# Detection of movement resistance and friction coefficient in the transport of building materials and construction materials

*Leopold* Hrabovský[1*]

[1]Faculty of Mechanical Engineering, Department of Machine and Industrial Design, VSB - Technical University of Ostrava, 17. listopadu 2172/15, 708 00 Ostrava - Poruba, Czech Republic

**Abstract.** In the production of building materials and construction materials, continuously operating conveying equipment is commonly used, including roller conveyors. Roller conveyors are devices designed for horizontal, slightly ascending or descending transport of piece products moving on a system of rotating rollers of different shapes (cylindrical, conical, disc, pulley or according to the profile of the conveyed object). The rotating rollers are placed in the track frame (supporting structure), which can be either stable, relocatable or adjustable (height and length adjustable, so-called scissor conveyors). An analogue of the roller conveyor is the pulley conveyor, where instead of rollers, discs - pulleys are mounted on a non-rotating axis. Several discs are installed on the axis with gaps. The pulleys on adjacent axes overlap so that there is no continuous gap. The track is used for handling flat building parts and objects such as metal sheets, glass panes, furniture parts, etc. When transporting item building materials or bulk building materials placed in storage boxes which are transported on a powered roller track on pallets, a driving force is required depending on the angle of inclination of the roller track, the weight of the load, the number of rollers on which the load rests and the coefficient of shear friction during movement. The paper presents a laboratory device that has been designed to detect the adhesion force during the transport of piece loads by a roller conveyor. On the implemented device, it is possible to determine in laboratory conditions the amount of resistance to the movement of the load on the driven roller conveyor depending on the weight of the load. The paper presents measured values of the shear friction coefficient during the movement of a steel storage box on a driven roller track. In this paper, a driven roller track is used for laboratory tests, where the drive of the rollers is implemented by so-called short chains. In addition to horizontal tracks, this chain drive allows you to drive rising tracks with variable gradients or even rising curved tracks.

## 1 Description of the measuring station

In the laboratory of the Institute of Research and Testing of the Department of Machine and Industrial Design of Faculty of Mechanical Engineering, VSB–Technical University of

* Corresponding author: leopold.hrabovsky@vsb.cz

Ostrava, an experimental device was designed and physically created which presents a powered roller conveyor with length $l = 1\ m$, the inclination angle of the roller conveyor $\alpha = 3\ deg$, see Fig. 1. The experimental apparatus consists of 7 conveying rollers with diameter $D = 0.06\ m$, mutual spacing of rollers $t = 100\ mm$.

The design, construction and manufacture of roller, pulley and pulley tracks, both powered and non-powered, is dealt with in ČSN 26 4501 [1], which specifies the recommended track width, standardised diameters and lengths of rollers, their spacing, load capacity and also, for example, the recommended lengths of straight track sections.

A powered roller conveyor is a device in which the rotation of the rollers is provided by an external force, thus overcoming the resistance that the roller conveyor imposes on the conveyed object [2].

A powered roller track used for laboratory tests (see Fig. 1), is fitted steel rollers, (casing length 700 mm, axis length 720 mm), which are fixed after their axes with screws to the side walls, which are made of 2 mm thick bent sheet metal. On both ends of the roller casings, sprockets (pitch diameter $d_1$ = 81.18 mm, number of teeth $n_z$ = 20, tooth width 6.98 mm) are mounted, which are secured against rotation against the roller casings by welding.

**Fig. 1.** Experimental device - powered roller conveyor a) 3D model created in SolidWorks, b) implemented roller conveyor.

The drive [3] is implemented by a three-phase asynchronous motor with short armature [4], type series 4A71-4 - four-pole, 1500 synchronous revolutions. The manufacturer MEZ Mohelnice k.p., see Fig. 2, whose basic data are motor power 370 W, revs 1370 min$^{-1}$, ratio of the nominal torque to the nominal torque $M_z/M_n$ = 1.9.

Worm gearbox type 63 [4], with gear ratio $i_p$ = 50, manufacturer ZŤS š.p. Moldava n/B., see Fig. 2.

