

# Monitoring Of Drag Anchor Embedment Parameters.

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## **Introduction.**

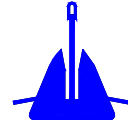
Drag embedment anchor installation typically consists of applying a pre-determined load to the mooring line to embed the anchor into the seabed. Upon completion of the anchor installation generally only the anchor drag length and the applied installation load are known. Anchor penetration depth is difficult to determine as the anchor is generally fully embedded in the seabed.

Newly developed technology allows key anchor parameters to be viewed real time on the installation vessel, resulting in a higher confidence level with regards to the anchor installation. Together with the anchor drag, the anchor penetration depth, applied load at the anchor shackle, roll and pitch of the anchor are transmitted to the vessel. This allows the installation contractor to determine at an early stage if the installation is going as required and to make any changes if so required.

This paper will discuss the technical challenges involved with the development of the system, results of actual anchor installations and the application of the technology in future drag embedment anchor installations.

## **System requirements.**

Currently if drag embedment anchors are installed, there is only a limited number of parameters that can be measured. These are the anchor drag (horizontal displacement) and applied tension. In some cases it is possible to also measure the anchor penetration depth (vertical displacement). Anchor drag can be measured by monitoring either the displacement of the installation vessel (the changing shape of the mooring catenary should then be accounted for) or by placing a transponder on the mooring line at a location close to the anchor (figure 1). The applied anchor tension is generally determined by taking the winch settings (or bollard pull) or other surface tension meter and the anchor tension is calculated by taking into account the friction of the mooring line on and in the seabed. Anchor penetration



depth can in some cases be measured by using a ROV and visually determining the length of the embedded mooring line.

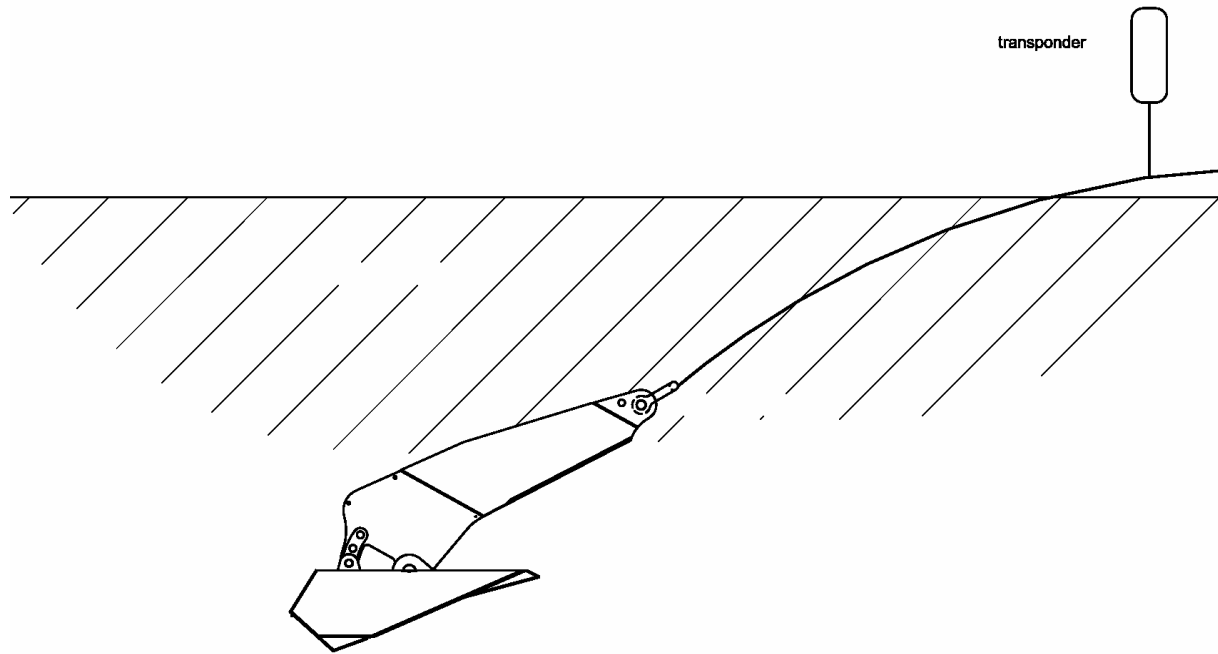
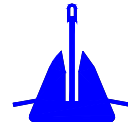


