A POSITION DETECTOR FOR EXTREME CONDITIONS WITH HIGH TEMPERATURE, PRESSURE AND SURROUNDING NOISE

P. Hrkút, R. Andok, P. Andris, I. Čaplovič

Institute of Informatics, Slovak Academy of Sciences,
9 Dubravska cesta SK-842 36 Bratislava, Slovakia
E-mail: Pavol.Hrkut@savba.sk

Received 04 May 2012; accepted 11 May 2012.

1. Introduction

In sensoric systems dedicated for extreme environments resistant to high temperatures up to 400°C and high pressures up to 1000 bar, and for environments with electromagnetic perturbation, standard position (displacement) sensors fail to operate. A resistant system of sensors is aimed for embedded control systems of technological processes, where the above mentioned surrounding conditions occur in various combinations. Among such systems where estimation of position is needed, belong applications of ultradeep drill holes for generation of electric energy from geothermal sources at the depth up to 10 km. Similar requirements can be found also in some complex metalurgic processes, demanding welding processes, in research and in production of novel materials at high temperatures and pressures, in military sphere and in controlling new hybrid electric automobiles, etc.

The basic requirement for a position sensor is to repeatedly provide information of the position (displacement). According to the operating principle the position sensors can be divided into mechanical, resistive, capacitive, inductive, magnetostrictive, optical, ultrasonic, pneumatic sensors, respectively, or any suitable combination of the above mentioned sensors. According to information reading they can be divided into continuous and discrete sensors; and from the point of view of the measurement technique into absolute and incremental measurement technique, or any combination of these two methods [1]. Most of these sensors, however, are unsuitable for extreme temperature, pressure and surrounding noise conditions.

2. Experimental

This article is describing a suitable set-up for position sensing in harsh environments, where mainly high working temperatures are the limiting factor where other standard sensors fail to operate. We have concentrated to an inductive type of sensor. According to literature most of inductive commercial sensors work up to temperatures of about 125°C [2], though some companies offer products working to max. 540°C [3]. For laboratory testing of such sensor behaviour we have chosen an inductive sensor using the linear variable differential transformer (LVDT). When the armature of such sensor is moved from one end to the other through the central position, the output voltages change from maximum to zero and back to maximum again but in the process it changes its phase angle by 180 degrees. This enables the LVDT to produce an output AC signal whose magnitude represents the amount of movement from the central position and phase angle represents the direction of movement of the core. The advantages of the LVDT compared to e.g. a resistive potentiometer are its linearity (i.e. its voltage output to displacement is excellent) and very good accuracy, high sensitivity as well as frictionless operation. Such sensor can be sealed against hostile environments.

In our experiment, the position sensor for extreme conditions with high temperature, pressure and surrounding noise was realized as a ratio inductive sensor with iron core. The coils (Cu wires of Ø = 0,14 mm) were reeled on 90 mm long silica glass tube, with Ø = 7,5 mm. The sidewalls of the coils were proposed to be of ceramic (capable to undergo temperatures above 1000°C). The upper coil (reeled along the whole tube) consists of 516 windings and the two lower coils have both 230 windings. To isolate each winding a special material is projected, developed at the Research Institute of cables and insulators. For testing purposes, to fasten the sidewalls of the coils to the silica glass tube a 2-component glue Gupalon 30 (Gussolit, Verbindungstechnik, Munich) was used, with high consistency and with thermal resistance up to 260°C. However, for higher temperatures, glass solder is proposed that may withstand temperatures up to 800°C.

The cross-section of such position sensor can be seen in Figure 1. The control semiconductor electronics must certainly be placed in a separate cooled chamber due to the limited temperature resistance. For the purposes described in this article, the ultradeep drilling, signal microcontrollers are needed to communicate with the control centre as well as with other sensors. E.g., for Texas Instruments electronic components the highest temperature resistance is max. 150°C, according to available datasheets for microcontrollers [4].

The coil L_1 is fixed and is driven by AC voltage. Below this coil, on the guiding tube are two coils L_{21} and L_{22}. These coils are identical. The magnetic core can move along the guiding tube. The amount of induced voltage then corresponds to the amount of coils introduction into the guiding tube. Moreover, the pair of coils (in antiparallel connection) permits to compensate eventual interfering magnetic fields.

If magnetic material (e.g. iron, T_C = 770°C) is used in the guiding tube, it is possible to gain higher electric signal with induced magnetic field in the flip coil, by slipping the coil on the silica glass tube.

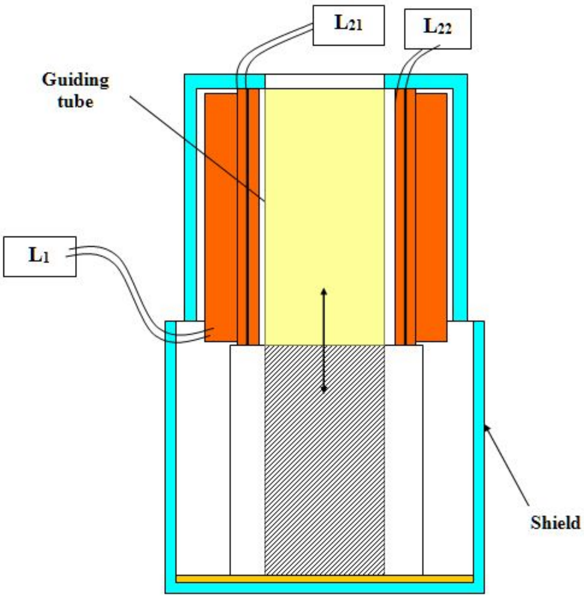

Fig. 1. *Cross-section of the position sensor. The coils L_{21} and L_{22} (fixed) are driven by AC voltage. The material inside the guide tube is made of magnetic material (iron).*

For mechanical functionality under harsh environment conditions of this set-up one must well consider a good securing of each winding against thermal damage (around 400°C temperature), as well as to protect the inner part of the mechanism against contamination (mechanical jamming of the moving parts, etc.).

