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EXPERIMENTAL ANALYSIS OF CARRYING ROLLERS OF THE CONVEYER ROUTES

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Abstract:
The aim of presented project was to design the gauger for measuring the rotary resistance of carrying rollers. Such device can replace an insufficient appliance on which the tests have been still executed. Further some theoretical calculations of rotary resistances were brought up from which the calculation coming out of experiment seems to be the most accurate. The realization of measuring table and theoretical calculation improvement is expected from the next project stage.

Key words: carrying rollers, rotary resistance, testing table

1. Introduction

The carrying rollers are one of the most important parts of the conveyer body. They are used both with the belt conveyers, where they support and carry the conveyer belt and with the roller conveyer. These requirements are insisted on them:

- small rotary resistance
- high durability
- low mass
- production simplicity

2. Carrying rollers tests

In dependence on the requirements insisted on rollers it is necessary to test some their mechanical characteristics. For that purpose the following tests are determined:

a) rollers bending tests
b) rotary resistances measuring
c) water tightness measuring
d) dust tightness measuring
e) lubricant leakage test
f) dynamic balancing measuring
g) vibration measuring
h) durability tests
i) roller jacket hardness, resistance measuring against faces bursting out from the jacket

3. Experimental rotary resistance

3.1. Rotary resistance definition

The rollers rotary resistance is supposed to be a force acting on the roller circumference which moment to the rotation axis is in the balance with the moment of passive resistances arising in the bearing and bearing packing. The rotary resistance intensity influences not only the rollers durability but also conveyers performance.

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3.2. Requirements laid on experiment

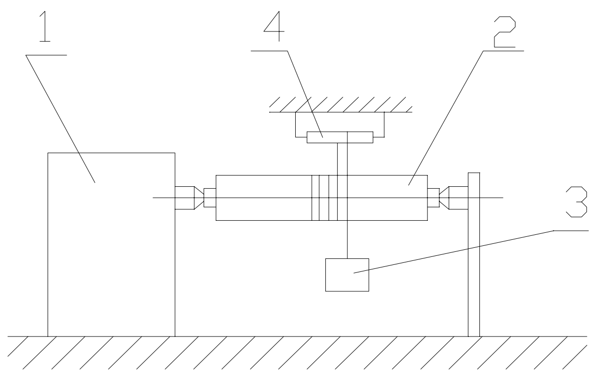
- real simulation of roller drive operating conditions, it means the roller jacket is driven
- maximum utilization of present measuring device
- measuring possibility when loaded
- output signal processing by computer technology
- possibility of graphical output on printer

3.3. Up-to-date measuring method

The rotary resistances measuring device is displayed in the picture 1. It consists of the drive with continuously variable speed (1), tested roller (2), weight on the twine (3) and roller (4). The roller shaft is driven with rated revolutions. The twine is reeled on the roller jacket circumference and over the roller is dead-wighted. The idea is jacket rotation stopping by weight adding. The sensitive device can replace the weight.

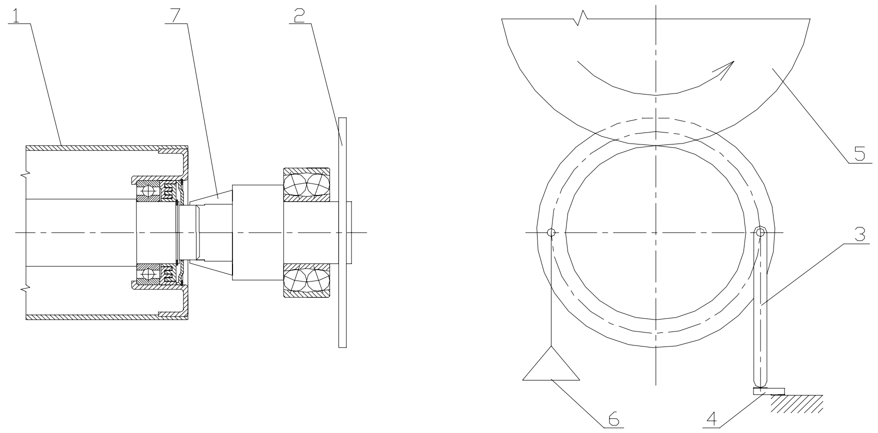
This system serves only to informative and considerably inaccurate determination of rotary resistances with idle running. Its inaccuracy is given:

