

2006-2031: LEARNING ABOUT PARTICLE SIZE CHARACTERIZATION WITH A WATER PITCHER FILTER

Devdas Pai, North Carolina A&T State University

DEVIDAS M. PAI is a Professor of Mechanical Engineering at NC A&T State University and Associate Director of the Center for Advanced Materials and Smart Structures. He teaches manufacturing processes and tribology related courses. A registered Professional Engineer in North Carolina, he serves on the Mechanical PE Exam Committee of the National Council of Examiners for Engineers and Surveyors and is active in several divisions of ASEE and in ASME.

Gukan Rajaram, North Carolina A&T State University

GUKAN RAJARAM is a PhD student in the Department of Mechanical Engineering. He received the B.E. degree in Mechanical Engineering from Madurai Kamaraj University, and his MS in Metallurgical Engineering from the Indian Institute of Technology – Madras. His doctoral research is in the area of electrode and electrolyte synthesis and characterization for solid oxide fuel cells. He has been involved in teaching mechanical engineering lab courses.

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Introduction

Particle technology deals with the production, characterization, modification, handling, and utilization of organic and inorganic powders, in both dry and wet conditions. Particulate systems as a core technology impact a number of industries including advanced materials ^[1], chemical, energy, environmental ^[2], mineral, agricultural, pharmaceutical, biotechnology, and food processing. With the emergence of nanoscience and nanotechnology, particles of increasingly smaller size are being synthesized for applications as catalysts, coatings, advanced ceramics ^[3,4], pharmaceuticals ^[5,6] and medical applications. The size and size distribution of these particles are of great importance to the end user because they affect key colloid properties such as rheology, film gloss, surface area and packing density. Before the invention of digital technology, the particle characterization was performed by sieving, which gives only a rough idea of the size distribution. More sophisticated techniques like using a Coulter counter or sedimentation technique do not provide any information on the crystal shape. Quantitative image analysis is one method which determines size and shape parameters. Increases in computer processing power has led to the emergence in recent years of both static and dynamic image analysis instruments that are capable of rapidly classifying tens, if not hundreds of thousands of particles. This has moved image analysis, for the determination of particle morphology, away from a qualitative technique where perhaps just a few 100 particles were analyzed, to a quantitative technique with statistically valid data being produced. Apart from particle count, size and shape characterization, image analysis can also be used to measure particle velocity, trace moving objects and measure deformation by recording successive scenes over a period of time ^[7]. We have developed an experiment for undergraduate mechanical engineering students to introduce concepts of particulate system using digital image analysis. In order to keep the experiment simple and relevant, we have used carbon particles (activated carbon, used in a household water pitcher) and coins (nickels, dimes and quarters) as examples of particulate materials. Digital surface images of the powder particles and the coins are captured using a digital camera with proper lighting conditions. The digital images are analyzed for particle size and particle count using PC-based image analysis software. The currency coins are measured with a caliper and the measured values are compared with the software results. The percentage error indicates the accuracy of the software. The carbon particle size and count is also measured using the same procedure. The experiment helps student to get exposed to modern characterization procedures.

Procedure

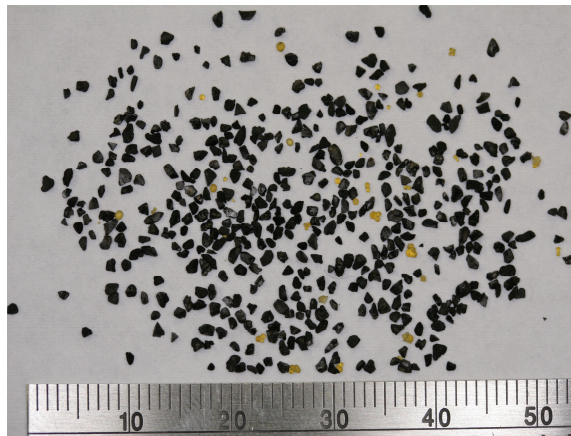
Initially, the digital images of the coins and were taken with coins arranged in a random pattern. We used six quarters, seven dimes and seven nickel arranged randomly. It was made sure that the coins were not touching each other. The reason is the Image analysis software would count the

necking particles as one single particle. Typically, it is possible to separate the particles to some extent using Filter tools present in the software. Since it is possible to separate these macro particles before taking image, we made sure that the coins were not touching. Similarly, the images of the carbon particles were taken. Since the household pitcher has wide range of particle size distribution, we took as many as four images using four different samples in order to study the mean and standard deviation of the particles.

