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The investigations of dynamic characteristics of a stepper motor

Łukasz Warguła, Piotr Krawiec*, Jarosław M. Adamiec, Konrad J. Waluś

Poznan University of Technology, Chair of Basics of Machine Design, Piotrowo Street 3, 60-965 Poznan, Poland

Abstract

The aim of the work is the examination of dynamic characteristics of a stepper motor. The results of the investigations will be applied to assess the usability of the stepper motor as a generator of the periodically variable motion of actuators. The examples of mechanical generators of periodically variable motion are gear, chain and cogbelt transmissions. The complex unevenness of the work can be achieved by the application of properly designed and manufactured gear wheels. The investigations have been performed with the application of versatile test stand which consisted of a set of shafts with torque sensors. The loads have been applied by a magnetorheological brake.

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Keywords: stepper motor; variable motion; design;

1. Introduction

The development of existing constructions and a need of elaboration of new constructions with a no typical characteristics of kinematic and dynamic features force the need of substitution of conventional generators of rotational or swinging motion by unknown or not used transmissions so far. The example of such solutions can be periodically variable motion generators which are called uneven transmissions [5-7].

Periodically variable speed of driven shaft at constant speed of drive shaft is a characteristic feature of these transmissions. Such solutions allow to obtain a variable transmission ratio during one full rotation. The advantage of such solutions is obtaining of constant and repetitive changes of kinematic and dynamic features irrespective of the operating environment.

The disadvantage of this concept is the need of design and manufacture of the wheels (gears, pulleys, chain) with different geometrical features. Simultaneously it is impossible to obtain other characteristics of transmission ratio. The alternative solution may be an attempt of application of stepper motors to generate the periodically variable kinematic features. The possibility of application of stepper motors as generators of periodically variable motion is presented in this paper.

* Corresponding author.
E-mail address: piotr.krawiec@put.poznan.pl

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2. The purpose of research

The aim of research was the analysis of dynamic features of a stepper motor in terms of its application as a periodically variable motion generator and the possibility of application of such transmission for research of vibration analysis and parametric resonances of a belt transmission with a toothed belt [1-4, 9]. The application of adjustable generator of variable motion will allow to simulate the operation of working machines for crushing, grinding, separation or transport of products using non-uniform movements.

3. Research test stand

The tests were conducted on a universal test stand designed for research of belt transmissions. The test stand is a part of equipment of transmission laboratory of the Chair of Basics of Machine Design at the Poznan University of Technology. It was also applied for research of kinematic and dynamic features of stepper motors (Fig. 1). The main element of the test stand is 2-phase stepper motor WOBIT 110BYGH601 controlled with the controller Ledshine Mikrostep Drive ND2282PbF. Motor control signals were generated by the software platform ARDUINO UNO. The brake RH-90-4/20 with magnetorheological fluid was applied to load the motor. Torque measurement was carried out with a versatile torque meter designed by a team of the Chair of Basics of Machine Design. The encoder MEGATRON MOB 2500/5/BZ/N was applied to register the temporary changes of the angular velocity of shaft. The results of measurements of torque and angular velocity were recorded by the original computer software which is an integral part of the test stand.

