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CONVEYOR BELT SCALE REALIZATION USING THE MICROCONTROLLER

REALIZACIJA VAGE NA TRAČNOM TRANSPORTERU PRIMENOM MIKROKONTROLERA

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Abstract: *Appliance of microcontrollers enables intelligent measuring devices generation development, which is characterized by very good flexibility due to specifications of measuring requirements and user demands. The main advantages of microcontroller-based belt conveyor scales are described in this paper, considering the measuring accuracy increase and the possibility of the realization of the complex control algorithms, which is not possible using the standard digital circuits.*

Key words*: belt scale, microcontroller, intelligent device, measuring accuracy*

Apstrakt: *Primena mikrokontrolera omogućava razvoj generacije inteligentnih mernih instrumenata koji se odlikuju velikom felksibilnošću, s obzirom na specifičnosti mernih uslova i zahteve korisnika. U radu su opisane osnovne prednosti primene mikrokontrolera kod vaga na transportnim trakama, s obzirom na povećanje merne tačnosti i mogućnost primene složenih kontrolnih programa koje nije moguće ostvariti upotrebom jednostavnijih digitalnih kola.*

Ključne reči*: vaga na traci, mikrokontroler, inteligentni uređaj, merna tačnost*

1 INTRODUCTION

Unearthed mass coal measurement has important place in coal digging and refining control as in coal valorization for sale. Coal distribubution to great consumers is frequently carried out by continual conveyor belts. Usage of the truck scales should be incompatible and unfeasible and this scales measuring efficiency should be unsatisfactory in this transportation system.

The mass measurement on conveyor belts forms the complex area as the measurement is being made on something, which is dynamic as material flow.

Based on various physical principles, there exist the numerous continuous mass flow measurement solutions. Some examples are: loss- in-weight scales, weigh feeders, impac flow metering t

1 UVOD

Merenje mase iskopanog uglja zauzima značajno mesto u kontroli procesa kopanja, prerade uglja i valorizacije uglja kroz prodaju. Prenos iskopanog uglja do velikih potrošača najčešće se obavlja preko neprekidnih, pokretnih transportnih traka. U ovakvom sistemu transporta, merenje mase kolskim vagama bilo bi nekompatibilno i samim tim neracionalno, a efikasnost ovakvog merenja bila bi nezadovoljavajuća.

Merenje mase na transportnim trakama predstavlja kompleksnu oblast s obzirom na činjenicu da se radi o dinamičkom merenju.

Postoji veliki broj rešenja kontinualnog merenja protoka mase, čiji se rad zasniva na različitim fizičkim principima. Neki od primera su: vage na principu gubitka težine, merni dozatori, vage na principu udarne sile i vage na traci.

scales and belt conveyor scales. By comparative analysis of their characteristics, and as a result of experience over years, belt conveyor weighers have proved to provide optimum solution to mentioned tasks.

The important advantages of belt scales appliance are:

- owing to its dimension and design, it can be easily incorporated into nearly every conveyor belt systems,
- possibility for real-time weighing applications in the most demanding environments, without the need for the conveyor to stop,
- with microcontroller-based measuring electronic, the high accuracy and numerous measuring functions can be achieved,
- with analog and digital outputs and serial interface, intelligent belt scales are also suitable for applications where material feeding have to be continuously regulated,
- good integration capabilities into the mining information system.

To better understand belt scale measurement system, its basic elements are briefly presented.

2. BELT SCALE BASIC OPERATION PRINCIPLE

The material flow rate on conveyor belt is obtained as the product of two measuring quantities: the belt load on a given belt selection and the belt speed [1]. The main parts of an inteligent belt scale measuring system are (Figure1):

- primary unit (load measuring unit and speed measuring sensor) and
- microcontroller-based electronic (signals conditioning and processing) secondary unit.

The load measuring unit comprises: weighing platform, which comprises defined section of conveyor belt and works as load receiver, and weighing idlers incorporated into the conveyor belt construction and supported by single or multi-load weighing system. There are variety of weighing platform constructions, which include one, two or larger number of weighing idlers.

