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THE CONTROL SYSTEM OF THE STEPPER MOTOR MOTION WITH POSITIONING ACCURACY VERIFICATION

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Abstract: *The paper demonstrates the laboratory stand for the stepper motor control. It was developed on the basis of the two-phase stepper hybrid motor with two shaft ends operated as bipolar. For the stand the following Wobit components were used: the stepper motor controller, the programmable trajectory generator for the stepper motor controllers, the rotary encoder, the programmable pulse and speed counter, a power supply designed for the stepper motor controllers, a power supply for the encoder, the pulse counter, and the trajectory generator. The stand was used for the positioning accuracy measurements and on their basis the errors were determined for several motion parameters such as: minimum speed, maximum speed, and acceleration. The tests were made for three values of the basic step division:1/2, 1/8, and 1/16 as well as for different values of the load moment. The stand also allows the implementation of various stepper motor motion trajectories by developing control programs.*

Keywords: Step motor, basic step, accuracy, bipolar control.

1. Introduction

The stepper motor is a motor that transforms electrical control pulse series into angular displacement series of a rotor or linear displacement of an "unrolled" rotor. The stepper motor is an electro mechanical energy converter, which is characterised by discrete mechanical displacement [Glinka T., Kulesza B., 2004], [Przepiórkowski J., 2012]. The motor converts the control signal (pulse) directly on the fixed position of the shaft without using feedback as, for example, in servomechanisms. The angular displacement of the rotor is proportional to the number of pulses and the rotational speed is proportional to the control impulse frequency of motor winding. The direction of the rotation depends on the control impulse sequences.

2. Description of the laboratory stand

For the research at the measurement stand, ECM 268-E2.8B-1 two-phase stepper motor with two shaft ends was used with rating: current rating 2.8 A (unipolar connection of the windings), current rating 4.0 A (parallel bipolar connection of the windings), rated voltage 2.8 V, basic step 1.8°, holding torque 1.2 Nm.

The motor can work as unipolar or bipolar, because there are eight wires ending the windings [Wróbel T., 1993]. The motor works with parallel bipolar connection of the windings in the laboratory stand.

The other basic functional components are subassemblies of Wobit company.

The motor is connected to SMC 104 controller with power stage designed for two-phase stepper motor with bipolar winding (8 or 4 wire) or unipolar 6-wire set as bipolar. This enables the motor control with division of the step in the range from 1/2 to 1/64 forcing the constant current value in the winging

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independently of the power supply voltage value. The controller has an option of choosing the current value in the range from 1.2 to 3.8A through configuration micro-switches located on the front panel. It is also possible to turn on the reduction, which limits the power consumption by half if CLK clock signals have a frequency lower than 1.5Hz. The motor starts working by giving the signal (+5 ÷ 24V) to the EN input (ENABLE). The direction of the rotation is controlled by DIR input [www.wobit.com.pl].

The controller is powered by ZN200-L unregulated power supply, which is designed for stepper controllers with rating: current 4A, voltage 36V, power 100W. The power supply enables reception of the motor return energy through the output capacitors of capacitance 4700μF.

At the laboratory stand, SMC104 controller is clocked by MG-ZT1 programming device, which is a programming trajectory generator for the controllers of the stepper motors. From the programming device to the controller two signals are primarily sent: clocking (CLK) that determines intervals between motor steps and direction signal (DIR) that determines the direction of the motion. The programming device in combination with the controller enables generation of stepper motor motion trajectory with parameters such as: position, speed, acceleration. It is possible to set the device and program the motor motion trajectory due to menu placed on the external panel. Therefore, it is not necessary to connect the module to the computer [www.wobit.com.pl].

