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FRICTION INFLUENCE REDUCING BY USING LINER BEARINGS AND BALL SCREW SHAFTS IN MINI-PLATFORMS

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Abstract: *With the constant progress of technology in mechanical engineering, a very rapid development of linear units and elements is present. Linear units and elements involves exercise and installations for rectilinear movement. This paper is an analysis of mini-platforms that uses plain bearings and power screw with trapezoidal thread. Friction resistance of platform movement is analyzed as well as its influence over the power of the machine drive. For the analysis of the friction resistance the known analytical models for plain and linear bearings and power screws are used. In terms of platform manufacturing, an analysis of the disadvantages of usage of these elements was also conducted. After the analysis with plain bearings and the power screw with trapezoidal thread, the change has been made to the replacement of these elements with linear bearings and ball screw shaft. After the change of mini-platform elements a comparative analysis related to the previous situation has been conducted. Through the paper the benefits of using these types of linear elements is highlighted. Paper concludes with given directions and possibilities for further investigation of this attractive research topic.*

Keywords: *platform, friction, linear bearing, ball screw shaft, plain bearing, power screw.*

1. INTRODUCTION

Modern tendencies in design consider a lower energy consumption, decreased cost of production and maintenance, increase of efficiency, etc. In order to meet these demands, it is necessary to implement adequate tribological design into the design process. Adequate tribological design includes decreasing operational friction resistance, thereby improving efficiency and decreasing energy use for machine operation. This aspect includes a decrease of friction resistance in the interaction of two or more machine elements. This is particularly the case with parts of machines where any kind of bearing, plain, joint, etc. is present. Tribological characteristics in this case are improved by using standard parts from the ranks of linear technics.

Linear technics include various types of guides, plains, threaded spindles, bearings, etc. which have the sliding friction resistance replaced with the rolling resistance using many small balls. Numerous researchers have worked on researching and testing aiming to improve these elements. A group of authors [1], researched how decreasing the ball size will influence ball screw shafts. Zhang et al. [2] examined how large momentary increases of speed influence ball screw shafts. A very important aspect of this research is dynamics

[3]. Using linear bearings, researchers tested small oscillations of balls in the bearing, [4]. These bearings are also examined for appearances linked to friction on a nano level, [5].

A small number of researchers have, however, worked on the connecting all these elements as a whole, and their influence on the decrease of friction resistance in machines as opposed to conventional solutions. This research tries to improve characteristics of a mini-platform by implementing observed elements. As the research was conducted in cooperation with a local company, and some parts are protected by a non-disclosure agreement, this paper will only give the key elements of the research. The paper concludes with notable indicators of improvement of the mini-platform construction.

2. PROBLEM FORMULATION

In the initial version the mini-platform used bronze sliding bearings. In this part the largest contact friction was apparent with the sliding of bronze on steel. The threaded spindle also had a bronze on steel contact. The initial mini-platform version is shown on figure 1.

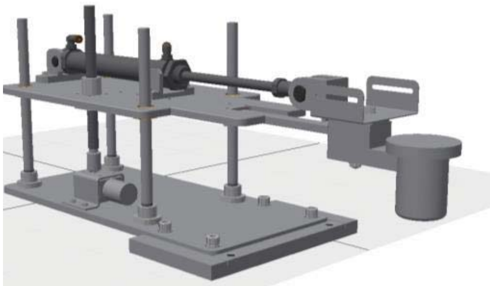

Figure 1. Initial version of mini-platform

Such a construction requires small tolerances and heat treatment of guides. This design also has a large energy use due to the stronger motor needed to overcome friction resistance.

2.1 Sliding friction resistance in plain bearings

In the initial platform design contact is achieved by sliding bronze bearing and heat treated steel guides. This type of sliding with friction resistance is shown in figure 2.

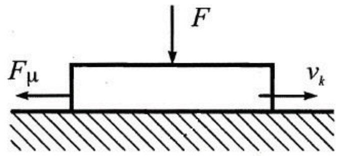

Figure 2. Plain bearing friction resistance

Figure 2 shows a segment of the plain bearing. The platform has sliding bearings and guides with a circular cross section. The relationship between force and friction is given in the expression (1).

$$F_{\mu} = F \cdot \mu . \qquad (1)$$

Where:
F_{μ} – Friction, N;
F – Force acting on the bearing, and
μ–Friction coefficient between the guide and bearing.

In this case of contact the friction coefficient from equation (1) is μ=0,16, [6].

2.2 Friction resistance in threaded spindles with trapezoidal thread

In the treaded spindles with trapezoidal thread there is a significant sliding friction resistance. Efficiency here is calculated using expression (2).

$$\eta = \frac{\tan\varphi}{\tan(\varphi + \rho_n)} . \qquad (2), [7].$$

Where:
η – Efficiency;
φ – thread taper angle, and
ρ_n – Friction angle.