The Image-pro software reads .gif, .jpeg, .tif images. So the digital image for particle size count should be in any one of the above said format. Also, the image should be taken with a standard ruler in order to calibrate the measured values.



Digital image of coins



Digital image of carbon particles

Collecting data

The currency coins were used for simplicity in understanding the working principle of the software. The coin size was measured physically and also measured using the software (Procedure to use the Image Pro software is given in the appendix). The results predicted by software exhibit a 3.5 – 4 % error when compared with the original values. This can be attributed to different factors like error in setting up the calibration scale and error in setting the threshold. Similarly, the carbon particle size distribution was measured. For any statistical distribution measurements, replication of samples is important. It allows the experimenter to obtain an estimate of the experimental error^[8]. Due to this reason, four different images were used for analysis. Most of the particles were between 0.8 – 1.2 mm range. The smallest particle was around 0.1 mm and the largest was around 1.8 mm.

The measured data can be stored in .xls format which can be used for further analysis. The software also gives the average particle size and the particle size distribution.

(All the pictures, graphs and tables presented here are based on the outputs from the Image Pro 4.5.1.22 software).

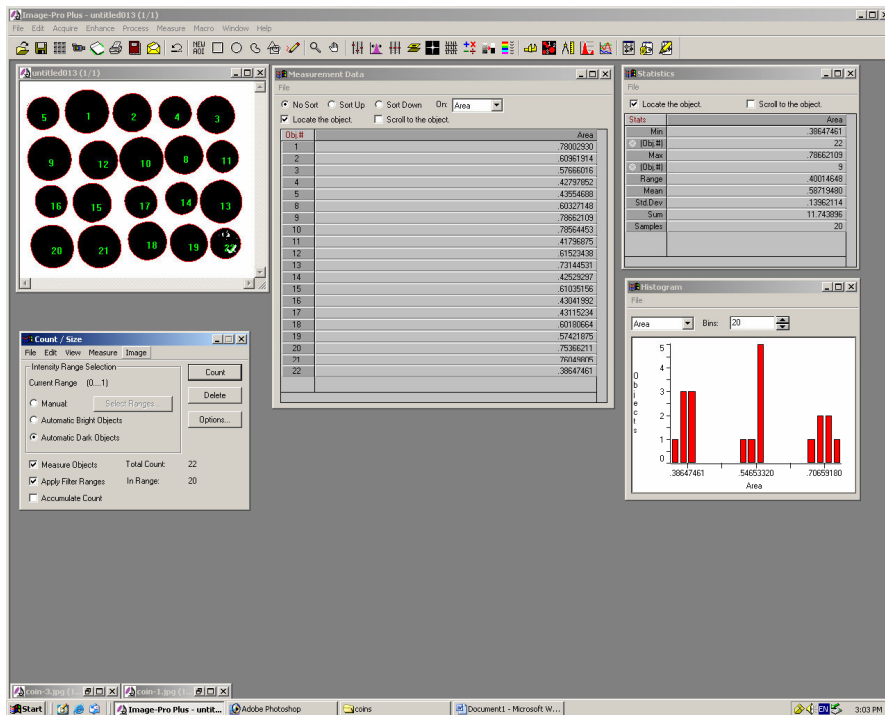


Image-Pro results for currency coins

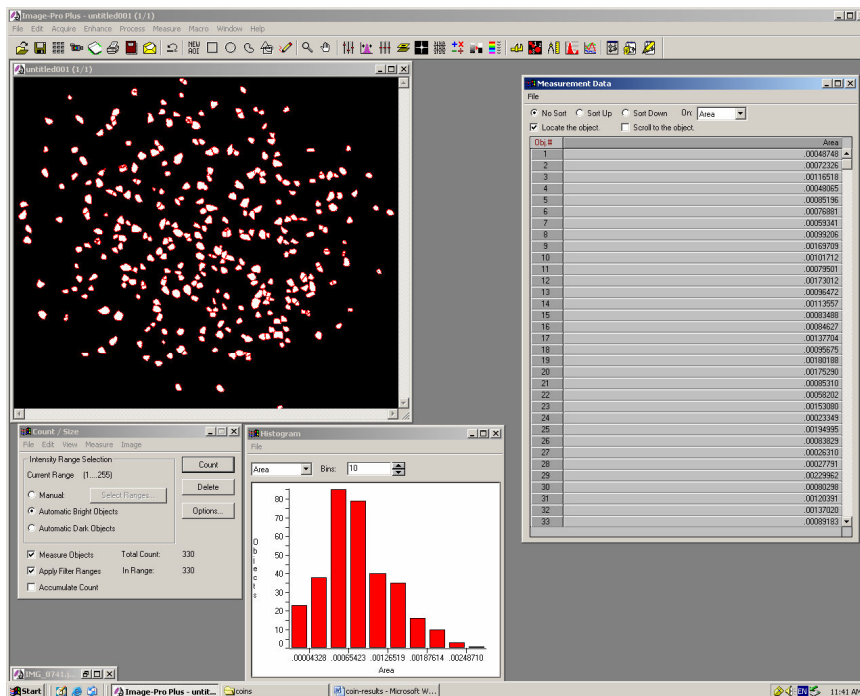
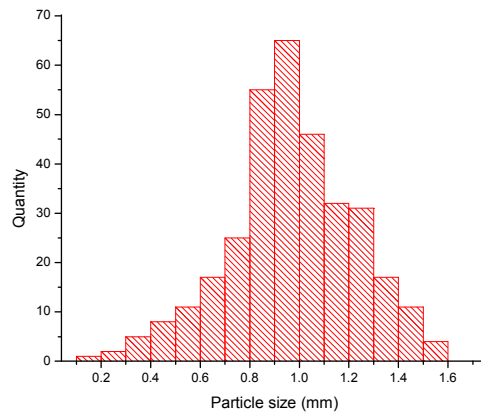
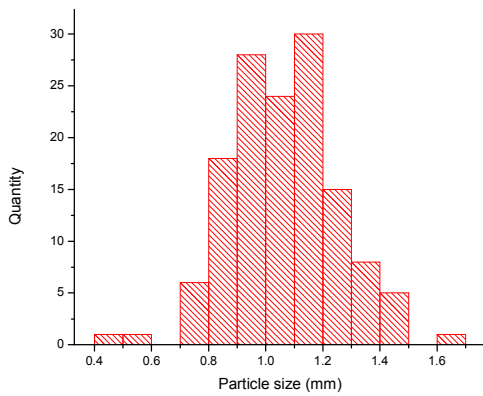
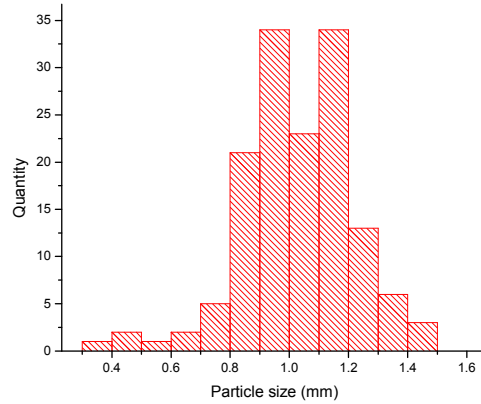
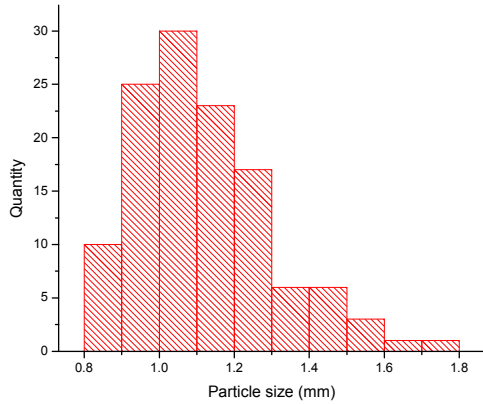


