| BULETINUL Universităţii Petrol – Gaze din Ploieşti | Vol. LXVI No. 3/2014 | 39 - 46 | Seria Tehnică |
|---|---|---|---|

# Comparative Study on the Performances of Modern Depth Sensors and Transducers used in Drilling Industry

Aurelian Oprea, Sanda Florentina Mihalache

Universitatea Petrol-Gaze din Ploiesti, Bd. Bucuresti 39, Ploiesti
e-mail: sfrancu@upg-ploiesti.ro

## Abstract

*Measurement and correlation of geological data is provided by depth sensors and transducers with which may be known with accuracy, at all times, the position of the drill bit into the well. This paper presents the types of depth sensors currently used in the drilling industry, associated transmitters that convert final digital data and the advantages and disadvantages of the presented types of transducers.*

**Key words**: *Logging-while drilling, smart sensors, data acquisition, qualitative analysis.*

## Introduction

Since the identification and exploration of oilfields to finished products resulting from the drilling industry, oil route is coordinated through a comprehensive set of processes covered by a wide range of scientific fields [1, 10]. The most sensitive step and most important is to obtain raw materials-oil and gas-by piercing different soil layers that are documented and studied by geologists. Measurement and correlation of geological data is provided by depth sensors and transducers with which it is known, at all times, with the precision of centimeters, the position of the drill bit into the well [6].

This paper presents depth sensors types currently used in the drilling industry, associated transmitters that convert final numerical data (metri cor imperial) and the advantages and disadvantages of the types of transducers presented. To cover these issues, the paper has been structured as follows: a first part that presents the role of depth transducers and their placement on drilling rigs, both on land and offshore, a second part that emphasizes the construction of the types of sensors used, in terms of mechanic and electronic point of view, as well as the principle of digital coding of the given physical measurements of mechanical components. All the issues presented in these chapters are summarized as conclusion, covering a series of advantages and disadvantages of the transducers presented.

## The Role of Depth Sensors and Transducers in Drilling Industry

In the following, the term transducer covers the assembly sensor and associated transmitter. Ultimate depth transducers are executing a digital conversion of rotary movement measured on different components of rig, directly related to the mechanical advance system of drill bit when the drilling component runs upward and downward movements. Another category of transducers directly analyze the upward or downward movement of the drill tubing. The data represent the distance of movement on which depends the movement distance in the entire well system, stored on computer systems in databases specialized in time or depth in determining instantaneous or average rate of penetration (ROP).Figure 1 shows a generic block diagram of moving the mechanical component of a generic drilling rig according to the authors, which outlines how to connect the depth transducer in different locations, directly related to the mechanism of advance of the drill bit.