From expression (7) in can be seen that the efficiency on the threaded spindle in this case is directly linked to the geometry of the connecting elements. According to the calculations the initial threaded spindle had an efficiency of η=0.36. This data later was shown as very precise.

3. MODIFICATION OF THE DESIGN USING LINEAR TECHNICS

In order have the mini platform improved (to decrease its friction resistance and with it the needed power for operation), the following actions were taken:

- Sliding bearings were replaced with linear bearings, and
- The trapezoidal threaded spindle was replaced with a treaded spindle with balls.

After the implemented improvements, the mini-platform looked as shown in figure 3.

a)

b)

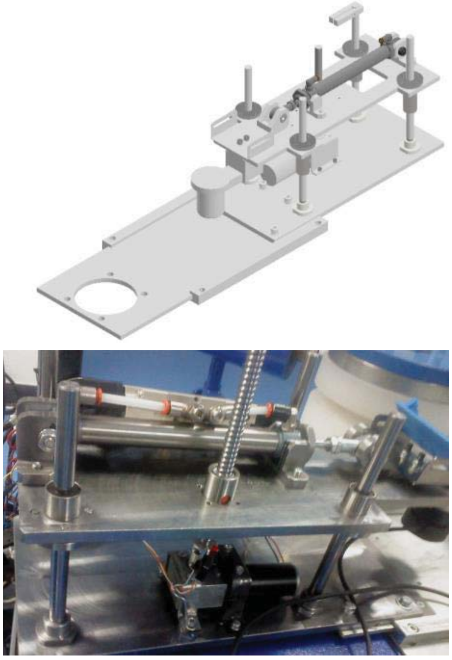

Figure 3. Mini-platform after improvements: a) 3D model; b) completed assembly

3.1 Replacing plain bearings with linear bearings

With a goal to increase efficiency and decrease friction resistance, the sliding bearings were replaced with linear bearings on the mini-platform. Linear bearings were selected from the LMFK series. The installed linear bearings are shown in figure 4.

Figure 4. Installed LMFK series linear bearing, [8]

The replacement of sliding linear bearings was done due to the nature of friction of these two bearings. In plain bearings the mechanism of sliding friction is present, while linear bearinfs have rolling. Rolling friction is favorable for this type of mini-platform, making linear bearings more favorable.

3.2 Replacing conventional threaded spindle with ball screw

Conventional threaded spindles with an internal and external thread are replaced with threaded spindles with balls. The ball screw is shown in figure 5.

Figure 5. Installed ball screw, [9]

This type of threaded spindle has the mechanism of sliding friction replaced by rolling. Many researchers have explored the efficiency of ball screws, [10]. Figure 6 shows the diagram of efficiency of a ball screw.

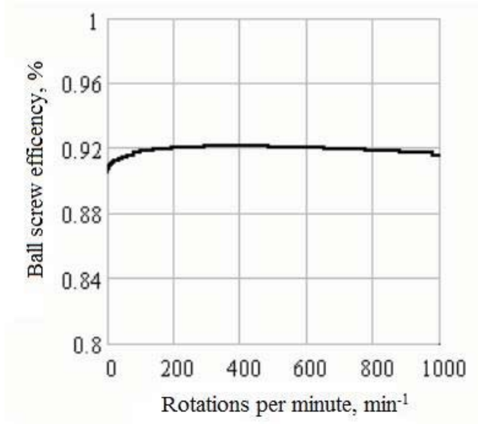

Figure 6. Efficiency of ball screw, [10]

From the diagram in figure 6 it can be seen that the efficiency of the ball screw is between 90 and 92%. At lower speeds the efficiency is lower, while the increase of speed leads to higher efficiency up to 800 min^{-1}, after which it declines. For this platform, a moto reducer with an output speed of 200 min^{-1}, which means the efficiency is around 91%. This data correlates with catalogue data.

4. CONCLUSION

Installing linear technics elements, linear bearings and ball screws achieved the following improvements:

- Friction decreased three times,
- Power needed to operate the platform decreased three times,
- Decrease of power decreases the moto reducer, thereby leaving more space for installing automated control platforms,
- Simplification of platform production,
- Specific elements can be created in wider tolerances.

All improvements were discovered by testing the initial and modified mini platforms.

There are some drawbacks as well:

- Decreased loading capacity of linear bearings from plain bearings,
- Decreased loading capacity of ball screw from threaded spindle,
- Increased difficulty of assembling due to possibility of balls falling out, from both the bearing and spindle.

Further research on this topic will be creating a mathematical model which would determine the energy savings and influence on improvement of efficiency of linear bearings compared to sliding bearings. This research will be conducted in general numbers due to non-disclosure agreements within the project.

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