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Determination of the torque characteristics of a stepper motor

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Abstract

The term motor should be understood as the converter of an electrical energy into a mechanical energy. The stepper motor converts electrical signals in form of impulses, for the angle of rotation. The relationship is proportional, so that the stepper motor rotation speed is dependent on the frequency of the control impulses. The research concerns developed prototype of glue distributing machine. Its task is to glue coating parts and seats used in machines and mass transit vehicles. Parts to be bonded are characterized by great variety and complicated geometry. Due to the high requirements for constant quality of applied adhesive layer and the shortest possible operation time, it is necessary to apply specialized propulsion and control system. The article presents the results of research regarding the identification of torque characteristics in a function of rotational speed of the stepper motor. In addition, torque variations for different values of the supply current of motor coils where determined. Actual characteristics of stepper motor were necessary due to the frequency increase selection method applied in the project. This will enable the accurate control of the stepper motor.

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Keywords: hybrid stepper motor; torque characteristics

1. Introduction

Obtaining a maximal positioning speed of manipulator head for triaxial machine requires the choice of steering system and power transmission system with proper parameters. This problem has been solved during the design of manipulator construction for gluing the surfaces with large dimensions (ca. 1000 × 2000 mm). Short positioning time is very important for such large operation areas of manipulator. Executive system of the machine (Fig. 1) consists of vertical guide 1 and special nozzle for glue spraying 2. This system is driven by ball screw drive 3 which cooperates with stepper motor 4. The aim of this device is to put a glue layer on elements with different shapes and

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curvilinear surfaces. Particular parts of seats for passenger transport services have been glued. The construction of these seats is based on the connection of few layers of different materials by glue in order to provide the effectiveness and high quality standard. Construction of main mechanism is based on linear motion of manipulator head for three reciprocally perpendicular axes. Ball screw drive and guiding system have been applied. This allowed to put the spray head in every place of operation area restricted by rectangular prism.

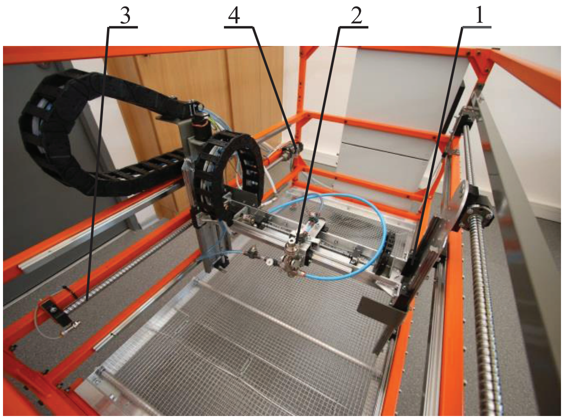

Fig. 1. Machine prototype for gluing: 1 – guide, 2 – nozzle, 3 – ball screw drive, 4 – stepper motor.

Device operation includes automatic detection of type of element placed by operator in workspace. This detection can be done by a vision system and control made by the authors [1]. This system should detect correctly the glued element regardless of its orientation in workspace. It should also correct the path of spray head so as to put the glue in the same manner for every group of elements. Presented solution results from the necessity of obtaining a good repeatability of glue layer on connected seat elements. The positioning accuracy of head and its short operation time play an essential role in the described process. The assurance of these requirements forces the designers to take into consideration these requirements in device construction and elaboration of control algorithm of the system. In case of power transmission system these requirements are connected with real characteristic of motors.

Diphase hybrid stepper motor ST5918L4508 from Nanotec company (parallel feed) was examined. Construction of this type of motor is a connection of solutions applied in motors with permanent magnets and variable reluctance. Rotor and stator are equipped with toothed pole shoes. Rotor is additionally equipped with permanent magnet and due to this fact the teeth are being alternate magnetized by poles N and S. Magnetic field in stator is induced by winding. For non-induced state the magnetic field is closed in circuit: stator – air gap – rotor. Providing the steering impulse is the reason of amplification of magnetic flux from permanent magnet for one stator pole and weakening for second one. Due to this fact the rotor makes one step so as to overlap the teeth axes of stator and rotor which have amplified magnetic flux [2, 3]. Basic parameters of examined motor are presented in Table 1 [4].

