APPLICATION OF LINEAR DRIVE TESTING METHODOLOGY

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Abstract
This article is devoted to the developing of the methodology of testing of operational parameters of linear drives. Article is mainly focused on the testing of timing belt driven linear positioner. The main comparative parameters were appointed and methods for measuring will be explained. Selected methods will be explained on real-executed experiment. The results of the experiment will be discussed and analyzed.

Key words: *Linear positioner, testing of linear drives, timing-belt, experimental stand*

INTRODUCTION

This article discusses a development and further application of methods for measurement of the operational parameters of a linear drive. Article is mainly focused on the timing belt driven linear positioners and is based on master thesis elaborated by the author (*Klíma,2016; Gates Metcrol Inc,2006; FORBO Siegling GmbH,2015*).
Methodology was developed as a tool for comprehensive and objective evaluation of operational parameters of commercially produced linear positioners. That could be used for finding of the performance standard of linear positioning applications for further projects in this field.

The main comparative parameters were appointed as:

a)	Maximal load capacity of Linear Positioner (hereinafter LP)	[N]
b)	Two-sided stiffness of LP	[N/mm]
c)	Accuracy of positioning	[mm]
d)	Efficiency of linear drive	[-]

MATERIALS AND METHODS

Basic principles of the parameters measuring

Measuring methods for the above mentioned comparative parameters were developed. These methods allow repeatable experiments in laboratory conditions. Methods require precise measurement of appointed characteristically values. These values are necessary for determination of real operational parameters of linear drive. These methods will be in this chapter described and explained individually (*Klíma,2016*).

Accuracy of Positioning

Accuracy of linear positioning is a crucial attribute in real industrial service and application of the linear drive. The accuracy depends not only on the linear positioner itself, but on every component inserted into the drive system. In our case is necessary to considerate the influence of stiffness and deformation of every element in the drive system (clutches, torque sensor, drive shafts, etc.). Positioning error is thereafter calculated as the difference between theoretically expected and the experimentally measured real values of strokes (*Klíma,2016*).

Efficiency of Linear Drive

The Efficiency of the linear positioner can be calculated as ratio of input and output mechanical work. These works are determined on the experimentally measured data. Input mechanical work is calculated as torque of the drive electromotor multiplied by its angular rotation. Output mechanical work is calculated similarly as the action force of platform multiplied by its velocity value. These values are divided and this quotient is the requested efficiency (1) (*Klíma,2016*).

$$\eta_{\,system} = \frac{P_{out}}{P_{in}} = \frac{W_{out}}{P_{in}} = \frac{F_r.s}{T_m.\alpha} = \frac{F_r.s}{T_m.\alpha.r_m.2.\pi} \qquad (1)$$

Where:

$\eta_{\,system}$	- Efficiency of linear positioner	[-]
$P_{\,out}$	- Power at the system output (positioning platform)	[W]
$P_{\,in}$	- Power at the system input (driven shaft of positioner)	[W]
$W_{\,out}$	- Mechanical work at the system output	[J]
$W_{\,in}$	- Mechanical work at the system input	[J]
F_r	- Force generated by LP in the direction of positioning	[N]
s	- Stroke of LP	[mm]
T_m	- Torque at the drive shaft of LP	[N.mm]
α	- Revolution angle of drive shaft	[rad]
r_m	- Revolutions of drive shaft	[rev]

Experimental Stand

The experimental stand was designed as energetically open system without energy recuperation. This solution is suitable for our relatively simple experiment. Individual sensors have been built into experimental system according to the diagram below (*Klíma,2016*).

