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THE USE OF LINEAR GUIDES TO MOVE HEAVY LOADS

ZASTOSOWANIE PROWADNIC LINIOWYCH DO PRZEMIESZCZANIA CIĘŻKICH ŁADUNKÓW

A b s t r a c t

The paper presents results of laboratory tests of linear guides in the application to move heavy loads. The first phase of the work included construction of a test bench in the form of a steel frame running on profiled rails using HIWIN type blocks. Subsequently, investigations involving movement of the frame with various loads were performed. In each case a driving force of an operator was measured. Based on the obtained results, average values of the resistance to motion coefficients were estimated.

Keywords: *linear guides, heavy load movement, resistance to motion coefficient*

S t r e s z c z e n i e

W artykule przedstawiono wyniki badań laboratoryjnych prowadnic liniowych w zastosowaniu do przesuwania ciężkich ładunków. Pierwszy etap prac obejmował budowę stanowiska badawczego w postaci stalowej ramy poruszającej się po szynach profilowych z wykorzystaniem wózków typu HIWIN. Następnie przeprowadzono badania polegające na przemieszczaniu ramy z różnymi obciążeniami i pomiarze, w każdym przypadku, niezbędnej siły napędowej. Na podstawie wyników badań oszacowano wartości średnie rzeczywistych współczynników oporów ruchu.

Słowa kluczowe: *prowadnice liniowe, przesuwanie ciężkich ładunków, współczynnik oporu ruchu*

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1. Introduction

Linear guides with profiled rails are usually used to provide movement of heavy loads over straight, short distances. The guides can have many practical applications. They can be used in the case of a constant load and low accuracy requirements, as well as when high positioning accuracy, stiffness, resistance to vibration and shock is needed, as stated in [1]. Example applications in the first case, with no special requirements for accuracy, include providing the X-Y movement in devices such as conveyors, packaging machines, welding machines, etc. On the other hand, obtaining the movement of strictly defined parameters, as accelerations, velocities and precise positioning is extremely important in the development of laboratory test benches, high precision measurement technology or numerically controlled devices, as machining centers, EDM machines, lathes, milling machines, cutting machines etc. [2].

A typical linear guide system consists of two rails with an attached even number of movable guide blocks (Fig. 1). Inside of each guide block, a set of rolling elements in the form of metal balls is placed. During the movement, the balls are rolling along a raceway of a rail, which causes a significant reduction of the friction force and allows the operator to perform a precise linear movement. One of the main characteristics of this type system is practically no difference between the static and the dynamic coefficient of friction [2]. This feature means that the load can be moved along the rails using a very small driving force, as well avoid the adhesion effect (slip-stick).

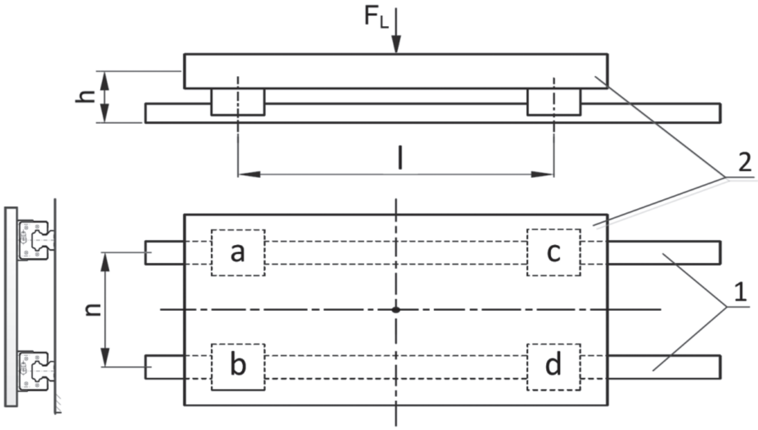

Fig. 1. A diagram of a typical linear guide system: 1 – rails, 2 – frame, a, b, c, d – guide blocks

Modeling and researching linear guide systems is the subject of many projects carried out by the leading research centers. One of the issues undertaken in the research work is to obtain the appropriate characteristics of the motion. For this purpose, M. Rahman et.al. proposed the use of special polymer materials and the proper design of guide blocks [6]. The alternative high-accuracy positioning system based on linear guides was developed by C. Brecher et.al. [5]. In terms of modeling and testing the linear guides' accuracy, the straightness error measurement methodology has been developed [4]. Furthermore, J.-M. Lai et.al. built a mathematical model and software for the accuracy error diagnosis and measurement using the nonlinear double-ball bar technique (DBB) [7]. Modeling of linear guide geometric errors was the subject of research carried out by P. Majda [3]. The conclusions of this work indicate that the geometric deformations of elements such as rails or guide blocks, which mainly result from the properties of the substrate, may cause additional inaccuracies in the system, what can lead to the increase of the resistance to motion coefficient.

