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# IMPROVING CONTINUOUS MASS WEIGHING USING THE SOFTWARE COMPENSATION METHODS

# USAVRŠAVANJE KONTINUALNOG MERENJA MASE PRIMENOM SOFTVERSKIH KOMPENZACIONIH METODA

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***Abstract:*** *Transportation of bulk solids is becoming increasingly important in many industries. Every year millions of tons of coal pass through large belt scale systems for the transport and distribution. An incorrect measurement of just one-tenth of a percent can make a significant difference in profit. This paper deals with software compensation methods of some parasite influences on continuous mass weighing system.*

***Key words:*** *transport, belt scale, accuracy, software, compensation*

***Apstrakt:*** *Transport velikih masa sve je značajniji u brojnim industrijskim oblastima. Preko milion tona uglja transportuje se i distribuira godišnje putem transportnih sistema sa ugrađenim protočnim vagama. Greška u merenju od samo desetog dela procenta može znatno umanjiti dobit. U ovom radu izložene su softverske metode kompenzacije parazitnih uticaja na sistem kontinualnog merenja mase.*

***Ključne reči:*** *transport, vaga na traci, tačnost, softver, kompenzacija*

## 1 INTRODUCTION

There is a general trend toward weighing on the move, because of the advantage of the ability to handle large tonnages without interrupting the material flow. Belt weighers are special type of continuous mass flow measuring instrument.

The bulk of material is guided over a weighing platform arranged below the belt and limited by two carrying idlers. The platform load applies a force on belt weigher load cells.

The measured mass flowrate normalized to physical magnitude t/h is given by:

## 1 UVOD

Merenje velikih količina materijala danas se najčešće obavlja u toku samog procesa transporta, s obzirom da se merenje mase obavlja bez prekida protoka materijala. Vage na traci predstavljaju specijalnu klasu instrumenata za merenje protoka mase.

Mereni materijal vodi se preko mernog mosta vage, koji obuhvata deo transportne trake ograničen nosećim valjcima. Merni most kao prijemnik opterećenja deluje na merne ćelije.

Normalizovana vrednost merenog protoka mase u t/h data je izrazom:

$$Q = \frac{3,6}{g \cdot L_{\text{eff}}} \cdot F \cdot v \text{, (t/h),} \qquad (1)$$

where: F - weight force of the load being measured,
$L_{eff}$ - effective belt length,
$v$ - belt speed and
$g$ is gravitational acceleration.

Weight force is transformed in the strain gauge load cells to an electrical signal and this signal is measured and further processed by appropriate weighing electronics (Figure 1).

$$Q = \frac{3,6}{g \cdot L_{\text{eff}}} \cdot F \cdot v \text{, (t/h),} \qquad (1)$$

gde su: F - sila merenog opterećenja,
$L_{eff}$ - efektivna dužina mernog mosta,
$v$ - brzina transportne trake i
$g$ - gravitaciono ubrzanje.

U mernoj ćeliji na bazi mernih traka, merena sila se pretvara u električni signal, koji se dalje procesira primenom odgovarajuće elektronike (slika1).

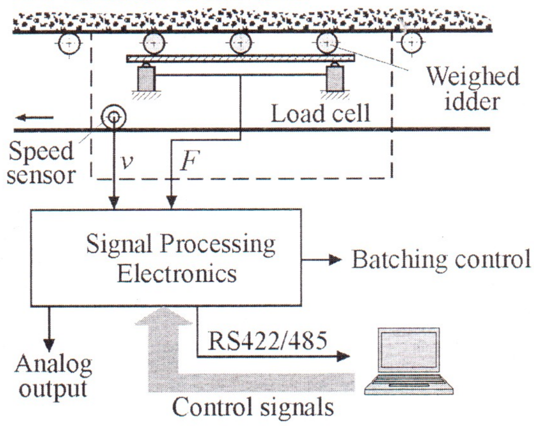


*Figure 1 Priciple view of a belt weigher*
*slika 1 Princip rada vage na traci*

For speed measurement, friction wheel optical encoder are used which is designed to acquire the belt speed at the inside of the return belt.