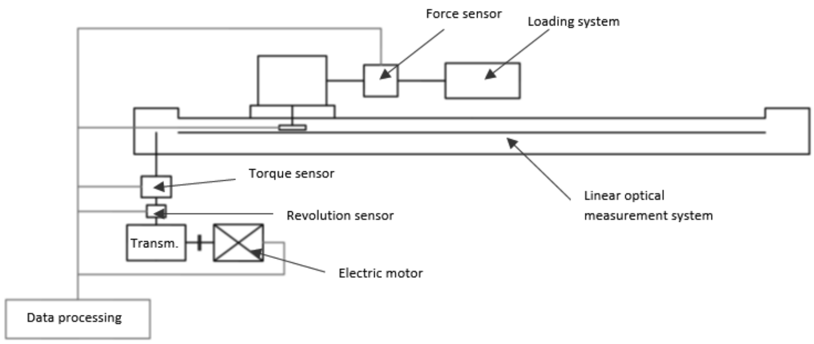

Fig. 1 Schematic chart of experimental stand (*Klíma,2016*)

The Screw-jack system ZIMM Z-5-SL with maximal stroke of 350 mm and maximal generated force of 5kN was chosen as the loading system. This screw-jack was used for experimental testing of load capacity and two-side stiffness of the linear drive. This screw-jack was driven by servo-motor FESTO EMMS-AS-70-S-RM (*Klíma,2016*).

Tab. 1 Used sensors

Measured Value	Sensor
Torque at drive shaft of LP	HBM T20WN
Action force of platform	HBM S9
Position of platform	JCXE 1- 450 mm
Safety end-switches	SAIP-CLS-111

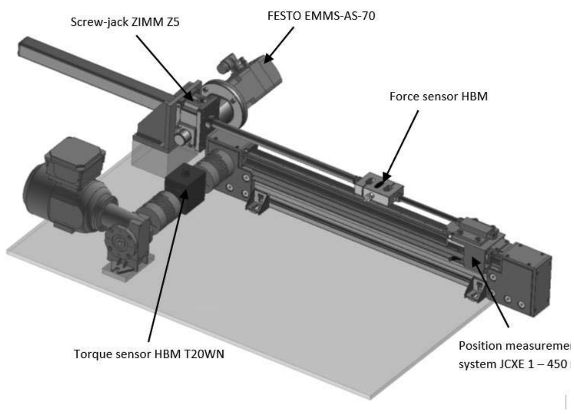

Fig. 2 3D Visualisation of experimental stand with student project linear drive (*Klíma,2016*)

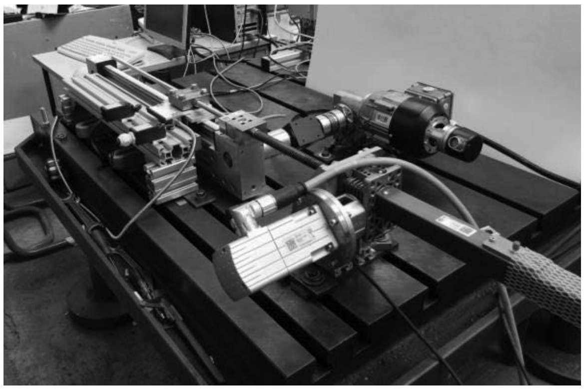

Fig. 3 Application of experimental stand in the department laboratory (*Klíma,2016*)

Practical application of selected methods

Developed experimental stand was realised and selected methods were verified in practice. Measurements of real load capacity and two-sided stiffness were realised on the student designed linear positioner. Target of this experiment was the verification of design parameters (*Klíma,2016*).

RESULTS AND DISCUSSION

Determining of Loading Capacity of Linear Positioner

At first phase of experiment was necessary to find the accurate value of loading force which can be transmitted by the platform of the linear drive. The external loading force was generated by screw-jack while the drive shaft of linear positioner was fully locked. The size of the force was increased from zero to maximal transmittable load in steps of 50 N. After skipping the belt through locked pulley was the experimental phase finished and the maximal stable transmissible force was recorded and plotted to graph (Fig.4) (*Klíma,2016*).