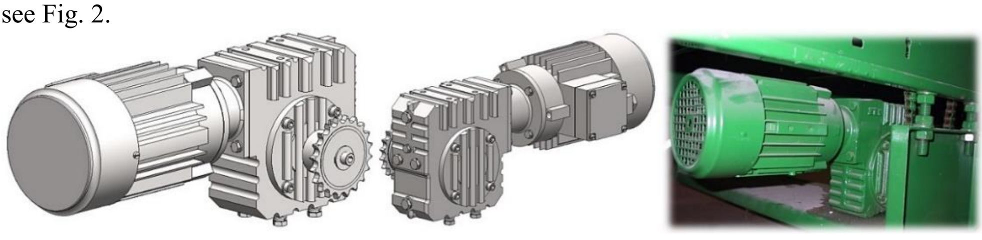

**Fig. 2.** Roller track drive unit consisting of an electric motor and worm gearbox.

The transmission of the driving force from the electric motor through the worm gearbox, which attaches the chain pinion with the number of teeth $n$ = 20 on the output shaft by means of a spring, is implemented by a roller single-row chain (type 08B according to ČSN 02 3311 [5]), which drives one roller, by means of endless roller chains the adjacent rollers are bound together, see Fig. 3.

**Fig. 3.** Transfer of traction force from the drive to the rollers of the roller conveyor.

## 2 Theoretical expression

When transporting piece building materials by roller conveyor, excessive sliding of the transported load on the rollers of the driven roller track is undesirable [6], the magnitude of acceleration is limited by condition (1).

$$G_b \cdot \mu = m_b \cdot a = \frac{G_b}{g} \cdot a \Rightarrow a = g \cdot \mu \ [m \cdot s^{-2}] \tag{1}$$

where $G_b$ *[N]* – weight of the transported load, $m_b$ *[kg]* – mass of the transported load, $g$ $[m \cdot s^{-2}]$ – acceleration of gravity, $a$ $[m \cdot s^{-2}]$ – acceleration of movement.

Equation (1) is valid only if $G_b$ *[N]* is also the adhesion weight, and only if all rollers of the roller conveyor are driven.

Based on Fig. 4, the adhesion equation (2) for the movement of the load on the rollers of the driven roller conveyor can be determined.

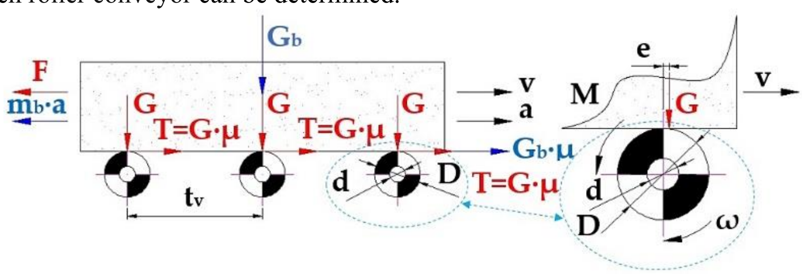


**Fig. 4.** Diagram of load distribution on a roller driven roller track.

The greatest possible angular acceleration of the roller is described by relation (3).

$$\varepsilon = \frac{2 \cdot a}{D} = \frac{a}{R} = \frac{\mu \cdot g}{R} \ [rad \cdot s^{-2}] \tag{3}$$

When calculating the power of the electric motor $P$ *[W]*, we must proceed from condition (3) and therefore consider the influence of dynamic effects.

The starting torque of the motor $M_z$ $[N \cdot m]$ (4) must overcome both moments of static resistances $M_s$ $[N \cdot m]$ (friction, etc.) and moments of dynamic character $M_d$ $[N \cdot m]$.

$$M_z \geq M_{max} = M_s + M_d \ [N \cdot m] \tag{4}$$

The moments of static resistances $M_s$ $[N \cdot m]$ (7) reduced to the motor shaft are given by the sum of the rolling (5) and pin (6) friction moments.

$$M_v = \sum_{i=1}^{z} G \cdot e = G_b \cdot e \ [N \cdot m] \quad (5)$$

$$M_c = \sum_{i=1}^{z} G \cdot \frac{r}{R} \cdot \mu_c = G_b \cdot \frac{r}{R} \cdot \mu_c \ [N \cdot m] \quad (6)$$

$$M_s = \left[ \frac{G_b \cdot k}{z} \cdot (e + R) + m_v \cdot g \cdot \mu_c \cdot r \right] \cdot \frac{1}{i_p} \ [N \cdot m] \quad (7)$$

The load on one roller $(G_b \cdot k/z)$ *[N]*, where the coefficient *k [-]* expresses the effect of uneven distribution of the load on the rollers. The coefficient $k > 1$ and its value must always be investigated on a case-by-case basis. The gear ratio between the roller and the electric motor is marked *i [-]*.