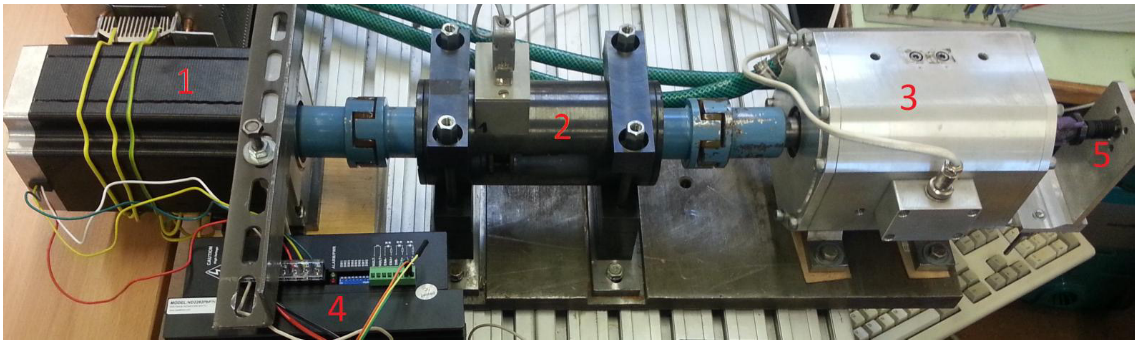

Fig. 1. Test stand: 1 - stepper motor, 2 – torque meter, 3 - brake with magnetorheological fluid , 4 - motor controller, 5 – encoder.

4. Research methodology

Stepper motor research was conducted in two stages. In first stage time and maximum torque during dynamic loading of the motor by brake until full stop were investigated. Time of obtaining the given speed after disconnection of load was also researched. The investigation was performed for different rotational speeds of motor from extremely low ones to extremely high ones. During research different types of control of the stepper motor were applied i.e. full-step, half-step and micro-step: 1/4, 1/16, 1/128. During second stage the periodically variable signals were generated by the module ARDUINO UNO and were recorded without load and with constant load generated by the brake. The registration of instantaneous changes of obtained characteristics allowed to estimate the generated oscillations of torque and rotational speed.

5. Research results

Research of dynamic features of loading of stepper motor during stopping and next dynamic features of unloaded stepper motor are presented as change characteristics of torque (Fig. 2). Speed and torque are two parameters which are dependent on each other and have an impact on dynamic characteristics of the stepper motor (Fig. 3 Fig. 4).

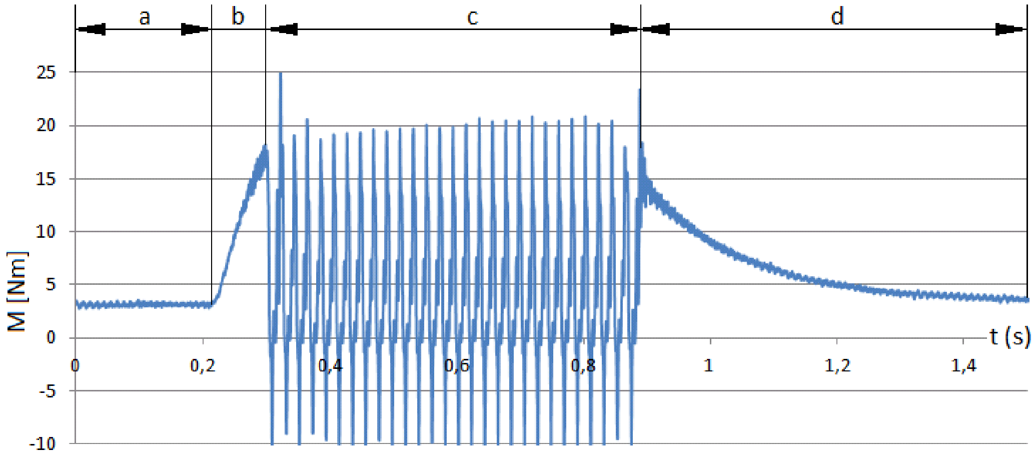

Fig. 2. Characteristics of torque in function of time during dynamic research of a stepper motor for full step control at speed of 50 rpm: a) without load, b) loading of stepper motor until stop, c) motor is stopped, d) starting of stepper motor

