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VOLUME FLOW MEASUREMENT OF BULK SOLIDS ON CONVEYOR BELTS

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Abstract: *Volume flow measurement is a special method of continuous measurement of bulk volumes on high-capacity conveyor belts. A measurement uncertainty of less than 0.5% can be achieved using appropriate measurement equipment. A measurement system for monitoring the volume or total mass of bulk solids on conveyor beltsis briefly described in the paper, focusing on its characteristics and suggesting possible areas of application*

Key words: *mass flow, volume measurement, surface contour, conveyor*

1 INTRODUCTION

The bulk solids surface contour on the conveyor belt represents a two-dimensional measured object in an infinitesimal time interval. As the volume moves continuously with the conveyor belt, the problem boils down to determining the three-dimensional volumetric flow of the bulk material.

Regardless of the type of implementation, the measurement system that determines the surface contour of the conveyed bulk material consists of: a coherent light source, a reflected signal detector and an electronic unit for signal processing and volume calculation using suitable software.

A laser scanner with a beam deflection lens system is used as a source of monochromatic coherent light with high intensity radiation in the PSD (Position Sensitive Detector). The distance between the receiver and the surface of the bulk material can be determined:
based on the length of time needed for the laser pulse travelling at the speed of light to reach the surface of the bulk material and be reflected back to the scanner (“time of flight“ measurement), from which the distance to the measured object is calculated (Sick’s measuring system Bulkscan) [1, 2],
using an optical radiation-to-photovoltage converter, where the position of the reflected light on the photosensitive surface of the receiver is used to indicate the distance between the receiver and the surface contour of the measured object (Jansen & Heuning’s VMS 2000) [3].

2 MATHEMATICAL MODEL

The conveyed bulk volume can be described with simple formulas using the quantities shown in Figure 1.

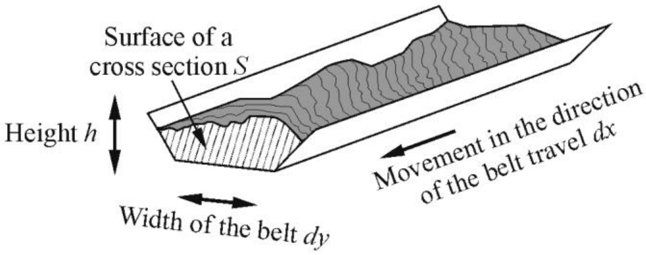

Figure 1 *Quantities used for conveyed volume flow measurement*

The volume *V* is calculated by integrating the measured height *h* along the infinitesimal distances *dx* and *dy* along the length *x* of the conveyor belt:
Zapremina materijala *V* računa se integraljenjem izmerenih visina *h* duž beskonačno malih rastojanja *dx* i *dy* na dužini trake *x*:

$$V = \int_0^x \int_0^y h dx dy \, . \tag{1}$$

If the width of the conveyor belt is divided into *N* equal parts of width *dy* and height h_i, and representing the distance Δx by the belt speed *v* and time unit t_s, $\Delta x = v \cdot t_s$, the volume is calculated by summing up the finite elements:

$$V = \sum_{i=1}^{N} \frac{h_i + h_{i+1}}{2} \Delta y \cdot v \cdot t_s \, . \tag{2}$$

The bulk solid volume moving on the conveyor belt is determined by: the belt speed, the height of the bulk material on the conveyor belt and the width of the conveyor belt. The measurement uncertainty ΔV is therefore determined by the measurement uncertainties of the said parameters and may be represented by the following expression:

$$\Delta V = \sqrt{\left(\frac{\partial V}{\partial h}\right)^2 \Delta h^2 + \left(\frac{\partial V}{\partial y}\right)^2 \Delta y^2 + \left(\frac{\partial V}{\partial v}\right)^2 \Delta v^2 + \left(\frac{\partial V}{\partial t_s}\right)^2 \Delta t_s{}^2} \,. \quad (3)$$

The volume measurement uncertainty is practically determined by the magnitude of the elements Δx, Δy and Δh. Assuming that ΔV is largely determined by the height measurement uncertainty, Δh, the accuracy of h needs to correspond to the desired accuracy of the volumetric flow.

