sciendo CzOTO 2020, volume 2, issue 1, pp.183-190

THE USE OF NAVIGATION IN OPERATIONS SUPPORTING DRILLING PROCESSES

doi:10.2478/czoto-2020-0022
Date of submission of the article to the Editor: 28/11/2019
Date of acceptance of the article by the Editor: 3/02/2020

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Abstract: The paper presents the analysis of navigation processes used in wells and around-drilling processes. Most common navigation systems used in drilling processes are described. The authors have presented a concept of applying navigation to operations supporting drilling processes, including operations ensuring the safety of drilling staff. Also, they have discussed around-drilling processes which have not been supported by navigation systems. Finally, they have presented ideas of their possible applications as well as benefits resulting from using navigation systems.

Keywords: GPS, HDD, drilling, navigation, work safety

1. INTRODUCTION

Navigation allows to determine the current position of and the optimal path to reach a moving object. Navigation should be understood as a process of directing of the movement of an object from the starting point to the destination point. Navigation not only provides information on the object location, but also on the object destiny. It also helps to control the object movement from the starting point to the destination point (Rutkowski, 2015).

The concept of navigation is tightly associated with the notion of positioning. The latter is the process of determining the position of the object in order to precisely localise the position of the object. In a broad sense, the positioning process includes all operations carried out to keep the object in the determined position, course or inside a predetermined space (area). In this sense, the term “navigation” functions in numerous descriptions of well-known systems of dynamic positioning, where computer positioning systems keep the object in a determined position, course or pre-determined area actively influencing the drive and/or control systems. Such defined space (area) is often frequently referred to as an object domain or zone of its safe operation (Rutkowski, 2015).

The GPS systems are useful to localise people and objects in time and in space. In some situations it is the only method allowing the determination of the location (position) and velocity of an object. The GPS receiver can be used autonomously or it can

be a part (one of the basic elements) of a more complicated positioning system. The construction of the GPS systems enabling the determination of the location of people and objects is presented in Figures 1 and 2.
As can be seen, the GPS system consists of three segments: a space segment, a user unit and a control unit. The space segment consists of satellites orbiting the Earth. The user segment consists of GPS receivers, while the control segment consists of control and monitoring stations located on the ground (Januszewski, 2010).

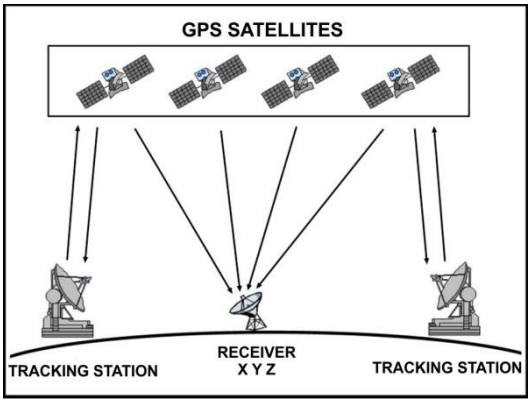

Fig. 1. Components of the GPS system
Source: (Lew, Czapla, 2013)

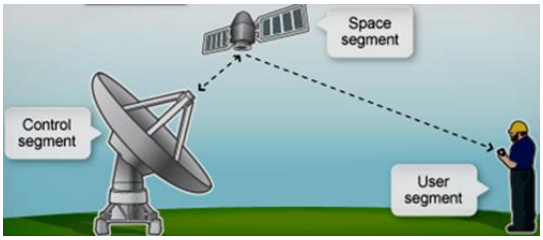

Fig. 2. Structure of the GPS system
Source: (EDGEFX, 2019)

Currently, navigation systems as well as guiding systems can be found almost anywhere. The GPS navigation is widely used in industry, transport, telecommunication, etc. The development of navigation systems also contributes to logistic improvement, increasing safety on roads, and also is used to find stolen vehicles.
GPS navigation also can be used in mining, increasing miners' safety (Grobler and van der Walt, 2017).
Navigation in drilling is mainly used for the so-called horizontal drilling (HDD). There is no comprehensive literature on the subject of navigation in gas wells, where vertical drilling is applied.
The paper presents the concept of using navigation in drilling processes in gas wells, where it has not been used before, and where its use can significantly increase staff safety while performing around-drilling operations and during the operation of the drilling machine. The use of navigation in drilling processes also facilitates the work of personnel handling the well or in emergency evacuation.