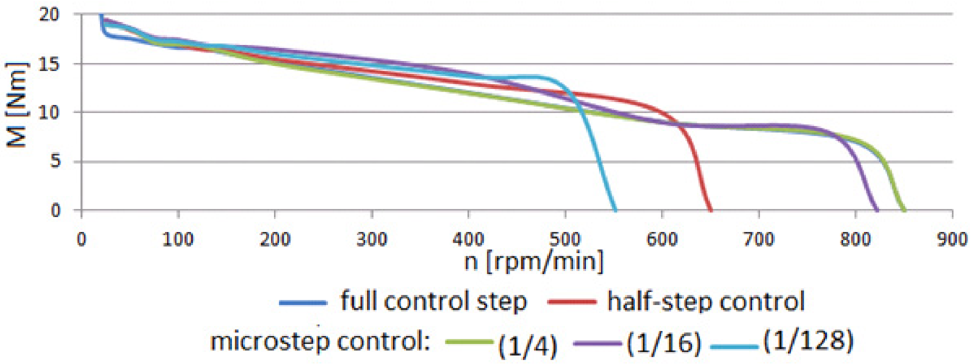

Fig. 3. The characteristic of maximum torque in function of the rotational speed for different stepper motor controls

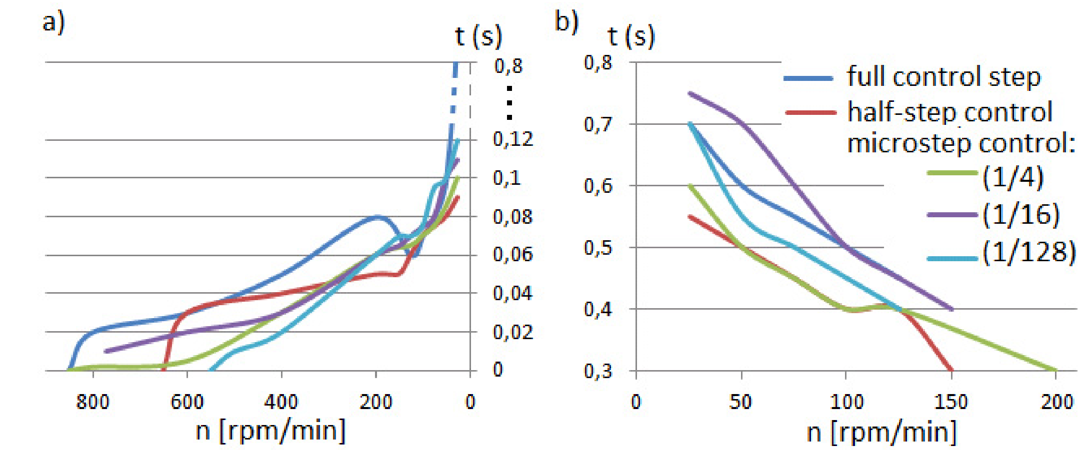

Fig. 4. The characteristics of time a) stopping the motor, and b) starting the motor

The tests for different types of motor control and rotational speeds showed the presence of vibrations – it is shown in Fig. 5.

