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Sensor for Deep Core Drilling Operational Parameters – Determination of the Drilling Capacity

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Abstract. The deep core drilling has currently wide application - construction drills, geological exploration, drills for measuring pendulums in dams etc. The most important parameters for the optimal drilling process are torque, pressure force and rotation speed. These parameters depend on the strength of the drilled material (drilling capacity) and of course on the drilled diameter and applied pressure force. The contribution describes the design of the special sensor for measurement of drilling torque, force and rotational speed. These data are further used for determination of the drilling capacity of the drilled material. There is no methodology to calculate this parameter. Two approaches are used and compared to determine desired parameter of the drilling capacity.

Introduction

The deep core drilling has currently wide application - construction drills, geological exploration, drills for measuring pendulums in dams etc. The most important parameters for the optimal drilling process are torque, pressure force and rotation speed. These parameters depend on the strength of the drilled material (drilling capacity) and of course on the drilled diameter and applied pressure force. In-time identification of the operational parameters enables the optimization of the drilling process directly during the drilling process, [1, 2]. This contribution builds on EAN 2019 contribution, where the design and sensor calibration were introduced. This contribution describes the final design of the sensor for monitoring above mentioned parameters. Data from new terrain measurement are further presented and analysed in detail to determine the drilling capacity of the drilled material. The usage of the sensor is described in the scheme in Fig. 1.

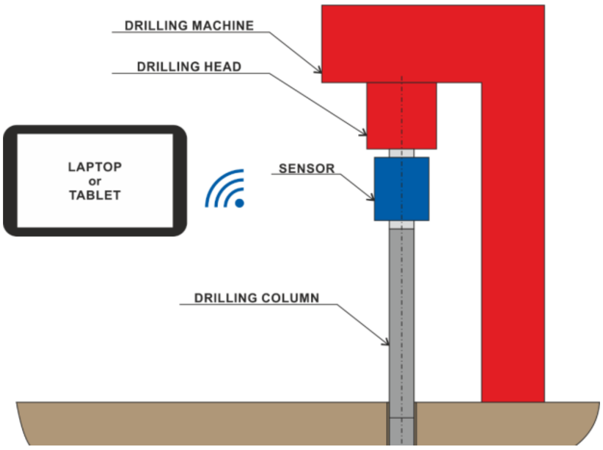

Fig. 1: Scheme of the sensor usage

Sensor final design, data acquisition and telemetry

The sensor design (see Fig. 2) and the principle of measurement and data acquisition were described in detail in [2]. Sensor design is based on the common drilling rod with hexagonal couplings, which is used in short version as a deformation member. Thus, it can be easily connected to the various drilling machines.

