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Development of a Computer-Based Stand for Research of the Methods of Sensorless Control of Electromagnets DC

Danil Shaykhutdinov, Nikolay Gorbatenko and Roman Leukhin
Department of Information and Measurement Systems and Technologies,
Platov South Russia State Polytechnic University (NPI), Novocherkassk, Russia

Abstract: The study presents the results of the developing of the method of controlling the position of plunger electromagnet DC without the use of special sensors. Stand for research according to flux-ampere characteristic of the position of the movable element of the electromagnet is designed. Neural network model for solving the inverse problem of determining the position of the plunger according to flux-ampere characteristic is developed.

Key words: Electromagnetic actuators, flux-current characteristics of the operating cycle, sensorless control, electromagnets DC, plunger

INTRODUCTION

At present time widely used system based on electromagnets DC. These systems require high precision and reliability (Shayhutdinov *et al*., 2015b) of operation of the electromagnets (Ovchinnikov, 2012). To control solenoid must be a precise definition of the position of the plunger. It is needed to know at what time and at what current the solenoid plunger begins its movement and is approaching the pole. It is also necessary to know the path traversed by the plunger in a certain period of time. Modern control systems are based statistics and current-position dependencies of the plunger. In this study we propose the method of determine the position of the plunger according to flux-ampere characteristic of its operating cycle.

The research problem is to find the relationship between flux-ampere characteristic and the position of the plunger of an electromagnet DC. Flux-ampere characteristic depends on the magnetic properties of the materials from which the electromagnet is made and has a non-linear view (Gorbatenko *et al*., 2011, 2015; Shaikhutdinov *et al*., 2015; Shaykhutdinov *et al*., 2013, 2015). Accordingly, the relationship between flux-ampere characteristic and the position of the plunger of an electromagnet DC also has a complex shape (Lankin *et al*., 2015a, b) as included in it are nonlinear components (Shayhutdinov *et al*., 2015a).

MATERIALS AND METHODS

To solve this problem, an automated stand based on triangulation optical sensor and the proportional solenoid is developed. The block diagram and the appearance of the stand shown in Fig. 1. Automated stand includes:

- PXIe: industrial computer of National Instruments with real-time controller with NI PXI-8133 multifunction device and NI PXI-6341, a controlled current source NI PXI-4130 installed in the chassis NI PXIe-1078
- LS5: digital optical encoder LS5-15/10-232-V-1-12-A with integrated microprocessor control system that allows to accurately measure the distance to the object under control without mechanical contact with him
- PS: DC power supply of 12 V for the optical sensor
- CCS: a device for obtaining information on the state of the electromagnet
- EM DC: proportional solenoid type KTS P25 A00 24 VDC, 0.63 A 0242

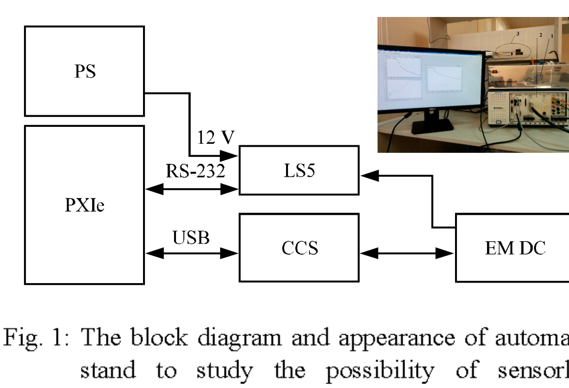

Fig. 1: The block diagram and appearance of automated stand to study the possibility of sensorless control electromagnet DC

Corresponding Author: Danil Shaykhutdinov, Department of Information and Measurement Systems and Technologies, Platov South Russia State Polytechnic University (NPI), Novocherkassk, Russia