- incredible simulation of operating conditions (the only shaft is driven, not jacket)
- impossibility of monitoring the rotary resistances when loaded
- inaccurate monitoring of measured data (weight)
- additional resistances (roller – even when it has far smaller resistance than followed rollers)



Picture 1

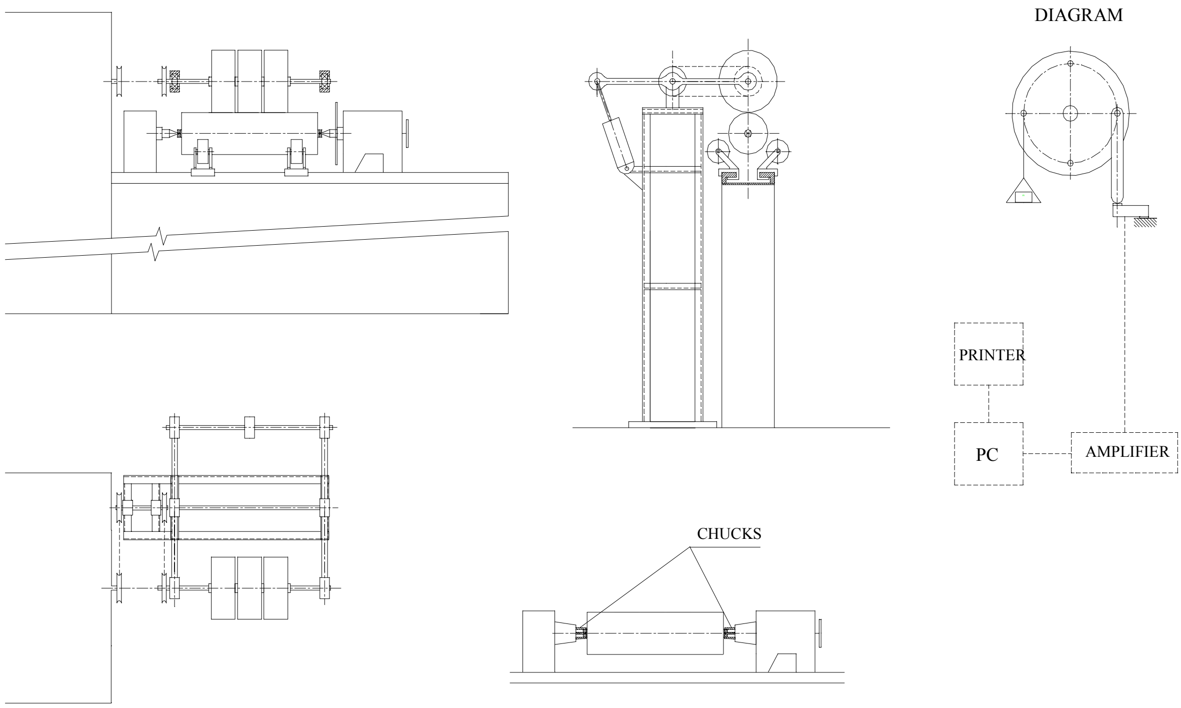
3.4. Projected measuring method



1…tested roller
2…measuring disc
3…draw bar
4…tensometric sensor
5…loading disc
6…counterweight
7…chuck

Picture 2

3.4.1. Construction of testing table



Picture 3

A precondition for repeatable determination of measured values of supporting rollers is the testing table with a minimum own resistance allowing an investigation in terms near to the operating conditions.