Figure 1 – monitoring of anchor displacement using a transponder on the mooring line

With safety and classification requirements becoming more stringent and clients wanting more information on the reliability of their assets, a more modern system for determining the anchor embedment parameters is required. After analysis of the available data, safety / classification requirements and client wishes, the following minimum requirements have been defined for an anchor embedment data acquisition system:

- Real time measurement and display of all data measured on the anchor itself
- Measuring of the applied load at the anchor
- Penetration depth of the anchor below seabed
- Drag of the anchor
- Trajectory of the anchor in the seabed
- Pitch of the anchor – this shows whether the anchor is capable of further embedment (fluke angle still sufficient) after completion of the installation
- Roll of the anchor – this shows whether the anchor is stable in the seabed
- In case equipment is left behind on the anchor this should be low cost. All expensive equipment should be recoverable upon completion of the anchor installation.



### Development of the system.

Based on the requirements set out for the project, the system was developed to consist of a load measuring anchor shackle connecting the mooring line to the anchor, inclinometers to measure roll and pitch of the anchor and pressure sensors to measure anchor depth. The off the shelf sensors are housed in a watertight canister in the anchor. All the data from the sensors is combined with a processor housed in the canister and transmitted by means of an umbilical cable to a subsea modem located above the seabed. This is shown in figure 2.

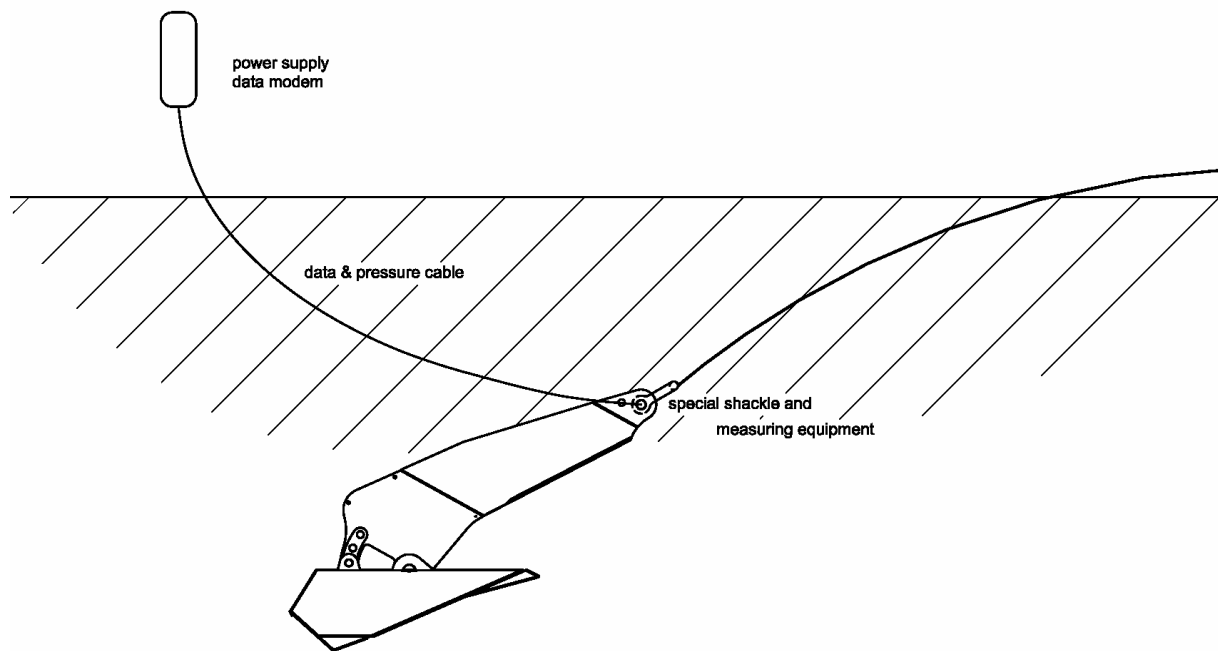
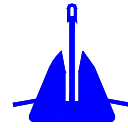


Figure 2 – monitoring of anchor embedment parameters using on anchor data acquisition

The subsea modem transmits the raw data from the seabed to the receiver hanging below the installation vessel. The data is then forwarded to a computer for real time processing of the data into the information required (roll, pitch, load, depth and drag). As the system is measuring the penetration depth of the anchor, the drag length and anchor trajectory can be constructed from this data using the pitch of the anchor. To ensure correct readings, all of the sensors are calibrated beforehand to ensure the correct zero settings.