Uporednom analizom njihovih karakteristika i kao rezultat dugogodišnjeg iskustva, vage na traci su se pokazale kao optimalan izbor s obzirom na pomenute zahteve.

Osnovne prednosti primene vaga na tračnim transporterima su:

- zahvaljujući različitim dimenzijama i konstrukcijama, mogu se ugraditi u skoro svaki sistem tračnog transportera,
- moguće je merenje u realnom vremenu u najzahtevnijim radnim uslovima, bez potrebe za zaustavljanjem transportera,
- primenom merne elektronike na bazi mikrokontrolera, moguće je postići visok nivo tačnosti i ostvariti brojne merne funkcije,
- s obzirom na to da su opremljene analognim i digitalnim izlazima i industrijskim serijskim interfejsom, inteligentne vage na traci su pogodne i za kontinualnu kontrolu doziranja,
- moguće je uključivanje u širi informacioni sistem rudnika.

U cilju boljeg razumevanja mernog sistema vage na traci, u radu su ukratko opisani njeni osnovni delovi.

2 OSNOVNI PRINCIP RADA VAGE NA TRACI

Veličina protoka mase kod vage na traci dobija se kao proizvod dve merne veličine: opterećenja na definisanom delu trake i brzine kretanja trake [1]. Osnovni delovi mernog sistema inteligentne vage na traci su (slika 1):

- primarni deo (sklop za merenje opterećenja i senzor brzine trake) i
- sekundarni deo (elektronski sklop za obradu signala) na bazi primene mikrokontrolera.

Osnovni delovi skopa za merenje opterećenja su: merna platforma, koja obuhvata definisani deo transportne trake i predstavlja prijemnik opterećenja i merni valjci, koji su ugrađeni u konstrukciju transportera i koji se oslanjaju na sistem mernih ćelija. Postoje različite konstrukcije mernih platformi, koje obuhvataju jedan, dva ili veći broj mernih valjaka.

According to accuracy viewpoint, optimal selection is so-called multi-idler belt scales.

Sa stanovišta tačnosti merenja protoka mase, povoljnije su merne platforme sa većim brojem mernih valjaka.

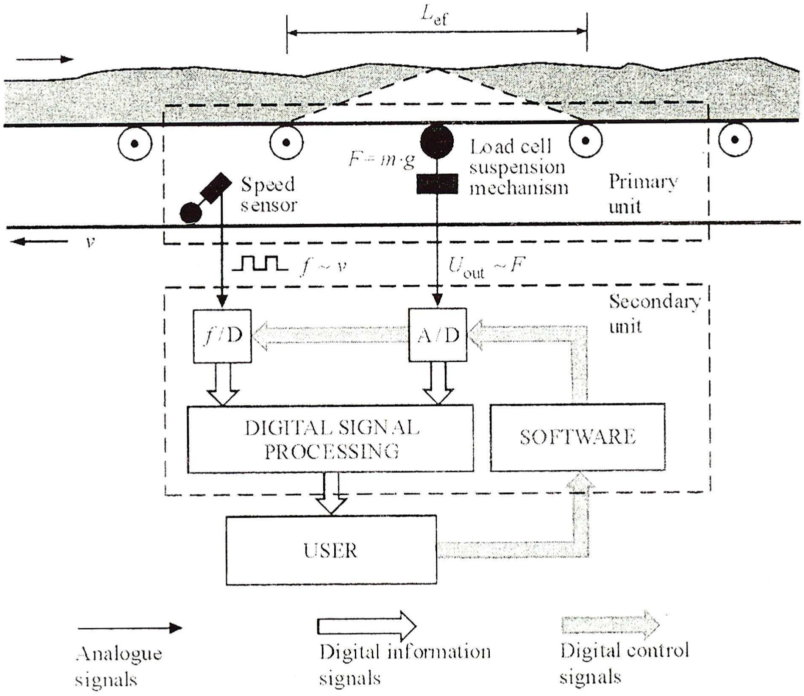

Figure 1 Inteligent belt scale concept
slika 1 Princip rada intelignentne vage na traci

However, the problem of weighing platform construction and its influence on measuring accuracy is more comprehensive and more complex. Its consists of series of structural, technology and exploitation parameters, as: dimensions, conveyor belt inclination and profile, rubber belt elasticity, belt tension mode and height, operation scale capacitance, environment temperature, wind impact and many others. Therefore, the mathematical model, which should comprise all mentioned effects, can be settled only approximately.