Many belt scale appliances require the accuracy of mass flow to be as high as ±0,5% of a set point and this requirement can only be satisfied by reliable measurement and compensation of each source of inaccuracy incorporated in the measurement method and procedure [1].

This paper describes some of the adaptive compensation methods that adjust belt weigher construction to minimize the influence of error sources.

Za merenje brzine primenjuje se optički enkoder sa frikcionim točkićem, koji se postavlja na unutrašnjoj strani povratnog dela transportne trake.

Brojne primene vaga na traci zahtevaju tačnost merenja protoka mase veću od ±0,5% nominalne vrednosti, što je moguće postići pouzdanim merenjem i naknadnom kompenzacijom svih parazitnih uticaja na smanjenje tačnosti merenja, a koji predstavljaju sastavni deo merne metode i postupka merenja [1].

U ovom radu opisane su neke od adaptivnih kompenzacionih metoda, kojima se smanjuje osetljivost mernog sistema vage na uticaj remećućih veličina.

## 2 COMPENSATION OF TEMPERATURE AND CREEP INFLUENCE

Strain gauge load cell output voltage varies not only with strain, but with ambient temperature as well [2].

## 2 KOMPENZACIJA UTICAJA TEMPERATURE I PUZANJA

Signal na izlazu merne ćelije sa otporničkim trakama zavisi ne samo od opterećenja, već i od temperature okoline [2].

If the load cell is a part of software controlled automatic belt weighing system, temperature influence compensation and response adjustment are performed in nominal conditions without additional resistors in load sensor circuit.

Ako merna ćelija predstavlja deo softverski praćenog automatskog mernog sistema vage na traci, kompenzacija temperaturnog uticaja i podešavanje ravnoteže i osetljivosti, obavljaju se u radnim uslovima, bez dodatnih otpornika u kolu pretvarača.

Fig.2 presents a classical type of temperature error compensation which is carried out by means of programmable gain amplifier (PGA), multiplexer, analog-to-digital converter (A/D) and by appropriate software.

Na sl.2 predstaljeno je tipično kolo za kompenzaciju temperaturnog uticaja, a koje se sastoji od programibilnog instrumentacionog pojačavača (PGA), multipleksera, analogno-digitalnog konvertora (A/D) i odgovarajućeg softvera.

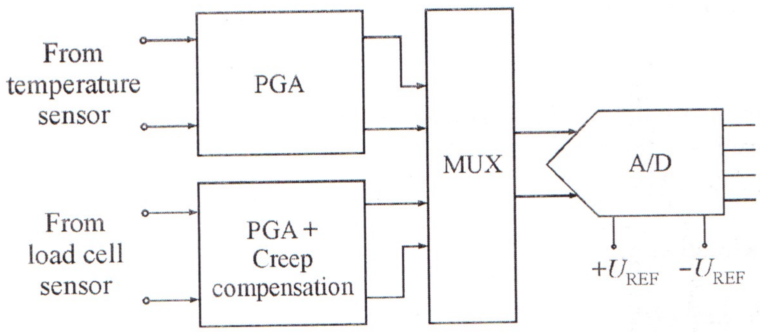


Figure 2 Software temperature influence compensation
slika 2 Softverska kompenzacija uticaja temperature

The creep is the temporal change of sensor output signal, under the constant load and with other influence factors unchanged. Error due to the creep is negligible in the usual technical applications, but it is often the basic limiting factor of achieving a high level of accuracy in strain gauge load cells.

Puzanje je promena izlaznog signala pri nepormenjenom opterećenju i konstantnim radnim uslovima okruženja. Greška usled puzanja može se zanemariti kod standardnih primena, međutim, često predstaljva jedan od osnovnih ograničavajućih faktora pri tačnom merenju sile mernim ćelijama sa otporničkim mernim trakama.

