Laboratory Tests of Force Sensor Applied in Agricultural Mechatronic Equipment

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Summary. The present article presents the results obtained from the test of a bolt with magnetoelastic sensor applied in agricultural mechatronic devices. This element is used in the electrohydraulic lift system applied in agricultural tractors in order to enable the measurement of tractor – agricultural machine system interaction force. The scope of works encompassed the measurements of the sensor output voltage vs. pressure force applied to the bolt with magnetoelastic sensor incorporated inside. Aforesaid tests have been performed for diversified bolt positioning towards applied force and for various values of the sensor power supply voltage.
Key words: laboratory tests, mechatronics, agricultural tractor, force sensor, force measurement, bolt, magnetoelastic sensor.

INTRODUCTION

Mechatronics is a discipline of science combining the concepts associated with the following fields: mechanical, electronic, IT engineering as well as signals control and transmission. The scope of mechatronics encompasses the devices, circuits and electromechanical systems incorporating sensors and actuators collaborating with signals processing system and with communication system. One of most important features of mechatronic devices consists in true representation of information in the form of electric signals and high automation level. The vehicles steering systems are the principal area for mechatronic devices application. The role of sensors converting the non-electric values(force, moment of force, rotation angle, movements etc.) into an electric signal (current, voltage, frequency, phase displacement etc.) is important in the operation of this type of systems.

Nowadays, the number of sensors installed in motor vehicles as well as in agricultural machines is significant. Many new designs and solutions are created in order to meet inter alia the following requirements [6, 7, 12, 13]: high accuracy, high sensitivity, durability, reliability, small dimensions, no impact of outside conditions on their operation. In order to ensure their correct operation in difficult conditions, the sensors must be provided with proper signal processing and forming signals [1]. The signal quality will be ensured by means of amplifying systems, A/D and D/A converters selected individually for specified sensor. Therefore the digital communication buses [3, 5, 14] are used in contemporary motor vehicles and agricultural vehicles for information transmission from sensors and communication between individual mechatronic devices. The signals in such systems are transmitted via proper buses using standard conductors or fibre optic cables [15, 19] to increase the system reliability and to provide the possibility of a quick and reliable diagnosis by means of "the best" available method [8, 17, 18] in case of damages.

The latest mechatronic solutions are used in contemporary tractors and agricultural machines in the scope of work management for majority of control circuits as well as for working elements functions. The purpose of various types of sensors is to provide precise information on current operation parameters for an element, circuit or system to enable their correct functioning.

BOLT WITH MAGNETOELASTIC SENSOR

Due to various types of automatic control systems applied in agricultural tractors e.g. for tool position towards the tractor and their interaction force, it is necessary to use adequate set of sensors for data acquisition and analysis. The magnetoelastic sensor incorporated in the bolt in order to supply information about interaction force between the tractor and attached tool is one of the basic sensors coupling the both elements of the tractor – machine system. The efforts intended to increase the effectiveness and work efficiency of the assemblies are continued since many years [2, 9, 10, 16].

KMB 060 magnetoelastic sensor with nominal force value of ±60 kN and overload capacity ±160 kN [20], man-

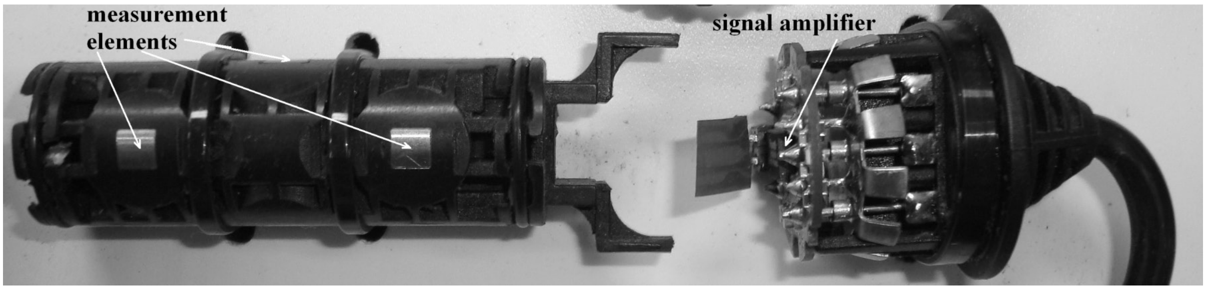

Fig. 1. Magnetoelastic sensor

ufactured by Rexroth Bosch Group and illustrated in Figure 1 has been used for tests. The sensor represents a group of parametric sensors operation in accordance with principle of electric signal variation vs. measured value [11]. Such sensors are used in electrohydraulic lifts system of agricultural tractors, where it is required to determine the traction force.

