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Testing and calibration of continuously operating belt weighers

***Abstract**. One of the factors affecting the accuracy of mass flow measurement by the application of belt weighers is, certainly, testing of not only a weigher on the whole, but some of its parts as well. This paper deals with belt weigher testing and calibration methods, according to conventional international metrolgical references. Testing of belt weigher system components in laboratory conditions during the manufacturing process as well as a weigher calibration and testing with operation conditions after installation are considered.*

***Streszczenie.** W artykule analizowano dokładność pomiaru masy w taśmociągu ważącym. Przedstawiono wyniki testów laboratoryjnych i kalibrację systemu. (**Testowanie i kalibracja wagi taśmowej o ciągłym systemie pracy**)*

Keywords: belt weigher, testing, calibration, metrological references.
Słowa kluczowe: waga taśmowa, kalibracja.

Introduction

Intensive industrial and technological development have imposed the necessity of constant advancement of existing methods and devices for measuring enormous moving masses, as well as, finding out the new ones. As a result, there have been developed numerous methods of continuous mass measurement whose work is based on various physical principles [1, 2]. By the comparative analysis of their advantages and disadvantages, as well as due to experience of many years, belt weighers have proved to be the optimal choice as regards technical characteristics, compatibility with the transportation system, work efficiency, as well as relatively low purchase price, regulation and maintenance.

The measuring accuracy of a belt weigher depends on the construction of its individual parts, as well as, its correct installation, adjustment and testing. Testing of belt weighers is carried out as early as in the course of their manufacturing process, in laboratory conditions, and it is completed by the adjustment and calibration of the belt weigher in the plant after its mounting [3, 4, 5].

Metrological characteristics of the mass flow continuous measurement, applying automatic belt weighers, are regulated by the international document OIML R50. The metrological quality of belt weighers was raised by the latest revision of OIML R50 recommendations from the year 1997: the accuracy class of 0.5 was adopted, the application of weighers was not limited only to conveyor belts with one speed any longer, and more serious conditions of weigher testing and mounting were established [6].

There are numerous other documents being in indirect relation with the belt weigher measuring process and testing, such as recommendations they are subject to: belt force transducers (OIML R60), resistance belts (OIML R62), static load used in testing belt weighers (OIML R20, R 47 and R 111), the hierarchy principle of carrying out metrological testing (OIML D5), the safety requirements of electronic measurement systems (OIML R74), as well as others. The development of measurement equipment and components, including load cells applied with belt weighers, is regulated by the National Type Evaluation Program (NTEP).

Our metrological conditions related to conveyor belt weighers are regulated by regulation books and instructions of the Federal Institute for Measures and Precious Metals and correspond, to a large extent, with recommendations of the International Organisation of Legal Metrology (OIML).

Accuracy control of some weigher elements

Before mounting of a belt weigher, the accuracy control of its basic elements: strain gauge load cells, belt speed transducer and belt weigher electronic unit, is carried out in laboratory conditions in relation to metrological characteristics, defined by adequate law regulations.

Load cells, used for weigher construction are tested according to metrological characteristics defined by the "Book of Regulations on Metrological Conditions for Electromechanical Belt Transducers for Mass Criteria" which is in accordance with adequate international regulated conditions [6]. Testing of load cells used with belt weighers is carried out within the whole working temperature range of weighers (from -10°C to +40°C), whereby they are considered to be accurate if aberrations lie within regulated limit of errors. There are tested: measuring accuracy, hysteresis, repeatability, and the change of output signal at the lowest load owing to the change of temperature, the change of output signal at the lowest load owing to the change of atmospheric pressure, load creep, and the output deviation at the change of load position.

The characteristics of a speed transducer are tested in the whole speed measuring scope (standard from 0.01 to 10 m/s), as well as in the whole working temperature range, whereby the measuring error must lie within the limit of errors defined by recommendations of OIML R50. The slipping of a friction wheel is checked for both loaded and unloaded belts by measuring of the converter impulse for the known length of the belt.

The electronic processing unit and the presentation of weighed signals is tested in the whole measuring scope of electronic parameters, as well as the whole working range of temperatures. Testing of accuracy and presentation of measuring results is carried out in one of the following ways:

- by the application of adequate load cells in working conditions and their connecting with secondary part of the weigher,
- by the simulation of electric signals from weighed transducers (force transducer and speed transducer),
- by the application of transducers in laboratory conditions and the simulation of load and belt moving.

On the basis of input parameters and the mathematical model of the weigher there are calculated values compared to the weighed values. The obtained errors of electronic part of the weigher must lie within the limit of errors defined by the recommendations of OIML R50 for automatic belt weighers with the class of accuracy of 0.5, 1 and 2.