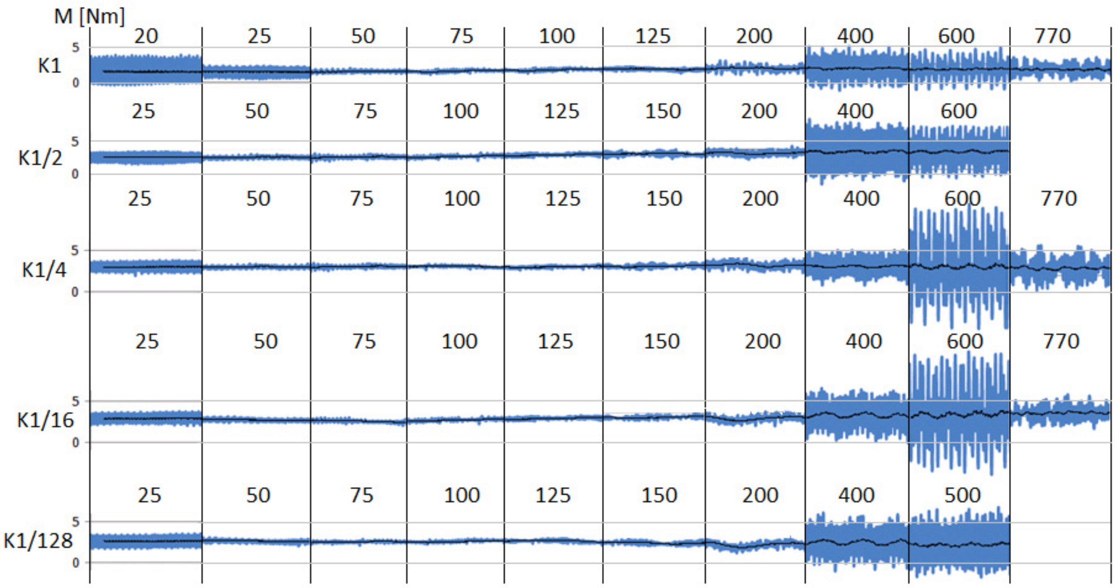

Fig. 5. The characteristics of the torque for speeds of 20, 25, 50 ... 770 rpm and for different types of the stepper motor control

The characteristics of rotational speed and torque for given periodically variable signal are shown in the following Figures 6-8.

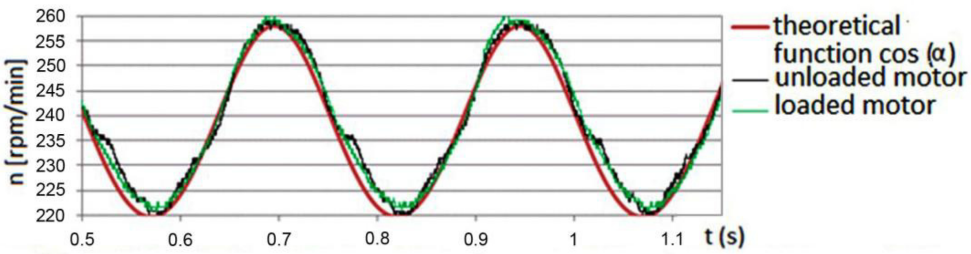

Fig. 6. The characteristics of the rotational speed of a stepper motor in function of time (theoretical, actual with load, without load)

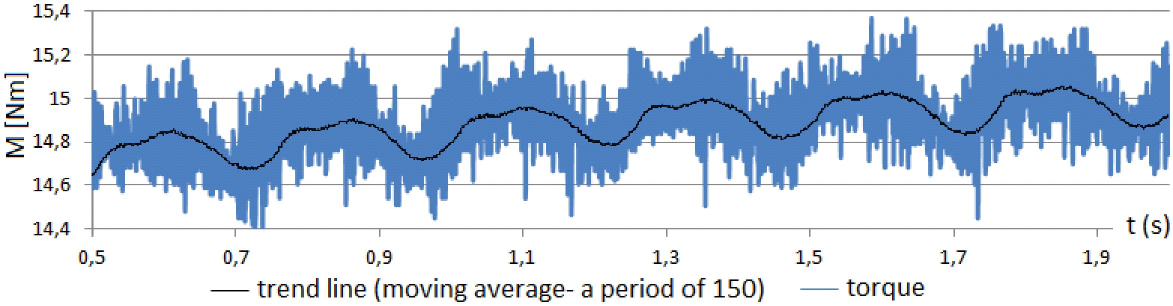

Fig. 7. The characteristics of the torque in function of time for unloaded transmission