The magnetoelastic sensors are based on the phenomenon of permeability variations in ferromagnetic in case of their deformation within elastic strains. Electromagnetic forces induced in measuring elements are insignificant, in order of magnitude equal to mV. Therefore the magnifying systems are applied in order to enable the measuring signal reading.

LABORATORY TESTS

The tests were completed on a laboratory station [4] prepared in the framework of a master thesis; its measuring system is illustrated in Figure 2. Research works consisted in changes of force applied to the bolt caused by the increasing of oil pressure in manual hydraulic pump with piston diameter of 33 mm.

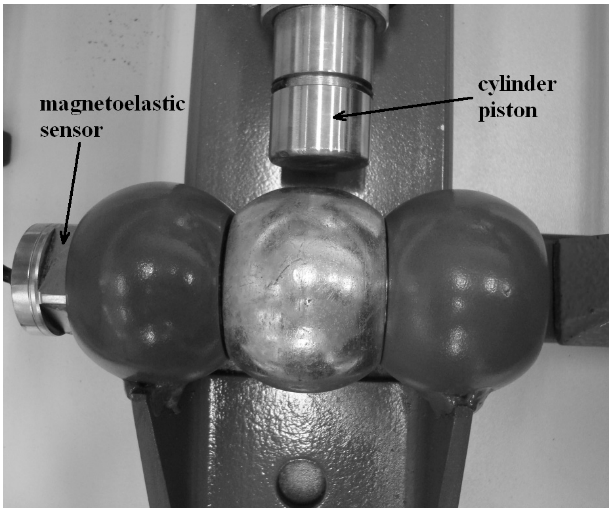

Fig. 2. Laboratory measuring system

In order to determine the curve representing the sensor output voltage vs. force applied to the bolt U=f(F), the measured value of pressure (by means of pressure gauge) applied to the bolt with magnetoelastic sensor incorporated inside was converted into force value, in accordance with the following equation:

$$F = p \cdot S, \tag{1}$$

where:

F – force applied to the bolt with magnetoelastic sensor incorporated inside,

p – pressure applied to the bolt with magnetoelastic sensor,

S – surface area of actuator piston cross-section.

The value of sensor output voltage vs. force applied to the bolt was measured by means of an universal meter. The measurements were carried out for various setting angles of the bolt (Fig. 3) and various values of power supply voltage of the magnetoelastic sensor (Fig. 4).

In order to obtain the negative value of force applied to the bolt, the latter was reversed by angle of 180°.

CONCLUSIONS

From the tests it appears that the obtained characteristics of magnetoelastic sensor is linear. The value of output voltage depends on the angle of bolt setting as well as on power supply voltage of the sensor.

From the analysis of sensor positioning angle towards applied force (Fig. 3) it appears that the sensor operation is correct up to the angle value of 45° only. The error is the greatest in case of limit measured values of force impact of ± 22 kN. In case of the bolt positioned perpendicularly to applied force (angle of 90°), the sensor becomes inoperative (only the value of idle voltage is present). Therefore, the working direction of magnetoelastic sensor must be polarized. Each change working angle may result in an incorrect force measurement.

From the analysis of the impact of sensor power supply voltage on its operation (Fig. 4) it appears that the sensor operation is correct in the scope of voltage values specified by the manufacturer (8-12 V). In case of voltage value lower than 11 V the shape of sensor curve becomes more flat.

The tests presented herein demonstrated the impact of basic operation parameters of magnetoelastic sensor on its operation characteristics. The measurements repeatability contributing to the correct operation of the whole tractor – machine system is extremely important from the measurement point of view due to its location in the agricultural tractor and heavy duty working conditions.

