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ACCURACY INCREASING METHODS OF BELT WEIGHER MASS MEASUREMENT

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ABSTRACT

The excavated coal mass measurement during transportation to large consumers is significant part of conducting of a coal mining and processing technological process, as well as of the evaluation of coal through sale. A measurement error of the order of the tenth part of percent can impact profit enormously. In this paper, there are presented some accuracy increasing methods of continuous belt weigher mass measurement on conveyor belts in real conditions.

INTRODUCTION

Nowadays the mass measurement of coal on large open pit mines is most frequently carried out during a transportation process as regards, in this way, it is conducted without interruption of material flow. The selection of a coal mass flow measurement method is conditioned by requirements such as the measuring scope, the accuracy and peculiarity of measurement conditions. Accordingly belt weighers basing their work on measurement of conveyor belt specific load in a specific time interval are the most convenient. Basic advantages of the use of this belt weigher are: mass measurement on a conveyor belt itself in most demanding working conditions, the high efficiency of measurement and the possibility of being integrated with the information system of a mine or a thermo - electric power plant.

Theoretically speaking, belt weighers can measure mass flow with 0.2% error. In practical experience, however, the measurement error is significantly greater and might reach several per cent.

Numerous parameters affect belt weigher mass measurement accuracy. Some of these parameters are related to work correctness testing of some elements of a belt weigher measurement system in laboratory conditions during production, as well as the verification of a belt weigher in plant conditions after its installation [1]. In real conditions, however, the measurement accuracy of belt weighers is determined to the greatest extent by conditions of utilization and characteristics of the transportation system itself [2].

The effect of disturbing parameters upon an output belt weigher signal can be compensated by the application of:

- conservative methods related to the activity reduction of the effect value itself,
- adaptive methods by which the weigher system measurement sensitivity on the impact of disturbing values is decreased.

Some of adaptive methods of unfavourable effect compensation on the measurement result of a belt weigher enabled by the application of microcontrollers, additional hardware and corresponding program algorithms are presented in this paper.

BELT WEIGHER MEASURING SYSTEM

The principle of flow mass measurement by a belt weigher is based on the integration of specific load on part of a conveyor belt. Belt weigher system is composed of: a weighed platform structure supported on force transducer, belt speed sensor and weigher electronic unit. (Fig. 1).

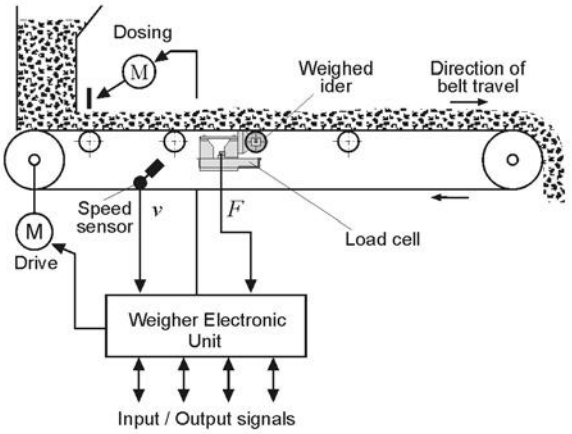

Fig. 1. Belt weigher principle

Presentation of the report. Presentation of The material is guided over a weighing platform arranged below the belt. The platform load applies a force on strain-gauge load cells

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via some or multiple weighed idlers, which are connected to the frame structure. Being proportional to platform load, load cells output voltage is routed to the electronic unit.

The electronic unit integrates the output signals from the load cells and belt speed transducer to arrive at a rate of material flow and the total platform mass m_{tot} passed over the belt weigher at definite time interval Δt is determined as:

$$m_{tot} = K \int_{t_0}^{t_0+\Delta t} F(t) \cdot v(t) dt \tag{1}$$

where K is device constant.

The electronics incorporate all features that allow evaluation, calibration, operation and diagnostics for the system.

THE LOAD CELL CHARACTERISTICS CHANGE RELATIVE TO TIME

The change of the transmission characteristics of the force transducer relative to time refers to the changes occurring due to the process of force transducer aging, such as material fatigue and creep.

The instability of characteristics due to fatigue occurs as the result of aging of the elastic element material of the force transducer. The duration of correct operation of force transducer, with belt weighers, is determined by the number of full load cycles, and approximates 10^7cycles [3].

Creep represents the change of strain gauge load cell output signal, occurring at constant load, in the same external and other conditions of measurement, and has a dominant impact with slowly changing load. The magnitude of the belt scale load cell creep is a few hundredths of a percent of the applied load.

A partial compensation of creep can be achieved through the adjustment of strain gauge creep characteristics and the adjustment of spring element of force transducer in the design and testing phase, or by the application of some special methods in the case of force transducers intended for special purposes [4].