2. NAVIGATION IN DRILLING MACHINES

The use of navigation in drilling machines, mainly limited to controlled horizontal drillings, allows, among others, guiding the tool precisely to the target, making a pilot hole

with the required accuracy, selecting appropriate operation parameters of the drilling machine. The data obtained thanks to navigation systems allows complete control of the curvature of the hole axis. In addition, it can be used to determine the technical condition of the hole. Therefore the selection of a navigation system is a key element in the process of designing the hole, as important as the selection of the drilling tool or drilling fluid (Makuch, 2010). Positioning systems localizing the drilling head are necessary equipment of every HDD drill.

These systems enable drilling of a pilot horizontal hole. The principle of operation of the systems is based on the cooperation between the transmitter located in the drill (underground) with the receiver operated by an operator on the ground. The transmitter sends electromagnetic signals containing encoded information about the drill position and location in space, the receiver processes and displays them on a monitor in a form which is understandable for the operator. The example of this positioning system is Digitrak system F5.

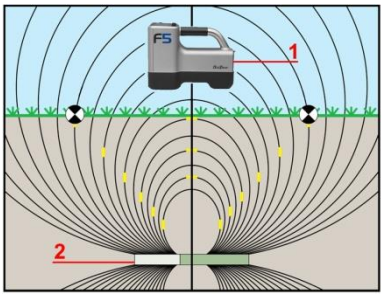

Fig. 3. Operational diagram of positioning system Digitrak F5, where: 1- receiver, 2- transmitter
Source: elaboration based on (Digital Control Incorporated, 2013)

Figure 3 presents the operational diagram of locator Digitrak F5 used for horizontal directional drilling. The Digitrak F5 system is the radio positioning system. As can be seen (Fig.3) the system consist of a transmitter (2) located in the steel casing and a receiver (1). The receiver has a form of a handy, portable box, equipped with a screen displaying drilling parameters. The principle of operation is the radio signal interpretation, transmitted by the transmitter and received with the use of the receiver box situated on the ground above the remote control device (Digital Control Incorporated, 2013).

In the horizontal directional drilling (HDD) navigation systems allow to direct (control) the trajectory of the hole. They allow to achieve the target exit point with the appropriate accuracy, where parameters of horizontal drilling like radius of curvature, deviation from the planned axis, specified depth and angle in the exit point are maintained. They allow constant monitoring of the horizontal drilling azimuth, its direction and the technical condition of the hole.

During the drilling process, the level difference could be a problem. With inaccurate control of azimuth and angle of drilling, the drilling process can be finished too soon or too late. It may pose risk of damage to the equipment and/or to the health of the drilling machine operators as well as may lead to some additional costs (Szostak, 1989). Therefore navigation and determination of the location of the drill is so important. Drilling under water is also difficult. In this kind of drilling, proper location of the transmitter may be a problem (especially for radio positioning systems). It can be done from a vessel (e.g. a boat, dinghy) which increases the cost of the project realisation (rent-

ing additional equipment, employing people with appropriate motorboating certificates). The velocity of the river current also can be a problem, especially for works under the river bottom.

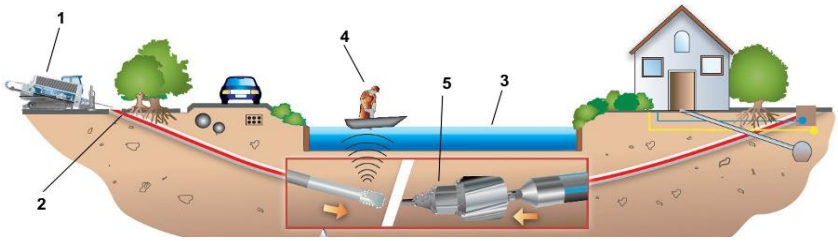

Fig. 4. Scheme of performing a horizontal drilling under a water reservoir, where: 1-drill, 2-drilling conductor, 3-water reservoir, 4-operator of the measurement system, 5-drilling head with transmitter

Source: elaborated based on (Traco - Technik, 2019)

3. THE USE OF NAVIGATION IN AROUND-DRILLING OPERATIONS

The proposition of the use of navigation in drilling is the use of the GPS system in gas drilling. Such a system can be used for localisation of determined elements of a drilling pipe, transported in containers. The purpose is to improve work performance in the well by quickly specifying the storage place of elements of the drilling pipe, e.g. mud pipes or pipes connections. The depth of the hole determines how deep the set is to be plunged what type of tool is to be used or how high pressure in the hole is to be applied, etc. The area where the well is located is limited (Fig. 5), which enforces economical and reasonable space management, as well as ensuring the most efficient movement around the area where well is located (Szostak, 1989).