The moment required to accelerate the part of the mass of the conveyed load pertaining to 1 roller (sliding motion) is given by relation (8).

$$M_{d1} = \frac{G_b}{z} \cdot k \cdot \frac{1}{g} \cdot \mu \cdot g \cdot R \ [N \cdot m] \quad (8)$$

if $\mu \cdot g = \varepsilon_v \cdot R$, then relation (9) holds (when reduced to the electric motor shaft).

$$M_{d1} = \frac{G_b}{z \cdot g} \cdot k \cdot \varepsilon_v \cdot R^2 \cdot \frac{1}{i_p} \ [N \cdot m] \quad (9)$$

The moments required to accelerate the mass of the driven parts of the rollers are determined by a known method (10).

$$M_{d2} = I_v \cdot \varepsilon_v \cdot \frac{1}{i_p} \ [N \cdot m] \quad (10)$$

Moment required to accelerate the rotor of the electric motor (11).

$$M_{d3} = I_m \cdot \varepsilon_m = I_m \cdot i_p \cdot \varepsilon_{v(max)} \ [N \cdot m] \quad (11)$$

The torque required to accelerate the rotating parts of the gearbox $M_{d4}$ *[N·m]*, which is usually not calculated [7], and its influence is expressed by the factor *1.2* by which the torque $M_{d3}$ *[N·m]* is multiplied.

Then the total dynamic moment (12).

$$M_d = M_{d1} + M_{d2} + M_{d3} + M_{d4} \ [N \cdot m] \quad (12)$$

The maximum moment $M_{max}$ *[N·m]* is expressed according to relation (13).

$$M_{max} = M_s + M_d = \left[ \frac{G_b \cdot k}{z} \cdot (e + R) + m_v \cdot g \cdot \mu_c \cdot r \right] \cdot \frac{1}{i_p} + \\ + \frac{G_b}{z \cdot g} \cdot k \cdot \varepsilon_v \cdot R^2 \cdot \frac{1}{i_p} + I_v \cdot \varepsilon_v \cdot \frac{1}{i_p} + 1.2 \cdot I_m \cdot \varepsilon_m \; [N \cdot m] \quad (13)$$

The magnitude of the driving force on the circumference of the conveyor rollers can be expressed by relation (14).

$$M_{max} = F \cdot \frac{D}{2} = F \cdot R \Rightarrow F = \frac{M_{max}}{R} \; [N] \quad (14)$$

The required power of the electric motor *P [W]* can be calculated according to relation (15).

$$P = F \cdot v = \frac{M_{max}}{R} \cdot v = \frac{M_{max}}{R} \cdot R \cdot \omega = M_{max} \cdot \omega = M_{max} \cdot 2 \cdot \pi \cdot n' = M_{max} \cdot \frac{2 \cdot \pi \cdot n}{60} = M_{max} \cdot \frac{\pi \cdot n}{30} \; [W] \quad (15)$$

where $n'$ *[rpm]* - electric motor revs, $n$ *[rpm]* - electric motor revs.

The nominal power of the motor is given by relation (16).

$$P = M_{max} \cdot \frac{\pi \cdot n_m}{30} \cdot \frac{1}{\eta \cdot \psi} \; [W] \quad (16)$$

where $\eta$ *[-]* - total mechanical efficiency of the gear train, $\psi = M_{max}/M_m = (1.75 \div 2.5)$ [-] - ratio of maximum and normal torque of the electric motor.

## 3 Experimental measurement and procedure

A storage crate of the manufacturer MARS with dimensions 600 x 400 x 300 mm and mass $m_p$ = 7.5 kg was installed on the driven roller track. The storage crate rests with its bottom side measuring 600 x 400 mm on $z = 6$ rollers, see Fig. 5.

The storage crate was mechanically connected by a carabiner to a strain gauge load cell type PW2G-2-72 kg manufactured by Hottinger Baldwin Messtechnik [8]. The induced adhesion force of the storage crate was detected as the measured driving force $F_{Mi}$ *[N]* by the load cell. A load sensor cable equipped with a D-Sub plug was plugged into the socket of the measuring module BR4-D of the strain gauge apparatus DS NET during the laboratory measurements. A PC (ASUS K72JR-TY131 laptop) was connected to the DS NET strain gauge using a network cable with RJ-45 connectors at both ends. The time record of the measured $F_{Mi}$ *[N]* driving force was displayed on the PC screen in the DEWESoft X2 SP5 software environment [9], see Fig. 6.

