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TESTING THE POSITIONING ACCURACY AND REGULARITY OF THE MOTION THREADED MECHANISM FEED DRIVE

L. Drahorádová*, J. Moravec**, V. Andrlík***

Abstract: *This paper introduces linear feed drives and design of the innovative motion threaded mechanism. The motion threaded mechanism use rolling elements in a similar way as the ball screw. It has sheaves instead of balls which circulate inside the nut. The paper continues by description of the test bed and measuring method of positioning accuracy and regularity. Next part of the paper includes results and discussion of the measurement. At the end outline of future research continuation is presented.*

Keywords: Motion Threaded Mechanism, Position Error, Positioning Accuracy, Amplitude Spectrum.

1. Introduction

Linear feed drive is a standard part of the mechanical equipment, for example machine tools, drives in additive technologies or manipulators and it is used for positioning the components. Ball screws are usually used in accurate mechanical linear positioning mechanisms. Ball screw changes the direction of motion, from rotational to linear. Whole mechanism consists of a screw, a nut and balls between them which reduce friction. The nut consists of a solid with grooves for the balls, segments transferring the balls, seals and end flange. A cutaway through the nut is shown in Fig. 1b.

Qualities of the ball screw are very good - high efficiency, long lifetime, high load capacity and preload endurance. The motion of the ball screw is smooth in comparison with a classical lead screw. The ball screw can change direction of motion not only from rotational motion to linear motion but also from linear motion to rotational motion. For example, that advantage can be useful for emergency opening of an automatic gate (Souček, 2004 and Souček, 2015).

2. Design and qualities of a motion threaded mechanism

An innovative mechanism – motion threaded mechanism (Fig. 1a) change the direction of motion, from rotational motion to linear motion in a similar way as ball screw. It consists of a screw, three rings and end flanges which are clipped by four rods. The number of rings can be higher or lower depending on requirements on the linear feed drive. Four small rollers with sheaves at 90° angle are placed inside each of the rings and fixed by threaded stoppers. Sheaves are fixed in the rollers with pins. Sheaves copy the groove of the thread like balls inside the nut of the ball screw but sheaves keep at the same position with respect to the nut in comparison with balls which circulate inside the nut.

The production of the nut prototype was very simple in comparison with the ball screw nut because it doesn't need any special machining technologies for grooves of thread inside the nut and the transferring segments. Then price of the nut could be much lower with no specialization on production of ball screw. The motion threaded mechanism has more silent and smoother running because of absence of the ball circulation which can produce vibrations and noise. Further advantages are possibility of very high pitch for high linear speed or variable pitch in additional change. Disadvantages are bigger size of the nut and

* Ing. Lucie Drahorádová: Faculty of Mechanical Engineering, Czech Technical University in Prague, Horská 3; 128 00, Prague; CZ, Lucie.Drahoradova@fs.cvut.cz

** Ing. Jan Moravec, PhD.: Faculty of Mechanical Engineering, Czech Technical University in Prague, Horská 3; 128 00, Prague; CZ, J.Moravec@fs.cvut.cz

*** Assoc. Prof. Ing. Vladimír Andrlík, CSc.: Faculty of Mechanical Engineering, Czech Technical University in Prague, Horská 3; 128 00, Prague; CZ, Vladimir.Andrlik@fs.cvut.cz

lower static stiffness because number of contacts between the nut and screw is lower. These are the main features in comparison with ball screw. (Drahorádová, Andrlík, 2016, CTU in Prague, 2013 and CTU in Prague 2014).