In this work tests of a HIWIN linear guide system were carried out. The system was designed to move large loads on a typical concrete floor. The floor was characterized by the following parameters: maximum undulation $u < 5.0$ mm/m, roughness $\mu < 50$ µm and inclination $i < 1.0\%$. During the tests, the force required to move the loaded frame was measured. As a result, the actual values of the resistance to motion between the rail and the guide blocks were calculated for various loads. The obtained values were then presented in charts and compared with those which were supplied by the manufacturer of the linear guide system.

2. Object of research

Laboratory tests of the linear guide system were carried out on a test bench, which is presented in Fig. 2.

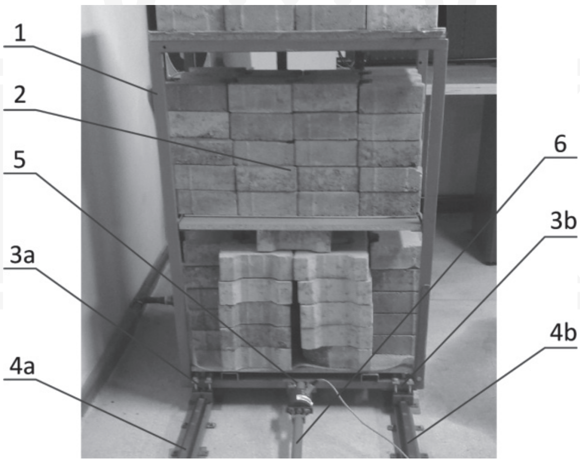

Fig. 2. Object of research: 1 – steel frame, 2 – payload, 3a, 3b – guide blocks, 4a, 4b – rails, 5 – driving force sensor, 6 – handle

The test bench consists of a steel frame 1, which is mounted on four guide blocks (3a, 3b). The guide blocks move on rails 4a, 4b. Cement cubes 2 are applied as a load. The whole system is driven by an operator using a handle 6 with mounted force transducer 5. A CL14U strain gauge force transducer with the symmetric range ± 0.2 kN is used. The HIWIN guide blocks have the total nominal carrying capacity of $C_{max} = 18.8$ kN.

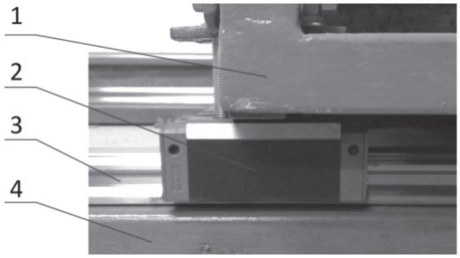

Fig. 3. Attachment of guide block: 1 – frame, 2 – guide block, 3 – rail, 4 – support

Fig. 2 shows the connection between the frame 1 and the guide block 2. As can be seen from the figure, the frame and the guide block are fixed inseparably. On the other side, the block may move on the rail 3, which is attached to the U-shaped section 4 in order to increase the stiffness.

3. Results of experiments

Experiments consisted in loading the frame using cement blocks of a certain weight, moving the system over a distance of 3.0 m, then stopping and moving back to the initial position. The experiments were performed with the load from F_{L1} = 2.0 kN to F_{L5} = 10.0 kN with the increment ΔF = 2.0 kN. The measurement data was acquired using a 14 bit D/A converter with the frequency f = 20.0 Hz. Examples of time plots of the driving force are shown in Fig. 4, while a summary of the results with calculated values of the resistance to motion coefficients are presented in Table 1.

Fig. 4. Time plots of operator force: 1 – F_L = 2.0 kN, 2 – F_L = 6.0 kN, 3 – F_L = 10.0 kN

The presented time plots of the driving force include the following phases of the movement: start of the forward movement **start1**, uniform forward movement **move1**, stop of the movement **stop1**, start of the return movement **start2**, uniform return movement **move2**. Average values of driving forces were calculated on the basis of measurements during both uniform movement phases.

