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BELT WEIGHER ACCURACY LIMITING FACTORS

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Abstract:

In practical experience, the accuracy of mass flow measurement by the use of belt weigher, is considerably lower than the theoretical, as the result of acting of a number of limiting factors. The analyses that have been designed and the practical experience point to the problems occurring in the installation, maintenance and testing of weighers. The weigher measurement accuracy, however, is mostly determined by the real conditions of using. This paper presents a mathematical model of all the disturbing effects on the belt weigher measurement system, as the result of a systematic analysis of their influence. We have listed a few of adaptive methods for the compensation of these influences, together with the directions for further development.

1. Introduction

Belt weigher is just one type of mass measuring instrument in the family of continuous weighing of bulk materials. It can be used wherever continuous materials are recorded in conveyor belt systems [1]. A complete defining of belt weigher measurement accuracy involves not just determining its technical and metrological characteristics, but understanding the ways of unfavourable factors acting, that exists in specific parts of the measurement system, changing the conditions of the measurement process, thus being the cause of a certain degree of measurement uncertainty. On the basis of the analysis of measurement uncertainty causes, some of them can possibly be eliminated or reduced by the application of adequate methods and procedures.

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. There are numerous parameters that affect the measurement accuracy of these weighers. Some of them are the consequence of design (high belt inclination, great belt length, the position of weigher placement [2]. Some result from the flaws in mounting, and others are the consequence of the manner of exploitation, maintenance and belt weigher verification [3].

Automatic belt weighers and the concept of continuous measurement of weight flow by the use of load cells are subject to specific metrological and technical conditions [4], [5]. In the most recent revision of OIML R50 recommendations, the metrological quality of belt weighers was increased and the accuracy class of 0.5 was adopted. The use of weighers is not limited only to one-speed conveyor belts, and there are stricter conditions for weigher mounting and testing.

Belt weigher testing refers not only to the control of operating characteristics of specific weigher elements, but the entire weigher measurement system, and is performed as early as in the production process in laboratory conditions, ending with weigher adjustment and verification at the plant, after it has been installed [6].

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2. Belt weigher system

A typical belt weigher system is composed of weighed platform structure supported on force transducer (FT), belt speed transducer (ST) and belt weigher electronic unit (WEU) which incorporates all features that allow evaluation, control, regulation, calibration and diagnostics for the system.

The material is guided over a weighing platform, arranged below the belt. The platform load applies a force on FT via some or multiple weighed idlers, which are connected to the frame structure. Being proportional to platform load, FT output voltage is routed to the WEU. The rotary digital pulse ST is mounted at the inside of the return belt and generates pulse signal which is directly proportional to the distance between the belt moves and the speed of the belt. The WEU integrates the output signals from the FT and ST to arrive at a rate of material flow and total material passed over the weigher.

The accuracy of the material weighed on belt weighers is dependent upon the accuracy of weight force and speed. Both of the measured values represent a potential source of deviation between the real and nominal, that is the recorded value of mass flow.

3. Acting of unfavourable factors

There are quite a few different designs and variants of belt weighers. However, problems related to the influence of unfavourable factors on the mass flow measurement accuracy are common to majority of these measurement systems.

The components of weighing accuracy can be divided into the following basic categories:

1. Measuring apparatus accuracy - force and speed measurement accuracy;
2. Weighing electronics accuracy - data acquisition accuracy;
3. Installation accuracy;
4. Calibration and belt verification accuracy.

The relevant influencing factors on the results of mass flow measurement by means of belt weigher and their subdivision into groups are shown in Fig. 1.