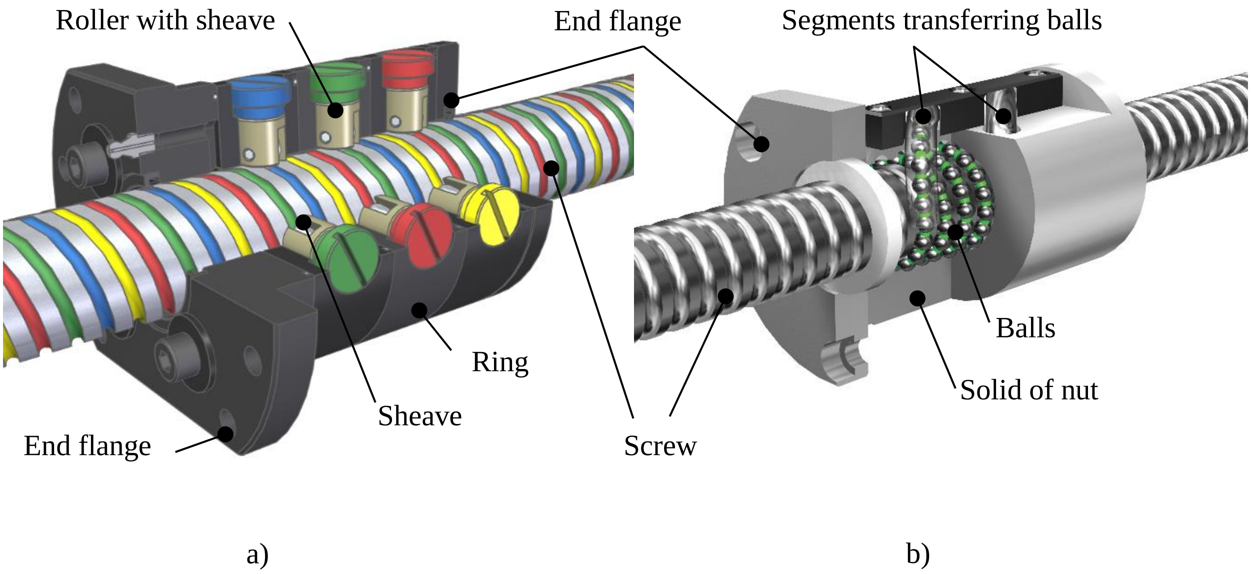

Fig. 1:a) Cutaway through the nut of motion threaded mechanism, (Drahorádová, Andrlík, 2016); b) Cutaway through the nut of THK SBN ball screw. (Motion Control Tips, 2011).

3. Description of the experiment

The motion threaded mechanism has a screw with gothic profile of grooves. The four starts screw diameter is 40 mm and pitch is 40 mm too. The screw is put in the axial-radial bearing and radial bearing in the test bed housing and connected with the servomotor by the jaw coupling (Fig. 2). The length of the screw between the centres of bearings L is 1200 mm and the active length is 800 mm. The position of the table is scanned by a rotary encoder in the motor and linear encoder on the table. It is labelled as y.

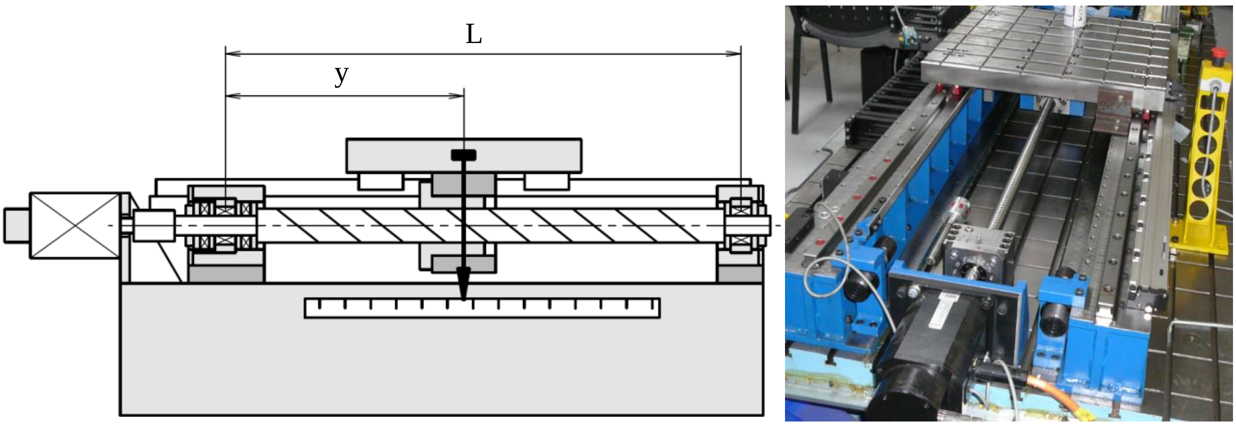

Fig. 2: The schematic picture and photo of test bed.