Table 1. Basic parameters of motor ST5918L4508.

Parameter	Value
Rotor Inertia	480 gcm²
Resistance per Winding	0.5 Ohm
Inductance per Winding	0.95 mH
Holding Torque unipolar	132 Ncm
Holding Torque series	186.68 Ncm
Holding Torque parallel	186.68 Ncm

2. Investigation methodology

Determination of characteristic of stepper motor required the construction of a special test stand for loading the motor shaft with defined value (Fig. 2). This test stand consists of screw 1 supported in ball bearings at two spots 2 and 3 mounted on foundation 4. The screw is equipped with roller 5 with diameter d = 38 mm. The moment is transferred from stepper motor 6 by flexible coupling 7. The strand was winded on roller and some bobs were hung at the end of this stand. The knowledge of values of bob weight and roller diameter allowed to calculate the load torque. Control of operation parameters of motor was done with the application of controller SMCI47-S-2 from Nanotec company. Microcontroller STM32 was responsible for generating the impulses which induced the motor – it was equipped with control program made by the authors. Real angular displacement was measured with digital encode NEO2.

Resistance connected with system inertia and losses in bearings have been taken into account during the measurements. The value of anti-torque was calculated during disengaged system loading – its value was equal M_{op} = 10 Ncm. Scheme of measuring system is presented in Fig. 3.

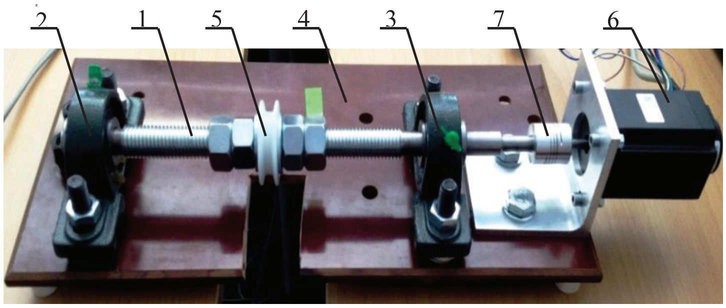

Fig. 2. View of measuring position: 1 – screw, 2, 3 – bearings, 4 – foundation, 5 – roller, 6 – stepper motor, 7 – clutch.

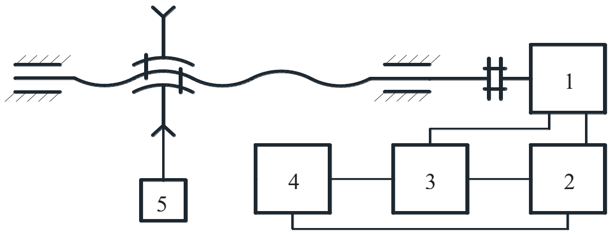

Fig. 3. Scheme of measuring system: 1 – stepper motor, 2 – encoder, 3 – controller, 4 – impulse generator, 5 – loading mass.

3. The investigation results

On the basis of conducted investigations the following characteristics were obtained: torque in function of rotational speed, static moment (holding moment) in function of supply current and starting frequency in function of current intensity. The value of load torque was calculated on the basis of the measurements of bob weight. Motor controller allowed to regulate the value of current intensity and impulse frequency. Rotational speed of motor shaft was calculated on the basis of the measurements form digital encoder – its resolution was equal 1000 impulses per step.

Mechanical characteristic is the most important characteristic for stepper motor – it combines maximal torque with rotational speed of the shaft. Characteristics from manufacturer are presented in Fig. 4.

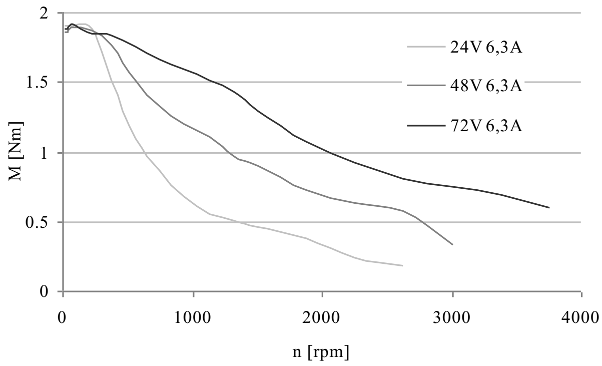

Fig. 4. Mechanical characteristics for stepper motor ST5918L4508 [4].

