The choice of a method for non-contact assessment of the composition of briquetted charge materials

A A Kul’chitskii and D A Kashin
Saint Petersburg Mining University, 2, 21st Line, St Petersburg 199106, Russia

E-mail: dmitrij.kashin.94@bk.ru

Abstract. The issue considered in this paper is concerned with the problem of quality control of non-ferrous briquetted metallurgical materials by volume-weight method. The article reviews and evaluates existing systems of contactless analysis of dimensions and structure of the material. The required accuracy of geometry control is calculated and the possibility of using optical control to determine the dimensions is experimentally confirmed. The choice of the optical system of active type consisting of the camera of technical vision and illumination for the solution of problems of control of the sizes and surface properties of a charge material is proved.

1. Introduction

Today, there is an obvious trend of growth in the number of different types of ferrous and non-ferrous metals, such as cable scrap, cans, chips. Recycling of raw materials, especially non-ferrous metals, is economically justified, as it requires much less energy comparing to primary production. Also, the load on the environment is significantly reduced: the amount of air pollutants and waste gases is reduced several times.

As a rule, various thin-walled wastes, such as aluminum cans, copper electrical scrap, scraps and chips of various metals are pressed into briquettes before being sent for melting [1], [2], [3]. Briquetting of the charge material facilitates its transportation, loading into the furnace and allows to reduce the melting time, thereby reducing energy consumption. For incoming quality control of briquetted scrap usually used visual inspection with selective destruction of several briquettes, which can allow the involvement in the production of raw materials with a critical content of foreign elements and impurities for the melting process. It is also possible to use high-precision radiation monitoring, but its cost and the lack of the possibility of analyzing raw materials in the stream mode are not economically justified in solving this problem [4], [5]. Therefore, to solve the problem of incoming control of the composition of the briquetted material, a method is needed to determine the percentage of the target metal content in the briquette in the continuous control mode.

The concept of quality of materials includes comprehensive indicator that includes the composition of materials, which can be determined on the basis of the true density (volume-weight method) or surface analysis of foreign matter that is in these materials. In addition, in some cases it is necessary to control the geometry of the briquettes (no spilling).
2. Research methodology

These problems can be solved by a control system that combines an optical system for determining the volume of the briquette with a weight control system.

According to the results of the analysis (surface analysis with the help of technical vision cameras or computed tomography), the average percentage of porosity (air availability) of the briquette is determined. This parameter is necessary to calculate the volume of airless space of the briquette.

In the continuous control mode on the belt, the package is weighed on the conveyor scales to obtain data on its mass \( m \). To determine the mass of the briquette in the flow mode, it is assumed to use a weight belt conveyor built into the line. Such devices are often used in industries where it is necessary to accurately determine the mass of moving objects [6].

Next, define its geometric parameters, the calculation of the amount of airless space briquette, is calculated true density.

According to the obtained data on the density and the average value of the degree of porosity, the calculation of the deviation of the true density of the object from the reference value of the target metal density - the degree of debris.

The choice of automation equipment for the implementation of this technique should be carried out taking into account the following requirements:

- conveyor belt width size should match the size of the briquettes is not less than 300x400x650;
- possibility of non-contact analysis of the volume in the continuous control mode;
- measurement accuracy of at least 3%.

The optical system for determining the dimensions of the briquette can be built on the basis of discrete distance meters, which control the surface [8]. The system consists of a measuring frame installed across the conveyor belt and distance sensors placed on the frame (figure 1a). The value of the volume of the briquette is obtained as a result of summing the elementary volumes for each time cycle of its passage through the frame.

A passive optical system consisting of two vision cameras can also be used. The passive principle uses light energy from third-party sources that are not connected to the measurement system (natural light, lamps) to transmit size information [9], [10]. The implementation of such a technique when using technical vision requires a minimum of two cameras located in mutually perpendicular planes (for example, the top and side). The layout diagram of the implementation of this method is shown in figure 1b. The resulting 2D images are an estimate of the geometry of briquettes in sections.

![Figure 1](image-url)  
**Figure 1.** Scheme of installations for determining the volume of the briquette: a - the use of distance sensors, b - the use of two cameras of technical vision.
3. Experimental research

Experimental studies to determine the size of the briquette, carried out in the installation, similar to that shown in figure 1A (but with three sensors) showed that the relative measurement error is within 1%. This satisfies the required accuracy for the correct estimation of the object parameters taking into account the scale of the experiment 1: 5 (figure 2).

In addition, the volume value clearly changes when the briquette is skewed figure 2B, which can be explained as a consequence of the inability of the sensors used in the experiment (Sharp GP2D12) to dynamic measurements.

![Graphs assessing the accuracy of control of the quantity of briquette at different positions: a) linear, b) angular.](image)

Increasing the number of sensors can improve the accuracy of control, but it increases the cost of system implementation. In addition, the use of this solution does not allow to control the absence of briquette spilling.

Upon usage of technical vision cameras in accordance with the scheme shown in figure 1B results are comparable with previous method accuracy (were less than 1% is obtained).

With the help of a program created in LabView, the image received from the camera is converted to black and white, 8-bit. Then a background is subtracted from the image. The area of the screen that contains the working image (region of interest – ROI) is pre-assigned. These preparation operations are necessary, as the algorithms embedded in the virtual devices of the IMAQ Vision library find the points of brightness difference to determine the boundaries of the object. For the most accurate detection of the object boundaries, the upper and lower borders of the pixel values are adjusted according to the gray scale.