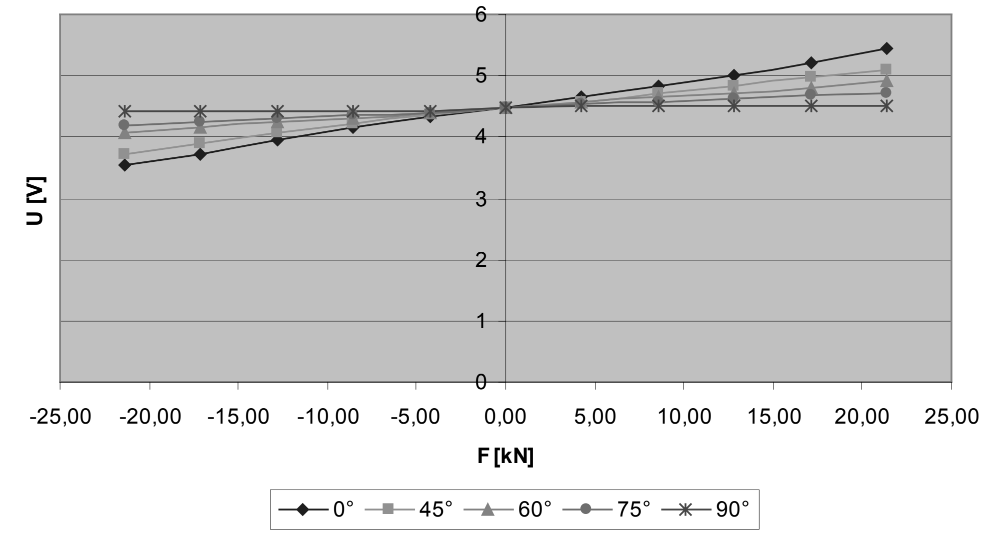

Fig. 3. Magnetoelastic sensor output voltage vs. force applied to the bolt depending on the bolt setting angle.

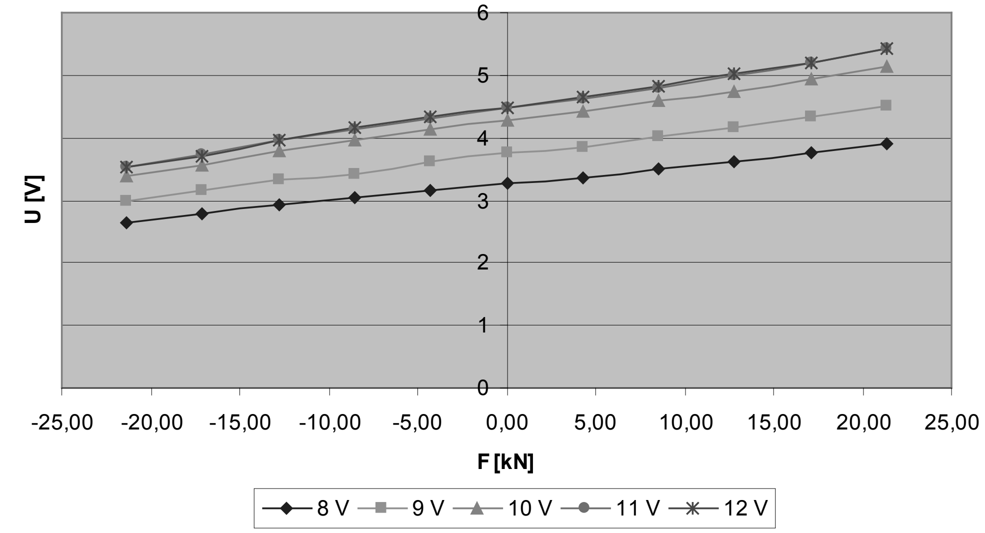

Fig. 4. Magnetoelastic sensor output voltage vs. force applied to the bolt depending on power supply voltage of the sensor

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BADANIA LABORATORYJNE CZUJNIKA SIŁY STOSOWANEGO W ROLNICZYCH URZĄDZENIACH MECHATRONICNZYCH

Streszczenie. W artykule zaprezentowano wyniki badań sworznia z czujnikiem magnetosprężystym jako elementu stosowanego w rolniczych urządzeniach mechatronicznych. Element ten stosowany jest w układzie elektrohydraulicznego podnośnika ciągników rolniczych. Jego rolą jest pomiar siły wzajemnego oddziaływania układu ciągnik-agregat.
W ramach prac wykonano pomiary wartości napięcia wyjściowego czujnika, w zależności od wartości siły nacisku wywieranego na sworzeń z umieszczonym wewnątrz czujnikiem magnetosprężystym. Badania te wykonano dla różnego ustawienia sworznia względem działającej siły oraz dla różnych wartości napięcia zasilającego czujnik.
Słowa kluczowe: badania laboratoryjne, mechatronika, ciągnik rolniczy, czujnik siły, pomiar siły, sworzeń, czujnik magnetosprężysty.