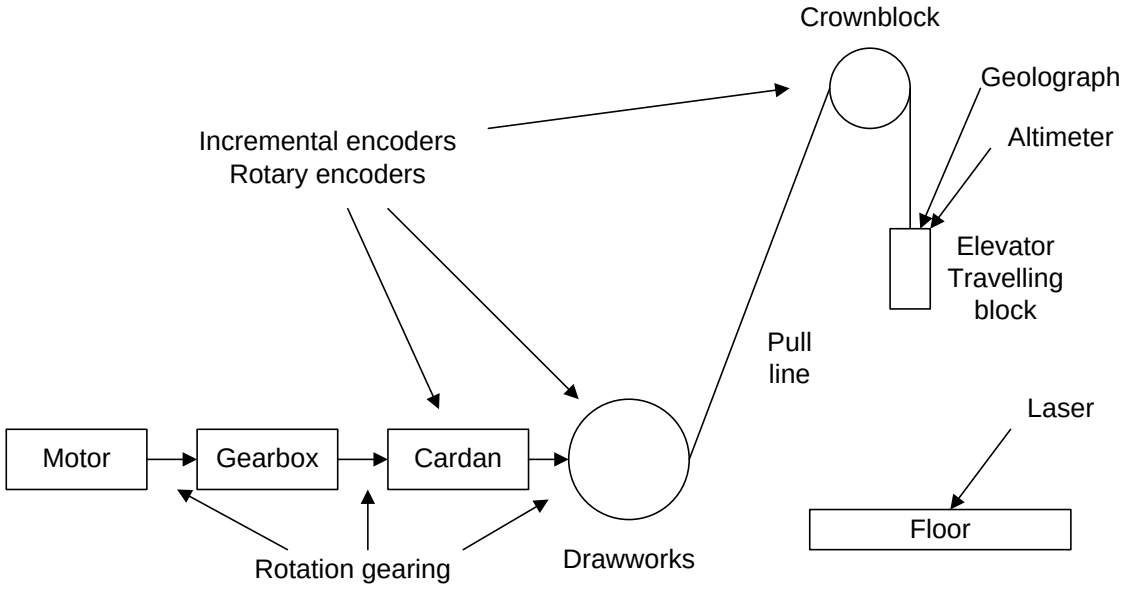


**Fig. 1**. Depth transducer location on a generic drilling rig.

The functioning of the mechanical advance of the drilling is similar to a crane operation, with the following components: drive motor; gearbox; drive shaft (hereinafter referred to as cardan), which transfers the movement of rotation to the draw works; winch which drives the pull line over the pulley (crown block); hook, which is attached to the surface motor (top drive – electric or hydraulic) for rotating the drill pipes. Depth transducers can be attached to the draw works, rotary table and pulley, measuring their rotation. Also, on the top hook assembly drive with a cable connected to the "geolograph" transducer that can track up-down movement of the drill pipes. On the hook this movement is followed by a hydrostatic pressure transducer with altimeter operation principle. On the top of the rig, the floor or at hook level can be placed a next-generation transducer with laser-based distance measurement. All these transducers generate analog or digital signals to the operating panel and real time databases. When mounting the first drill pipe, top hook assembly drive is powered up to the pipe rack, and this time is considered as the initial depth and value provided by the sensor depth-whatever its type-as the initial depth 0. With every pipe that enters, initial depth is considered the combined length of the drill pipes. In other words, depth transducer measures always less than or equal to the length of the formed drill pipes, and this value is subtracted or added up to the total depth by the drill string operations performed: lowering, lifting, digging or draining.

## Types of Depth Transducers in Drilling Industry

As noted above, the transducers used in drilling transmit unified signals within 4 .. 20mA dc range and digital signals. If depth transducers have both types of outputs (analog and digital), for greater precision it is preferable to use digital signals. The main types of depth transducers are incremental rotation encoder, sinusoidal rotary encoder, geolograph transducer, hydrostatic pressure transducer, and the laser-based distance transducer.

For drilling rigs on land, all the transducers mentioned above can be used. Locations from which they can gather information directly related to depth are shown in Figure 1 and summarized in Table 1.

**Table 1.** Depth transducers mounted on mechanical components for land drilling rigs

| Sensor/Transducer | Location |
|---|---|
| Incremental rotation transducer | Cardan, draw works, top pulley |
| Sinusoidal rotary encoder transducer | Cardan, draw works, top pulley |
| Geolograph transducer | On floorrig, information collected by moving a cable attached to the hook assembly crown block |
| Hydrostatic pressure transducer | Traveling block (hook-top drive-elevator) |
| Laser distance transducer | Mounted on rig floor with reflection on top drive;<br>Mounted on top drive with reflection on rig floor<br>On traveling block with reflection on crown block. |

Incremental rotation transducer measures the movement of different reference points located on the transmission drive shaft from the gearbox to the draw works, the winch body or the body of the crown block. The sinusoidal rotary encoder takes the rotation motion of the cardan shaft that is coupled; the coupling location can be the shaft of draw works or crown block. Geolograph transducer is composed of either an incremental encoder or a sine wave rotation encoder with a winch which is used as drill line supply. This cable assembly is connected to top drive hook assembly (traveling block), in most cases on the elevator. By moving up and down the drill string, the cable is held or wrapped on the winch, the latter having a rotation directly related to depth.