The constructive principle of testing table (picture 2 and 3) is specified for loads up to 300 kg and circumferential velocities up to 7 m/s. The shaft is gripped among chucks ositioned in doable-raw pendulum ball bearings, so that a roller support standard in practice is observed. Nevertheless it is possible to keep a free stage during optional load necessary for twisting moment measuring when turning round the longitudinal axis of supporting roller. Radial load is executed with the help of pneumatic lever mechanism and pressure roller, which simultaneously serves to roller jacket drive (picture 3).

3.4.2. Rotary resistance measuring (picture 2)

The roller jacket (1) is driven by disc (5). Owing to friction in roller bearings it happens to transmission of twisting moment from jacket to shaft being placed in chucks.
Owing to this twisting moment it happens to shaft and chuck turning as well as measuring disc (2) fit on chuck. Such originated circumferential force is absorbed by draw rod. The size is measured with tensometric sensor (4). A signal is further led through the amplifier to the measuring computer card, where it is evaluated.

With rollers run-up it happens to the creation of extreme forces:

- separate force – it appears during output from mounting owing to unsettling the bearings, oil hardening, impurities presence
- starting force – the force necessary to overrun the static bearing resistance

Against these extreme forces a counterweight operates (6). After starting the weight is taken down.

4. Theoretical calculation

4.1. Calculation of friction moment according to [5]

A total friction moment is determined by friction moment M_0, that does not depend on load, moment M_1 which depends on load, moment depending on axial load M_2 (by the rollers carrying the axial load) and friction moment caused by packing presence [5]:

$$M = M_0 + M_1 + M_2 + M_3$$

Friction moment M_0 free on load:

$$M_0 = 160 \cdot 10^{-7} f_0 \cdot d_m^{\,3}$$

d_m …medium diameter of bearing
f_0 …coefficient depending on bearing type and lubrication

Friction moment M_1 depending on load:

$$M_1 = f_1 \cdot P_1^{\,a} \cdot d_m^{\,b}$$

f_0 …coefficient dependent on bearing type and load
P_1 …load component
a,b…indexes depending on bearing type

Friction moment M_2 depending on axial load:

$$M_2 = f_2 \cdot F_a \cdot d_m$$

F_2 …coefficient depending on bearing design and lubrication
F_a …axial load

Friction moment M_3 caused by packing:

$$M_3 = \left(\frac{d+D}{f_3}\right)^2 + f_4$$

d …bearing hole diameter
D …external bearing diameter
f_3,f_4… coefficients depending on bearing design

Rotary resistance w:

$$w_{SKF} = \frac{M}{d_m}$$

d_m = 0,5 (D+d)… medium bearing diameter

4.2. Calculation per ČSN (Czech Standard)

The main resistances introduced in ČSN 26 3102 for the calculation of belt conveyers include rollers rotary resistances, fulling and pressing resistances.

$$O_H = f \cdot L \cdot [(q_1 + 2 \cdot q_2) \cdot \cos\varepsilon + q_{rh} + q_{rd}]$$

$$f = f_1 \cdot k_2$$

f …global friction coefficient
f_1…friction coefficient depending on operating conditions
K2…temperature coefficient
L…conveyer length
q_1…acceleration force of transported material on 1m of belt
q_2…acceleration force from 1m of belt
ε …conveyer slope
q_{rh}…acceleration force from rotating part of top rollers to 1 m of length
q_{rb}…acceleration force from rotating parts of bottom rollers to 1m of length

4.3. Calculation derived on basis of measured values

The simple analytical relations for preliminary calculation of rotary resistance depending on circumferential velocity and ambient temperature in equation of comparative line are determined from orientation values measured on current testing device (chap. 3.3.)

$$w = (c_k + c_m \cdot v) \cdot \alpha_t$$

c_k …coefficient depending on carrying roller design, form of packing and mounting accuracy, free on revolutions
c_m…coefficient free on revolutions respecting the quality of lubrication oil, its quantity and temperature
v… circumferential velocity of carrying roler
α_1…medium temperature coefficient

4.3.1 Influence of radial load

Various form distortions of carrying roller parts cause angular deviations in axis of the rolling bearing between inner ring (firm shaft φ_H) and outer ring (carrying roller jacket φ_P). From this the angle of position the rolling bearings position $\varphi = \varphi_H - \varphi_P$. This angle causes the a change of current radial clearance of rolling bearing and thus invoking improvement of rolling friction in bearing.