**Fig. 5.** Positioning the storage crate on the roller track rollers.

The storage crate was gradually filled with Carolith (marble grit) of a given mass, which was weighed in advance. The dependence of the weight of the pallet, including the bulk mass, on the force in the sensor was measured.

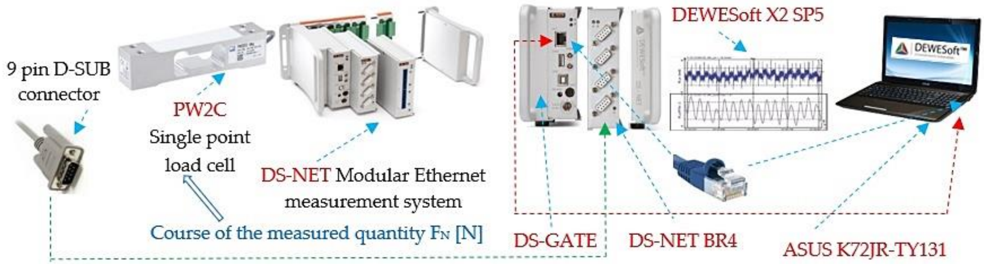


**Fig. 6.** Components used to detect, and record measured values of horizontal forces $F_{Mi}$ *[N]*.

## 4 Measurement results

The measurements were repeated 5 times in succession, Table 1 shows the values of one measurement, the measured force was sensed 5 times within one measurement (see forces $F_{M1}$ *[N]* to $F_{M5}$ *[N]*). After reading the value $F_{M1}$ *[N]*, the storage crate was released from the sensor tension and after setting the roller track in motion, the measured force was $F_{M1}$ *[N]* to $F_{M5}$ *[N]*, series 1 Fig. 7 shows the curve of the shear friction coefficient in motion on the roller track for the values of the first measurement, the numerical data of which are given in Table 1.

Fig. 8 presents a graphical plot of the mean value of the measured driving force $F_M$ *[N]* versus the load weight $G_b$ *[N]*.

The measured force values at the sensor were statistically processed using Student's distribution [10]. The determination of the mean value and error of the directly measured quantity for n times repeated measurements is shown in Table 1, where the individual values of the $F_{Mij}$ *[N]* force obtained by *i* times repeated measurements have been sequenced. From these tables (see Table 1 to Table 5), the arithmetic mean of all measured values was calculated. The deviations of the measured values from the arithmetic mean were calculated. By summing the values of the deviations with the corresponding signs, the correctness of the calculation of the arithmetic mean and the deviations was checked. The calculated sum must be equal to zero.

In the next step, the absolute values of the deviations were summed, and the standard deviation was calculated with the arithmetic mean according to formula (38) of the cited literature [10]. For a chosen risk, e. g. $\alpha = 5\%$ or $\alpha = 1\%$, the Student's $t_{\alpha,n}$ *[-]* (see Table 8 of literature [10]) was found in the table of critical values of the Student's distribution.

Extreme error $\kappa_{\alpha,n} = t_{\alpha,n}.\ s\ [N]$. The measurement result was written in the form $F_M \pm \kappa_{\alpha,n}$ $[N]$. With a probability of 95.0% or 99.0% depending on the chosen risk $\alpha\ [\%]$, the actual value of the measured physical quantity lies in the interval ($F_M$ - $\kappa_{\alpha,n}$; $F_M$ + $\kappa_{\alpha,n}$).

**Table 1.** Values of the measured driving forces for a known magnitude of the load.

| $G_b$ [N] | $F_{M1}$ [N] | $F_{M2}$ [N] | $F_{M3}$ [N] | $F_{M4}$ [N] | $F_{M5}$ [N] | $F_M = \sum_{i=1}^{5} F_{Mi}$ [N] | $F_M \pm \kappa$ [N] | μ [-] |
|---|---|---|---|---|---|---|---|---|
| 73.6 | 57.5 | 49.2 | 49.8 | 50.3 | 49.7 | 256.6 | 51.3 ± 4.3 | 0.70 |
| 171.7 | 99.1 | 102.0 | 105.0 | 100.1 | 98.1 | 504.2 | 100.8 ± 3.7 | 0.59 |
| 269.8 | 154.0 | 157.0 | 162.8 | 152.1 | 146.2 | 772.0 | 154.4 ± 7.7 | 0.57 |
| 367.9 | 196.2 | 217.8 | 209.0 | 212.9 | 209.0 | 1 044.8 | 209.0 ± 8.8 | 0.57 |
| 466.0 | 269.8 | 268.8 | 258.0 | 264.9 | 236.4 | 1 297.9 | 259.6 ± 17.2 | 0.56 |
| 564.1 | 284.5 | 293.3 | 285.5 | 282.5 | 274.7 | 1 420.5 | 284.1 ± 7.7 | 0.50 |
| 662.2 | 321.8 | 325.7 | 324.7 | 328.6 | 326.7 | 1 305.7 | 325.5 ± 3.1 | 0.49 |
| 760.3 | 351.2 | 357.1 | 360.0 | 385.5 | 354.1 | 1 808.0 | 361.6 ± 16.7 | 0.48 |
| 858.4 | 393.4 | 390.4 | 390.4 | 409.1 | 393.4 | 1 976.7 | 395.3 ± 9.5 | 0.46 |
| 956.5 | 439.5 | 443.4 | 446.4 | 432.6 | 433.6 | 2 195.5 | 439.1 ± 8.3 | 0.46 |