The next operation is to calculate the area occupied by the object for the top view image (figure 3) and calculate the distance between the edges to calculate the height (figure 4) by the method of fixing (clamping). The volume of the briquette is the product of the height of the briquette by the area of its upper part.

Since the dimensions are calculated in pixels, the system is pre-calibrated to assign real coordinates to each point displayed and to compensate for system-specific errors.
Figure 3. Processed image of the prototype briquette.

Figure 4. Fragment of the program with the found edges of the object.

The graph (figure 5) of the briquette volume relative value from the angle of its skew in the transverse position clearly demonstrates an advantage of this method in comparison with the previous one. The volume value does not change practically at any turn of the prototype.

![Graph](image)

**Figure 5.** The dependence of the relative measurement error on the angle of rotation of the briquette in a linear position.

Another advantage of this method is the implementation of direct measurements with a direct estimation of the size of all coordinates, where no need to take into account additional parameters such as the speed of the conveyor. In addition, cameras can also be used for superficial analysis of extraneous inclusions, using software blocks for recognition of individual elements by means of pattern matching or neural network.

However, it should be noted that briquettes made of charge material can vary significantly in reflective properties, which can negatively affect the accuracy of the size estimation.

4. **Suggested solution**

According to the results of the experiments, it was found that it is advisable to use digital cameras to obtain measuring information.

However, when using a passive type of measurement system, significant distortions are possible, since the image processing uses a contrast selection of the object on the border formed by the points of the brightness drop or by the calibration model used for a fixed position. Deterioration of accuracy is possible with insufficient or incorrectly selected lighting.

Active type optical systems allow usage of initial information generating device most often used like laser source of structured illumination, which is a light strip or a system of strips. The light silhouette of
the object formed in this way falls into the lens of the registration device installed in a way forming a triangle with the radiation source and the object of control.

The most widely used systems are active type, in particular 2D laser scanners. For example, the scanners series RF627 company Realtek or series LMS 4 from Sick. In the case of determining the profile and volume of a cubic body, it is sufficient to use only one scanner of this type. At the same time, high measurement accuracy is provided, not more than 0.2% of the measuring range [10], [11].

However, the considered problem of briquetted material composition control also requires the ability to analyze the surface composition of the charge these scanners cannot provide. Therefore, for the simultaneous solution of these two problems, it is proposed to use an active type system based on a digital camera and a laser illumination system.

The layout solution of the proposed control system is shown in figure 3.

![Figure 6. Active type optical measuring complex.](image)

Such a system can be described as a compromise solution between the two previously considered, since in this case the use of automation equipment is minimized while maintaining the required control accuracy. At the same time, it is possible to control the absence of briquette spillage and the possibility of surface analysis for the type of scrap and impurities.

Of all the methods considered, the most accurate are systems based on 2D scanners and a system with a technical vision camera and illumination. The passive type system does not provide acceptable accuracy in streaming control, and the accuracy of the system from the distance sensors is tied to their number, which leads to a potentially high cost relative to other solutions. Control of surface properties can be carried out only by two of the above systems using machine vision cameras.

Obviously, the most suitable way to determine the size and surface properties of the briquetted charge material is to use an active system with a camera and laser illumination.

5. Conclusion

The proposed method of composition of briquetted charge materials is a relatively inexpensive solution for streaming of non-contact analysis of briquetted charge materials. The results of experimental studies have shown the possibility of using optical control of briquettes volume to solve the problem.

Comparative analysis of technical means and based on them possible layout solutions for the creation of briquette geometry control systems, allowing to determine the volume of briquetted raw materials with sufficient accuracy (up to 1%), and having ease implementation with relatively low cost, in comparison with devices for radiation control, showed their inadequate adaptation to the implementation of comprehensive control of the dimensions and composition of raw materials.
The optical system of the active type consisting of the technical vision camera and the structured illumination can allow to solve a problem of complex control: the sizes and surface properties of a charge material.

References

[1] Capuzzi S and Timelli G 2018 Preparation and Melting of Scrap in Aluminum Recycling *Metals* 8 249
[2] Fedorova E R and Firsov A Yu 2018 *IOP Journal of Physics: Conf. Series* 1015 032035
[3] Pawlek R P 2000 *Secondary Aluminum Industry* (Light metal Age) pp 13-20
[4] Alekseev A I 2016 Scientific bases of processing of aluminum-containing waste *Journal of Mining Institute* 219 428-34
[5] Spencer D B 2005 The High-speed Identification and Sorting of Nonferrous Scrap *JOM* 57 (4) 46-51
[6] Artemyev E A, Artemyev A A and Tsarenko E V 2010 *A method of continuous measurement of the weight of moving materials on belt conveyors, a system for its implementation and the weight roller support of the belt conveyor* (The patent of the Russian Federation 2401994C1)
[7] Sarvin A A, Kulchitsky A A and Naumova A K 2011 *Optical methods of contactless measurements of linear displacements* (St. Petersburg North-Western correspondence technical University)
[8] Heyduk A 2016 Laser triangulation in 3-dimensional granulometric analysis *Archives of Mining Sciences* 61 15–27
[9] Matthew B White 1975 *Laser distance measuring device* (United States Patent US3901597A)
[10] Molleda, J, Usamentiaga R and Garcia D 2013 On-Line Flatness Measurement in the Steelmaking Industry *Sensors* 13 10245–72
[11] Stringer B S and Elwood M K 1997 *Laser-based dimensioning system* (United States Patent US5606534A)