Glamorized load diagram for permanently loaded roller jacket and fixed roller shaft, balanced loaded with two forces F_r, applied in bearing positions, is illustrated on picture 4. Mathematical determination of deflextion curve, if need be the angle of mutual position is determined through the equations:

Carrying roller jacket: $$\varphi_P = \frac{2 \cdot F_r \cdot a^2}{24 \cdot E \cdot J_P} \text{ (rad)}$$

Roller fixed shaft: $$\varphi_H = \frac{F_r \cdot c \cdot a}{2 \cdot E \cdot J_H} \text{ (rad)}$$

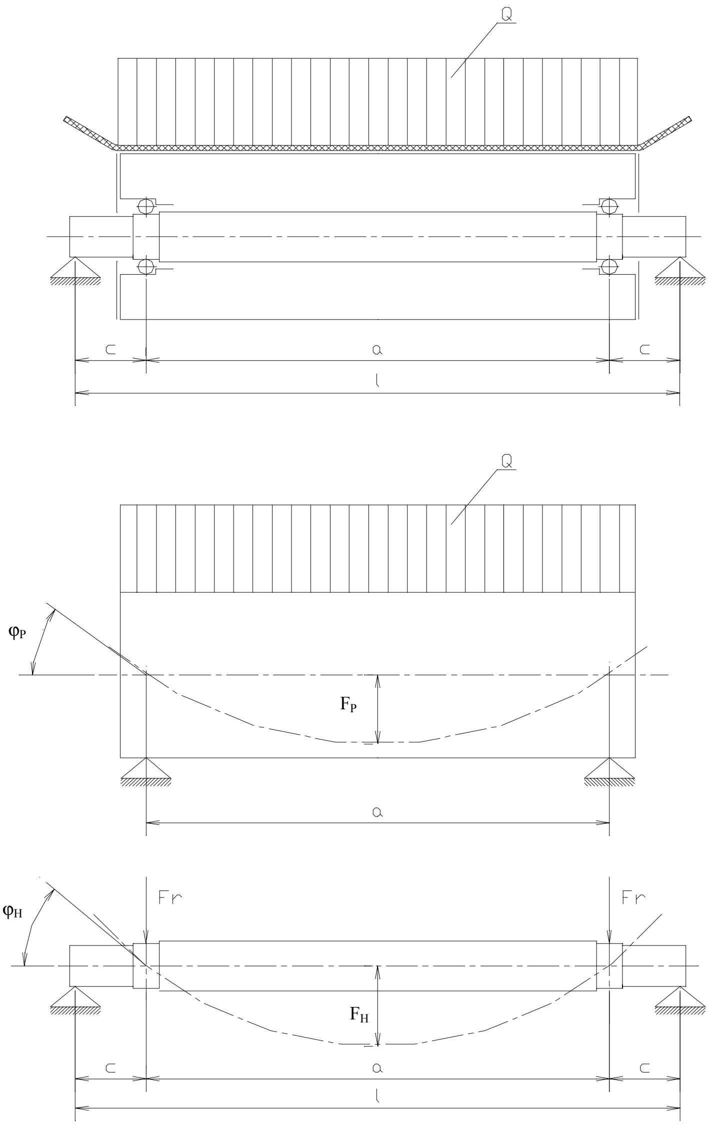
The angle of mutual adjustment:

$$\varphi = \varphi_H - \varphi_P = \frac{F_r \cdot c \cdot a}{2 \cdot E \cdot J_H} - \frac{2 \cdot F_r \cdot a^2}{24 \cdot E \cdot J_P} = \frac{F_r \cdot a^2}{12 \cdot E} \cdot \left(\frac{6 \cdot c}{J_H} - \frac{a}{J_P} \right) \text{ (rad)}$$