Hydrostatic pressure transducer, called the altimeteris, coupled with travelling block, especially with the hook, and transmits the pressure difference according to the height to which the hook is located. Laser distance transducer is a relatively new technology and involves using a laser distance measurement in locations that can not be disturbed by foreign objects or materials (probe operators, gas, oil, mud). It is installed preferable on the hook with the fixed measuring point located on the crown block.

Because of water movement (waves), in offshore drilling rigs is required a compensator between the hook and top drive and an additional compensator transducer for measuring motion of the top drive engine to the crown block (heave compensator encoder). Also, another sensor for measuring movement compensation is necessary because the waves affect the position of rotary table to the wellbore [8]. When the correct parameters are met and it is drilling, depth and the rate of penetration are measured by the depth transducer located in a mechanical component directly related to travelling block. Saline atmosphere also prevents the use of both optical transducers (laser) and hydrostatic pressure transducers.

### Incremental rotation transducer

The incremental rotation transducer (figure.2) has the same operating principle of the coding system in the XY-axis ball mouse devices, the incremental encoder includes a disc section100separated by transparent lines. On one side of the disc are located two light sources.

On the other side of the disc are located two receivers, as shown in figure 2. This transducer is mounted by screwing on the cardan shaft, draw works or top pulley. The diameter of draw works must be known. For calibration purpose, when mounting the draw works, one must know in addition the drill line diameter and the number of turns. The elevator is lowered on rotary table and initial height determines the starting position 0. Advantageously, the calibration procedure takes about two minutes.

**Fig. 2**. Incremental rotation transducer (in section and ready to be mounted) [4] ,[7]

There are two main disadvantages, judder in rig quickly lead to damage bearings and erroneous measurements occur and most of the energy or drilling sites is derived from diesel generators [7]. Due to faulty maintenance and unbalanced consumption on phases, voltage fluctuations can lead to erroneous measurements. If the measurement error is determined, the calibration procedure should be repeated.

## Sinusoidal rotary encoder transducer

It consists of a magnet rotor assembly and a stator having a pair of coils. By rotating the shaft, the encoder provides two signals corresponding to the sine and cosine of the angle of rotation. The schematic diagram is shown in Figure 3.

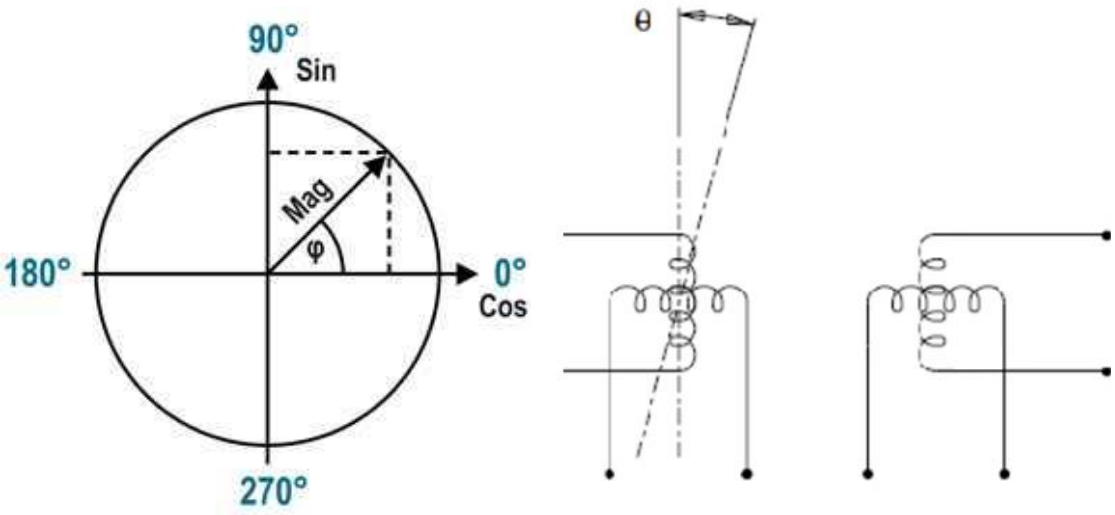


**Fig. 3**. The principle of operation of the rotary encoder sinusoidal [4], [7]

Rotary encoder is fed with sinusoidal alternating voltage in the coil input. By training rotor the encoder modulates the input voltage proportional to the sine and cosine of the angle gear. In