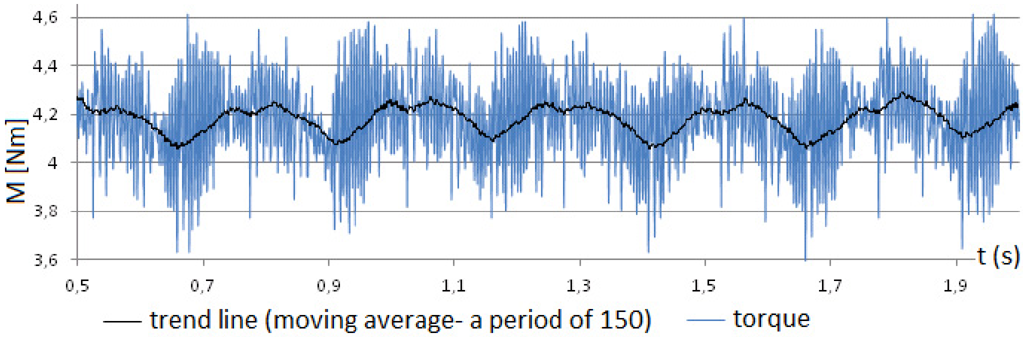

Fig. 8. The torque characteristics in function of time for loaded transmission

6. The analysis of results

Time of stopping and starting of a stepper motor loaded with torque is different irrespective of the obtained maximum torque, rotational speed and type of step control. Significant oscillations of torque during motor stopping have been observed (Fig. 2). The higher the rotational speed, the lower the torque becomes until the motor stops spontaneously for the load equal to zero (Fig. 3). Operation of the stepper motor during control with microstep 1/128 allows to achieve the lowest maximal rotational speed for different types of control. While the highest values of maximal speed were achieved during control with full-step and microstep 1/4. Microstep 1/16 control allows to achieve higher maximal speeds than half-step control. A lack of relationship between the maximal rotational speed and type of step control may result from changes in temperature of the stepper motor which were not monitored and can affect this parameter. Time of increase and reduction of the maximum torque depends on the obtained maximum torque values, type of control step and motor rotational speed. The higher the motor rotational speed, the shorter time of increase and reduction of maximum torque becomes (Fig. 4). The stepper motor moves in the direction specified in accordance with control signal and next it stops with maximum holding torque. Due to step operation of the stepper motor some vibrations occur at low speeds. The reason of their appearance is the inertia of the rotor and axle loads. The motor exceeds the set position and then returns to the desired position - it takes some time to reach the desired position. Stepper motor has also different vibration characteristic for the given mechanical system frequency. Segmentation of a step on microsteps leads to increase of resolution and this should increase the smoothness of work. The application of microstep is the reason of high reduction of the input energy because of pulsation of input energy – this leads to motor resonance [8]. Maximal rotational speed is also the reason of resonance increase. The tests also showed that the motor is characterized by relatively limited range of rotational speeds at which it can operate (Fig. 5). The higher the motor temperature, the lower the range becomes. During tests the temperature was changed, but it was not monitored. The obtained rotational speeds and torques during investigations of periodically variable motion are not dependent on motor load and represent the given signals (about 99.5% for loaded motor and 99% for unloaded motor). However, these results include higher oscillations than the results for a stepper motor with constant speed in the same range of rotational speed (Fig. 6). The obtained diagram of torque characteristics is deformed at the vicinity of maximum torque because inertia force acts on the rotor and it leads to overshoot and motion disturbance. Research of the motor during periodically variable work with a constant load has showed a "drift" of torque signal. The reason of this fact is the increase of load which is generated by the brake - where heating of magnetorheological fluid leads to increase of resistance.

7. Summary

The experimental investigations have shown that during transfer of periodically variable signal the following matters should be considered: minimum and maximum rotational speed of stepper motor, occurrence of zones of resonance frequency of stepper motor operation, starting and stopping time of the motor, value of the generated torque, environmental conditions (operating temperature). The increased value of torque oscillations of stepper motor during periodically variable motion may significantly interfere other registered vibroacoustic signals. It should be expected that the resonance of a stepper motor will not allow to measure the parametric resonance of cogbelt in a strand transmission. In case of assessment of the achieved maximum rotational speeds and torques one should also take into account the effect of motor temperature which was not monitored during the tests. Further research will be conducted for the analysis of the impact of periodically variable dynamic control signals on obtained characteristics of kinematic and dynamic features of transmissions.

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