Recording drill data

Preface

Our company is Environmental Mechanics AB or short Envi. A Swedish company developing, producing and marketing systems for drill data recoding (also known as MWD, which stands for Monitoring While Drilling) and soft soil investigations using several kind of probes. All development and production is done in Sweden.

This documents is intended as a introduction to MWD.

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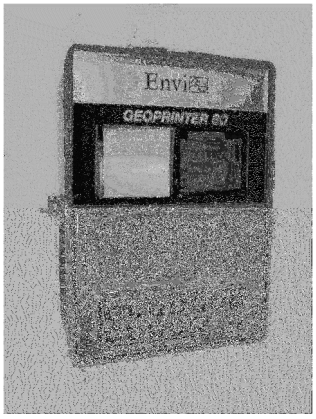
History

In Scandinavia drill data has been recorded since early 1970s. Methods have been derived from oil industry and later also from mining industry. In the beginning, mechanical instruments where used, recording parameters from the drilling equipment, as well as from the penetrometers or other kind of equipment (like e.g. the Swedish weight sounding, which was very common in Sweden and still is used). A common name for drill data recording is MWD (Monitoring While Drilling), even though the meaning of that expression varies a bit depending on who you ask.

When electronics more suitable for field use came on the market, in the mid 1980:s, companies started to investigate the possibility to develop an electronic data logger suitable to be mounted on a drill rig for collecting drill data. Challenges were many due to the harsh environment in which they are to operate when doing Geotechnical and Geological Site Investigations.
Mr. Kjell Elmgren, former owner of Environmental Mechanics AB, was the first in Sweden who managed to develop a functioning system. Together with his colleagues at Envi, he designed the first MWD data logger called Geoprinter 50.
Geoprinter 50 was, at that time, a high technology data logger, water proof and suitable to be mounted on Geotechnical Rigs, used in any environment from the North Pole down to the Sahara Desert.



The old Geoprinter50 datalogger

Since then several generations of data loggers have been developed by Envi. The current model is called Envi Logger G1 was introduced to market in early 2010. It is PC based and fully digital and uses a CANopen data bus for data transfer to and from sensors. Below are the building blocks of our new G1 system. More details about that system later in this document.

Gate *or transforming analogue to CANopen format*

Trim *Yuma, IP67 tablet PC* *Wirehouse* *Regular proximity switch*

What is measured?

Drill data recording means measuring sensor data from a drill rig. These data can be produced anywhere on the rig. The only things that actually matters are:

1. Your measurement is correct and complete

2. You know how to translate your sensor data to real world aspects (e.g. how to translate strain gauge bridge output to feed force or pulses from a proximity switch to rotation count and RPM)

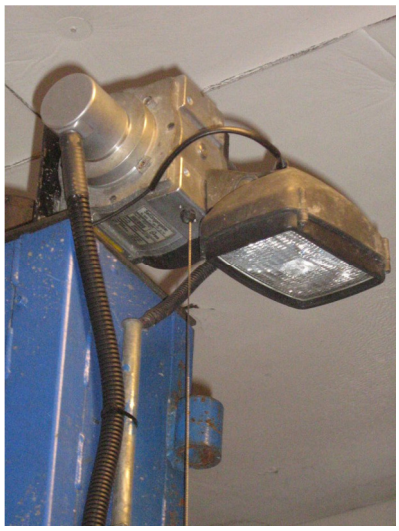
Parameters normally measured are:

- Time
- Drill hole length, often referred to as Depth but drilling may be executed horizontally or even vertically in the opposite direction. When you combine Time and Depth you can get rate of penetration or short ROP which describes how fast you are drilling. Depth resolution varies between different systems but Envi Logger G1 has default resolution 1 cm/10 mm when plotting depth
- Number of rotations for each centimeter. When combined with Time you can get Rotations Per Minute or abbreviation RPM by dividing number of rotations with the time it has taken to drill the current centimeter
- Feed force (also known as *bitload*) by using a strain gauge solution attached properly on the drill rig or by calculating theoretical force from pulldown pressure and holdback pressure on the feed cylinder.
- Hammer pressure to determine hammering force
- Rotation pressure to determine torque
- Flush- or mud pressure
- Flush- or mud volume

How are parameters measured?

Different parameters are measured in different ways by specialized sensors. below is a list of sensors for each measure parameter as suggested above. I will skip describing time since that is not an actual parameter but more like an index.

Depth is measured using a multiturn encoder with 12 bits single turn resolution and 18 bits multiturn resolution and CANopen interface. The transducer is normally IP67 but also IP69k is available. The sensor is typically mounted on a wire house module as per image to the left below or using a mounting bracket on the drill unit and supplying the axle with a cogwheel + a chain will be mounted all along the mast as per image to the right below.



Rotation is counted by using a proximity switch that gives pulses (=counts) on bolts or equivalent on the drill unit. This pulses are converted to CANopen messages in a CAN converter unit and sent to gateway box on the CANopen bus.

Rotation pressure is determined using a 400 Bar IP67 pressure transducer with CANopen interface. This transducer gives you a raw value between 0 and ~2000000 and those values are calibrated towards pressure values (measured in MPa or kPa) in our system.

Hammer pressure is handled in the same way as described above.

Feed force can be measured in several ways:
1. You use a strain gauge to get data. This is typically done using an S-shaped transducer
2. You read hydraulic pressures on both sides of the hydraulic piston and consider piston area on both pulldown and holdback side of the piston to get feed force.
Either way above you still need to calibrate the sensor output to an actual force which cabn be done using several segments to compensate for possible non linearities. This is done by using a very accurate scale and and reading pressure or strain gauge output for many forces.