Through the known constructional parameters and properties of used material is possible then to calculate the maximum radial load of carrying roller in dependence on bearing design:

$$F_r = \frac{12 \cdot E \cdot \varphi_{\text{prípust.}}}{a \cdot \left(\frac{6 \cdot c}{J_H} - \frac{a}{J_P} \right)} \text{ (N)}$$

F_r…radial load of rolling bearing (N)
a …distance of rolling bearings (m)
c …distance among supports and rolling bearings (m)
E …modulus of roller jacket elasticity and fixed shaft (Pa)
J_H…moment of inertia of the fixed shaft (m^4)
J_P…moment of inertia of the roller jacket (m^4)



Picture 4

4.3.2. Axial load effect

According to the performance tests [4] it is possible to take off the values of acting axial forces at the trough rolling tables, if any at oblique built rollers (with regard to longitudinal axis of the conveyer).

To express this influence on the rotary resistance we shall realize location between two special positioned points for radial and axial forces absorption.On the centring thrust ring the thrust bearing is fixed form the roller jacket side, its dimension ranks with the carrying roller diameter. In this way there is possibility to transfer continuously axial force on the revolving and radial loaded carrying roller jacket.

The rotary resistance increase is expressed by the coefficient c_{λ}.

4.3.3. Circumferential velocity and grease filling effect

On the basis of tests (chapter 3.3.[4]) was learnt, that a part of resistance (coefficient c_k) is constant and specific for this roller, while the speed effect of eventual revolutions is determined by the grease quality and its quantity. It is necessary to define the coefficient c_k and c_m from the great number of measured results of new and running rollers form the factory, because of the mounting and production effect can be only taken from statistical evaluation.

The coefficient c_m is possible to determine separately and in this way the specific (variables) values of used grease. At present time applicated grease tests and the values received from them are unsuitable or are not acceptable for dynamic ratio specifying. That is why the testing device is suggested (3.4).

4.3.4. Ambient temperature effect

The intensity of rotary resistance is influenced by the ambient temperature. Therefore the temperature effect shall be included in the calculation of the rotary resistance through temperature coefficient α. There are suggested two methods:

a) through overage temperature coefficient

$$\alpha = \frac{w}{w(+30°C)}$$

w …rotary resistance during testing temperature
w(+30^{0}C)…rotary resistance at + 30^{0}C

b) by analytic evaluation [4]

$$\alpha = e^{(\beta_1 - \alpha_1 \cdot T)}$$

e…the base of real logarithmes
T…ambient temperature (^{0}C)
α,β…coefficients identified on the basis of tests

4.3.5. Rotary resistance calculation

According to the mentioned correlations it is possible to realize the rotary resistance calculation of the carrying roller radial and axial load as a function of the circumferential velocity, ambient temperature and load.

$$w = (c_k + c_m \cdot v) \cdot \alpha + c_A \cdot F_A + c_r \cdot Q$$

5. Conclusion

Three methods were presented here to the theoretical rotary resistance calculation of conveyers carrying rollers. In this calculation according to the bearings SKF producer the factor of the ambient temperature is not taken into consideration. In the calculation according ČSN standard is in coefficient of friction also covered blocking resistance, which is in consideration to requirements inadmissible. Regarding theoretical values comparison and the values measured on the current devices for rotary resistance measuring, the most accurate calculation is according to 4.3. It is necessary to take into consideration eventual test inaccuracy in consequence of disadvantages of the measurin device mentioned in the Chapter 3.3.

Recommended measuring table enables to get the values similar to the real values in practice.

From the values received on the actual measuring device it can be confirmed that the rotary resistance depends especially on the circumferential speed, used grease, ambient temperature, load and the roller structure. Further it is influenced by radial and axial load, grease capacity inside of the antifriction bearing and the production and assembling accuracy of the carrying rollers.

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Technics of VUT Brno and Tranza, joint stock company Břeclav.

In another stage the construction of designed measuring device and testing is calculated.

6. Literature

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