Međutim, problematika konstrukcije merne platforme i njenog uticaja na tačnost merenja znatno je šira i kompleksnija. Ona obuhvata niz konstruktivnih, tehnoloških i eksploatacionih parametara, kao što su: dimenzije, nagib i profil transportne trake, elastičnost gumene trake, način i vrednost njenog zatezanja, radni kapacitet vage, ambijentna temperatura, udari vetra i još mnoge druge uticaje. Prema tome, matematički model koji bi obuhvatio sve navedene uticaje, može se postaviti samo aproksimativno.

Transformation of the mechanical force, by which the load affects the conveyor belt due to gravity, into the electrical quantity is carried out by means of the strain-gauge load cell. About 80% of all electromechanical scales in the world are manufactured with this type of transducer [2] and one of their main favorable characteristics is the fact that, depending on the spring element design which has been used (shear, bending or compression) they may have many different sizes and shapes, and each of them is the best selection over a particular load range.

Transformacija mehaničke sile, kojom materijal deluje na transportnu traku usled sile gravitacije, u električni signal obavlja se u mernoj ćeliji baziranoj na primeni mernih traka. Oko 80% svih elektromehaničkih vaga u svetu izrađeno je sa ovom vrstom pretvarača [2], a jedna od njihovih osnovnih prednosti je činjenica da se, u zavisnosti od konstrukcije elastičnog elementa (izložen smicanju, savijanju ili kompresiji), mogu ostvariti njihovi različiti oblici i dimenzije, pri čemu svaki predstavlja optimalan izbor u određenom opsegu opterećenja.

The belt speed sensor is realized as optical sensing units, equipped with friction wheel which

Senzor brzine ostvaruje se kao optički merni uređaj, opremljen obrtnim točkićem koji se is mounted at the inside of the return conveyor belt. In contact with belt, it generates a stream of pulses, whose number represents a unit of belt displacement and the frequency is directly proportional to belt speed.

Signals proportional to measured load and conveyor belt speed lead into electronic processing unit. By usage of microcontroller, in this unit the feed rate and the total conveyed mass in the defined time interval are calculated and the communication with external devices such as master computer and printers are provided.

Depending on belt width and idler troughing, belt conveyor scales can be used on flow rates between approximately 0.1t/h to 10000t/h. Theoretically, these scales can be used on mass flow measurement with error of about ±0.2%. In the practice, however, their measurement uncertainty is larger and can achieves until few percentage. There are some limitative factors in practice realization, which have to be taken into consideration, as: incomplete definition of the measuring method, unideal scale performance and the other factors which may affect the measuring result. One way of achieving the higher levels of mass flow weighing system performance is the application of load cells with digital output (so-called smart load cells [3]) and microcontroller-based signal processing system.

3 SECONDARY BELT SCALE UNIT

Microcontroller application in the scale systems, especially in belt scales, has the enormous importance considering the measurement accuracy, the reliability and efficiency. Hardware nonperfection and the systematically errors existence in every measurement result, can be reduce by means of microcontroller. By developing of the information system, belt scales become their elements, which include acceptance of technical standards and philosophy of information technique: transmission, acquisition processing, archiving and presen-tation of measuring results.

On the Fig.2. the microcontroller-based belt scale basic concept is presented by the means of the data flow block diagram.

Given that intelligent belt scale works either as an independent measuring instrument, or coupled

montira na unutrašnjoj strani povratnog dela trake. U dodiru sa transportnom trakom, on generiše povorku impulsa, čiji broj predstavlja jedinicu pomeraja trake, a frekvencija je direktno proporcionalna brzini trake.