Flush pressure is handled in the same way as described above for rotation pressure.

Flush (or flow) volume is determined using a flow meter of some kind and translating readings to digital CANopen data

Why measure and record drill data?

Generally said drill data is recorded to:

- Safeguard quality in drilling
- Analyze ground structures from interpretation of recorded data
- Optimize drilling. Drill operator can see all parameters in real time and fine tune the drilling parameters to get optimal drill speed

If you use the logger system for analyzing ground structures you will probably use some equation for energy or equivalent to conclude what kind of ground material it is that you drill through. However experienced drill operators and drill managers can say from recorded drill parameters what kind of ground it is.

The equation for specific energy has been used to include several drill parameters and correlate them to ground stratigraphy.

Specific energy

$$E_s = \frac{F}{A} + \frac{2 \pi N T}{A V}$$

F (kN): Bit Load
A (m^2): Area of Bit
N: rpm
T (kN x m): Torque
V (m/sec): Rate of Penetration

From this equation one can deduce ground condition and categorize it like:

- Soft material
- Hard soil
- Harder material with bolders
- Bedrock (High energy)
- Cavity (almost zero energy)

etc etc

If you consider also the flush and flow parameters you can verify existence of fissures and cavities. This can be very valuable information when you need to build some structure on the ground or if you need to anchor something in the ground.

An MWD system can be mounted on any type of drill rig and for any drill method (rotary, percussion, roto-percussion, etc)

The modern MWD is the development of old methods to record the drilling parameters used in oil drilling. Due to the accuracy and the reliability of new equipment, together with powerful and affordable electronics, MWD can be considered a very powerful tool in almost every drilling application, for example in geotechnical drilling:

- Integrate continuous core drilling with cheap and reliable data obtained with no-coring drilling, (not influenced by the quality of the coring)
- In case of very variable stratigraphy (e.g. cobbles alternated with gravel, clay, sand, very common in some zone) the use of many MWD no-coring drilling can give even more information than the continuous coring drilling. For example it is very difficult to detect a thin layer (10-20 cm thickness) of clay between two gravel layers by using continuous core drilling; on the other hand the use of MWD with data acquisition every 1 or 2 cm can assess very well the stratigraphy.
- MWD can be used while continuous coring drilling with wire-line method.
- The use of MWD can give help to interpretate the soil behaviour, through analysis and interpretation of specific energy and other formulas. In case of very deep drilling (like in oil drilling or offshore drilling) MWD is the only available tool (apart from logs) to interpretate the stratigraphy.
- MWD can help to control the drilling by measuring all the important parameters.
- MWD is used together with other tools (i.e. CPTU in CPTwd) can give additional geotechnical information
- MWD might be (in some cases) among the few methods to assess the soil behavior (i.e. in some landslides)

In foundation drilling (piles, micropiles, anchors, jet-grouting, etc):

- MWD is the only available tool to check stratigraphy during no-coring drilling for piles, micropiles, jet-grouting
- MWD reports can be used in some cases as Quality assurance certificate. The Client and/or the Consultant can check every drilling the final depth, the stratigraphy, the volume of fluid, the grouting pressure and volume, etc.
- MWD results can be used to calculate directly some behavior of the deep foundation (like in the above mentioned example related to anchors)
- Reliability of the results, if compared in the same site, can give some important information about the homogeneity of the soil in large areas.

In hydrogeological, environmental drilling:

- MWD (more than the above listed features) can be used (in addition to the cutting examination) to know some important behavior of the strata (rough estimation of aquifer permeability, thickness,etc). However the CPT is a better choice.

In well drilling and energy drilling:

- MWD can be used to optimize the drilling to get maximum production. You register ROP in correlation to other drill parameters and tune the other parameters until you get optimal drill speed.
- The system can also be used to get a report on the drilling done to ensure accurate depth has been reached and even generate reports instead of hand writing them.

The different parameters measured and the use of them are:

Rotation pressure is read to estimate the torque applied to the drill bit. Rotation torque is linearly proportional to rotation pressure so most users read rotation pressure without calibrating it towards torque.

Hammer pressure is read to estimate the impact of hammering. Most users (maybe all) use the same hammer frequency and pressure every time since this parameter is not included in in the equations for specific energy.

Pulldown pressure is the hydraulic pressure on the side of the hydraulic piston making the drill string go down the hole.

Holdback pressure is the hydraulic pressure on the side of the hydraulic piston reducing the drill string down hole movement. This is normally used to balance the drill unit when unloaded.

Flush pressure is the pressure with which fluid (water or mud) or air is inserted into the hole.

Flow volume is the volume of the fluid. With constant pressure but increased flow there must be a fissure or cavity receiving the increased flow.

Feed force or Thrust is a parameter in the specific energy equation and has direct impact on energy used and hence on determining ground type.

Rotation is measured as number of rotations per unit length down hole but also as rotations per minute (RPM). Rpm is used as a parameter in the specific energy equation.

Depths measured to know position for all the other parameters. This is our base unit for most parameters.

ROP (Rate Of Penetration) is measured to show how fast the drill string is advanced into the ground. This parameter is used in the specific energy equation.

Some case stories

On our homepage www.envi.se you can see several case stories. We have tried to gather information about some different types of users and how they benefit from having our systems.