Check of belt weigher installation accuracy

The accuracy of belt weigher installation is related to the position and the way of installation of some weigher elements and the connection, both of particular elements of measuring system of the weigher and parts of a belt conveyor which do not represent part of a measuring system, according to technical documentation and installation instructions [7, 8].

When installing a belt weigher, there is tested:

- whether the position of a weigher installation matches conditions for achieving maximal accuracy (alignment and off-centricity of weighed idler set, and the like),
- protection of weighed idler set against corrosion and clog,
- whether a conveyor belt is strong enough to withstand static load (motion resistance along weighed idler set and the friction resistance of a belt edge against beams at the spots of material loading and unloading) and dynamic load (at drive, lifting and transportation, moving along idlers, drums, at the change of direction and the like),
- whether there is slanting of a belt and its slipping off bearing idlers (if it is stated, directing idlers are set on the loaded side of a belt on both belt sides at places where the belt slipping off idlers is expected),
- whether the mass per meter length of a conveyor belt is constant along its whole length and to what extent the places of the belt link affect the result of weighing,
- the change of the belt moving speed during weighing (this speed must not vary more than 5% of the nominal value, namely of the established value in case of a changeable speed conveyor belt),
- whether the belt stretching is independent of temperature, wear out, load, sliding between the belt and the drive pulley (if the length of a belt exceeds 10 m, the weighed idler set, being force conveyors, must have a bend not less than 90° at the spot of the contact with the belt),
- functioning of the protection against overloading in case that a belt conveyor load exceeds the maximally allowed,
- independence of weighing results of the presence of auxiliary devices such as devices for belt cleaning and others.

Besides the check of the mechanical way of linking, the accuracy of electrical connections of some elements of a belt weigher is tested with regard to existing technical documentation as well as the weigher power supply, namely the accuracy of protective grounding.

Weigher zero setting

Functional check of a weigher implies to determine whether all elements of the weigher and control elements realize projected functions. It is checked whether the change of input parameters of a weigher: load and speed, realize expected changes of output values. The functions of the weigher zero setting and automatic calibration are checked as well [8, 9, 10].

Setting the weigher zero to a great extent affects measurement accuracy, since this error is constantly being integrated into the measured mass flow. A zero deviation of a belt weigher results from: the deviation of force transducer zero, the preload of the weighing platform and the conveyor belt, the susceptibility of analogous components at the input level of electronic unit of the weigher, and drift owing to both temperature and weather impact. Setting the weigher zero is carried out after its mounting, before and after testing the loaded weigher.

If a conveyor belt is not in motion for a longer period (over two hours), setting the weigher zero is carried out 15 minutes after the transportation system initiating in order to support the system and enable the belt to take its operating position. By applying additional hardware and software control with automatic belt weighers, the display of weighed values is hindered until reaching a stable temperature.

Setting the weigher zero is carried out at the unloaded conveyor belt moving at constant speed, and in the duration recommended in the technical manual as a minimal zero testing period (with automatic zero setting, the control interval amounts 3 minutes or the period of full rotation of a conveyor belt, depending on what lasts longer). Testing of weigher zero stability comprises a set of control procedures, which are repeated until, in three successive tests, there is established the error not exceeding $\pm 0.06\%$ of the full weigher capacity or ± 1 the belt weigher (depending on what is smaller). The weigher zero deviation can be shown as a reference level, percent amount of the full belt weigher capacity or as a change in the full load during one full rotation of the conveyor belt. Zero setting is repeated after completed testing of weighed load whereby the repeated testing is considered positive if a zero setting error exceeds $\pm 0.12\%$ of the full belt weigher capacity or ± 2 belt weigher degrees (depending on the fact which is smaller).

There is the possibility of automatic zero setting of contemporary belt weighers. The algorithm of automatic zero control is carried out periodically during a measuring regime, when the measuring process is stopped temporarily, and there are measured parameters by which potential deviation of weigher zero is detected. The prerequisite of activating of the automatic zero setting software is the defining of limit of errors in the percent of maximal load such as:

- limit difference values of two successive zero settings (it can be within the range from 0 - 10% of maximal load, commonly 0.5% of maximal load),
- mean limit values of two successive zero settings (range: 0 - 1 0 % of maximal load, commonly 1% of maximal load),
- the highest values of zero setting limit of errors (commonly 5% of maximal load can be widened up to 100% of maximal load, whereby load cells must be adjusted to operate in a wider range than it is marked on the device).

The result of automatic zero setting is presented in the form of tare correction (in kg/m) and each exceeding of set limit values is signalled in an adequate way. The duration interval of zero testing is calculated on the basis of the belt length and the measured moving speed, or it is set by software (most frequently of the order of a foot of several hours).