other words, the decoder function is to decompose a vector into components of sine and cosine. Rotor position (angle $\Phi$ ) is calculated as:

$$\Phi = arctg\, V_{\sin} / V_{\cos} \tag{1}$$

where $V_{\sin}$ is output voltage of sine winding and $V_{\cos}$ is output voltage of cosine winding.This relationship has the advantage of mathematical suppressing the background noise (parasite voltage) induced in the cable connecting the sensor to data acquisition unit. Advantages and disadvantages are the same as the incremental encoder. In addition, the sinusoidal encoder has a variable resolution, which is controlled by the frequency of the excitation voltage [4].

## Geolograph transducer

The geolograph transducer consists of the reel-running cable along with one of the above encoders (incremental or sine). Movement travelling block (hook top drive elevator) is taken by geolograph cable which is run with the rise of taking over a new tubing. The geolograph spooler is pneumatically with drawn along with penetrating the hole [9]. Cable movement is recorded by the encoder and transmitted in digital form to the server. Figures 4 and 5 present a geolograph transducer operating on a real rig.

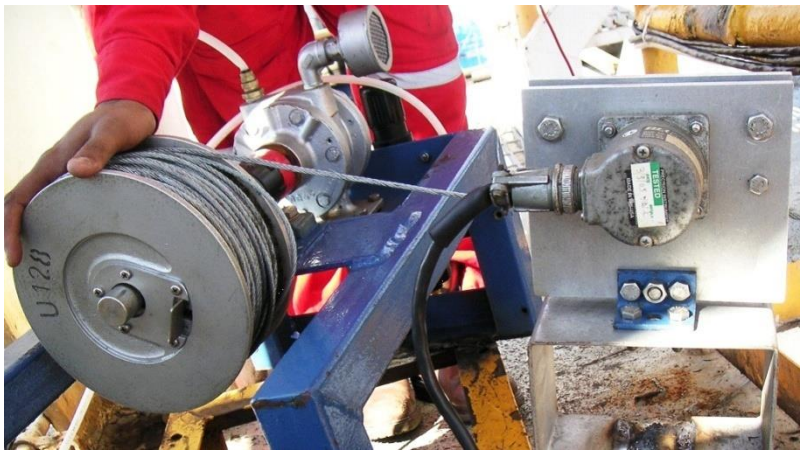

**Fig. 4.** Detail on pneumatic spooler from a geolograph transducer[9].

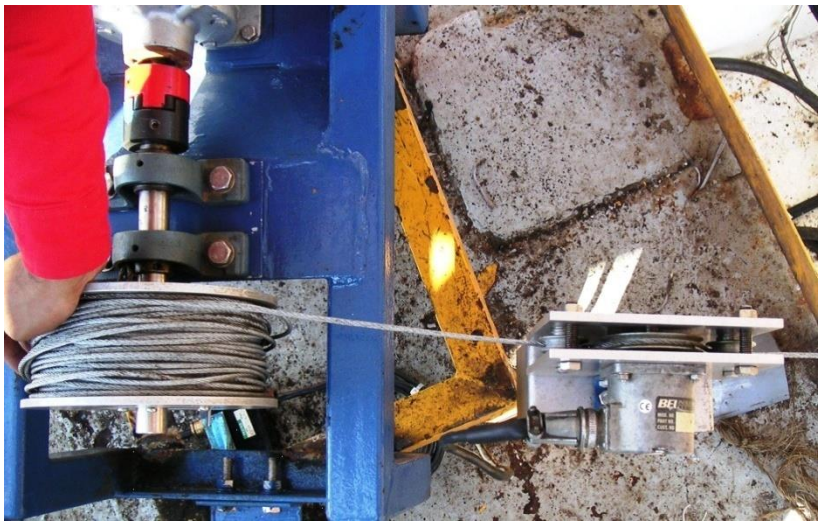

**Fig. 5.** Detail on rotary encoder [9].

Advantages and disadvantages of the above are based on used rotary encoder component.The geolograf presents the following characteristics: very high weight (50 ... 60Kg), maintenance at every 3-4 hrs. 4:00 (visual inspection, mechanical, pneumatic) [9]. Due to faulty maintenance of pneumatic system (moisture, full filters) water can penetrate the feed line. This effect combined with low ambient temperatures leads to blocking of the power line and the cable tension disappears.