Signali proporcionalni merenom opterećnju i brzini trake dovode se u elektronski sklop za obradu signala. Primenom mikrokontrolera izračunava se veličina protoka materijala i ukupna masa protekla u nekom definisanom vremenskom intervalu i obezbeđuje komunikacija sa spoljnim uređajima, kao što su nadređeni računar, štampač ili drugi.

U zavisnosti od širine trake i profila nosećih valjaka, vage na traci mogu se koristiti za merenje protoka materijala u opsegu od približno 0.1t/h do 10000t/h. Teorijski, ove vage mogu meriti proteklu masu sa greškom od oko ±0.2%. U praksi, međutim, njihova merna nesigurnost je znatno veća i može dostići red veličine nekoliko procenata. Postoje izvesni ograničavajući faktori, koji se moraju uzeti u obzir u uslovima praktične primene, kao što su: nepotpuna definicija mernog metoda, neidealna karakteristika vage i drugi faktori koji mogu uticati na merni rezultat. Jedan od načina postizanja višeg nivoa radnih karakteristika sistema merenja protoka mase je primena mernih ćelija sa digitalnim izlazom, (takozvane inteligentne merne ćelije [3]) i obrada signala na bazi mikrokontrolera.

3 SEKUNDARNI DEO TRAČNE VAGE

Primena mikrokontorolera u vagarstvu, naročito kod vaga na traci, od ogromnog je značaja sa stanovišta tačnosti, pouzdanosti i efikasnosti merenja. Nesavršenost hardvera, prisustvo sistematskih grešaka u svakom rezultatu merenja moguće je u velikoj meri redukovati primenom mikrokontrolera. Razvojem informacionih sistema, vage na traci postaju elementi ovih sistema, što podrazumeva i prihvatanje tehničkih standarda i filozofije informacione tehnike: prenosa, akvizicije, obrade, arhiviranja i prezentacije rezultata merenja.

Na slici 2 predstavljen je osnovni koncept vage na traci bazirane na primeni mikrokontrolera, s obzirom na dijagram toka podataka.

Kako inteligentna vaga na traci radi kao samostalni merni instrument, ili u sprezi sa with master computer, the indicators of measurands, scale operating mode, change of parameters and hardware operation correctness can be therefore shown on display in two different ways: through alphanumeric indicator on the secondary unit case, or on the master computer, which has been connected to microcontroller by means of adequate interface system.

nadređenim računarom, postoje dva načina za izbor indikacije mernih veličina, režima rada vage, promenu parametara i kontrolu ispravnosti rada hardvera: preko tastature ili preko alfanumeričkog pokazivača na kućištu sekundarnog dela uređaja ili pomoću nadređenog računara sa kojim je mikrokontroler povezan preko odgovarajućih sistema sprege.