Maximal torque for different values of current intensity was also calculated. Fig. 5 presents the statement of these parameters with the values from manufacturer's mechanical characteristic. We can observe that the increase of rotational speed is connected (frequency of control impulses) with the decrease of the torque. Moreover, the registered characteristic shows higher values for the increase of current intensity. The range of measured values fulfilled the required conditions of operation parameters of the device for gluing.

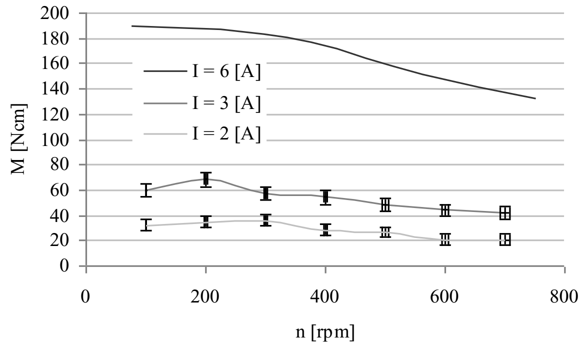

Fig. 5. Statement of measured mechanical characteristic and manufacturer's mechanical characteristic for stepper motor.

On the basis of obtained results one can conclude that the increase of maximal static moment is connected with the increase of current intensity. Obtained characteristic is similar to linear function and this fact can be found in literature [3]. Due to resistance and losses it was not possible to calculate the static moment for null of current intensity. For this type of motor, some value of moment will always exist even without any induction – this is a positioning moment of rotor [3]. Fig. 6 presents the characteristic of measured values. Relationship between maximal starting frequency and current intensity is presented in Fig. 7 – the curve is almost linear.

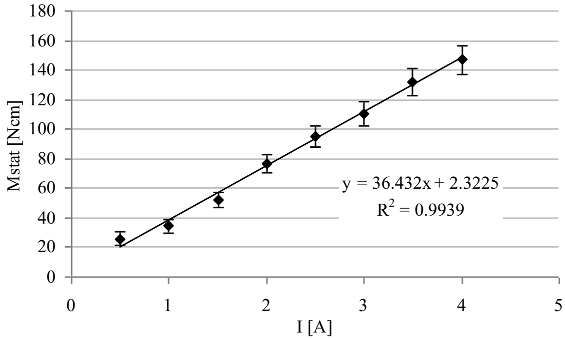

Fig. 6. Relationship between static moment and current intensity.

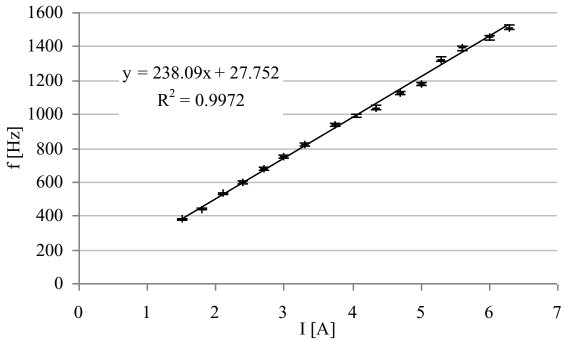

Fig. 7. Relationship between limit starting frequency and current intensity.

4. Conclusions

Obtained characteristics are similar to exemplary characteristics from literature [2, 3, 5, 6]. The increase of both starting frequency and maximal static moment is connected with the increase of current intensity – this increase is almost linear. The higher the rotational speed, the lower the torque of stepper motor – its value is connected with the value of current intensity.

Obtained results will be applied to correct the control algorithm for gluing machine. These results allow to choose correctly the values for system controller and improve the dynamic features of power transmission system and the accuracy and speed of positioning. Taking into consideration the real characteristics connected with operation and power supply of stepper motor will allow to improve the efficiency of the gluing process.

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