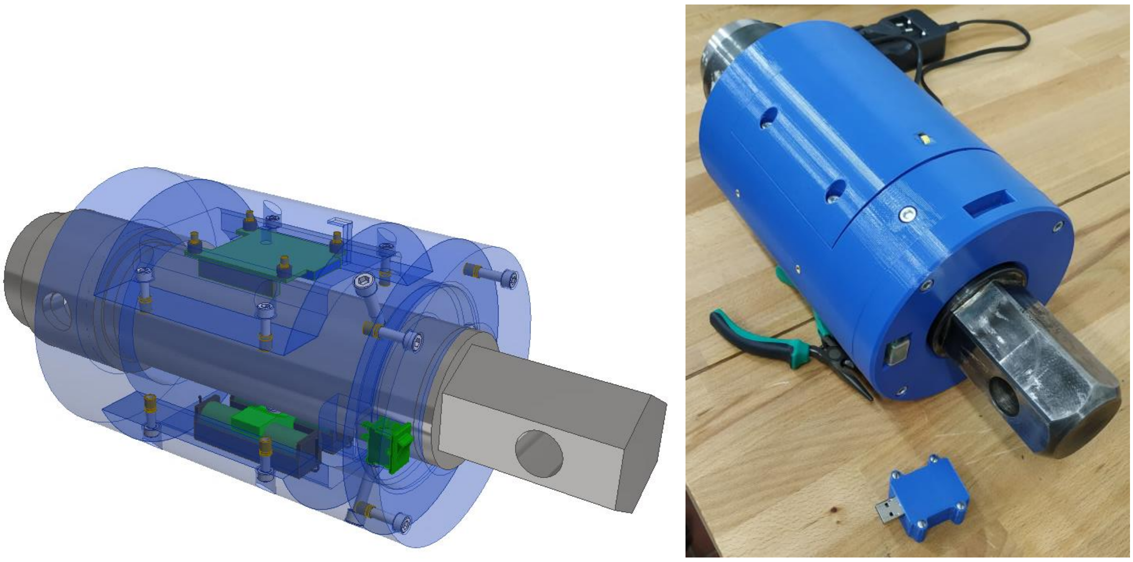

Fig. 2: Sensor design - CAD model and final product with Digi XBee receiver

Above mentioned operational parameters are identified by means of foil strain gauge rosettes (torque – HBM 1-XY21-6/120, axial force – HBM 1-XY91-6/120) and Hall probe in combination with the neodymium magnet (rotational speed), [3, 4]. Data are acquired by means of the special datalogger LPDR with 24bit A/D converter and with sampling frequency 500 Hz per channel. The telemetry is realized by the Digi XBee 2.4 GHz transmission. The power supply is realized by means of two Li-ion batteries of type 18650.

After the problem with insufficient strength of steel S355, the deformation member material was changed to 42CrMo4 with heat treatment. Whole sensor is encapsulated by the FDM printed cover made of PETG material. The design was optimised to achieve better ergonomics.

Terrain measurement

The terrain measurement is carried out with the final sensor and the RDBS mini drilling machine, see Fig 3. The location of the drill is in Pátek near Poděbrady. From the regional geological point of view, the location belongs to the Czech Cretaceous Basin. Turonian sedimentation is represented by calcareous siltstones (marlstone) with positions of limestone. Sediments of the lower and middle turon (marlstone) in the total thickness of about 90 m, are the part of the artesian collector in Poděbrady hot-spring structure. Quaternary cover consists mainly of sandy to clayey-sandy loam. The thickness of the coverings does not exceed steady ground water level, usually 2 m below ground level. The drilled core can be seen in Fig. 4.

Fig. 3: Drilling in Pátek, Poděbrady region

Fig. 4: Drilled core – 1.4 m of backfill then marlstone (one column represents 1 m depth)

Data evaluation

Acquired date are post-processed and evaluated to get the time-behaviour of the drilling torque, pressure and rotational speed. These data are correlated with the depth of the drill and the geological description of the drilled core. The time behaviour of the torque and pressure force can be seen in Fig. 5. The first 1.4 m through the backfill are very quick to drill. The rest of the drill goes through the marlstone. There are several depth measurements during the drilling. These measurements are done by the tape measure. The graph of rotation speed is not presented here, because the rotation speed remains constant 30 rpm.

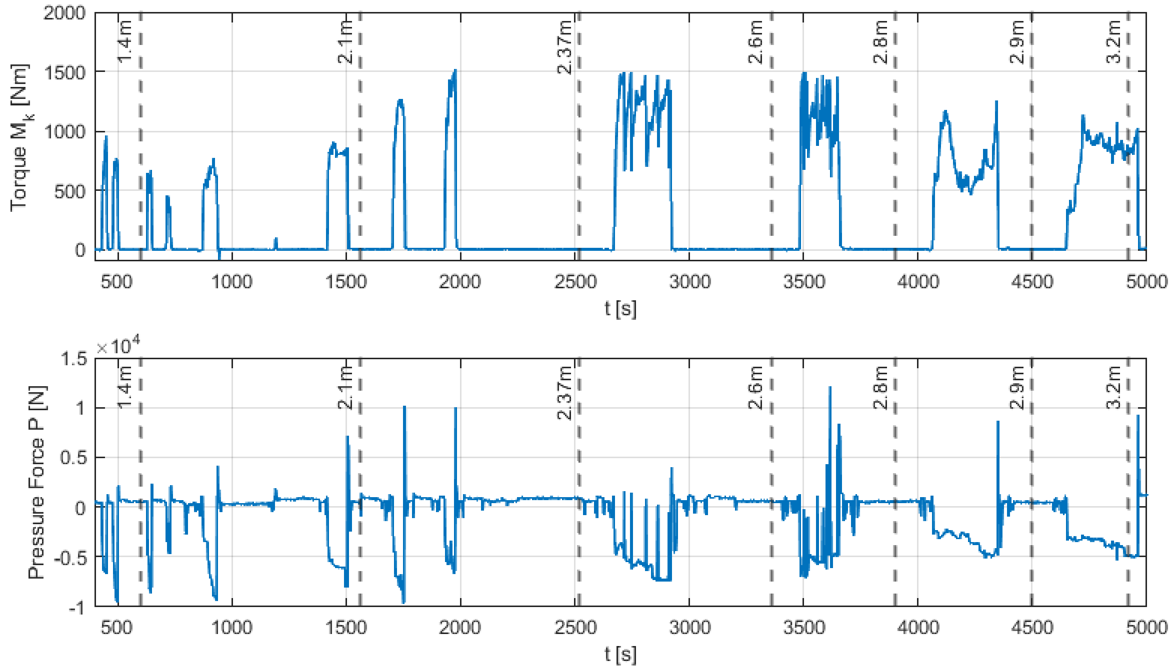

Fig. 5: Time behaviour of the drilling torque and pressure force during terrain measurement