As can be seen from the presented results of the experiments, the value of the summary resistance to motion coefficient decreases as the load increases, from $\mu = 0.01$ for $F_{L1} = 2.0$ kN, to $\mu = 0.0057$ for $F_{L5} = 10.0$ kN. The values of the coefficient as a function of the load force are presented in Fig. 5 with a second degree polynomial approximating curve. The required driving force as a function of the nominal load percentage and its extrapolation is shown in Fig. 6.

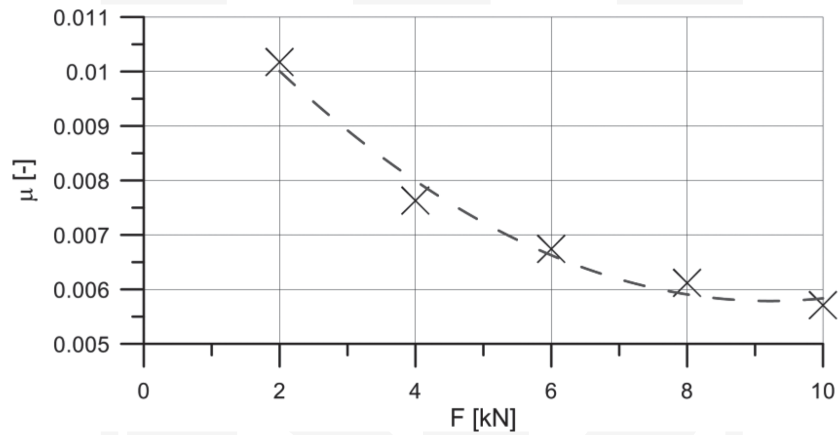

Fig. 5. Resistance to motion coefficient as a function of load force

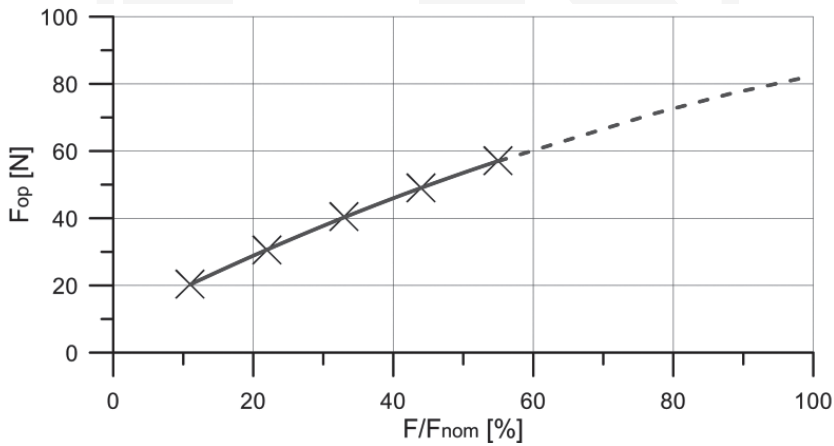

Fig. 6. Required operator force as a function of nominal load percentage

Table 1

Summary of driving forces and resistance to motion coefficients

F_L [kN]	*Average operator force* [N]		*Average operator force* [N]	*Resistance to motion coefficient*
	Forward	*Backward*		
2.0	19,90	20,77	20,34	0,01017
4.0	30,54	30,48	30,51	0,00763
6.0	39,62	41,27	40,45	0,00674
8.0	47,87	50,11	48,99	0,00612
10.0	56,42	57,68	57,05	0,00571

4. Conclusions

This article concerns the use of a linear guide system to move heavy loads under typical conditions of industrial halls. The test bench was built using typical assembling techniques without any special measuring devices. Neither smoothness nor hardness of the floor was increased. Profiled rails and HIWIN guide blocks were used. Typical cement cubes were used as the load. The experiments were conducted with the load value from 2 kN to 10 kN. It can be seen from the results, that the minimum value of the resistance to motion coefficient $\mu = 0.0057$ was obtained for the largest load. This result is similar to the catalogue data, which gives the value of the order of 0.004–0.005. The results indicate, that linear guides can be successfully used under the typical conditions of industrial halls or warehouses.

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