### Depth transducer based on hydrostatic pressure

The transducer registers the pressure difference corresponding to the height at which is located a travelling block. Also known as digital barometric sensor, it works on a piezo resistive pill ([3], [5]) that changes its electrical resistance depending on the pressure applied. The output signal is provided by digital interrogation protocols SPI (Motorola) orI2C. This depth measuring technology is less prevalent due to a major disadvantage, namely the interference due to changes in atmospheric conditions.

### Laser depth transducer

This technology is an innovation in drilling, the first transducers of this type were developed for drilling industry in 2013 [2]. The transducer measures the distance from the travelling block to a fixed point located on crown block. This distance is taken into account by the server operating system while moving he drill string. The operating principle is similar to the radar on the basis of electromagnetic waves. Laser light from baseline t0 is reflected by the target and reach the receiver (photodiode / phototransistor) at time t1. Distance traveled is calculated from the numerical computation unit and transmitted to the data acquisition unit as numerical or unified industrial signal (4 .. 20mA).

Mounting the transducer should be performed so that there is no fillings in the laser beam path all the way to the target location. The method recommended by the manufacturer is that the transducer is mounted in a fixed position on crown block and the target is the hook.

The disadvantage of this transducer is only great purchase price, which includes the price of its certification drilling industry and the price of the materials in standard housing built anti explosive. Also it cannot be used on offshore platforms due to permanent atmospheric wet that lead to condensation of water vapor on the lens transducer. Advantages: This sensor requires no maintenance and calibration is performed at the factory.

## Conclusions

Following the analysis in the previous section, some conclusions are summarized and shown in Table 2. In addition to the laser distance sensor, the other transducers have the analog output signal unified industry and Namur digital output (pulse information conveyed by the feed line 8 V maximum).

Transducers latest industry supports HART protocol - serial data line by line analog 4 .. 20mA - which involves digital data query and providing both numerical and sensor self-diagnostics. Laser based transducer, besides HART protocol, are digital polled communication protocols high speed, including wired Ethernet shielded twisted. From the point of view of the calibration range, as specified in the previous chapter, one transducer "immune" to mechanical disturbances - such as shock resulting from a layer of hard rock breaking and entering in a layer of sand - are transducers hydrostatic and laser-based. Both incremental encoder and easily breaks the sinusoidal component mechanics, especially bearings, leading to uncontrolled vibration of

internal components. In addition to the tremendous weight (50 ... 60 kg), inherits the advantages and disadvantages of the geolograph transducer rotary encoder fitted to the (incremental or sinusoidal), in particular due to the impossibility of storing the current distance and adoption in the case of a power disturbance or mechanical. In addition, the smooth operation of geolograph is directly related to proper maintenance of pneumatic system, especially its clean water and impurities. At low temperatures, the presence of water (frozen) leads to clogged hoses, decreased air pressure, insufficient tension of the drum and finally blocking the winch.

**Table 2.** Advantages and disadvantages of depth sensors and transducers

| **Transducer** | **Output signal type** | | **Calibration range** | **Calibration time** | **Precision** | **Other disadvantages** |
|---|---|---|---|---|---|---|
| | **Analog** | **Digital** | | | | |
| **Incremental** | 4..20mAdc | NAMUR HART | Disturbance from electrical network or mechanical type | 2...3 minutes | Depending on disk gradation | Does not memorize the current state at power shutdown |
| **Sinusoidal** | 4..20mAdc | NAMUR HART | "--------" | "-------" | Depending on frequency excitation voltage | "----------" |
| **Geolograph** | 4..20mAdc | NAMUR HART | "--------" | "-------" | Depending on component encoder | "----------" Faulty operation on low temperatures |
| **Hydrostatic** | 4..20mAdc | NAMUR HART | Athmospheric disturbances | "-------" | Metric | Insufficient precision |
| **Laser** | Digital | HART Serial I2C SPI Ethernet | NO | It is not the case | Mm | Cannot be used on offshore rigs |

The altimetric transducer is disadvantageous because it is sensitive to atmospheric conditions and require frequent calibration. There are cases where penetration is of the order of 0.5 .... 1 meter per hour, enough time to produce a storm "out of nowhere" and the consequently the appearance of false data by the pressure recorded.