Image-Pro results for carbon particles

	Standard Size (in)	Measured Size (in)
Quarter (25 cent)	0.955	0.99
Nickel (5 cent)	0.835	0.87
Dime (10 cent)	0.705	0.73

Comparison between the standard and the measured value of the currency coins



Histogram of carbon particle size distribution for different samples

Sample #	Minimum Particle Size (mm)	Maximum Particle Size (mm)	Mean	S.D.
1	0.8	1.8	1.116	0.181
2	0.3	1.5	1.026	0.188
3	0.4	1.7	1.063	0.187
4	0.1	1.6	0.967	0.256

Particle size distribution for different samples

Comments

Image-pro software is used for the particle size measurement and particle count. It is essential for the student to get familiarize with the software tool before starting work on his image file. This tutorial help the student to get familiarize with the software and also to understand the fundamentals of particle characterization. This experiment is intended to include in the junior level mechanical engineering lab course.

The same ideas can be executed using ImageJ, free software available online. This software is pretty simple and easy tool for beginners. Though it does not have the several different advanced features like Image-Pro, it gives a very good idea about how to use the software for image analysis and particle characterization, the knowledge which can be used for getting mastered in advanced softwares.

Acknowledgement

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Appendix

Procedure to use Image-Pro Plus (version 4.5.1.22)

Before starting with the image file, familiarize with the different icons and its function, present in the screen. Standard icons like *File, Edit, View* etc work similar way as Microsoft office tools.

Explore and familiarize with icons like *Process*, *Measure* etc which are used frequently for particle size measurement.

1. Open the Image-pro software in your computer
2. Click on File – Open – *your image file*
3. Calibrate the scale on the image
 - a. Click Measure – calibration – spatial
 - b. In spatial pop up window click NEW
 - c. Select a name for the new calibration and select the unit similar to the scale units
 - d. Click *Image* icon
 - e. Using the marker set the reference unit and enter the number of units in the unit window
 - f. Click ok to close the calibration window
4. Select an area on the image for particle measurement
 - a. select  icon
 - b. Using the rectangular block select the desired area on the image. (while selecting the area, make sure that the ruler is not included in the selected area)
 - c. Click Edit – Gray scale – Gray scale 6
5. Click Process – Threshold – apply mask
(The threshold can be adjusted based on the required darkness/brightness of the particles. It should be made sure that the particle is not too bright/dark which can affect the particle size)
6. Click Measure – count/size
 - a. Select count bright object/count dark objects (in the Measure pop up window)
 - b. Click Count
7. Click View – measurement data (in the Measure window)
(It shows the particle numbers in the image with corresponding particle area)
8. Click View – Histogram
(It shows the particle size distribution in bar chart)

Procedure to use ImageJ

- Convert scanned color image to grayscale:
Image Type 8-bit
- Set measurement scale:
Draw a line over the section of the ruler then **Analyze - Set Scale**
- In *Set Scale* window enter 50 into the 'Known Distance' box and change the 'Unit of Measurement' box to mm , check 'Global'
- Draw a new line and confirm that the measurement scale is correct.
- Threshold the image using the automated routine:
Process - Binary - Threshold
- The automated threshold includes only the dark areas.
- Calculate area of dark portion:
Enclose the area with the rectangular selection tool
Analyze - Analyze Particles
- Enter 500 as the minimum particle size, toggle 'Show Outlines' and click 'OK'
- Outline of analyzed area is automatically drawn.