The data acquisition system uses relatively cheap sensors and electronics onboard the anchor as these parts will stay in place after completion of the anchor installation. The more expensive subsea modem can be recovered after the anchor has been installed and reused at a different location.



### Test results.

A prototype of the anchor data acquisition system was tested using a 2 mT Stevpris anchor. At the time of the test the load measurement system was not completed and only the roll, pitch and anchor penetration depth were measured. The unit was housed in a metal container in the fluke of the anchor. Figure 3 shows the recovery of the system from the fluke upon completion of the test.

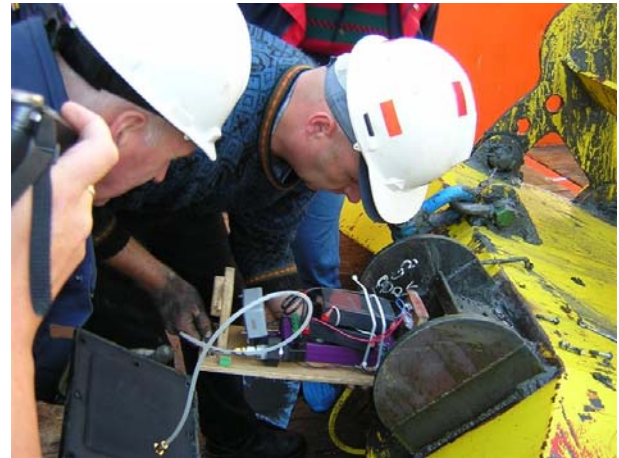


Figure 3 – prototype system

The test showed that the measurement were feasible and that the system gave meaningful and correct data. Figure 4 shows the pitch of the anchor as function of time during the tensioning of the anchor. The horizontal section before 18:29 corresponds with the anchor sitting on the seabed resting on the fluke tips and shackle.

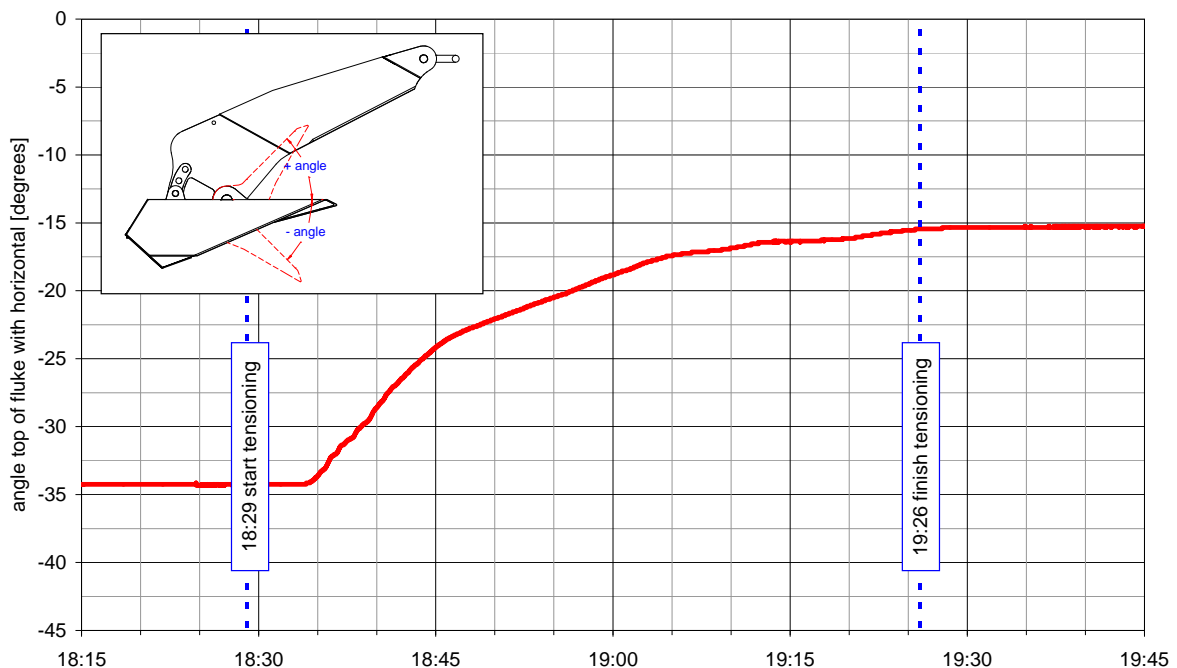
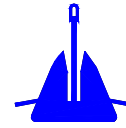