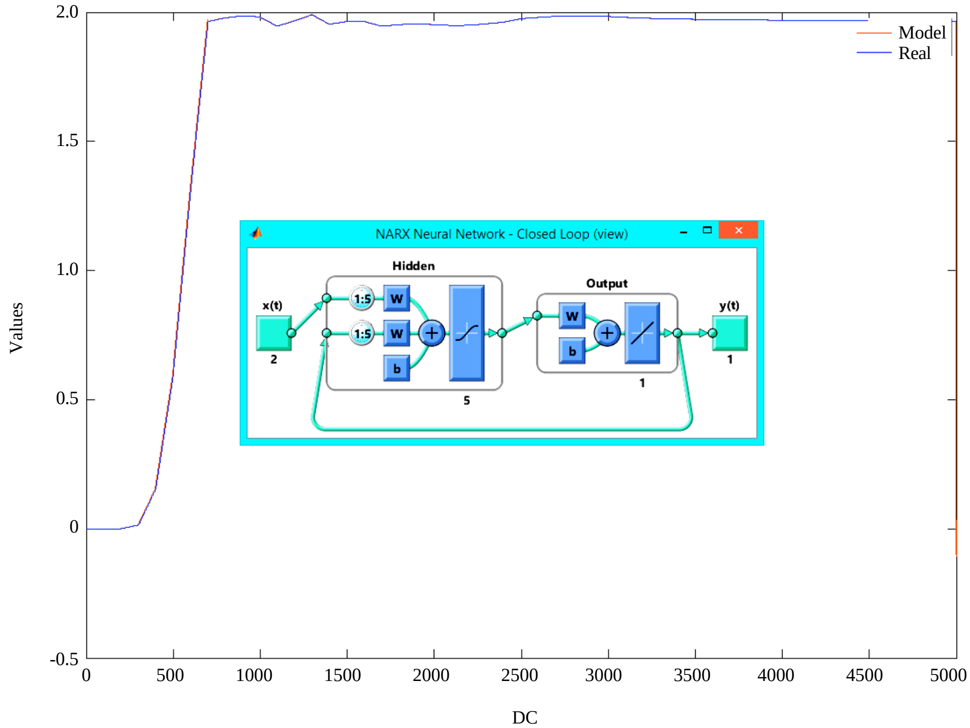

Fig. 2: Graphs of the movement of the plunger of the electromagnet DC

To manage the process of research, the special software in graphical programming language LabView is developed. The developed software enables to synchronize the device CCS, the optical sensor LS5 and PXIe. Automated stand operates as follows. For the magnetic characteristics of the electromagnet used special software and the device CCS. The device CCS has a card I/O NI USB-6211 installed in it and a controlled current source. The first stage of the operating cycle of the electromagnet is the process of movement of the electromagnet. It starts with the power controlled source of current to the coil. After energizing the coil of the electromagnet the current and magnetic flux is increase as long as the pulling force overcomes the opposing forces. Then the plunger starts to move, going from its initial position Sh to the final Sk. During the movement of armature device CCS fixed current and flux linkage, the data is transmitted in PXIe. Optical sensors LS5 fixed plunger position, data is transmitted in the format of five-byte ASCII-code in PXIe where it is converted into the position coordinates of the plunger. Then, using special software, implemented in Matlab (Marques de Sa, 2007), the correlations obtained flux-ampere characteristic of the electromagnet and the coordinate position of the plunger is analyzed.

Figure 2 is a graph of the motion of the plunger of the electromagnet (real-blue color) and the output of the program under Matlab in which the measured flux-ampere characteristic used to simulated position of the plunger (model-red color). In addition, Fig. 2 shows the structure of a neural network, through which the coordinate values of position of the plunger by flux-ampere characteristic is calculate. In Fig. 2, the vertical axis is position S (mm), horizontal axis-time t (msec). As seen in Fig. 2, the plunger is moved to a distance of Sk = 1.97 mm. After activation of the electromagnet and the impact of the plunger on the yoke of the electromagnet there is chatter plunger with the end position of the plunger Sk change.

RESULTS

The developed neural network model provides a definition of the position of the plunger from the measured flux-ampere characteristic with a high accuracy (error is no >5%). Thus, it becomes possible to implement the method of precision sensorless control proportional solenoids without using special sensors.

DISCUSSION

The automated stand to investigate the dependence of the current position of the plunger and the applied voltage to the coil, the analysis of the data obtained. The developed neural network model provides a definition of the position of the plunger from the measured flux-ampere characteristic.

CONCLUSION

In the study developed the method of controlling the position of plunger electromagnet DC without the use of special sensors. Stand for research according to flux-ampere characteristic of the position of the movable element of the electromagnet is designed. Neural network model for solving the inverse problem of determining the position of the plunger according to flux-ampere characteristic is developed.

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