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OPTICAL ANALYSIS OF FRACTIONAL PARTICLES

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Abstract

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Analysis of fractal particles, like sawdust or dust, by sieve method is rather difficult in terms of the measuring system and time-consuming at samples evaluation. The results give only partial information of the particle dimensions in an examinable sample. Modern optical methods of fractal particles analysis in the industry complexly acquaint with the sample; they provide information about the particle rate and size, average, maximum and minimum occurring dimension, particle surface, and shape composition of a sample.
In our experiment were evaluated wood particles with IP camera IQEye 702. Camera captures the scene with sawdust and send video via ethernet. In program Matlab is in time captured in this video one picture, which is further processed and in it are found measured particles. Subsequently are measured required parameters of captured particles.

Keywords: particle dimensions, sawdust, camera, image analysis, Matlab

INTRODUCTION

Measurement of fractal particles dimensions is an important part of the industry. Such an analysis allows to evaluate the characteristics of the machines used in woodcutting and optimizes the selection of a suitable separating device for contingent sorting of sawdust from the dust. The measurement evaluation informs about the potential emissivity of the working environment and the health risks at working in such environment, since small wood dust may have negative effects on the human body, even it was found that oak threshold is carcinogenic.

Currently, the detection of sawdust dimensions uses the sieve analysis. This results in a weight proportion of a certain dimensional fraction based on the total weight of the sample. During this analysis the sample is damaged, whereas the sample is shaken down through the sieves. Therefore it is not possible to repeat the measurements of the same sample. Due to these deficiencies, an optical method of sawdust dimensions measuring is preferable; it also gives more information about the measured sample.

MATERIALS AND METHODS

For an experimental fractional particles measuring by optical method the measuring area was constructed that consists of a support frame carrying the camera capturing downward. As measured particles wood sawdust was used that was placed into the scene captured by the camera under the support frame.

Camera IQEye 702, used in measuring, have maximum resolution 2 megapixels. At scanning, the full camera picture is not processed, as unnecessary data would have appeared in the peripheral parts of the scanned image. This step also increases the transmit speed of data from the cameras to remote computer. To download images from the camera, the Matlab function imread is applied:

I1 = imread('http://194.160.160.167/now.jpg').

In the term (1), the picture from the camera with IP address 194.160.160.167 is written into variable I1. Therefore, this variable represents the scanned picture from camera.

Configured camera system brings up some measurement distortion. Rotating the camera to scanned plane causes perspective distortion; the camera lenses bring to the images the spherical distortion. In terms of experiment results relevance, both these distortions must be removed before the measurement.

Spherical (barrel) distortion occurs when the magnification of the lens decreases with axial distance causing each image point to move radially towards the centre of the image. This results in the characteristic "barrel" shape. Following algorithm removes this picture distortion:

Determination of distortion centre coordinates:

$$dx = x_c + x_b,$$

$$dy = y_c + y_b,$$

where

x_c, y_c.....image centre coordinates,

x_b, y_b..... offset for the optical centre.

The computing of distance between the centre of distortion and currently calculated point in distorted image is calculated by following equation:

$$R_d = \sqrt{(x_d - dx)^2 + (y_d - dy)^2}\ ,$$

x_d, y_d ....distorted image coordinates.

Magnification factor is determined as follows:

$$M_d = 1 - k + \frac{k}{x_c^2} R_d\ ,$$

where

k ....distortion parameter.

The resultant image has then undistorted coordinates:

$$x_u = d_x + M_d \times (x_d - d_x),$$

$$y_u = d_y + M_d \times (y_d - d_y).$$

Original image without spherical distortion is on the picture Fig. 1a, spherical distortion removed by described technique is shown in the Fig. 1b.

Perspective distortion is caused by deviation of cameras from the axis perpendicularly to the plane of scanning. The robustness of assembled cameras does not allow simultaneous scanning perpendicularly to the scanned plane, so the cameras have to be rotated at an angle to scan the same scene.