Figure 4 – measured anchor pitch angle

From the collected data with regards to the pitch of the fluke and the penetration depth of the anchor, the drag versus penetration curve was developed. The plotted calculated data is shown in figure 5. The curve shows the anchor penetrating into the seabed after some initial



horizontal movement and based on the curve, the anchor had not yet reached its maximum penetration depth.

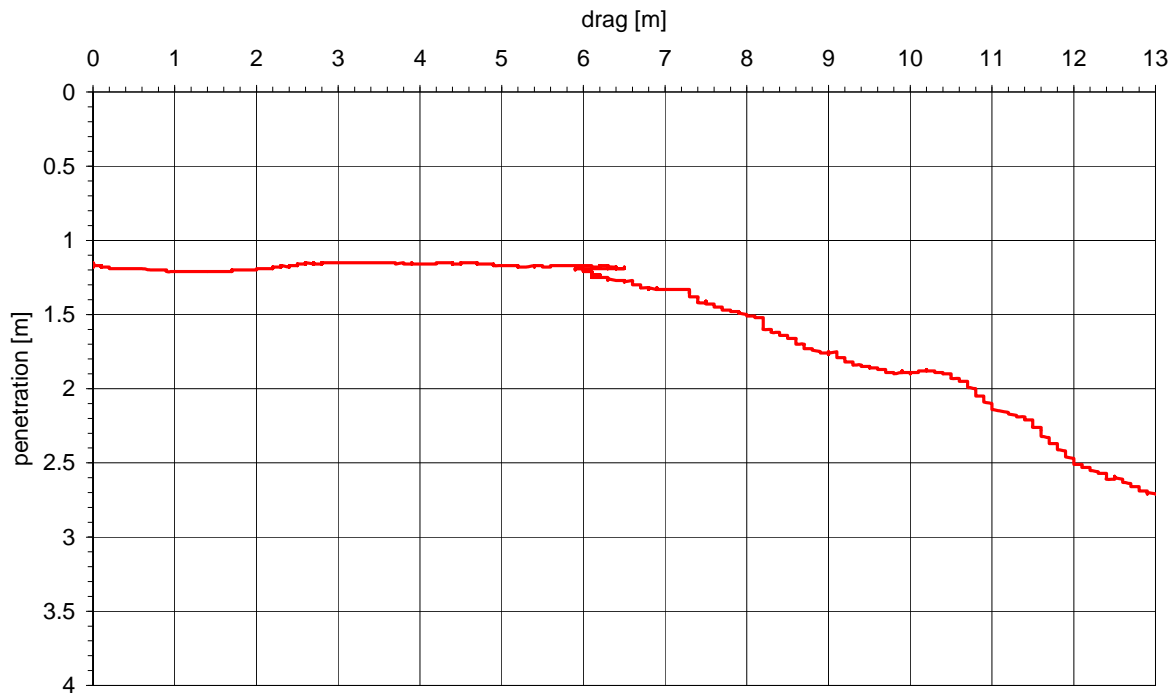


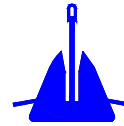
Figure 5 – constructed drag versus penetration curve

Trails are underway with a full system whereby all the information required for the system will be tested. The test data is however not yet available at this time and will be published at a later time.

### Application of the system.

The anchor embedment data acquisition system has benefits for both the supplier and the user of the anchor. For the supplier (manufacturer) the system will generate anchor installation data of high quality in varying soil conditions. This will give insight into the anchor behavior that can be more clearly seen with full scale anchors instead of testing with scale models in the laboratory. The data can then be used for better advising clients on the application of the drag embedment anchors in specific soil conditions and also lead to the development of new anchors with improved embedment characteristics.

