Measurement 129 (2018) 625–632

Contents lists available at ScienceDirect

Measurement

journal homepage: www.elsevier.com/locate/measurement

Compensation of automatic weighing error of belt weigher based on BP neural network

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ARTICLE INFO

Keywords:
Error compensation
BP neural network
Automatic weighing
Dynamic material experiment
Belt weigher

ABSTRACT

A belt weigher is widely used in industrial production and trade settlement; however, it is difficult to maintain its nominal measuring accuracy in service. With the belt weigher indication, average speed of belt, variation in belt sag, running deviation of belt, environmental temperature, and humidity as inputs, and the control instrument indication as output, a BP neural network model to compensate the automatic weighing error of the belt weigher is built. We obtained the sample data depending on the test system for the type evaluation of the belt weigher in the Jiangsu Institute of Metrology, as well as supplemental relevant parameters for the monitoring devices. The BP model is trained and validated using MATLAB. The validation results show that the absolute value of the maximum relative automatic weighing error output by the BP model is less than 0.5%, significantly lower than the error before using the BP model for compensation. The BP model is effective, feasible, and practical for compensating the automatic weighing error of the belt weigher.

1. Introduction

An electronic belt weigher (hereinafter referred to as belt weigher) can dynamically weigh bulk materials without interrupting the movement of the conveyor or quantitative segmenting material and is critical in industrial production and trade settlement [1]. The International Recommendations (OIML R) 50 2014 (E) state that a belt weigher can be divided into four accuracy classes as follows: 0.2, 0.5, 1, and 2 [2]. Typically, owing to the material flow rate, speed of belt, environment, accumulated belt creep over time, and other influencing factors, it is difficult for a belt weigher to maintain its nominal measuring accuracy during actual use. For example, for a belt weigher of accuracy class 0.5, experienced technical personnel have found that its absolute value of relative automatic weighing error in-service between two periodic verifications is typically more than 0.5% ruled in OIML R 50. However, the error is higher than 5% when it is used in a port, warehouse, and power plant with bad environmental conditions [3]. The lower measuring accuracy of the belt weigher negatively impacts the trade settlement of bulk materials, energy metering, energy conservation, and emission reduction. Therefore, the method to maintain a belt weigher within the nominal level of accuracy becomes an urgent industry problem and must be overcome before scientific and technological workers can be measured.

Since the invention of the belt weigher, its measuring accuracy has attracted much attention. In Germany (1962), A. Malting and P. Vierling first added the mechanics characteristic of a material in the dynamics analysis of belt and changed the model of the belt from an elastic rod to a viscoelastic rod [4]. In the former Soviet Union (1967), experts calculated the complete dynamic equation of stress wave in belt transmission [4]. In Netherlands (1994), LODEWIJKS first proposed to simplify the belt as a unit model of beam and subsequently introduced the dynamic analysis of the belt conveyor into a two-dimensional model [5]. In Australia (2016), Paul Munzenberger and Craig Wheeler built a laboratory test facility to measure the indentation rolling resistance of conveyor belts and improved the accuracy of the conveyor belt tension [6]. In China, Bingao Hong and Yiping Wei established a mechanics model of the belt weigher with a single roller and compensated the error in its operation process based on mechanics analysis [7]. Bin Dan of Chongqing University analysed all aspects of the influencing factors of the belt weigher in detail, built the mechanics model, and compensated for errors in its operation process [8].

However, both in China and abroad, studies regarding the automatic weighing error of a belt weigher primarily focus on analysing the mechanical properties of the belt and establishing a mechanical model to calculate and compensate for errors [4–11]. In fact, the influencing factors of a belt weigher in service are numerous, nonlinear, and interactive; therefore, it is impractical to determine their regularity and build an accurate compensation model of error based only on

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https://doi.org/10.1016/j.measurement.2018.07.080
Received 11 August 2017; Received in revised form 9 July 2018; Accepted 25 July 2018
Available online 29 July 2018
0263-2241/

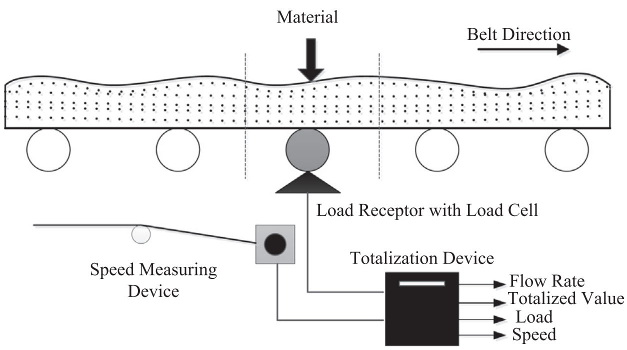

Fig. 1. Assembly diagram of belt weigher.

theoretical analysis. The following method is more feasible and practical in comparison: first, analyse the sources of automatic weighing error of the belt weigher, excavate their relatedness, and design a multiparameter monitoring program; subsequently, obtain sample data through proper calibration and, finally, determine the available empirical formula by supervised learning such as a neural network.