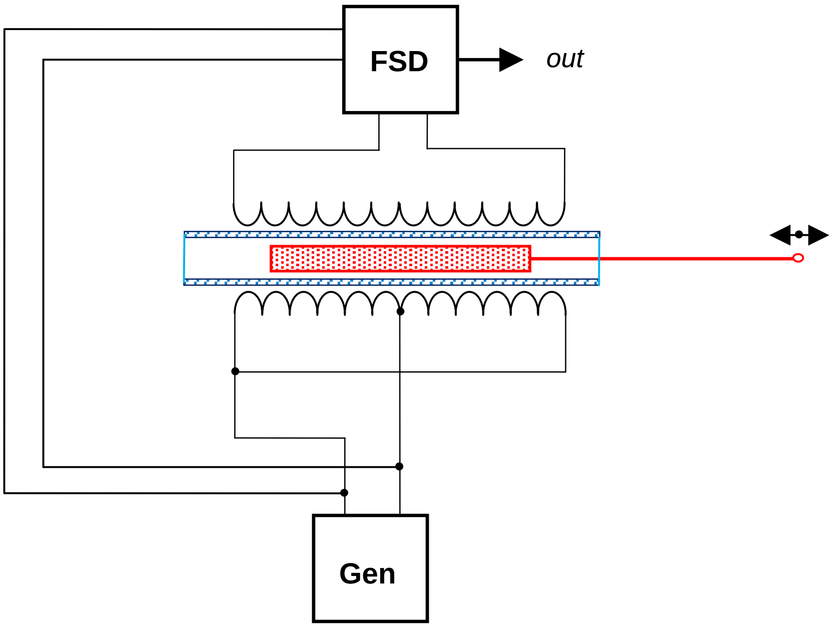

Fig. 2. *Block diagram of the set-up.*

Figure 2 shows the block diagram of the described set-up. The signal generator is synchronized with the phase sensitive detector (PSD).

3. Results and Discussion

Figure 3 shows the dependence of the output signal *vs.* the core position, measured at room temperature. Other measuments at higher temperatures and the corresponding dependences are subject of future publication. This method shows that it is possible to construct a position sensor with linear behaviour (in certain area), which depends on the ratio of the coils lengths against the core shift. At suitable construction such sensor may work also under extreme conditions where commonly available sensors fail to operate and/or can be damaged.

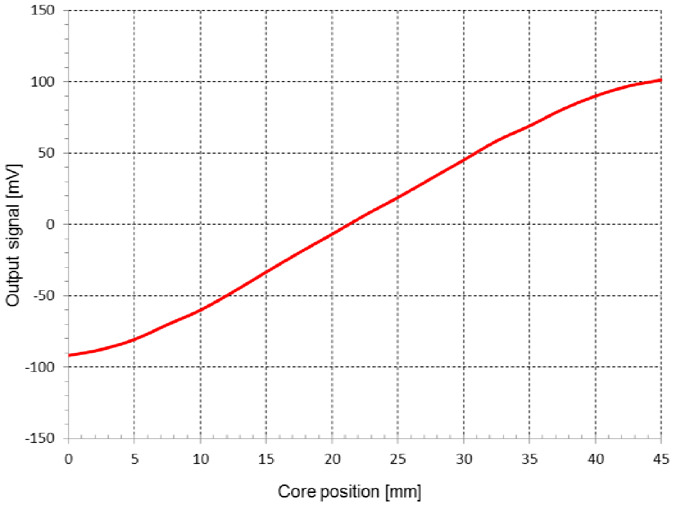

Fig. 3. *Dependence of the output signal versus the core position.*

An advantage of this sensor is that the coils are fixed and only the core moves, that is why the whole configuration can be placed in a (shielded) case. Such sensor is then mechanically resistant and linear for certain area.

Acknowledgement

This publication is the result of the project implementation: "Robust sensoric system for industrial environments with high pressures, temperatures and high degree of electromagnetic interference", ITMS code 26240220037, supported by the Research & Development Operational Programme funded by the ERDF. We support the research activities in Slovakia / The project is co-financed by the EU resources.

References

[1] Soloman, S.: *Sensors Handbook,* 2nd Edition. 2010. McGraw-Hill Comandies, Inc.
[2] Blade60: Non-Contact Position Sensor. *Gill Sensors* Datasheet.
[3] Extreme - KD-1925. *Global Spec* Datasheet.
[4] MSP430F2619S-HT microcontroller Datasheet, *Texas Instruments*.