To remove the perspective distortion, the function *imtransform* in Matlab is applied:

$$B = imtransform(A, tform),$$

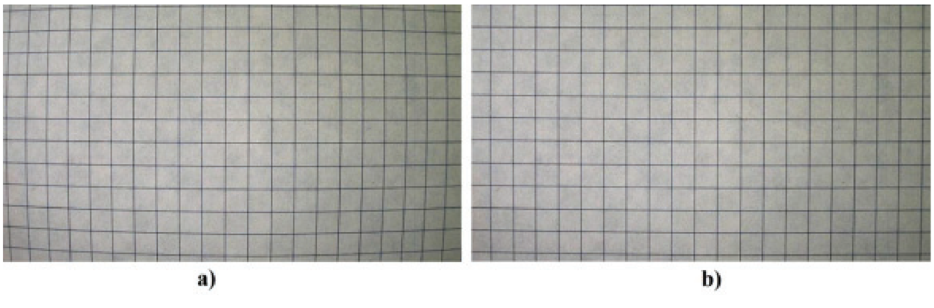
where

B..........input transformation image,

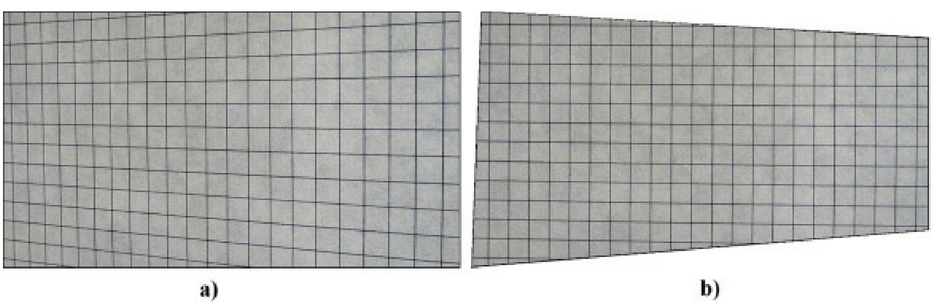
A .... output transformation image,

tform.... transformation structure.

Transformation structure *tform* includes transformation vectors that modify the position of input image corners (Fig. 2a) whereby the image is straighten out into desired shape (Fig. 2b).



1: *Spherical distortion in the image: a) original image, b) removed spherical distortion*



2: *Perspective adjusting a) original image, b) adjusted perspective*

Transformation vectors for scanned image format are found out experimentally; the structure tform is created in program Matlab by the function maketform:

$$tform = \text{maketform}(\text{'projective'}, U, X).$$

The equation (9) builds a transform structure *tform* for a two-dimensional projective transformation that maps each row of U to the corresponding row of X. The U and X arguments are each 4-by-2 and define the corners of input and output quadrilaterals. No three corners can be collinear. The size and shape of perspective distortion are given by the position of scanning camera compared to the scanned plane.

After removal of the spherical and perspective distortion, the objects in scanned image have their real proportions, the measuring of sawdust dimensions follows. Using the proposed optical method of sawdust volume characteristics measurement, the perimeter and volume of particles, average particle size, and maximum and minimum size can be measured beside the particle dimensions. The proposed program determines:

- the smallest and the biggest particle dimension,
- the volume and perimeter of every particle.

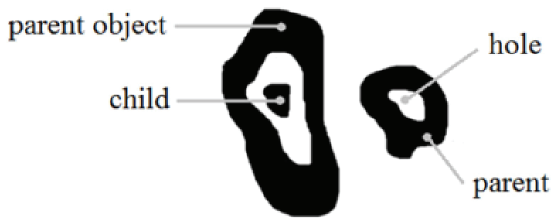
Before the measurements, the individual sawdust is identified in the image by thresholding. Choosing the threshold is therefore very important and must be appropriately selected. If the threshold is too high, marginal points could be eliminated from the sawdust; if it is too small, the sawdust could be artificially enlarged. To search the objects it is necessary that the image remains binary after thresholding; white spaces represent measured sawdust and the background remains black.

After removing of the measured sawdust background by thresholding, the necessary parameters of measuring samples are detected. Identification and determination of the necessary characteristics of sawdust in the image are performed in the program Matlab using function bwboundaries:

$$[B, L, N, A] = bwboundaries(I1, \text{'}noholes\text{'}).$$

The function *bwboundaries* traces the exterior boundaries of objects, as well as boundaries of holes inside these objects, in the binary image I1. *bwboundaries* also descends into the outermost objects (parents) and traces their children (objects completely enclosed by the parents, Fig. 3. I1 must be a binary image where nonzero pixels belong to an object and 0 pixels constitute the background.

