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Continuous weighing on a multi-stage conveyor belt with FIR filter

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Abstract

Today higher speed of operation and highly accurate weighing of packages during crossing a conveyor belt has been getting more important in the food and distribution industries etc. Continuous weighing means that masses of discrete packages on a conveyor belt are automatically determined in sequence. Making the proper use of new weighing scale called a multi-stage conveyor belt scale which can be created so as to adjust the conveyor belt length to the product length, we propose a simplified and effective mass estimation algorithm under practical vibration modes. Conveyor belt scales usually have maximum capacities of less than 80 kg and 140 cm, and achieve measuring rates of 150 packages per minute and more. The output signals from the conveyor belt scales are always contaminated with noises due to vibrations of the conveyor belt and the product in motion. In this paper digital filter of finite-duration impulse response (FEB) type is designed to provide adequate accuracy. The experimental results on conveyor belt scales suggest that the filtering algorithm proposed here is effective enough to practical applications. As long as spaces between successive products are set within a specified range, the products can be weighed correctly even if products having different lengths are transported in random manner.

Keywords: Mass measurement; Continuous weighing; Conveyor belt; FIR filter

1. Introduction

Conveyor belt scales among these are most important for the production of a great variety of prepackaged products [1]. When a product is put on a conveyor belt, a measured signal from the conveyor belt scale is always contaminated by noises. Since the measured signal is usually in the lower

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frequency range, a filter which will effectively cut down noises at the high-frequency end can be easily designed. If, however, the product (like a cardboard box and a parcel etc.) has a low frequency component, where the noise intensity is high, it is practically impossible to separate the measured signal from noise. There still exist real problems for which engineering development in noise-filtering is needed.

The recent techniques of dynamic mass measurement have been investigated to find a way to obtain mass of the product under dynamic conditions. The key idea of dynamic measurement is that we take into consideration the various dynamic factors that affect the measured signal in the instrument to derive an estimation algorithm [2]. Ono [3] proposed a method that determines mass of dynamic measurement using dynamic quantities of the sensing element actuated by gravitational force. Also, Lee [4] proposed the algorithm of recursive least squares regression for the measuring system simulated as a dynamic model to obtain the mass being weighed. Successful dynamic mass measurement depends mainly on a mathematical model to achieve accurate measurement. But even the simple structure of a conveyor belt scale makes it difficult to obtain the exact model.

On the other hand, some filtering techniques have been applied to a signal processing for the conveyor belt scale [5]. In order to reduce the influence of dynamics and to improve the accuracy of mass measurement without losing the quickness, we have proposed a simplified and effective algorithm for data processing under practical conveyor belt's vibrations [6–9].

2. Basic configuration

2.1. Outline of conveyor belt scales

The fundamental configuration of the conveyor belt scales may be represented schematically as shown in Fig. 1. The load receiving element is a belt conveyor supported by a loadcell at the edge of the frame. The detected signal by the loadcell is sent into a FIR digital filter through a DC amplifier. The mass of the product can be estimated as the maximum value evaluated from the smoothed signal.

The simulations and the experiments are carried out under the following conditions:

length of product: $l_i = 20–140$ cm length of the belt conveyor:

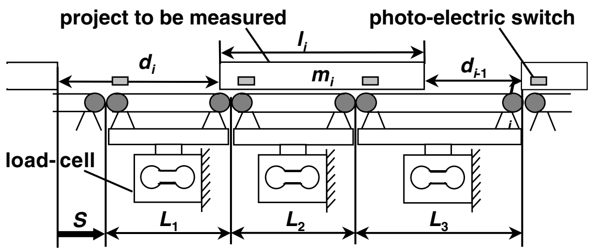

Fig. 1. Multi-stage conveyor belt scale.

L_j ($L_1 = 40$ cm, $L_2 = 40$ cm, $L_3 = 60$ cm)
mass of the product: $m_i = 20–80$ kg distance between products:
$d_i = 20–100$ cm conveyor belt speed: $v = 132$ m/min required accuracy: $\leqslant \pm 0.7\%$ sampling frequency: $f_s = 2000$ Hz (sampling period: $T_s = 0.5$ ms)

The total length of the multi-stage conveyor is considered in the following patterns:

$L = L_3$(=60 cm): for the single-stage conveyor belt scale,
$L = L_1 + L_2$(=80 cm): for the two-stage conveyor belt scale 1,
$L = L_2 + L_3$(=100 cm): for the two-stage conveyor belt scale 2,
$L = L_1 + L_2 + L_3$(=140 cm): for the three-stage conveyor belt scale.

2.2. Minimum distance between products

The minimum distance between products must be examined correctly by the geometrical conditions. In case of a three-stage conveyor belt scale, let the minimum travelling distance which is necessary for reaching the steady state value of an output signal be S and the minimum distance which is shorter, d_{i-1} or d_i, be d_S. The hypothetical time changes of a loading input can be shown in Fig. 2 under the condition that $d_S < L - l_i$. When the product m_i is transported onto the conveyor belt scale, the minimum travelling distance S is necessary for measuring the mass of products accurately. As can be seen from Fig. 2, the minimum distance d_S between products can be expressed by:

$$2d_S \leqslant L - l_i + S(d_S = \min(d_{i-1}, d_i)) \quad (1)$$

By applying actual values of the product length l_i and the minimum distance S (=20 cm) to Inequality