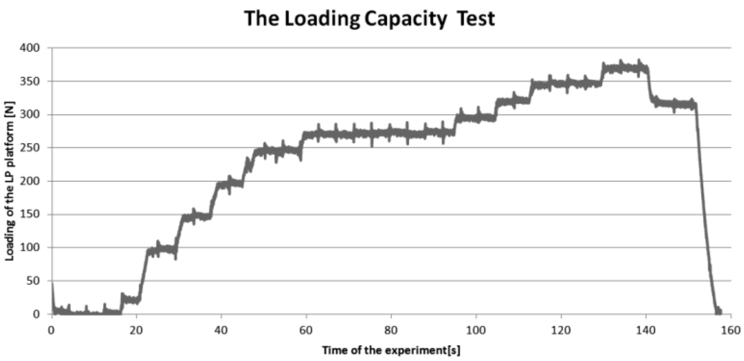

Fig. 4 Maximal transmissible force of tested linear drive (*Klíma,2016*)

According to the graph above we could say the maximal loading capacity of tested LP in the direction of positioning is equal to 350 N. When the external load reaches the level of 375 N, the deformation of position significantly increases. In this point the linear positioner wasn't able to positioning under loading and the reaction force had been reduced to zero (*Klíma,2016*).

Two-sided Stiffness of Linear Positioner

In previous part was determined the maximal loading force to value of 300 N. Twelve suitable stroke positions were chosen for measuring the two-sided stiffness. This stiffness calculation was based on the immediate change of platform position under the influence of the loading force (*Klíma,2016*).

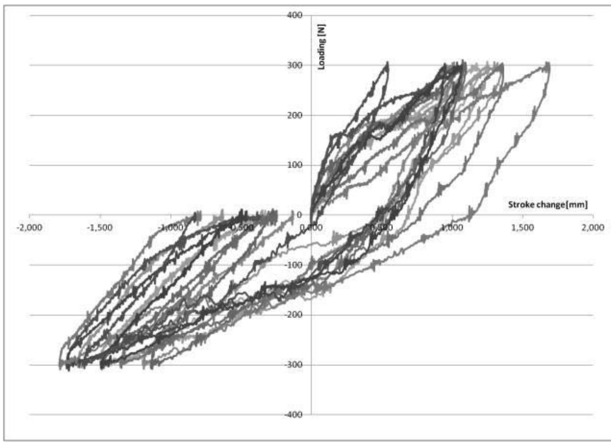

Fig. 5 Curves of the stroke changes under the loading force (*Klíma,2016*)

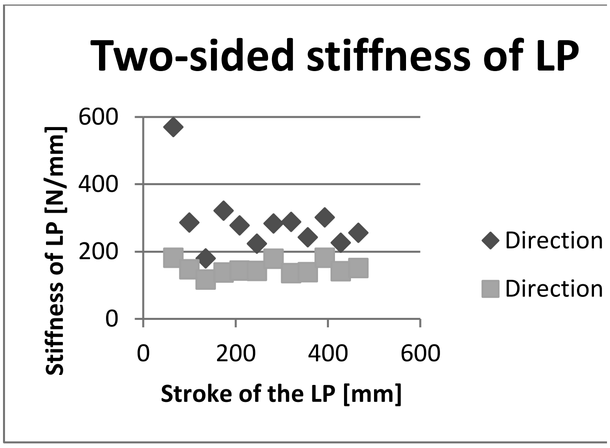

Fig. 6 Two-sided stiffness of linear positioner (*Klíma,2016*)

In the graph above can be seen the influence of the pre-loading force to the stiffness of LP during the first measuring cycle. On the hysteresis curves area of decreasing of stiffness is in the loading level about 180 N. This area indicates the compensation of the backslash in the timing belt mechanism (backslash between the teeth of belt and the drive pulley). This phenomenon does not occur in the first measurement cycle after pre-loading of the positioner. The difference between position of the platform at start of the loading sequence and the position after relief from loading sequence is obtained positioning error (*Klíma,2016*).

CONCLUSION

Functionality of developed methods for testing of linear drives was experimentally verified with application on the real linear drive system. Maximal operational parameters were discovered and compared with expected values. The measured results match the real-life behaviour of system and clarified effects and phenomenon incurred during the experiment. The weak points of the structural design of student project were appointed. Areas of future development in order to improve the operational parameters were recommended (*Klíma,2016*).

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