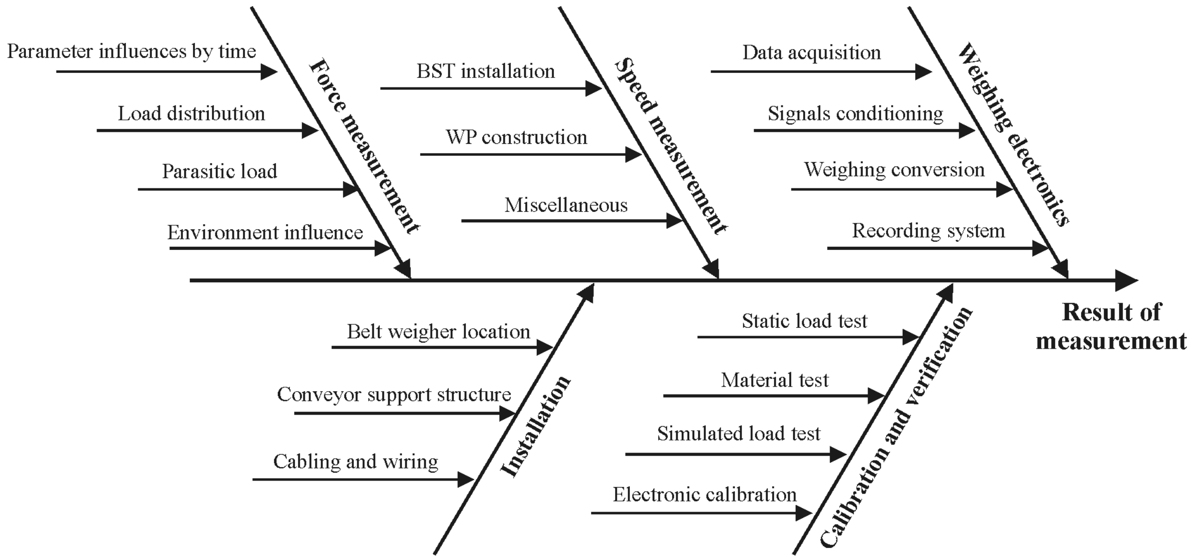

Fig. 1. *Influencing factors diagram*

In nominal operating conditions and prescribed conditions of mounting, the belt weigher accuracy is mostly determined by FTs measurement accuracy. One of the ways of systematization of unfavourable factors acting upon the accuracy of force measurement, can be represented by the following mathematical model

$$F = f_t(\vec{F}) + [f(\vec{F},\vec{P}) - f(\vec{F})] + [f(\vec{F},\vec{T}) - f(\vec{F})] + [f(\vec{F},\vec{C}) - f(\vec{F})] + [f(\vec{F},\vec{E}) - f(\vec{F})], \quad (1)$$

where:

$\vec{F}$ - measured force, as a vector value that represents the input to the measurement system, which is reduced at FT output to the scalar value of its module *F.* The vector reduction to the scalar value implies the definition and constancy of the direction, sense and point of application;

$f_t(\vec{F})$ - the change of measurement system characteristics, during exploitation relative to time *t*;

$\vec{P}$ - the vector of parasitic load;

$\vec{T}$ - the vector that represents the unfavourable effects of reception and guiding of the measured force from the load receiving element;

$\vec{C}$ - the vector that represents the influence of the conveyor and WP construction;

$\vec{E}$ - the vector that represents environmental influence.

The change of the transmission characteristics of force transducer relative to time *t* refers to the changes occurring due to the process of force transducer aging, such as material creep and fatigue. According to OIML R 60 recommendations, there is: short-term creep, which is observed in 30 min interval, and depending on the class accuracy it is in 0.01- 0.1% range, and long-term creep, lasting for 4 hours, which is in 0.02- 0.1% range [5]. The instability of characteristics due to fatigue occurs as the result of aging of the elastic element material of the force transducer. It is manifested as the instability of zero and the instability of weigher sensitivity. The duration of correct operation of force transducer, with belt weighers, is determined by the number of full load cycles, and typically approximates 10^7cycles.

A form of parasitic load is the one that doesn't change with measured load, and that is calculated as the weigher initial load. However, there are extra loads, which 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.

The deviation of the measured from the exact force value occurs as the consequence of the measured force transmission from the load receiver to the force transducer. There are measurements performed in order to establish the magnitude of this deviation in practical experience.

Measurement accuracy is affected by the location and manner of positioning of the weighed platform, which 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 transmission and weigher protection from disturbing effects, have been defined by specific recommendations. The majority of these conditions have been precisely defined by provisions to do with belt weighers [4].

External influences are the most important class of measurement uncertainty sources and refer to: environment influence (temperature, pressure, humidity, precipitation, wind), mechanical influences (mechanical impacts and vibrations) and electromagnetic interference. The effect of temperature is the most conspicuous of them and is manifested through different occurrences with specific parts of belt weigher measurement system. Temperature has an immediate influence - changing the resistance of the measurement belts and an indirect influence - changing the force transducer parameters - modulus of elasticity and sensitivity. There are numerous design methods and procedures for reducing temperature impact on force measurement accuracy, by adding resistors into the transducer circuit in the process of production. The range of operating temperature, pressure and humidity, and other referent values of influencing parameters, as well as the scopes in which they vary, are defined by regulations, as well as by recommendations of the manufacturer [5]. In circumstances where significant snowfall or ice accumulation is likely, the use of protective barriers should be considered [7].