**Table 2.** Values of the measured driving forces for a known magnitude of the load.

| $G_b$ [N] | $F_{M1}$ [N] | $F_{M2}$ [N] | $F_{M3}$ [N] | $F_{M4}$ [N] | $F_{M5}$ [N] | $F_M = \sum_{i=1}^{5} F_{Mi}$ [N] | $F_M \pm \kappa$ [N] | μ [-] |
|---|---|---|---|---|---|---|---|---|
| 73.6 | 36.3 | 46.1 | 49.1 | 49.1 | 50.0 | 230.5 | 46.1 ± 10.2 | 0.63 |
| 171.7 | 85.3 | 104.0 | 108.9 | 87.3 | 90.3 | 475.8 | 95.2 ± 23.2 | 0.55 |
| 269.8 | 155.0 | 147.2 | 138.3 | 132.4 | 137.3 | 710.2 | 142.1 ± 12.6 | 0.53 |
| 367.9 | 198.2 | 199.1 | 193.3 | 190.3 | 182.5 | 963.3 | 192.7 ± 8.7 | 0.52 |
| 466.0 | 245.3 | 245.3 | 245.3 | 250.2 | 232.5 | 1 218.4 | 243.7 ± 7.7 | 0.52 |
| 564.1 | 294.3 | 277.6 | 285.5 | 297.2 | 291.4 | 1 446.0 | 289.2 ± 10.6 | 0.51 |
| 662.2 | 308.0 | 344.3 | 313.9 | 364.9 | 348.3 | 1 371.4 | 335.9 ± 34.6 | 0.51 |
| 760.3 | 387.5 | 399.3 | 371.8 | 371.8 | 371.8 | 1 902.2 | 380.4 ± 18.0 | 0.50 |
| 858.4 | 424.8 | 422.8 | 428.7 | 426.7 | 425.8 | 2 128.8 | 425.8 ± 2.7 | 0.50 |
| 956.5 | 457.1 | 474.8 | 468.9 | 471.9 | 465.0 | 2 337.7 | 467.5 ± 9.0 | 0.49 |

**Table 3.** Values of the measured driving forces for a known magnitude of the load.

| $G_b$ [N] | $F_{M1}$ [N] | $F_{M2}$ [N] | $F_{M3}$ [N] | $F_{M4}$ [N] | $F_{M5}$ [N] | $F_M = \sum_{i=1}^{5} F_{Mi}$ [N] | $F_M \pm \kappa$ [N] | μ [-] |
|---|---|---|---|---|---|---|---|---|
| 73.6 | 35.3 | 45.1 | 48.1 | 48.1 | 49.1 | 225.6 | 45.1 ± 6.9 | 0.61 |
| 171.7 | 84.4 | 103.0 | 107.9 | 86.3 | 89.3 | 470.9 | 94.2 ± 15.7 | 0.55 |
| 269.8 | 154.0 | 146.2 | 137.3 | 131.5 | 136.4 | 705.3 | 141.1 ± 12.6 | 0.52 |
| 367.9 | 197.2 | 198.2 | 192.3 | 189.3 | 181.5 | 958.4 | 191.7 ± 8.7 | 0.52 |
| 466.0 | 244.3 | 244.3 | 244.3 | 249.2 | 231.5 | 1 213.5 | 242.7 ± 7.7 | 0.52 |
| 564.1 | 293.3 | 276.6 | 284.5 | 296.3 | 290.4 | 1 441.1 | 288.2 ± 10.6 | 0.51 |
| 662.2 | 307.1 | 343.4 | 312.9 | 344.3 | 347.3 | 1 347.9 | 331.0 ± 29.1 | 0.50 |
| 760.3 | 386.5 | 398.3 | 370.8 | 370.8 | 370.8 | 1 897.3 | 379.5 ± 18.0 | 0.50 |
| 858.4 | 423.8 | 421.8 | 427.7 | 425.8 | 424.8 | 2 123.9 | 424.8 ± 2.7 | 0.49 |
| 956.5 | 456.2 | 473.8 | 467.9 | 470.9 | 464.0 | 2 332.8 | 466.6 ± 9.0 | 0.49 |