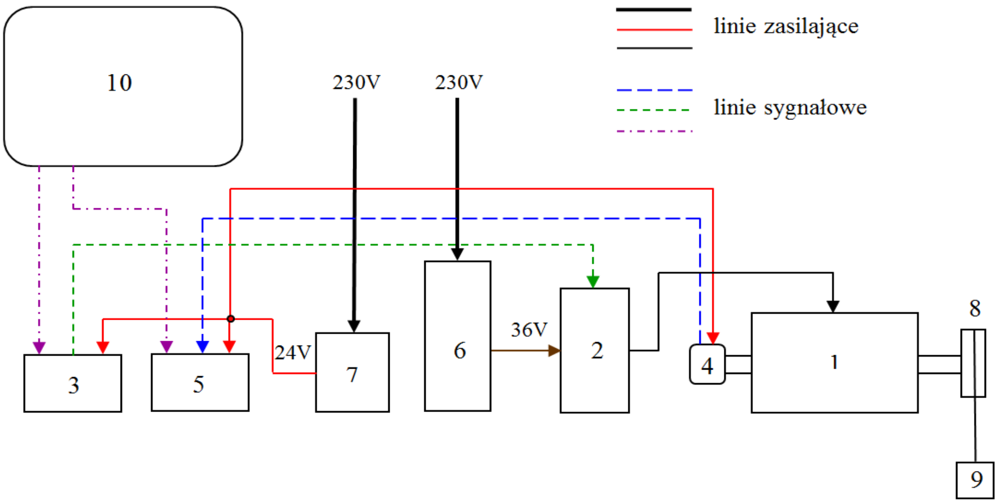

Fig. 1: Block diagram of the laboratory stand for controlling the stepper motor: 1-stepper motor, 2-SMC104 controller, 3-MG-ZT1 programming device, 4-enkoder, 5-MD 150E pulse counter, 6-ZN200-L power supply, 7-DR-4524 power supply, 8-rope reeler, 9-changeable load, 10-PC computer.

The stepper motor has two shaft ends. Rope reeler is attached to the one of them, which enables suspension of the load with different values on it. MHK-40 rotary-pulse encoder with a hole for axle with resolution of 3600 divisions per rotation.

The encoder is connected to MD 150E programmable pulse and speed counter. On the external panel there is the menu and the display which presents the number of counted pulses, cycles and pulse frequency (speed).

MG-ZT1 *programming device*, MD 150E counter and the encoder are powered by DR-4524 power supply with a voltage of 24V. The *programming device* and the counter can be connected to the PC computer through USB interfaces whereby it is easier to control the stepper motor and visualisation of measurement results.

3. Positioning accuracy measurements

Positioning accuracy measurements were carried out for specific motion parameters, such as: minimum speed $v_{min} = 1\,\text{impuls/s}$, maximum speed $v_{max} = 1600\,\text{impuls/s}$, maximum acceleration $a_{max} = 800\,\text{impuls/s}^2$.

The values of the measurement are determined for the programming device in pulses, which sends the clocking signal CLK to the controller of the stepper motor. The measurements were carried out for the following settings of the basic step division (1.8°): 1/2, 1/8, 1/16. The settings were conducted in the front panel of the controller by using micro-switches. The accuracy positioning tests were carried out for various values of rope reeler loads, i.e.: without load m_1 = 0 kg, load of m_2 = 0.5 kg, load of m_3 = 1 kg, load of m_3 = 1.32 kg (load torque M_0 = 0.42 Nm).

The radius of the rope reeler disc (fig. 1, item 8) r = 32.5 10^{-3} m. Load torque M_0 was determined from the formula

$$M_{o} = m_i g r \quad i = 1, 2, 3, 4 \tag{1}$$

During the research, there were carried out repeatedly measurements of positioning for selected setting of the basic step division of the stepper motor as well as for given load value during a rotation of the motor shaft. The number of pulses corresponding to one rotation for set basic step division was entered from the programming device. Whereas the actual position of the stepper motor shaft after one rotation was determined by the encoder and the pulse counter. For the used encoder there were 10 pulses for 1° of rotation sent from the encoder to the counter.