The experimental results of the applied research confirm the possibility of creep error compensation by means of linking a classical type strain gauge load cell, electronic hardware and appropriate software. The examples of application of programme controlled creep compensation are rare, the most prominent of them being intelligent strain gauge load cells: C2G1-6K (made in Japan) and MPS-2 (Institute “Nikola Tesla” in Belgrade).

The software compensation of load cell creep is a complex assignment as it is the result of varied effect values, whose operating mechanisms and directions are varied, as well as sizes and time constants. It is impossible to define a unique mathematical expression which could be applicable for the creep reduction of all load cell types. The complexity of numerical problem solving is also affected by the prior history of load cell loading being analysed by regulated testing before the measurement begins.

However, due to the obtained exponential dependence of creep with time, it is possible to realise mathematical correction of the creep by applying the compensation function:

$$f_k = a \cdot \left(1 - e^{-t/t_P} \right) \tag{2}$$

where parameters a and t_{p} may be determined from the condition that the compensated creep error δ_{Pk} is minimal. Compensated creep error δ_{Pk} is given with:

$$\delta_{Pk} = \delta_P - f_k \tag{3}$$

The measurement system of the compensation of the resistance strain gauge load cell creep comprises standard load cells, a corresponding electronic assembly and software. The compensation procedure comprises several basic steps.

- determination of measurement signal deviation owing to creep,
- calculation of compensation function f_{k} (parameters a and t_{P}) on the basis of corresponding mathematical model (most frequently, it is the method of least squares) and
- calculation of compensated creep δ_{Pk} on the basis of the expression (3).

The experiments were conducted by the applying of constant input mechanical load directly, by means of accuracy class M1 (OIML R 20) under stable environmental conditions. The parameters of function f_{k} (equation 2) were calculated through the application of minimal sum of squares criterion. According to the results of C2G1-6K type and MPS-2 type load cell software creep error compensation, the compensated creep error δ_{Pk} is more than tree times smaller comparative to creep error δ_{P} of the classical load cells and it confirms the possibility of the creep compensation by means of software techniques in an intelligent load cell [5].

CONVEYOR BELT PAREMETERS

There are numerous design and exploitation parameters of conveyor belt that affect the mass measurement accuracy. Some of them are: dimension, inclination, profile, elasticity and the degree of conveyor belt tension.

Belt slip refers to the percentage of change of the measured belt length relative to the established value. Horizontal belt drift is defined as shifting of the belt perpendicularly to the direction of the belt movement, and is expressed as the percentage value relative to the nominal position, whereby the value of 50% corresponds to the deviation of 1/2 triangle width, b in Fig. 2.

The compensation of the conveyor belt slip and horizontal drift is performed by using an extra sensor of the belt circle (“Namur sensor”, NS in Fig. 2). A metal identifier is placed on the conveyor belt (triangular markings made of metal, usually aluminium). Depending on the registered triangle width, “Namur sensor” gives at its output a cluster of impulses of suitable signal breadth, which is then used in measurement data processing.

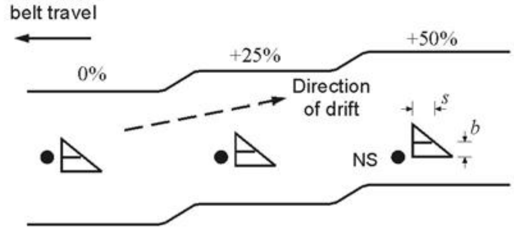

Fig. 2. Belt influence compensation

The belt inclination change in relation to the referential position in part where a load cell is placed, owing to the activity of unfavourable external effects, directly, impacts measurement accuracy. In order to compensate for these influences on the measuring result, belt weigher is equipped with an extra circuit with a so-called “Cosinus pendulum”. The pendulum is switched into the strain gauge load cell supply voltage U_i, as shown in Fig. 3, where R_{LC} is load cell input resistance, R_P is pendulum potentiometer resistance which depends on belt inclination and R_V is zero point position potentiometer. Due to the change in belt inclination, resistance R_P changes and the result is that the strain gauge load cell output voltage U_o is proportional to the belt inclination.

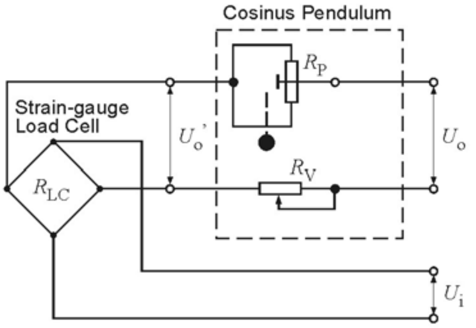

Fig. 3. Compensation of belt inclination

By continuous measurement of belt impact and constant entering of alterations, during a measurement process, adequate compensation is provided, whereby measurement accuracy is increased to a large extent [6].