The drilling torque is dependent on the input pressure force and also on the strength of the drilled material. To get the information about the strength of the material – drilling capacity, the torque is divided by the pressure force – drilling coefficient, see Fig. 6 top. The higher the drilling coefficient, the higher the material strength. There is evident increase of the drilling coefficient during the depth of the drill. Especially, there is significant increase in 2 m depth of the drill. Approximate depth of the interface of the backfill and the marlstone is about 1.4 m.

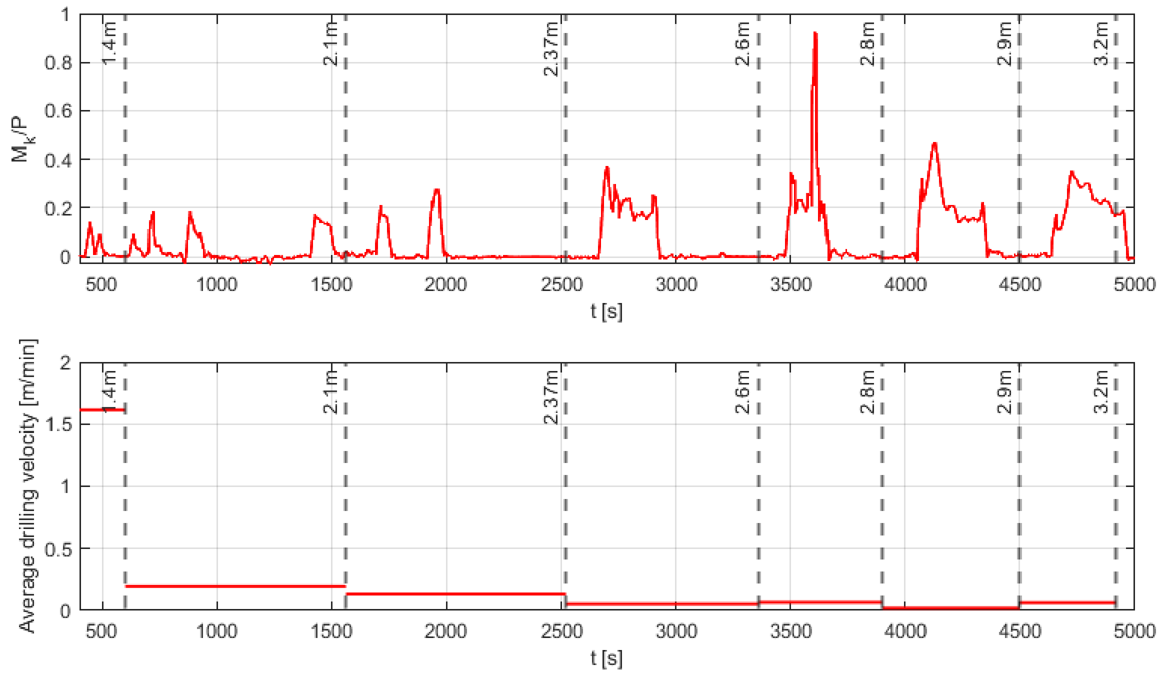

Fig. 6: Time behaviour of the drilling coefficient and the average drilling velocity

As a second indicator of the drilled material strength, the average drilling velocity is calculated. That is calculated between every depth measurement from the time duration of the drilling sequences. The time behaviour is described in Fig. 6, bottom. The difference between the drilling capacity of the backfill and the marlstone is distinct. The average drilling velocity in the marlstone is approximately 10x – 20x lower than in the backfill. The average drilling velocity decreases slowly till the depth 2.37 m and then remains almost constant.

Conclusions

The contribution summarizes the development and testing of the sensor for monitoring deep core drilling parameters. Measured data from the drill in Pátek location are presented and analysed. The main goal of deep core drilling parameters monitoring is the drilling capacity assessment. For this purpose, two quantities were calculated form measured data. The first one is the drilling coefficient – the ratio of the drilling torque and the pressure force, the second one is the average drilling velocity. Both parameters indicate the significant difference of the strength – drilling capacity of the backfill and marlstone in Pátek drilling location. During next improvement of the sensor there should be developed the online drill depth measurement and also online drilling velocity measurement. The main goal is to obtain the detail information of the drilling to determine the continuous information about the strength of the drilled material.

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