A number of the hardware creep error compensation techniques are well known in technical literature. New smart type force sensors are equipped with appropriate software creep error compensation techniques which are insufficiently researched as yet. One of the compensation methods is based on the assumed exponential function:

$$f_k = a \cdot (1 - e^{-t/t_p}) \quad (2)$$

where parameters $a$ and $t_p$ may be calculated from the condition that the compensated creep error is minimal [3].

Brojne hardverske kompenzacione tehnike dobro su poznate u tehničkoj literaturi. Savremeni "inteligentni" senzori sile opremljeni su odgovarajućim, još uvek nedovoljno istraženim softverskim kompenzacionim tehnikama. Jedna takva kompenzaciona metoda zasniva se na pretpostavljenoj eksponencijalnoj funkciji:

$$f_k = a \cdot (1 - e^{-t/t_p}) \quad (2)$$

gde se parametri $a$ i $t_p$ određuju iz uslova minimalnog kompenzovanog odstupanja puzanja [3].

According to the experimental results made in Electrical Engineering Institute "Nikola Tesla" in Belgrade software compensated creep error is more than tree times smaller relative to equal hardware compensation creep error.

Na osnovu eksperimentalnih rezultata dobijenih u Elektrotehničkom institutu "Nikola Tesla" u Beogradu, softverski kompenzovana greška puzanja tri puta ja manja od odgovarajuće iste hardverski kompenzovane greške.

## 3 CONVEYOR CHARACTERISTICS INFLUENCE COMPENSATION

### 3.1. Slip and belt drift

Belt slip and horizontally drift can be compensated by means of additional belt circuit sensor ("Namur", NS in Figure 3). Belt is also equipped with triangle metallic marking with the side towards direction of travel right-angled to belt. "Namur" sensor output is pulse signal proportional to width of triangle. (A 50% belt drift corresponds to half width $b$ of triangle, Figure 3).

After a few belt circuits and by means of signal processing electronics, belt influence is automatically compensated [4].

### 3.2. Variable belt inclination

Belt weighers with variable belt inclination are equipped with a so-called cosinus pendulum which compensates this influence on mass measuring results. The additional potentiometer ($R_P$ in Figure 4) is switched into the load cell circuit and its resistance depends on pendulum position. $R_V$ is calibration resistance and $R_{LC}$ is load cell input resistance in Figure 4.

## 3 KOMPENZACIJA UTICAJA KARAKTERISTIKA TRANSPORTERA

### 3.1. Klizanje i pomeranje trake

Kompenzacija uticaja klizanja i horizontalnog pomeranja trake može se izvršiti pomoću dodatnog senzora ("Namur", NS na slici3). Na transportnoj traci nalazi se i metalna oznaka trouglastog oblika, sa pravim uglom u smeru kretanja trake. Namur senzor daje na svom izlazu povorku impulsa proporcionlanu širini trougla. (Pomeranju trake od 50% odgovara odstupanju širine trougla $b$ za 1/2, slici 3) .

Nakon određenog broja punih obrtaja transportne trake i primenom elektronike za obradu signala, uticaji trake automatski se kompenzuju [4].

### 3.2. Promena nagiba trake

*U slučaju transportnih traka sa promenjivim* nagibom, vage se opremaju kolom sa tzv. kosinusnim klatnom, kojim se kompenzuje ovaj uticaj na rezultat merenja mase. U kolo merne ćelije ubacuje se dodatni potenciometar ($R_P$ na slici 4) čija otpornost je određena položajem pozicionog klatna. Na slici 4 $R_V$ je kalibracioni otpornik, a $R_{LC}$ je unutrašnja otpornost merne ćelije.