3 TRIANGULATION METHOD

One of the ways to determine the bulk solid height h on the conveyor belt is to apply the triangulation method - an angle measuring method (Figure 2.a). Using converging lenses, the photosensitive position sensor receives a part of the reflected light and any change in the height of the measured object, Δh, is detected as a position change Δh_D relative to the reference level:

$$\Delta h_D = \frac{\Delta h}{\mathrm{tg}\alpha} \,. \quad (4)$$

For volumetric flow measurements, a laser with cylindrical lenses, which projects a line along the width of the measured object, is used instead of a point laser source.

For two-dimensional detection of reflected light a Charge Coupled Device (CCD camera) composed of photo-sensitive elements is used. CCD detectors convert light into electrical signals that differ in voltage depending on the intensity of the reflected light from a measuring surface [4, 5]. Each pixel corresponds to one photo-element and the CCD detector, which consists of, say, 512 by 512 separate pixels, has 512 by 512 photo-elements, spaced along the sensor array (Figure 2.b). With this CCD detector resolution and a sampling rate of, say, 50 images per second, the data processing speed is 12.5 Mbyte/s

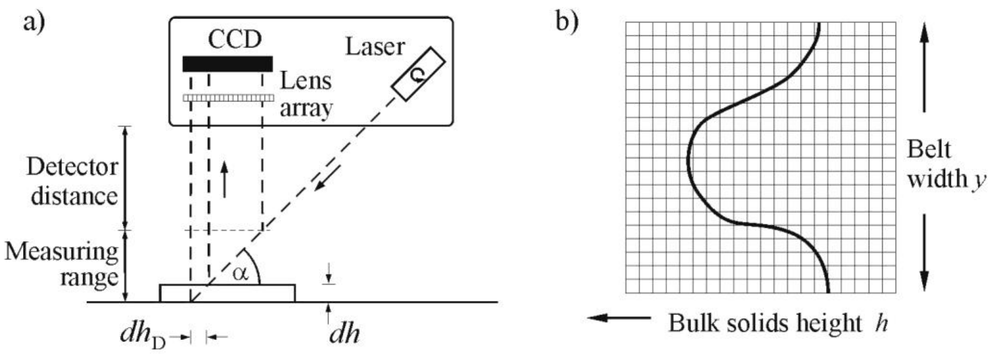

Figure 2 a) Height measurement applying the triangulation method
b) Image of laser beam reflected on a camera

4 ELECTRONIC PROCESSING OF MEASURED DATA

The electronic data processing unit is comprised of a digital signal processor and a video module, whose basic functions are to:

- determine the height of the bulk material based on received video data;
- detect measurement uncertainties of the system; and
- communicate with peripheral optical sensors.

Output signals from the CCD detector are transmitted to the A/D converter and video processing unit. In the data reduction unit, useful information (i.e. the position of the laser beam) is extracted from the digitized video signaland a data reduction factor of the order of 100 can be applied

Communication software is used for exchanges between the user and the measurement system. It links different parts of the measurement system and controls measurement operations, data readout and entry, and system analysis and management.

Applying cutting-edge software, hardware-reduced video signals are "read out" at a predefined sampling rate, their validity is verified and the surface contour is computed [6].

To determine the volumetric flow based on the derived surface contour, the distance traveled on the belt needs to be known. It is obtained from the optical encoder, which is mounted on the inside of the return conveyor belt [7].

The software can be made to support the following control functions as well: presence of video signal, contamination of the front end of the laser scanner or camera, proper operation of data reduction hardware and speed-measuring optical encoder, operating temperature, etc. The measurement system can also be used for other control and regulation functions, as well as for: determining the weight/mass of bulk solids (if density is known), adjustment of production and correction factors, dispensing of large amounts of bulk material, power supply, correction of measured data and presentation of measured data in a text file

5 CONCLUSION

Identification of the surface contour of moving bulk solids is a classic problem of modern measurement technology. The optoelectronic method is commonly applied today for that purpose, based on the reflection of the optical signal from the surface of the object whose volume is to be determined. Using a suitable measurement system and software, the volume flow on a moving conveyor belt can be determined with 99.5% reliability. If the bulk density of the material is known, the measurement system can also be used to determine the mass flow and total mass without interrupting the conveyance process.

Da bi se na osnovu dobijenog profila odredio protok zapremine materijala, neophodan je i podatak o pređenoj dužini trake, koji se dobija sa izlaza optičkog enkodera, koji se postavlja na unutrašnjoj strani povratnog dela trake [7].

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