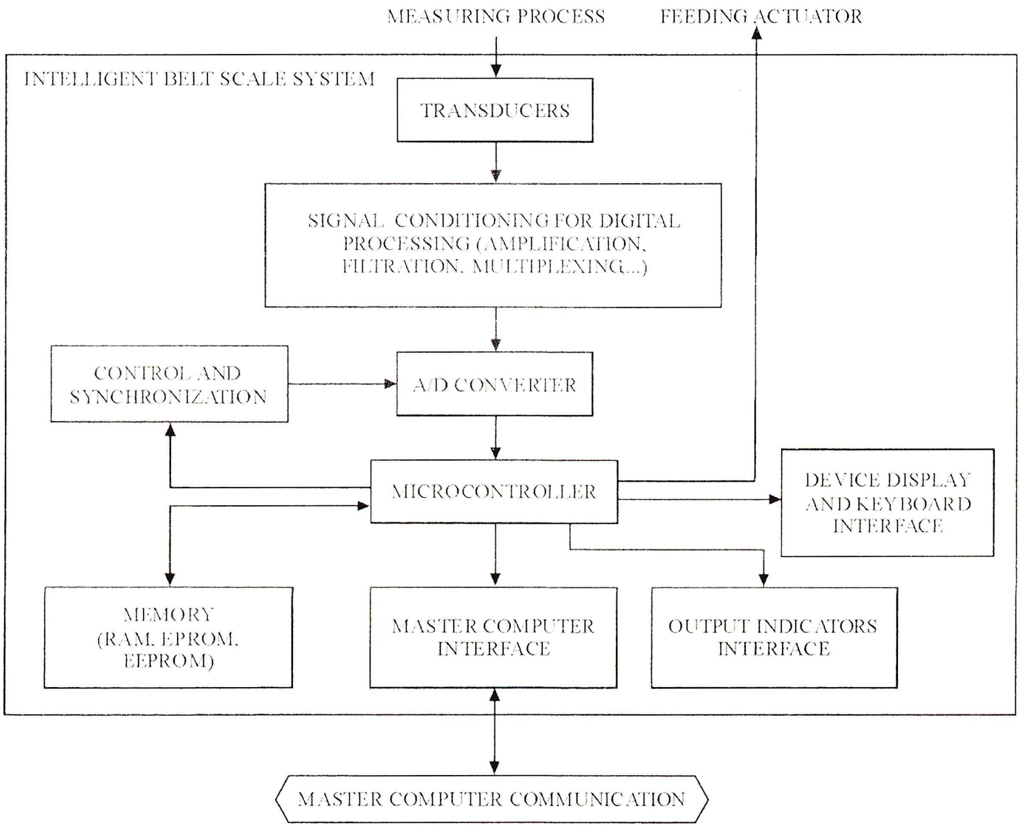

Figure 2 Microcontroller-based belt conveyor scale data flow diagram
slika 2 Dijagram toka podataka kod vage na traci na bazi primene mikrokontrolera

4 MICROCONTROLLER APPLIANCE ADVENTAGES

Considering the measuring accuracy, microcontroller application enables:

- zero (offset) regulation and automatic statically and dynamically scale zero setting;
- automatic belt scale calibration by check weights to correct a belt scale constant, due to the exploitation scale parameters varation;
- digital signals filtering in order to reduce the noise signal level;

4 PREDNOSTI PRIMENE MIKROKONTROLERA

S obzirom na tačnost merenja, primena mikrokontrolera omogućava:

- kontrolu nule (ofseta) vage i automatsko statičko i dinamičko podešavanje nule vage,
- automataku kalibraciju vage, ispitivanjem sa materijalom, u cilju korekcije konstante vage, nastalu kao rezultat varijacije eksploatacionih parametara vage,
- digitalnu filtraciju signala, u cilju smanjenja signala smetnji,

- measuring signal digital processing: multiplication, addition, difference, integration and others;
- linearization of transducers performances;
- automatic correction measu-ring results considering the measured ambiental parameters: temperature, pressure and others.

By the means of the belt scale reliability, microcontrollers enable:

- the main elements belt scale operation control via device keyboard or by application of the master computer;
- statistic measuring process control;
- measuring data accomodation to control, regulation and archiving requirements;
- measuring information comparasion due to the defined mathematical model;
- wrong operating states diagnosis in regard to the conventional standards [4]: operating with nonallowable minimal load, external vibration level increase, overloading and others;
- checking belt scale system for faults, and setting the scale in the out of operation if an error is found.

Measuring data distributions via standard interfaces, modems and networks, by usage of standard, reliable communicational protocols allows:

- transmission of the measuring information at the large distances,
- larger transmission speed,
- multi-load-cells systems communication possibility.

The adventages of microcontroller usage in belt scale, especially are noticable in the way of measuring results presentation. By linking belt scale and the master computer and by usage of the appropriate software, there exist possibility of measurands monitoring via comupter monitor in real-time. However, the new computer graphic attainments enters very slowly into the scale systems, considering the thousand years practice of mechanical scales.