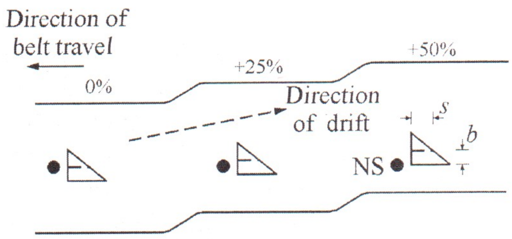


*Figure 3 Automatic compensation belt influence*
*slika 3 Automatska kompenzacija uticaja trake*

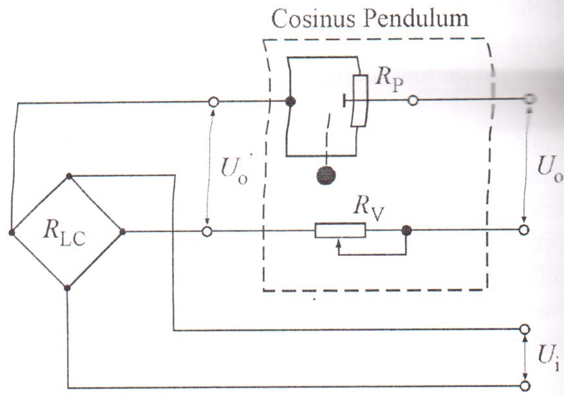


*Figure 4 Variable belt inclination correction*
*slika 4 Korekcija promenjivog nagiba trake*

The position of the cosinus pendulum is right next to the weighing platform and aligned with spirit level. When belt inclination ($\alpha$) change occurs it is manifested as resistance $R_P$ change and voltage power supply $U_O'$ change. Load cell output voltage $U_O'$ is proportional to inclination change ($\alpha$) and it can be used for appropriate software compensation [4].

Poziciono klatno postavlja se neposredno uz merni most vage i poravnava primenom libele. u slučaju promene nagiba transportne trake ($\alpha$) menja se otpornost potenciometra $R_P$ i napon napajanja kola mosta Uo'. Napon na izlazu merne ćelije porporcionalan je promeni ugla nagiba trake ($\alpha$) i ova promena može se iskoristiti za softversku kompenzaciju [4].

### 3.3. Batching control

If belt weigher is used for batching control for constructional reasons there is certain distance between the batching point and the weigher platform location. Therefore, the measuring mass flow does not correspond to the current feed rate on discharge point.

The point of measurement can be shifted to the point of feeding by means of appropriate software and special speed dependant delay element (Figure 5).

Batching can be controlled via belt drive or via material feeder.

### 3.3.Kontrola doziranja

U slučaju primene vage na traci za regulaciju doziranja, iz konstrukcionih razloga, postoji izvesna pomerenost tačke doziranja u odnosu na položaj mernog mosta vage. Zbog toga, izmerni protok mase ne odgovara stvarnoj količini materijala u tački doziranja.

Poklapanje merne tačke sa tačkom doziranja može se ostvariti primenom odgovarajućeg softvera i specijalnog elementa koji unosi kašnjenje u zavisnosti od izmerene brzine (slika 5).

Doziranje materijala može se kontrolisati regulisanjem pogona transportera ili kontrolom utovara materijala.

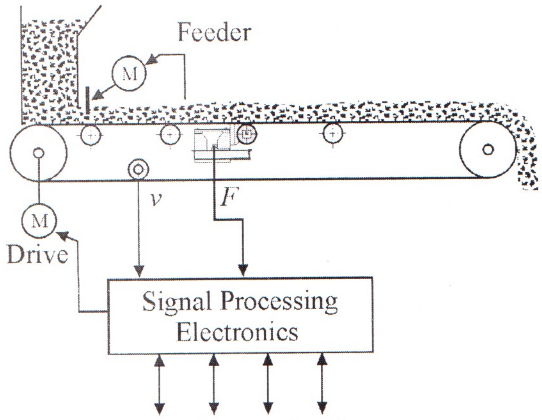


*Figure 5 Feeding control*
*slika 5 Kontrola doziranja*

## 4 CONCLUSION

The purpose of this paper is to present sources and practical experiences in the belt weighing error suppression. Brief descriptions of some adaptive standard and special compensation methods are brief reviewed.

## 4 ZAKLJUČAK

U ovom radu predstavljeni su uzroci i praktična iskustva vezana za smanjenje greške merenja primenom vage na traci. Ukratko su opisane neke od adaptivnih standardnih i specijalnih kompenzacionih metoda.


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