In addition to the mentioned belt sensors, the measurement system of an automatic belt weigher can be relatively simply widened by additional size measurements being of interest for the increase of measurement accuracy by minimal alterations of software routines and the hardware of a weigher.

WEIGHED PLATFORM LOCATION AND CONSTRUCTION

Measurement accuracy is also affected by the location and manner of positioning of the weighed platform that is by the manner in which the weigher leans on the conveyor mechanical system. The requirements of proper installation, which enable the optimum of force have been defined by specific recommendations and provisions [6, 7].

It is concluded by an analysis of impact factors that the location of the weighed platform closer to loading station is more favourable than the farther one. However, the close proximity of the weighed platform to a loading station is limited as, then, dynamic effects of a loading material act on a conveyor belt.

In case of the application of a belt weigher for dosing regulation, from already stated reasons, the weighed platform is not mounted at the material drop point, thus the weighed material flow differs from the real value at a dosing point. The correction of this impact is carried out by giving an adequate command (via the keyboard on electronic part of a weigher or via a superior computer) and by the application of an element entering delay depending on the size of a measured velocity. This way of correction implies the program entering of a distance value of a weighed platform central point in relation to a drop point which is given as the percentage value of the overall conveyor belt length (within the scope of 0 - 50% of this length). Material dosing can be controlled by conveyor drive regulation, by material loading control or the combination of these two ways (Fig.1).

The manner in which the conveyor belt is loaded presents one of the basic factors affecting the accuracy of continuous mass measurement. This influence is especially evident with materials of high or different granulation, like in coal transportation in surface mining, or in the conditions where there is potential for vibration and belt deflection occurrence.

In practical experience the theoretically defined point of the measured force application, boils down to force reception via a specific surface. In real circumstances, the condition of constancy of the measured force direction is not fulfilled, due to the technical and design imperfections of force transducers.

Moreover, despite the selectivity of force transducer measurement system, it still, to a certain degree, reacts to the present parasitic forces and moments. Some parasitic loads don’t change with measured load, and can be calculated as the weigher initial load. However, there are extra loads that change together with the weigher deflection.

The deviation that occurs due to these elastic loads can be either estimated through calculation or empirically established. Reduction of these influences is most often achieved by a combination of design and compensatory actions and procedures.

In order to achieve higher measurement accuracy while working with high and unstable belt velocities as well as with pronouncedly uneven filling of a belt profile, it is economically justified to apply weighers containing a larger number of series-connected measuring modules [6 8]. By increasing the number of measuring modules, namely load cells, a longer effective length of the weighed platform is obtained which enables a longer time interval of mass flow integration (equation 1) and minimizing of measurement errors owing to flow asymmetricality and the change of the weighed mass gravitation centre on the surface of a weigher platform.

In case of n load cells of identical characteristics with one power supply and with adjusted connection resistances, the equivalent output voltage U_o is determined by the expression:

$$U_o = \frac{1}{n} \cdot \sum_{j=1}^{n} U_{oj} , \tag{4}$$

namely it represents the mean voltage value U_{oj} from individual load cell outputs.

There are also different types of weighed platform design, with one, two, four or more carrying idlers. From the point of accuracy of mass flow measurement, weighed platforms with more carrying idlers have proved to be more favourable.

To diagnose working parameter deviations from determined regulated values is a general feature of intelligent belt weighers. Thus, there is continuous monitoring of maximal and minimal weigher flow, as well as the load of a weighed platform. In case of recording of improperly operating state, such as overload, or the existence of increased vibrations which can lead to a weigher damage, there is a possibility of work error signalizing, as well as the possible blockage of the measurement system work.

Although software techniques, such as autocallibration, linearization and reduction of environmental influences are already used, the possibilities of software compensation are insufficiently researched as yet.

CONCLUSION

Each measurement in real conditions contains measurement uncertainty to some extent as a result of the existence of varied impact factors. In case of a belt weigher, impact factors are related to characteristics of measuring part of a weigher, conditions of the installation of a weigher and the level of adjustment of transportation system to metrological requirements of a weigher. Some of compensational techniques with contemporary belt weighers related to predominant impact factors on measurement accuracy are presented in this paper. In addition to compensation methods of unfavourable impacts, a set of technical recommendations is presented in which considerations related to a belt weigher mass measurement accuracy can be summarized as regards characteristics of transportation system.

The direction of belt weighers further improvement, in terms of increasing the mass measurement accuracy, refers to expanding the mathematical model of the programme of control and compensation of all accompanying effects to do with measurement accuracy.

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