The experimental test bed with the motion threaded mechanism feed drive axis was assembled and prepared. Programs for motion control and data evaluation was written in the software Matlab with Real Time Toolbox. The experimental feed drive axis was equipped with a direct and indirect measuring system. Position and velocity feedbacks were enclosed from the motor encoder and both cascade control loops were embodied in PC. The direct measuring system was used only for comparison with main motor encoder and e. g. for evaluation of an appropriate backlash. Current control was enclosed in Control Techniques converter. Communication between PC with Matlab Real Time Toolbox and frequency converter Control Techniques was analog via AD card Humusoft MF614. Basic experiments with regularity of motion were carried out.

Testing speeds of the table were from 0.1 m/s to 0.5 m/s (from 150 rev/min to 750 rev/min at the motor) and desired/actual position, velocity and current were monitored. The motion of the table was performed on a 750 mm long track with positive and negative rotation of the motor.

4. Results and discussion

The position error was calculated as a difference of the desired position p_{des} and the actual position p_{act} from motor encoder Δ_{me} and linear encoder Δ_{le}:

$$\Delta_{me} = p_{desme} - p_{actme} \tag{1}$$

$$\Delta_{le} = p_{desle} - p_{actle} \tag{2}$$

The position error (for velocities 0.1 m/s, 0.15 m/s and 0.28 m/s – Fig. 3) was rising with the velocity of the table in the interval 0.02 – 0.095 m and with mismatch between motor encoder and linear encoder which can be up to 0.85 mm. On the detail is shown small mismatch between them. This is due to the backlash in mechanism.

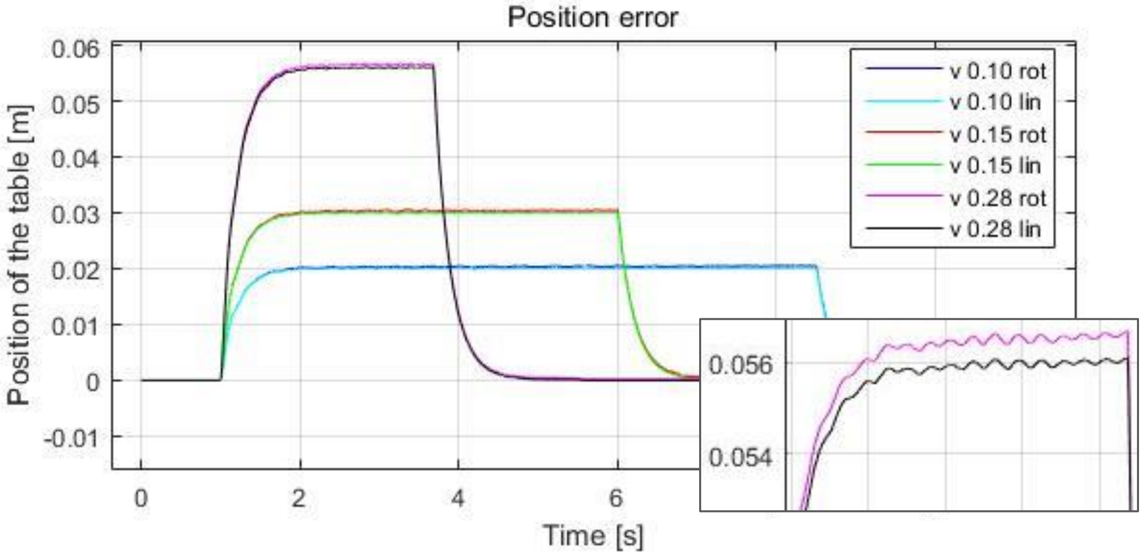

Fig. 3: The graph of position error for velocities 0.1 m/s, 0.15 m/s and 0.28 m/s.