**Table 4.** Values of the measured driving forces for a known magnitude of the load.

| $G_b$ [N] | $F_{M1}$ [N] | $F_{M2}$ [N] | $F_{M3}$ [N] | $F_{M4}$ [N] | $F_{M5}$ [N] | $F_M = \sum_{i=1}^{5} F_{Mi}$ [N] | $F_M \pm \kappa$ [N] | μ [-] |
|---|---|---|---|---|---|---|---|---|
| 73.6 | 37.3 | 48.1 | 47.1 | 49.1 | 48.1 | 229.6 | 45.9 ± 6.0 | 0.62 |
| 171.7 | 90.3 | 105.0 | 101.0 | 99.1 | 101.0 | 496.4 | 99.3 ± 6.4 | 0.58 |
| 269.8 | 154.0 | 157.9 | 154.0 | 150.1 | 145.2 | 761.3 | 152.3 ± 6.4 | 0.56 |
| 367.9 | 185.4 | 188.4 | 212.9 | 198.2 | 211.9 | 996.7 | 199.3 ± 18.1 | 0.54 |
| 466.0 | 242.3 | 257.0 | 240.3 | 246.2 | 248.2 | 1 234.1 | 246.8 ± 8.0 | 0.53 |
| 564.1 | 268.8 | 277.6 | 277.6 | 289.4 | 277.6 | 1 391.1 | 278.2 ± 7.7 | 0.49 |
| 662.2 | 321.8 | 348.3 | 328.6 | 303.1 | 316.9 | 1 296.9 | 323.7 ± 20.5 | 0.49 |
| 760.3 | 360.0 | 372.8 | 381.6 | 374.7 | 346.3 | 1 835.5 | 367.1 ± 19.3 | 0.48 |
| 858.4 | 406.1 | 418.9 | 380.6 | 415.0 | 390.4 | 2 011.1 | 402.2 ± 23.2 | 0.47 |
| 956.5 | 420.8 | 450.3 | 458.1 | 419.9 | 471.9 | 2 221.0 | 444.2 ± 33.2 | 0.46 |

**Table 5.** Values of the measured driving forces for a known magnitude of the load.

| $G_b$ [N] | $F_{M1}$ [N] | $F_{M2}$ [N] | $F_{M3}$ [N] | $F_{M4}$ [N] | $F_{M5}$ [N] | $F_M = \sum_{i=1}^{5} F_{Mi}$ [N] | $F_M \pm \kappa$ [N] | μ [-] |
|---|---|---|---|---|---|---|---|---|
| 73.6 | 41.2 | 45.1 | 47.1 | 44.1 | 48.1 | 225.6 | 45.1 ± 3.4 | 0.61 |
| 171.7 | 100.1 | 88.3 | 102.0 | 93.2 | 99.1 | 482.7 | 96.5 ± 8.0 | 0.56 |
| 269.8 | 150.1 | 145.2 | 138.3 | 145.2 | 149.1 | 727.9 | 145.6 ± 5.6 | 0.54 |
| 367.9 | 188.4 | 201.1 | 195.2 | 192.3 | 197.2 | 974.1 | 194.8 ± 6.3 | 0.53 |
| 466.0 | 254.1 | 223.7 | 248.2 | 248.2 | 232.5 | 1 206.6 | 241.3 ± 18.4 | 0.52 |
| 564.1 | 263.9 | 298.2 | 258.0 | 279.6 | 300.2 | 1 399.9 | 280.0 ± 26.7 | 0.50 |
| 662.2 | 332.6 | 338.4 | 314.9 | 305.1 | 332.6 | 1 291.0 | 324.7 ± 20.5 | 0.49 |
| 760.3 | 361.0 | 343.4 | 388.5 | 369.8 | 394.4 | 1 857.0 | 371.4 ± 27.9 | 0.49 |
| 858.4 | 435.6 | 424.8 | 411.0 | 402.2 | 369.8 | 2 043.4 | 408.7 ± 31.5 | 0.48 |
| 956.5 | 464.0 | 419.9 | 476.8 | 447.3 | 465.0 | 2 273.0 | 454.6 ± 29.1 | 0.48 |