Weigher testing with load simulation

Weigher testing and calibration comprise: simulated load testing (by using measurement chains or simulating electrical measurement signals) and mechanical equipment and belt load testing [4, 5]. On the basis of the obtained results of testing, automatic correction of calibration measurement results is performed, according to the earlier adopted software algorithm.

Weigher testing with load simulation is carried out in order to control operating characteristics of the measuring system and it is recommended by the manufacturer. This kind of testing is carried out between two cases of weighed load testing and it is not used to obtain official certificates on the correctness of a weigher work.

Weigher testing by load simulation comprises at least three successive measurements which are required to be carried out in a time interval not longer than 12 hours after the complete weighed load accuracy testing in order to determine the factor of the relationship between the results of load simulation control and the results of weighed load testing. Results of weigher testing by load simulation should be repeatable with the accuracy of 0.1%. There is a great number of belt weigher testing methods [3, 6], and as testing load, there is applied static load or roller chains.

The simulation measurement method with static load (Fig. 1) does not take into account all systematic measurement accuracy deviations in real operating conditions. It is estimated that the error of this way of testing is of the order of a foot even to some percent. Nevertheless, this testing is regularly carried out in practice as control testing, for by its application, the impact of belt speed change, of load point change, of zero setting and stability, of temperature change, of feeding, alignment and measurement repeatability can be checked in a very efficient way.

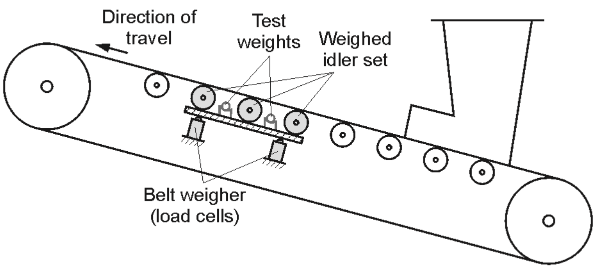

Fig.1. Belt weigher testing with static load

As there are various constructions of belt weighers, it is the manufacturer that regulates static load and the ways of its setting during testing. The control of belt weigher correctnes by Schenk company, one of the largest manufacturers of belt weighers, can serve as an example [11]. Mass of static load M_{stmax} [kg] in maximal weigher flow Q_{max} [kg/h] is determined on the basis of the expression:

$$M_{st\,max} = \frac{Q_{max} \cdot L}{3600 \cdot v} \tag{1}$$

where: L - effective belt length on a weighing platform [m], and v - belt speed [m/s].

Time interval of mass measurement t_m is given with:

$$t_m = k \cdot t_o \tag{2}$$

where: k - a whole number, and t_o - the time interval of one belt rotation.

Proportional relation of mass m_{st} in the given load and the mass of static load with maximal capacity M_{stmax} can be represented as:

$$m_{st} = \frac{M_{st}}{M_{st\,max}} \cdot 100\% \tag{3}$$

If there are:

Σm_{st} - total mass that should be weighed in time period t_m with control static load M_{st} and

Σm_W - weighed mass for time t_m,

limits of permissible error (LPE) are determined on the basis of the following conditions:

- for the accuracy class 0.5:
  $\mathrm{LPE} = 0.0018 \cdot \Sigma m_{st} > \left|\Sigma m_W - \Sigma m_{st}\right|$,
- for the accuracy class 1:
  $\mathrm{LPE} = 0.0035 \cdot \Sigma m_{st} > \left|\Sigma m_W - \Sigma m_{st}\right|$,
- for the accuracy class 2:
  $\mathrm{LPE} = 0.007 \cdot \Sigma m_{st} > \left|\Sigma m_W - \Sigma m_{st}\right|$.

The other way of load simulation implies the application of a special load chain. According to this method weigher load testing is simulated by means of specific load chain of specific length. The load chain is at its ends bolted and tied by idlers which rotate as the belt moves, whereby the friction between the belt and chains is reduced (Fig.2).

The roller chain length L_{rc} is determined as the sum of effective weighing platform length L_{wp} and triple distance among bearing idlers (L_1):

$$L_{rc} = L_{wp} + 3 \cdot L_1 \tag{4}$$

whereby the load by which the roller chain affects the belt is defined by this length and longitudinal chain load m'_{rc}:

$$m_{rc} = L_{rc} \cdot m'_{rc} \tag{5}$$

Although testing of a weigher by the application of roller chains simulates, truly, effects of the impact of a conveyor belt on the accuracy of weighing, this way of testing is rarely used in practice. The reason for that can be seen in the following disadvantages:

- the application of various roller chains,
- the change of belt stretching does not affect simulated load by a roller chain,
- roller chains of large specific weight are not convenient for handling,
- in case of conveyor belts with inclination, tested load depends on the force of chain tightening, whereby this control method becomes more complex,
- construction, calibration, and control of rolling chains are expensive as regards that the same accuracy is achieved by other ways of load simulation.