Monotonous vibrations which are in higher resolution in Fig. 4 below, are caused mainly by mounting imperfections between the motor and the screw. This implies the frequency spectrum of vibrations (Fig. 5), where the first harmonic of the screw is dominant. Other harmonics are negligible in comparison with it. Harmonics and proportions of frequency spectrum were similar in all measures.

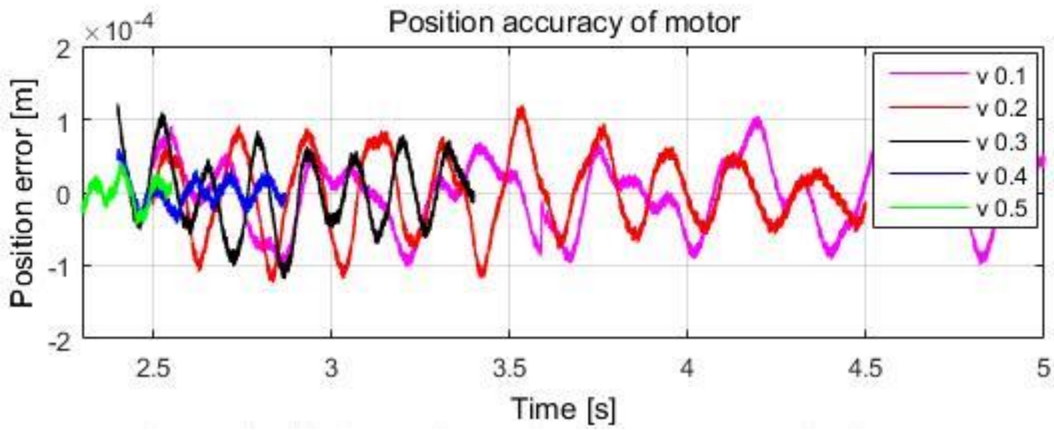

Fig. 4: The graph of position accuracy for velocities 0.1 – 0.5 m/s.

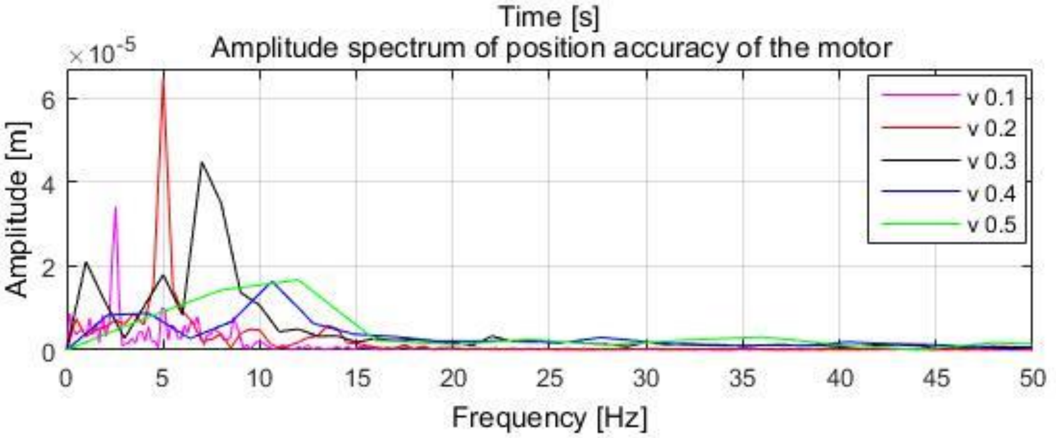

Fig. 5: The graph of amplitude spectrum of position accuracy for velocities 0.1 – 0.5 m/s.

5. Conclusions

The experimental test bed and appropriate HW and SW was commissioned and first experiments were carried out. Experiments shows assembly imperfections in mechanism which are caused presumably by mounting and backlash in the mechanism and coupling. Because the nut is consists of rings it can be preloaded by using a very thin spacer. Now the mechanism is being disassembled and setting-up of these imperfections as backlash and shaft misalignment are in focus. Other experiments will be done and compared with the ball screw.

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The threaded shaft was made by the company Kuličkové šrouby Kuřim, a.s.

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