The manner in which the conveyor belt is loaded presents one of the basic limiting factors to achieving high 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. The load receiver and mounting hardware are considered to be such that the maximum impact force does not cause unacceptable long-term damage [7].

Sensitivity to electromagnetic interference is checked by suitable testing, and the exertion of this influence is better to be observed on the level of the entire belt weigher system.

The deviations in mass flow measurement accuracy also occur as the result of:

- measurement of conveyor belt speed,
- incorrect mounting of speed transducer,
- the difference between speed of the material weighed on belt weighers and the belt (a loading chute too near the belt weigher causes the material to be moving faster than the belt),
- the slippage between the belt and the ST wheel,
- the change in temperature and other environment conditions, which deform conveyor belt.

The usual conveyor belt speed ranges from 1 - 4 m/s which is rather narrow, and is maintained as constant during operation by the use of asynchronous engine, so the deviation of speed measurement results from the nominal value, can to a great extent be compensated by weigher calibration. The accuracy of conveyor belt speed measurement is 0.01%.

A part of deviation occurring at mass flow measurement appears as the result of acquisition and conditioning of the measured signals, the criteria of determining mass flow and the total mass, sampling and the resolution of analogue-digital conversion, as well as the measurement results registering. The deviation due to the change in supply voltage and WEU frequency is negligible, given that with the application of microprocessors, we can control the correctness of the electric parameters and perform automatic correction due to their variation.

The weigher zero drift is determined at cancelling the excitation to the measuring part of the weigher, which corresponds to an unloaded belt conveyor. The acquired value is being updated by recording it in the suitable weigher memory part.

Testing of specific weigher parts (FT, ST and WEU), as independent measurement parts, is performed in laboratory conditions. After making the weigher, its installation in real conditions, final calibration and testing are performed, which comprise: checking the correctness of mounting and connecting of weigher elements, functional check of weigher operation correctness, balancing the weigher forces, adjusting the weigher zero and weigher verification.

Correct mounting of belt weigher refers to proper positioning of weigher elements, mechanical fastening and connecting of weigher elements, according to the technical specifications of the manufacturer, the requirements and directions to do with mounting [7]. Functional check of the weigher implies establishing if all the weigher elements and operating elements perform the intended functions. It is checked if, by changing the input parameters to the weigher, load and speed, the expected output value change occurs. In practical experience, force balancing is achieved by loading the weigher by weights, chain or material, and then setting the height of weighed platform in such a way that the impact of tension force of conveyor belt is the smallest, that is the reading from the weigher changes insignificantly with stretching of the belt.

Setting the weigher zero to a great extent affects measurement accuracy, since this error is constantly being integrated into the measured mass flow. With modern belt weighers that contain microprocessors, it is possible to have automatic zero setting. The precondition for activating the automatic zero setting programme is defining the allowed error limit in percentage of maximum load [4]. The calibration shows how the nominal value of the indication of a mass flow relates to the conventional true values of the measurand, realized by a traceable reference standard [7] under defined conditions and at a specified date and time.

There are many tested belt weigher verification methods [3, 4], but only simulation of part of the linear load by special weights, which in turn add a load to the loading device of two belt weigher channels during work with the conveyer under load, include all factors affecting the belt weigher accuracy [3]. The letter mentioned method is free of the disadvantages of the verification, and it requires little labor without stopping the technological process.

4. Conclusion

Modern belt weighers are faced with the requirement for increasing accuracy, which can be achieved only by a thorough analysis of environment conditions, action of disturbing effects, and the influence of mechanical and physical processes which ocur during he measurement. The accuracy of weigher measurement system is determined by the accuracy of its basic elements - measuring apparatus and weighing electronics, as well as by the conditions of weigher mounting and the level of compliance of the conveying system to the metrological requirements of the weigher. This paper presents the dominant limiting factors to achieving the satisfactory level of belt weigher accuracy, the sources of these disturbing effects and the mechanisms of their action. The direction of further improvement of belt weighers, 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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