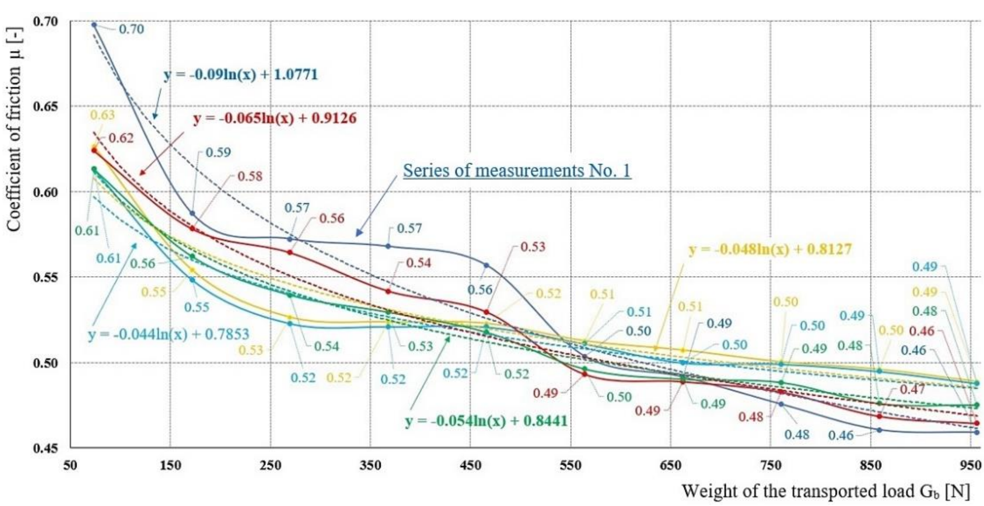


**Fig. 7.** Graphical progression of the shear friction coefficient in motion on a driven roller track.

Fig. 8 presents a graphical plot of the mean value of the measured driving force $F_M$ *[N]* versus the load weight $G_b$ *[N]*.

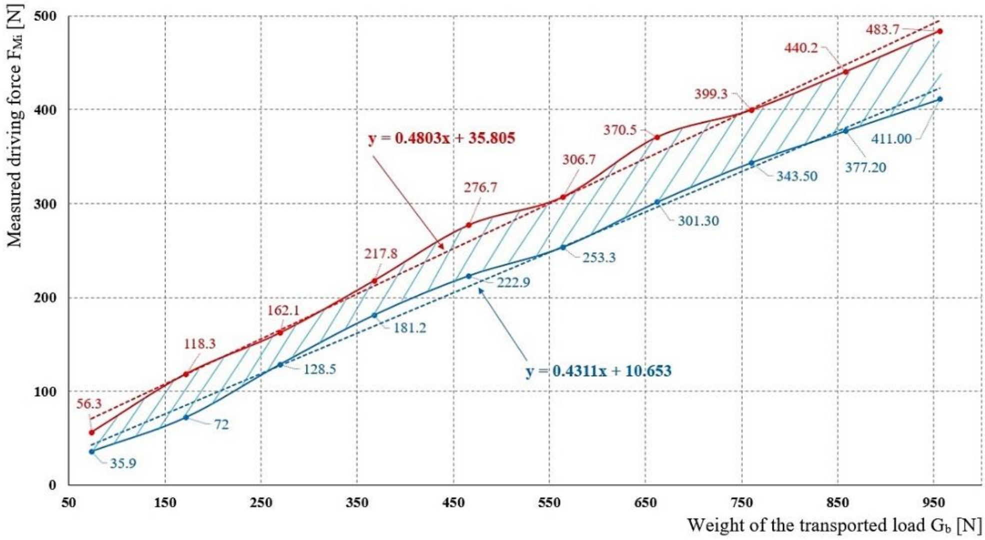


**Fig. 8.** Graphical plot of the mean value of the measured driving force $F_M$ *[N]* versus the load weight $G_b$ *[N]*.

## 5 Conclusion

According to general assumptions, the spacing of the conveyor rollers is chosen so that the transported piece load lies on at least three rollers simultaneously. On the experimental device, which is the roller conveyor used in this paper, a steel plastic crate was in contact with six driven conveyor rollers simultaneously.