2. Analysis of the sources of automatic weighing error

2.1. Weighing principle of belt weigher

A belt weigher dynamically, continuously, and automatically weighs materials in a conveying process. Its assembly diagram is shown in Fig. 1.

Currently, a belt weigher obtains the totalised value of a material by integration: When the belt conveys a material to the weighing segment, the load cell obtains the instantaneous weight of the material$W_L(t)$ (kg), and the speed sensor obtains the instantaneous velocity of the belt (m/s). *Assumingthat* (m/s). Assuming that the weighing length is (m (m), and the duration of the whole weighing process is T(s), the totalised value $(kg)of$ (kg) of the material conveyed can be calculated as [4]

$$I = \int_0^T \frac{W_L(t)v(t)}{L} dt \tag{1}$$

The transmission chain of the corresponding measuring signal is shown in Fig. 2 [11].

By observing Fig. 2, and one can intuitively infer that the process of testing and transferring the signals of *and* and $W_L(t)$ may cause an automatic weighing error.

2.2. Sources of automatic weighing error

The sources of automatic weighing error can be summarised in five categories as follows [4]:

(1) Error of weighing gravity

According to literature research, the error of weighing gravity constitutes the largest source of automatic weighing error, i.e. approximately 85% of the total automatic weighing error [11]. The error of weighing gravity has a complicated composition and is the most difficult to analyse. Ideally, the load cell bears the real load value of the material on the weighing segment. In fact, owing to the conveyor belt with properties of a viscoelastic material, it will respond to changes when affected by external forces, and subsequently causes the load cell to receive unexpected signals and output a signal of weighing gravity $\hat{W}_L(t)$ that is different from $W_L(t)$, thus causing the error of weighing gravity. The sources of error of the weighing gravity contain the 'belt effect', vibration of belt, running deviation of belt, sag resistance, centrifugal force, and running resistance of belt. Although the sources of error of the weighing gravity are complicated, most of them can be reduced, eliminated, or consolidated by appropriate methods. Finally, they can be approximately summarised as the influence of tension and running deviation of the belt [9–12].

(2) Speed-measuring error

The speed measuring point is inconsistent with the stress point because of the improper installation location, the skid phenomenon that occurs randomly between the measuring wheel and conveyor belt, or the uneven speeds of the up and down surfaces of the belt. These may cause the speed sensor to output a signal of belt speed*thatisdifferentwith* that is different with, *thus*, thus leading to errors in speed measuring. However, with the improvement in signal processing technology, the error of speed measuring will not be the major source of automatic weighing error provided that the installation location of the speed sensor is reasonably selected.

(3) Signal processing error

In theory, the hardware and software designs of the functional units such as the multiplier, integrator, or display may affect the weighing result. However, with the popularity of high-precision integrated chips and display modules as well as algorithm optimisations in signal processing, signal processing errors will be negligible.

(4) Calibration error

A belt weigher requires regular calibrations to ensure its normal operating state. Occasionally, owing to the limitations of conditions, a belt weigher is calibrated under the static condition that is significantly different from the actual operating condition, and may cause errors in its subsequent automatic weighing. In principle, calibration errors also affect the accuracy of the output signal of the load cell. However, calibration errors can be effectively avoided provided that the actual material and the control instruments meet the regulation requirements during calibration.

(5) Environmental error

The belt weigher is often used in relatively poor conditions, e.g. unstable temperature and humidity . The volatile temperature and humidity will change the belt status and will significantly affect the stability and linearity of the weighing result of the belt weigher [13]. Temperature may also affect the electrical performance of the belt weigher body and the performance of the load cell. Therefore, the temperature and humidity should be monitored.

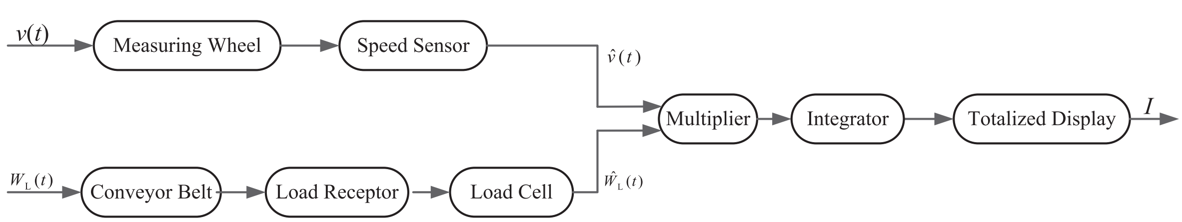

Fig. 2. Transmission chain of measuring signal.