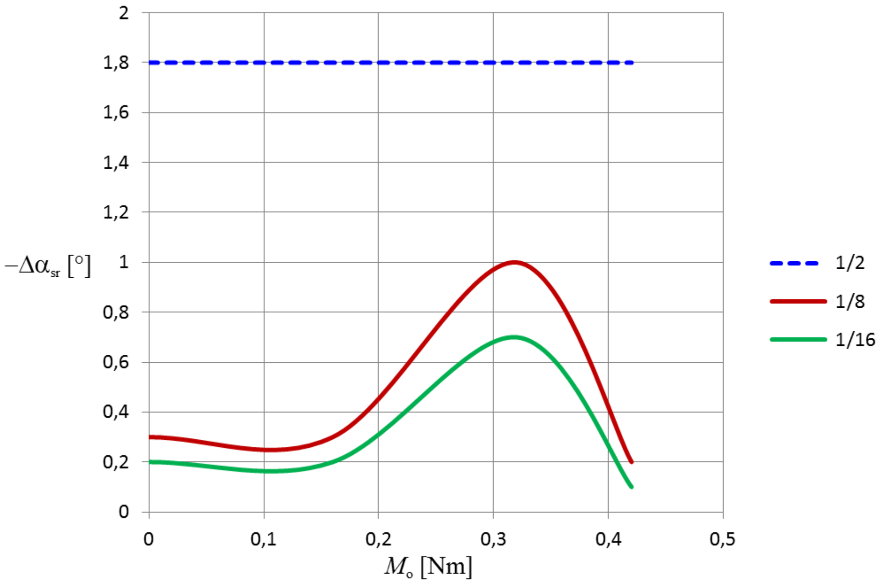

Fig. 2: Diagram of positioning errors for the function of load torque for different basic step divisions.

Based on the measurement, the following could be determined:

– the average absolute angular error of positioning for full 360° rotation

$$\Delta\alpha_{sr} = \sum_{i=1}^{n} \frac{\Delta\alpha_i}{n} \tag{2}$$

where: $\Delta\alpha_i$ – absolute error of positioning to the ith implementation of the measurement, n – the number of measurements.

–the average relative percentage error of positioning for full 360° rotation

$$\delta\alpha_{sr} = \frac{\Delta\alpha_{sr}}{360} \cdot 100 \tag{3}$$

A diagram of average angular error of positioning for the function of load torque for different basic step divisions is presented in Fig.2, whereas a diagram of the same error in the function of basic step division multiplicity in Fig.3.

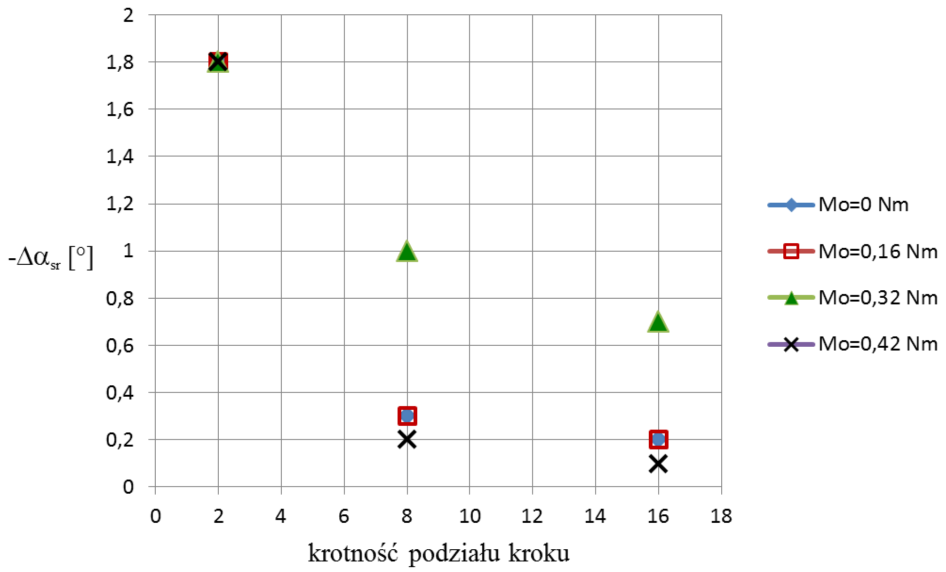

Fig. 3: Diagram of positioning errors in the function of basic step division multiplicity for different values of load torque.

4. Summary

Based on the measurements, it can be stated that the increase of basic step division affects the decrease of positioning error value, which is between -1.8° (-0.5%) and -0.1° (-0. 03%) depending on the loads.

The positioning error has the same value -1.8° (-0.5%) for applied basic step division ½ independently from the load torque. For the divisions 1/8 and 1/16 under the load torque $M_o = 0,32 \mathrm{N \cdot m}$ ($m = 1 \mathrm{kg}$), there are increased positioning error values, respectively -1.0° (-0.28%) and -0.7° (-0.19%) as compared to the other loads as well as no load.

There is repeatability of measurements for the same settings of the basic step divisions and load values for right rotations (lifting a load) as well as for left rotations (lowering a load). The breaking, which means losing a step, happens only in case of the basic step division 1/2 (400 pulses from the programming device) and the load torque $M_o = 0,42 \mathrm{N \cdot m}$ ($m = 1,32 \mathrm{kg}$) for left rotations (in the direction of load).

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