The drive of the rollers by the experimental device was provided by a sufficiently sized drive (electric gearbox) of 370 W with a suitable chain gear. All conveyor rollers were driven on the roller conveyor. It was used to drive the individual rollers of the chain loop transmission system (roller to roller).

The paper presents a 3D structural model created in SolidWorks software environment and a laboratory device that was designed for the purpose of detection, measurement and recording of adhesion force values by experimental procedure during transportation of piece loads by roller conveyor. By using a strain gauge load cell, which was mechanically attached to the supporting steel structure of the roller conveyor and at the same time to the storage box, it was possible to record the value of the generated driving force. The time course of the magnitude of the driving force exerted by the driving force of the driven conveyor rollers transmitted by friction to the bottom surface of the storage box at the moment of starting and steady running of the roller conveyor was recorded using DEWESoft X2 SP5 software.

From the experimental measurements carried out on the implemented device, it was possible to determine by an indirect method the magnitude of the resistance against the movement of the load on the driven roller conveyor depending on the load weight. Table 1 shows the analytically calculated values of the coefficient of shear friction during the movement of a steel storage crate on a powered roller track, which were quantified as the ratio of the driving force measured by the load cell and the weight of the load.

In the article in the Measurement results chapter, there are presents the curves describing the graphical progression of analytically calculated values of the shear friction coefficient during motion on the driven roller track as a function of the weight of the transported piece load, for 5 times repeated measurements under the same laboratory conditions.

The article presents a graphical plot of the mean value of the measured driving force of a stacking crate carried by a driven roller conveyor versus the weight of the piece load being conveyed.

In this paper, a driven roller track is used for laboratory tests, where the drive of the rollers is implemented by so-called short chains. In addition to horizontal tracks, this chain drive allows you to drive rising tracks with variable gradients or even rising curved tracks.

## Acknowledgments

This work has been supported by The Ministry of Education, Youth and Sports of the Czech Republic from the Specific Research Project SV3402256 (SP2022/2) and Ministry of Industry and Trade of the Czech Republic from the Specific Research Project EG20_321/0024559 (MP342132).

## References

1. ČSN 26 4501, *Válečkové, kladičkové a kladkové tratě. Základní parametry a rozměry*. In English: *Roller conveyors and wheel conveyors. Basic parameters and dimensions*. (Český normalizační institut, Praha, 1993), pp. 1–12.
2. P. Michalik, J. Dobransky, L. Hrabovsky and M. Petrus, "Assessment of the manufacturing possibility of thin-walled robotic portals for conveyance workplaces", Advances in Science and Technology. Research Journal **12(1)**, 338–345 (2018).
3. L. Hrabovsky, O Ucen, L. Kudrna, D. Cepica and K. Frydrysek, "Laboratory Device Detecting Tensile Forces in the Rope and Coefficient of Friction in the Rope Sheave Groove", Machines **10(7)**, 590 (2022).
4. Worm Gear Units 2007. Available online: http://www.sjt-moldava.sk/dokumenty/TS-Katalog.pdf (accessed on 11 March 2007).
5. ČSN 02 3311, *Kloubové řetězy. Válečkové řetězy. Rozměry*. In English: *Steel roller-chains. Dimensions.* (Český normalizační institut, Praha, 1973), pp. 1-12.
6. Single Point Load Cell PW2C Available online: https://www.hbm.cz/wp-content/uploads/B01990.pdf (accessed on 11 November 2020).
7. M. Mantic, J. Kulka, M. Kopas, E. Faltinova and L. Hrabovsky, "Limit states of steel supporting structure for bridge cranes" in Zeszyty Naukowe. Transport/Politechnika Śląska, (2020), pp. 141-158.
8. A. Durna, J. Fries, L. Hrabovsky, A. Sliva, and J. Zarnovsky, "Research and development of laser engraving and material cutting machine from 3D printer". Management Systems in Production Engineering **28(1)**, 47-52 (2020).
9. L. Hrabovsky, V. Molnar, G. Fedorko, J. Tkac and K. Frydrysek, "Experimental determination of force acting on a sandwich conveyor's pressure roller in transport of bulk materials for the needs of failure analysis", Measurement **202**, 111832 (2022).
10. V. Madr, J. Knejzlik, I. Kopecny, I. Novotny, *Fyzikální Měření* (In English: *Physical Measurement)*; SNTL: Praha, Czech Republic, 1991; p. 304.