This function returns N, the number of objects found, and A, an adjacency matrix. The first N cells in B are object boundaries. A represents the parent-child-hole dependencies. A is a square, sparse, logical matrix with side of length max(L(:)), whose rows and columns correspond to the positions of boundaries stored in B.



3: *Areas in objects*

In such founded out objects, the required information is searched using the function *regionprops*. With this function, multiple parameters can be specified in binary objects, such as the number of pixels in the objects (their surface), coordinates of the object, the corner points of the object, the object perimeter, and many others.

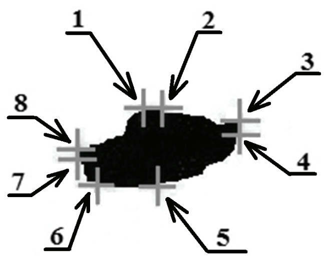
Biggest and Smallest Sawdust Dimension

The dimension of measured sawdust is determined by eight edge points (Fig. 4) obtained using the function:

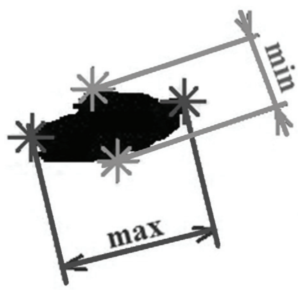
$$I1 = regionprops(I, \text{'}Extrema\text{'}).$$

Parameter *Extrema* specifies the extreme points in the region. Each row of the matrix contains the x- and y-coordinates of one of the points. The format of the vector is [top-left top-right right-top right-bottom bottom-right bottom-left left-bottom left-top]. This property is supported only for 2-D input label matrices.

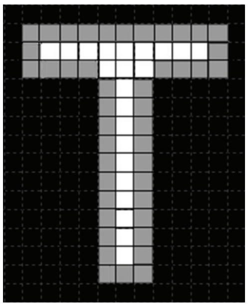
Maximum, respectively, minimum dimension is determined as the largest, respectively, the shortest distance between the opposite extreme points (Fig. 5). All combinations of opposite points (left and right, top and bottom) are being compared,



4: *Eight extreme points of area*



5: *Largest and shortest distance*



6: *Perimeter of the region*

while the longest and the shortest distance between them is not found.

Volume and Size of Sawdust

Similar to sawdust dimensions, the perimeter and volume of particles is calculated using function regionprops applied to the founded particles. The volume of sawdust is determined by:

Volume = regionprops(*I1*, '*Volume*').

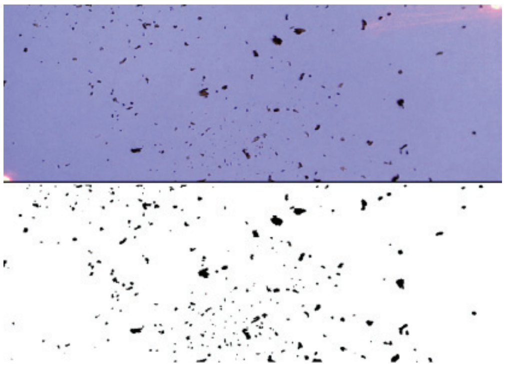
This function returns a matrix of actual pixels regions in input binary image *I1*. The particle perimeter is calculated by the function:

P = regionprops(*I1*, '*Perimeter*').

This function returns a distance around the boundary of the region. regionprops computes the perimeter by calculating the distance between each adjoining pair of pixels around the border of the region (Fig. 6).

Using the described functions, the measured samples of sawdust are analysed and the required information about the sample is evaluated. All numerical data about sawdust are in picture units - pixels. For the correct expression of the measured data, those values have to be converted into metric system units. Conversion is performed by the transmission coefficient obtained by measuring the properties of an object with known dimensions by means of the proposed system.