For the user of the anchors the measurement system will also give benefits. During the installation phase of the anchors, the computer on the installation vessel shows the actual behavior of the anchor (figure 6). Deviations from the expected anchor behavior can be easily identified and correct. The load measurements at the anchor will also provide additional



confidence that the anchor has seen the required installation load. In addition the system will be able to give an accurate as-built position of the anchor for future reference.

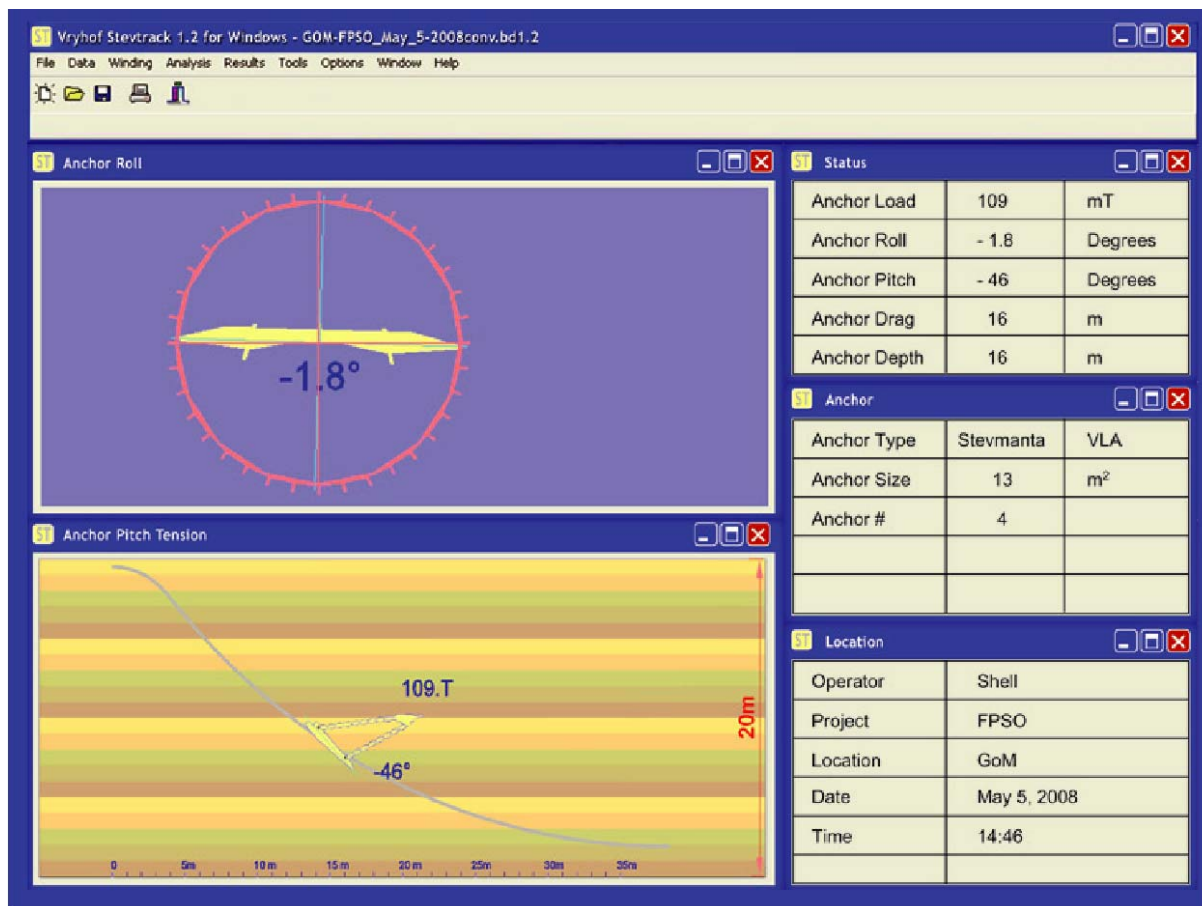


Figure 6 – possible user interface with data display

### Future developments.

A anchor embedment parameter measuring system has been developed that can send the data by means of an umbilical cable to a subsea modem to give real time information on the installation vessel. After the anchor installation has been completed, the modem is recovered from the seabed for re-use. Future developments to the system could consist of (a) making the system wireless from the anchor and (b) providing anchor parameters during the time the anchor is used – for example load data during the complete time it takes a MODU to drill a well. Making the system wireless will make the installation and recovery of the anchor more simple and also less prone to damage.