The GPS navigation can also be used to precisely determine the location, where the parts of the pipe needed for drillers are placed (pipes connectors, mud pipes, drills). This kind of system can consist of an identifiers mounted in a container (Fig 6a) and a reader (Fig. 6b) for the person responsible for placing the containers in the area.

Fig. 5. Gas Well

Source: (NetTG.pl, 2019)

After placing the containers with parts, the reader (equipped with a wireless communication module) sends the data about the location of the container and the information about its content (based on POI's points used in car navigation systems) to the computer situated e.g. in an office. There a map would be created which would contain localisation of containers with their contents. This would significantly accelerate putting the parts together to assembly the drilling pipe.

Navigation systems can be also applied in gas drilling to improve the safety within the gas well. The system would include transmitters with sensors detecting (among others) hydrogen sulphide (Fig. 7).

Since the gas is extremely toxic its early detection is very important (Trzebiatowski 1978).

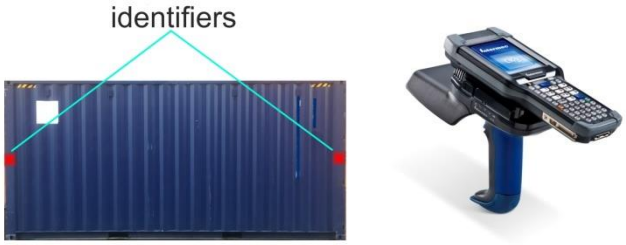

Fig. 6. Identification of location of the places of the parts of the drilling pipe: a) arrangement of identifiers on the container, b) reader of the firm Intermec CK3
Source: (Ivanhoe Group, 2019)

Fig. 7. Sensor detecting hydrogen sulphide H_2S of CZ-TGS825 type
Source: (SOS Electronic, 2019)

Early detection of the hydrogen sulphide gas allows planning and carrying out efficient evacuation from the area of the well. Additionally, equipping the well with a station that measures direction and power of the wind, would facilitate the determination of evacuation ways and the safety zone not contaminated with this dangerous gas. All components connected to the navigation system GPS would allow precise determination of the location of possible gas leaks. This safety system could be further equipped with a notification system allowing to alert emergency services to protect the area of the well (Szostak 1989). Figure 8a presents an exemplary diagram of the use of gas sensors in the well.
The operational diagram of a controlling system which monitors the well (and the surrounded area) for the occurrence of hydrogen sulphide is presented in Figure 8b. When the sensor has detected the gas in the air, it sends a signal to the control–measuring station. Next, with the use of the meteorological station, the direction and power of the wind is determined by the control–measuring station (arrow no 5). This data allows to determine safe evacuation paths leading to an area free from gas contamination (arrow no 1). Figure 8c presents the operational flowchart of the proposed system.
To indicate the evacuation paths, a light signalling (mounted e.g. on the evacuation exit) can be used. The staff could determine easily the direction of evacuation which would improve its efficiency.
The use of the meteorological station mounted on the well in order to measure the direction and the velocity of the wind would allow to precisely determine the evacuation path. An example of such device is the meteorological station LB-741 (Lab-el, 2019) (Fig. 9).
Meteorological station LB-741 is designed for an ongoing monitoring of the basic climatic parameters: air temperature [C^o], air humidity [%], ground temperature [C^o], barometric pressure [hPa], wind velocity [m/s], wind direction, precipitation (rainfall)

[mm/m2], solar radiation [W/ m2], near-surface humidity [%], water level in rivers [m], ground humidity [%], concentration of pollutants in the air [%].