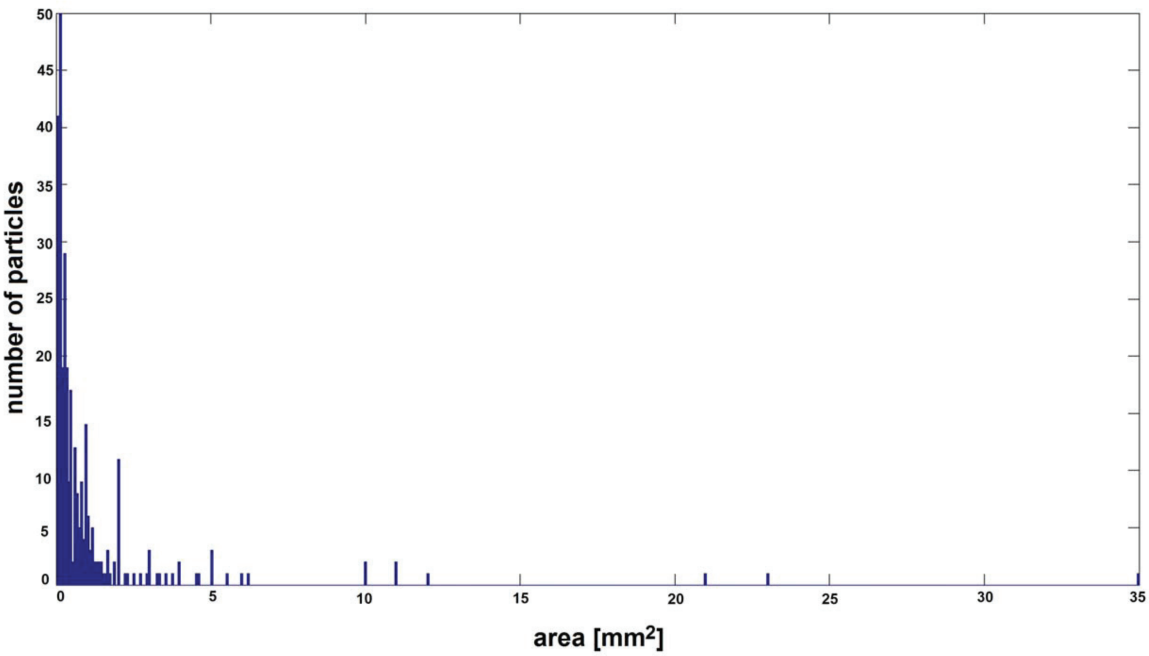
The image of examinable sample of sawdust and identified particles are shown in the Fig. 7.