From the point of view of accuracy of measurement, in addition to the millimeter resolution laser-based sensor, the advantage of the adjustment sine-wave encoder scale - this resolution can be adjusted according to the desired measurement accuracy - limiting the excitation frequency is determined by manufacturer.

Future studies focusing on international laser based transducer, whose cost / maintenance is reduced. The only currently existing transducer is studied in [7], with only a few minor drawbacks: very high price, installed to a height of about 30 meters (tip of the rig) and periodic inspection target for cleaning.

# References

1. Collett,T.S., Lee,M.W., Zyrianova, M.V., Mrozewski,S.A. Guerin,G.- Gulf of Mexico Gas Hydrate Joint Industry Project Leg II logging-while-drilling data acquisition and analysis, *Marine and Petroleum Geology*, **34**, Issue 1, June 2012, pp. 41-61.

2. Dragan Technologies, Inc. - *TERRA DP3 Drilling Depth laser sensor*, 1477 Wellington Ave.,Winnipeg, Manitoba, Canada, R3E 0K4, http://www.dticanada.com/index.php/products/item/7-terra-dp-3-laser-distance-sensor
3. * * * - http://www.st.com/web/catalog/sense_power/FM89/SC1316/PF251601 LPS331AP – altimeter, ST Microelectronics Inc., U.S.A.
4. * * * - https://www.dynapar.com/Technology/Encoder_Basics/Resolvers/ Dynapar, Inc., 1675 N. Delany Rd., Gurnee, IL 6003, U.S.A.
5. * * * - https://www.sparkfun.com/datasheets/Components/General/BMP085_Flyer_Rev.0.2_March 2008.pdf, BMP085 – digital altimeter, Bosch Sensortec GmbH, Deutschland.
6. Jaiswal, P., Al-Bulushi, S., Dewangan, P.- Logging-while-drilling and wireline velocities: Site NGHP-01-10, Krishna–Godavari Basin, India, *Marine and Petroleum Geology*, Available online 21 May 2014.
7. Weatherford, Inc. - *Surface Logging Systems - General Sensor Maintenance Manual*, No. 5-3-GL-GL-MSL-00002, (2011), pp. 4..31.
8. Weatherford, Inc. - *Surface Logging Systems: Technical Data Sheet – Depth Compensation System for Floating Rigs*, No. SPECS-DRL-042, Ref. 2, pp 1..2.
9. Weatherford, Inc. - *Surface Logging Systems: Geolograph Wire Line Retriever and Rig Heave Sensor Manual*, No. 5-3-GL-GL-MLS-00009, USA 2011, pp 4..30.
10. Zhang Yongqin, Liang Jian, Li Kuan, Wang Hanbao, Li Xinmiao, Wu Jixiu - Research Progress of Drilling Coring and Mining on the Permafrost Natural Gas Hydrates in China, *Procedia Engineering*, **73**, 2014, pp. 362-367.

# Studiu comparativ asupra performanţelor senzorilor şi traductoarelor moderne de adâncime din industria de foraj

## Rezumat

*Măsurarea şi corelarea datelor din punct de vedere geologic este asigurată de senzorii şi traductoarele de adâncime cu ajutorul cărora se cunoaşte în orice moment, la precizie de ordinul centimetrilor, poziţia sapei de foraj în interiorul puţului. Lucrarea de faţă prezintă tipurile de senzori de adâncime utilizate la momentul actual în industria de foraj, transmitterele asociate acestora care efectuează conversia finală în date numerice (sistem metric sau imperial), precum şi avantajele şi dezavantajele asociate tipurilor de traductoare prezentate.*