on the drill bit. Instead of logging the values measured as a function of depth (typically each 2 cm), the prototype registers all the parameters as a function of time resulting in a much more detailed dataset.

The collected data can be displayed both as the conventional physical parameters in their respective units (MPa, Nm) of measurement and in terms of energy spent or power in kW delivered to the motors. Calculating the power spent by each motor also has the advantage of providing the total energy spent during the survey, which can be used to confirm the battery indicator and visualize which motor spent the most energy at a given moment.

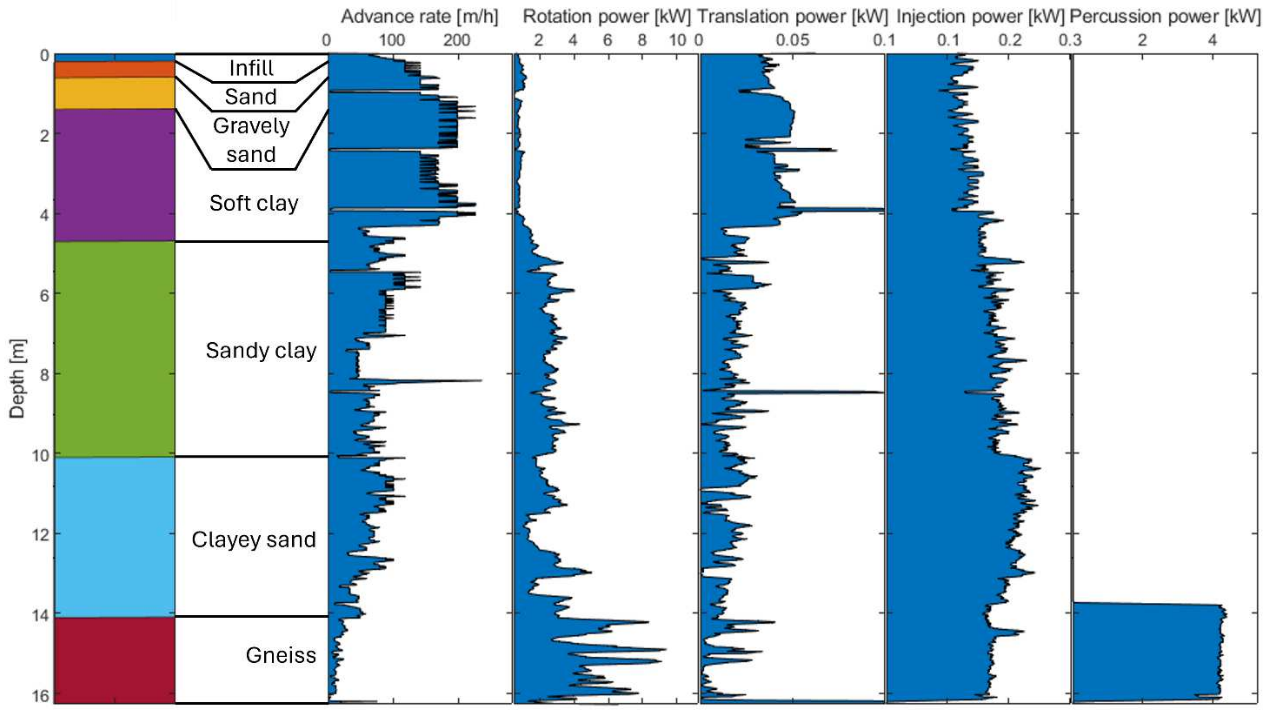

Figure 3. Example of MWD logs for electrical rig.

As shown on Figure 3, the motor responsible for vertically translating the drilling assembly (related to the down thrust parameter) consumes the least power, while the motor that rotates the rods and the hammer consume equivalent amounts of energy. Changes in soil layers are clearly visible, as indicated by the reduction in penetration rate and rise in rotation power at about 4.0 m. It can also be seen that the hammer was only used to excavate through the layer of gneiss below 14 m accompanied by a rise in rotation power. The layers of sandy clay and clayey sand above the gneiss can be differentiated by the change in injection power and larger variations in rotation power. These logs suggest that parameters based on electrical consumption can be used to determine lithology, much like the hydraulic parameters typically recorded.

5 CONCLUSIONS

This paper has presented the architecture of a new model of drill rig that uses electrical motor instead of hydraulic ones fed by an internal combustion engine. The prototype tested in situ has performed better than expected, with autonomy for over a week of surveying without recharging, all the while being more silent and not generating greenhouse gas emissions. The data collected by logging the current and voltage used by the various motors has been shown to be as detailed or more so than the data registered while using pressure transducers in a conventional drill rig. The data can be displayed as the conventional physical parameters or in terms of power spent by each motor and can be interpreted in the same manner as regular MWD logging.

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