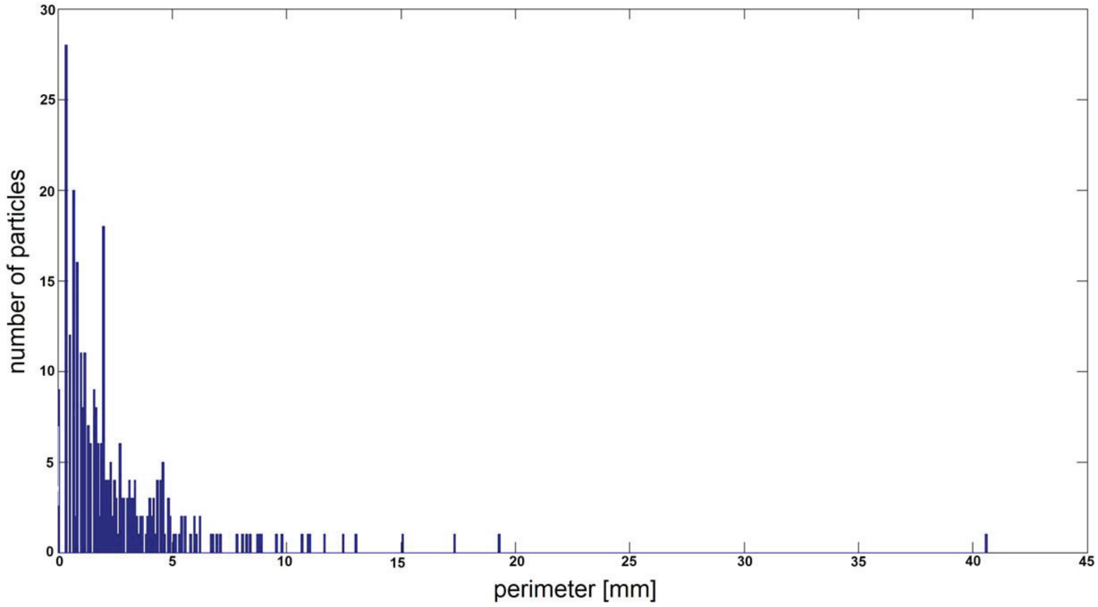
7: *Identified sawdust*

RESULTS

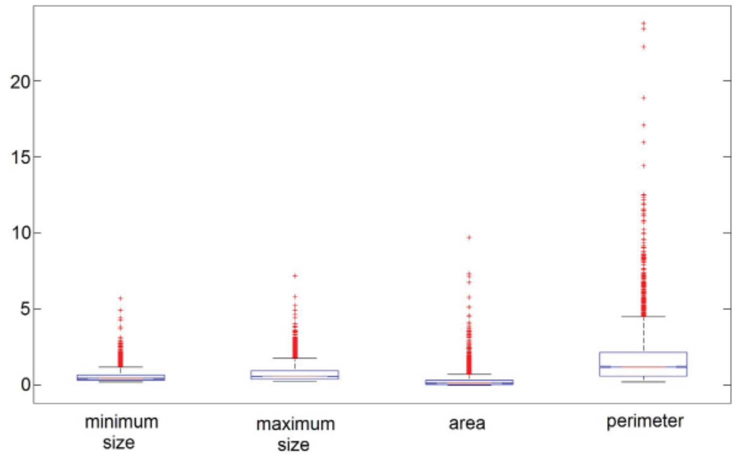
Measured data can be analysed directly by Matlab. After measurements the statistic parameters are computed as follows: histogram of sawdust surface (Fig. 8), histogram of sawdust perimeter (Fig. 9), analysis of variance ANOVA (Fig. 10). Obtained data of the sample can be exported into excel table for next processing (for example a chart of distribution of sawdust size as in Fig. 11).



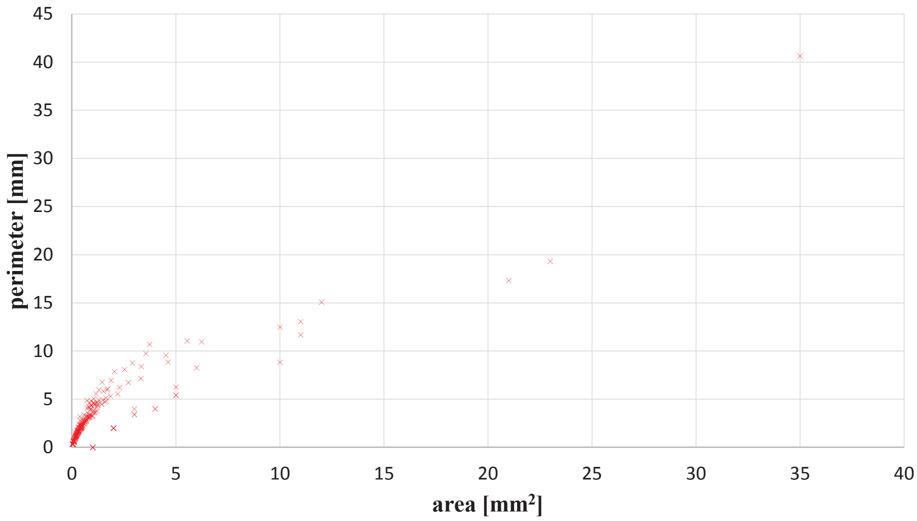
8: *Histogram of sawdust volume*



9: *Histogram of sawdust perimeter*



10: *Analysis of variance*



11: *Distribution of sawdust size*

SUMMARY

By described method, the dimensional characteristics of fractal particles can be measured. The minimum scanned dimension depends mainly on the applied optical lens and camera system. Although the camera used in the experiment was unable to capture particles smaller than 0.2 mm, it is suitable for the measurement of dust particles in proposed application. For measuring the dimensions of smaller particles, the different, more appropriate camera for close-up shooting should be considered.

The data measured by given method are relatively easy to process, because the output values are saved into MS Excel tabular editor. Compared to other methods, the optical measuring systems provide a much wider data about measured sample and are easier for operating.

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