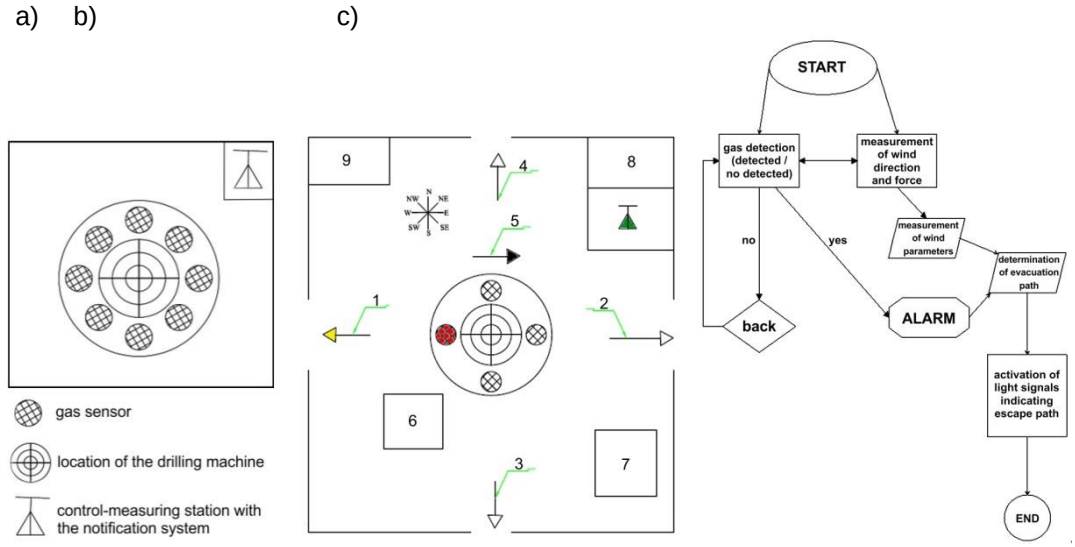

Fig. 8. Well monitoring system detecting hydrogen sulphide: a) diagram of the use of gas sensors in the well, b) operational diagram of the system, c) operational flowchart of the well monitoring system, where: 1,2,3,4-directions of evacuation, 5-wind direction, 6-mud pits, 7 – store, 8- social room, 9-parking

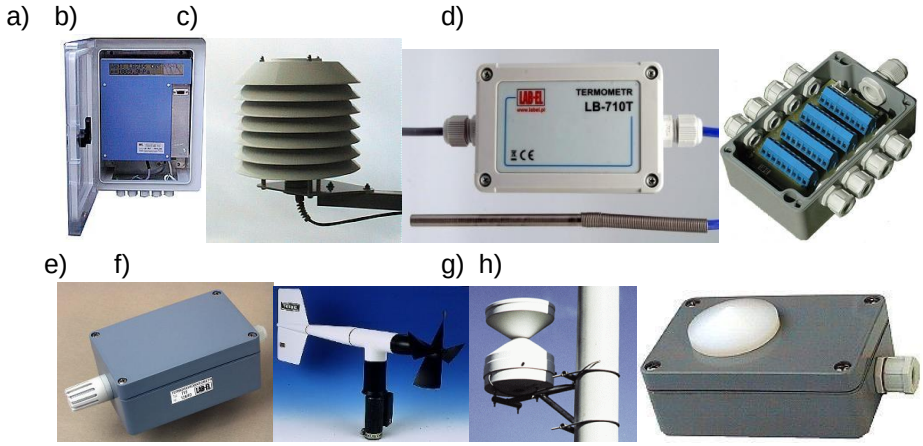

Fig.9. Meteorological station LB-741: a) panel, b) hytherograph, c) thermometer, d) multichannel thermometer, e) barometer, f) anemometer, g) rain gauge, h) solar radiometer Source: (Lab-el, 2019)

A user can read the data from the meteorological station with the use a standard computer PC, which needs to be equipped with appropriate software and interface devices. The software ensures communication with the meteorological station, which allows data processing and visualising (Lab-el, 2019). Thanks to this analysis, the reaction can be immediate. Thus the direction of evacuation may be indicated by announcing appropriate messages as well as warnings about wind direction and power.
In the presented meteorological station, it is possible to mount a 12V/4Ah battery and attach an external solar battery, which allows locating the station in places, where there is no power supply. A separate power source is especially important because it makes the station independent from any power supply. If the temperature inside the panel is lower than -15°C or if relative humidity inside the panel increases above 85%,

internal heating system starts to operate (only when the station is powered by 230V), which ensures correct operation of the device in various and changing climatic conditions (Lab-el, 2019) and also ensures operating safety of the well.

4. CONCLUSIONS

Navigation in drilling is often used when horizontal directional drilling is realised, especially when the holes, which are to be performed with high accuracy, are carried out under buildings, water reservoirs or under existing tunnels.

In vertical drillings, on the other hand, navigation is not used frequently, due to the depths of the performed drilling holes and due to difficult working conditions.

The solutions proposed in this paper aim at safety improvement during drilling as well as at improving working conditions on the well.

The improved safety would result from the fact that emergency services would be alerted faster and the evacuation process would be more efficient.

Additionally, the navigation system, apart from being used for identifying the contents of containers, would facilitate the localisation of particular parts of the drilling pipe and also would enhance the process of assembling the parts of the drilling pipe.

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