Primary unit signal processing possibility, using the complex mathematical algorithms, has considerable influence on the belt scales accuracy increase. Besides the device is capable of autocontroling the secondary unit operation, by implementation the adequate methods of sensors signal software analysis

digitalnu obradu mernih signala: množenje, sumiranje, diferenciranje, integraciju i drugo,
- linearizaciju karakteristika mernih pretvarača,
- automatsku korekciju rezultata merenja s obzirom na izmerene ambijentalne parametre: temperaturu, pritisak i druge.

S obzirom na pouzdanost rada vage na traci, mikrokontroleri omogućavaju:

- kontrolu ispravnosti rada svih osnovnih elemenata vage preko tastature uređaja ili primenom nadređenog računara,
- statističku kontrolu mernog postupka,
- prilagođavanje mernih podataka zahtevima upravljanja, regulacije, arhiviranja,
- poređenje merne informacije prema projektovanom matematičkom modelu,
- dijagnosticiranje statusnih stanja koji odstupaju od propisanih vrednosti [4]: rad vage sa nedozvoljenim minimalnim opterećenjam, povećan nivo vibracija, preopterećenje vage i slično,
- provera grešaka u menom sistemu vage i prekid rada vage u slučaju otkrivene neispravnosti.

Prenos rezultata merenja preko standardnih interfejsa, modema i mreža, primenom standardnih, pouzdanih komunikacionih protokola, omogućava:

- prenos merne informacije na veće udaljenosti,
- veću brzina prenosa,
- mogućnost komunikacije sa sistemima koji se sastoje od većeg broja mernih ćelija.

Prednosti primene mikrokontrolera posebno su evidentne u načinu prezenntacije rezultata merenja. Povezivanjem sa nadređenim računarom i primenom odgovarjućih softvera, postoji mogućnost praćenja merenih signala na monitoru računara, u realnom vremenu. Nova dostignuća računarske grafike, međutim, relativno sporo prodiru u praksu vagarstva, s obzirom na hiljadugodišnju praksu primene mehaničkih vaga.

Mogućnost obrade signala sa primarnog dela primenom složenih matematičkih algo-ritama, bitno utiče na povećanje tačnosti vaga na traci. Osim što je uređaj u stanju da vrši samokontrolu ispravnosti funkcionisanja sekundarnog dela, implementiranjem odgovarajućih metoda it can be possible to obtain extended information about the primary unit operating states.

Intelligent belt scale is an universal measurement device, which could be used in different application areas, simply by changing the microcontroller algorithm.

softverske analize signala dobijenih sa senzora, moguće je dobiti dodatne informacije o stanju primarnog dela uređaja.

Inteligentna vaga na traci predstavlja univerzalan merni sistem, koji se može prilagoditi različitim primenama, jednostavnom promenom programa mikrokontrolera.

5 CONCLUSION

Accuracy of material mass measurement on conveyor belts is one of the basic prerequisite according to which overall effectiveness of conveyance system is calculated. The high accuracy level can be achieved by means of so-called inteligent belt scales, where the main controlled processing functions and error compensation methods are carried out by means of microcontroller and adequate software techniques. Attention is not given here to the technical details of these measuring concept, as it is adequately addressed elsewhere, than to the advantages of the microcontroller-based mass flow measurement is made of, by reason of the possibility of expanding the mathematical model of existing belt scale measuring system.

5 ZAKLJUČAK

Tačnost merenja mase tereta na tračnim transporterima predstavlja jedan od osnovnih preduslova određivanja ukupne efektivnosti transportnog sistema. Postizanje visokog nivoa merne tačnosti moguće je ostvariti primenom takozvanih inteligentnih vaga na traci, kod kojih se osnovne funkcije obrade signala i metode kompenzacije grešaka ostvaruju primenom mikrokontrolera i odgovarajućih softverskih protokola. Rad nije baziran na tehničkim detaljima ovog mernog principa, s obzirom na to da se njihov opis može naći u brojnim analizama iz ove oblasti, već na prednosti primene mikrokontrolera u oblasti merenja protoka mase, obzirom na mogućnost proširenja matematičkog modela postojećeg mernog sistema vaga na traci.

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