Linear position sensing through conductive wall without permanent magnet

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Summary

A linear position sensor for pneumatic actuators is presented. Position of the piston rod made of ferromagnetic material is detected by low frequency magnetic field which penetrates the aluminum wall of the cylinder. The sensor consists of an array of micro-fluxgates and two excitation saddle coils mounted outside the actuator. The method does not need a permanent magnet attached to the piston as required by common magnetic position sensors.

Motivation and results

The presented sensor is motivated by application of position sensing through conductive sheath presented in [1]. A low frequency magnetic field excitation penetrates thin conductive material and allows to detect metallic objects behind it. Active excitation allows synchronous demodulation of sensor signal to suppress off-band noise fields including DC. In the study ([1]) a 100 Hz excitation was used to detect position of objects through a 2.5 mm thick aluminum wall.

This method can be used for position detection of a piston in a pneumatic actuator which has usually an aluminum wall. So far for position sensing a permanent magnet had to be installed in the piston and a DC-field sensor detected its position [2]. Magnetic field of the permanent magnet then has to be strong enough to ensure good signal to noise ratio to suppress DC field noise.

The proposed sensor does not need modifications to the piston, it is installed externally on the actuator wall (Fig. 1). The magnetic field response of the steel rod to the radial excitation field is sensed by micro-fluxgate sensors in axial direction. The response is frequency dependent. At very low frequencies only permeability effects contribute to the signal, at 64 Hz eddy current effects change noticeably the shape of characteristics (Fig. 2). The selection of the used excitation frequency depends on the required dynamic properties of the designed sensor. We evaluated the error of position measurement with excitation frequency of 32 Hz and 16 sensors in the array with 3-cm spacing (Fig. 3). Using least mean squares fitting method the positioning error is below ±2 mm throughout the central 300 mm stroke of the 500 mm long pneumatic actuator. This is initial accuracy achieved without any corrections.

Due to the low amplitude of the signal measured, which is about 1/1000 of the amplitude provided by a piston magnet, the position sensor is susceptible to the background magnetic noise. Methods of noise suppression which does not compromise the sensor frequency response will be evaluated in the full paper.

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References

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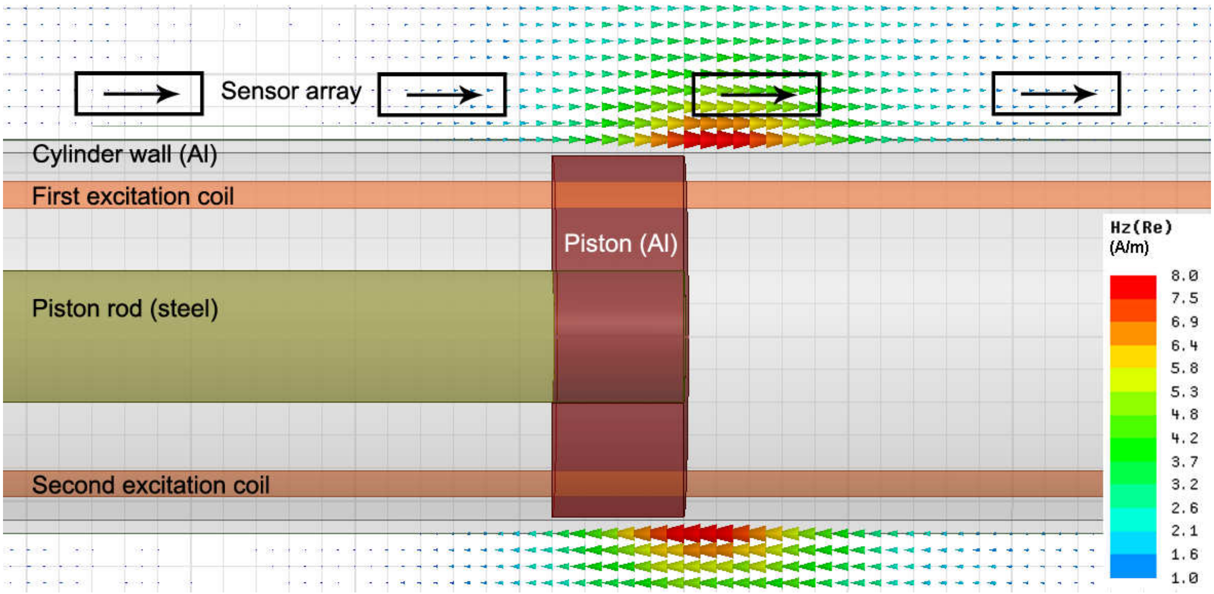

Figure 1: Magnetic field component in axial direction outside a pneumatic cylinder 6 cm in diameter simulated by FEM. Excitation field of 4 Hz in radial direction penetrates the aluminum wall and is substantially deformed near the end of the piston rod made of common magnetizable steel. Sensors are oriented in the axial direction and perpendicularly to the excitation field.

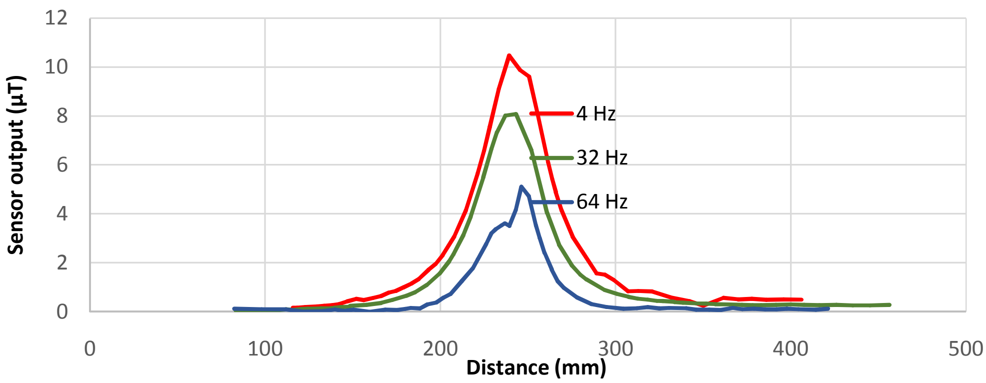

Figure 2: Single sensor output vs. piston position for excitation frequency of 4 Hz, 32 Hz and 64 Hz .

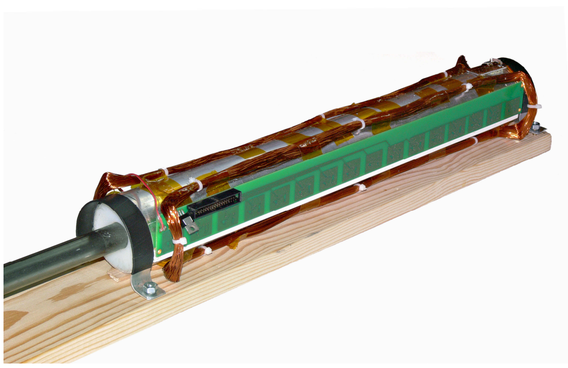

Figure 3: The position sensor made of 16 integrated fluxgate sensors and two excitation saddle coils is attached to the pneumatic actuator model.