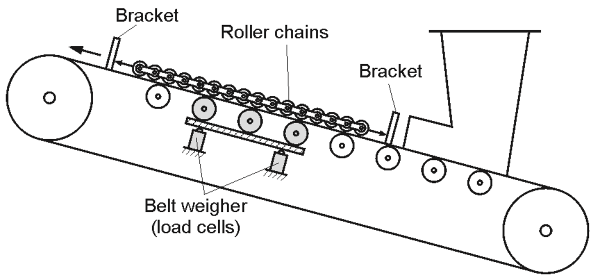

Fig.2. Belt weigher testing with roller chains

Testing of the repeatability of output signal and the check of the whole electronics of the weigher measurement system can also be achieved by the simulation of electric signals from weigher load cells, which represents the fastest, the most economical and the simplest way of control. This testing method, however does not take into account all parameters affecting the accuracy of load cells and effects of a belt conveyor and it is applied in cases when a weigher is installed at the accessible location.

Belt weigher automatic software calibration is performed on the basis of the entered parametres, such as the characteristic value of the force transducer friction wheel, the value of nominal belt speed, nominal weighing platform load, effective weighing platform length and other exploitation parametres of the weigher.

Weigher testing by load simulation is significant in case of determining of repeatability and stability of some weigher elements, however, the only valid testing in plant conditions is weighed load testing.

Weighed load testing

Taking into account the impact of dynamic effects and systematic deviations of measurement results owing to imperfectness of measuring system and environmental impact, as well as the achievement of the highest defined measurement accuracy of a weigher can be realized completely only with weighed load testing.

This method of belt weigher accuracy control implies the comparison of the measured load mass at the tested weigher with the value obtained by measuring of the same load on the testing (reference) weigher. The reference weigher can also be flow weighers of continuous or discontinuous type, or static (for example railway or hopper weighers relying on strain gauge load cells, Fig. 3).

The accuracy check of a weighed load is carried out in real operating conditions at various points of a belt load, with varying grain size of the load, by, at least, one more belt speed in both directions of belt moving. With the initial weigher calibration, there are carried out at least three cases of independent testing, and in each next control, two cases of testing at least, whereby results of testing must be within the limit of tolerance.

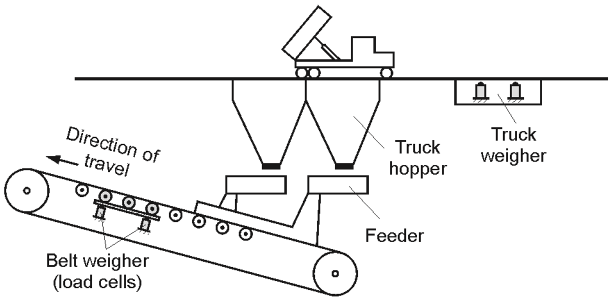

Fig.3. Belt weigher testing using a truck weigher

With automatic belt weighers, testing is carried out for two values of load flow: from 20% to 50% of maximal weigher flow and from 80% to 100% of maximal weigher flow. Allowed value variations during weighed load testing depend on the accuracy class and are regulated to 0.5 limit of error in operating conditions.

The procedure of weighed load testing itself depends on the capacity of a belt weigher and availability of a control weigher. To secure the measurement to be as accurate and definite as possible, the following conditions must be taken into account:

- containers (lorries, wagons, or hopper measuring bin) must not be overloaded to the level of load emptying,
- testing process implies the setting of effective zero or the tare of a container weight whereby multiplied tare of wagons or lorries is not used, and both gross weight and tare weight are set at the same weigher,
- before and after testing with load, the storage of belt load is tested in order to determine whether it is empty and clean from weighed load, as well as whether only the weighed load passes to the weigher,
- if possible, the testing of reference weigher is carried out in the time interval of 24 hours before the weighed load testing,
- if in case of weighed load testing, load different from the attested one is used, the verification of reference weigher accuracy must be carried out before the testing start.

Weighed load testing is an accurate method, but very expensive, time-consuming and frequently not easily feasible. While realizing this control method in practice, there is the problem of charge and discharge of belt load in order to carry out weighing on a control weigher, which is particularly pronounced with weighing large flow masses and distant control weighers, which must be taken into account in the phase of transportation system designing

Conclusion

Belt weigher measuring accuracy depends on the verification of measuring devices a great deal. In this paper, there are defined metrological and technical characteristics of belt weighers, as well as of some of their parts regulated by leading international institutions for metrology which should be fulfilled in order to achieve required accuracy classes and measurement reliability of mass flow. There have been analysed testing methods and belt weigher verifications related to operating accuracy testing of some elements of the weigher measurement system in laboratory conditions during manufacturing, as well as adjustment and verification of a weigher in plant conditions, after its installation.

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