Particles and Geometric Shapes Analyzer APOGEO

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INTRODUCTION

Historically, the fluidization technology has been closely related to traditional manufacturing processes such as petrochemical, pharmaceutical, food and fertilizer. In those processes, the characterization of solid particles is vital to obtain higher efficiencies and lower process costs. Recently, many clean energy processes (e.g.: fermentation, direct combustion, pyrolysis, gasification, mechanical processes, biodigestion and cracking) involving biomass (non-woody and woody plants, organic wastes and biofluids) need fundamental parameters to understand energy conversion (physical, thermal and biological) in obtaining biofuels (gas, liquid or solid), electricity or heat. All of them require versatility in a wide range of chemical reactor configurations and designs (Cui & Grace, 2007; Dai & Grace, 2011).

Fundamental parameters are necessary to understand the dynamic behavior of solids in these reactors because the particles have irregular non-spherical shapes. According to Guo, Chen, and Liu (2012), biomass particles are extremely irregular due to their high content of cellulose, hemicelluloses and lignin. Mando and Rosendahl (2010), and also, Tannous, Lam, Sokhansanj, and Grace (2013) reviewed fundamental definitions for solid particles such as mean diameter and shape. Mean particle diameters may be used to describe and model general properties of solid materials containing dispersed phases.

In the literature, different definitions have been presented to calculate shape factors based on two-dimensional (2D) and three-dimensional (3D) analyses of particles. Depending on the shape, two-dimension representations may be insufficient to represent the true shape of particles (Zavala, 2012; Rodriguez, Edeskär, & Knutsson, 2013; Tannous, Lam, Sokhansanj, & Grace, 2013). The geometry of biomass particles is complex because depends of the type of raw material and process applied. A particle can change its size and shape from the beginning to the end of the process (Dai & Grace, 2011). There is a need to develop appropriate geometrical definitions as well as algorithms to describe particles shapes (Rodriguez, Johansson, & Edeskär, 2012).

This article will present a new software, Particles and Geometric Shapes Analyzer (APOGEO), that determines major and minor axes, aspect ratio and sphericity of solid particles (mainly biomass) by image analysis without any experimental work. This software was developed to reach users from academy and different experts from industry (e.g.: chemist, physicist and engineers).

BACKGROUND

The influence of biomass particle shapes cannot be ignored in particle transport, mixing and fluidization. Various particle shapes result in different particle surface areas, which are heat and mass transfer processes (Guo et al., 2012). Rodriguez et al. (2013) have presented a review about different methods and techniques to determine the geometrical shape of the particles. They observed that there is no agreement on the usage of the descriptors and is not clear which descriptor is the best. A large scale shape classification has been a problem. In addition, the authors considered that image analysis is a promising tool; it presents advantages like low time consumption or repeatability.

When non-spherical solid particles are observed through a microscope, various methods can be used for their sizing, resulting in terms of an equivalent spheri-

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cal particle. Projected images in microscopes (optical, scanning and transmission) are in two-dimensional and depend on the orientation of the particles (Turbitt-Daoust, Alliet, Kaye, & Matchett, 2000). Particles in a stable orientation tend to have a maximum area causing microscopic measurements larger values than those presented by other methods, i.e., when smaller particle sizes are discarded.

This technique requires the analysis of a number of particles statistically significant, which has required the use of automatic image analysis programs, conducted with the aid of computers and specific software. This process includes several steps: 1) acquisition and image scanning, 2) pre- and post-processing of the scanned image, 3) measurements (shape, size and count), 4) analysis and data presentation (Papini, 2003).

Currently, different equipment can be found on the market, but a few of them can be use for biomass particles, for example: Olympus BX51 from Olympus Corporation; Morphologi G3 and Sysmex FPA3000 from Malvern Instruments Ltd; Camsizer and Camsizer XT from Retsch Technology GmbH; CILAS granulometer and expert Shape from Compagnie Industrielle des Lasers; and, Nikon E200 and ImagemJ software. These equipments calculate, in general, the aspect ratio, the roundness, the convexity, the elongation, and the linearity of the materials. Remarking that, the quality of the analysis results is dependent on the skill and experience of the operator and the correct calibration of the microscope.

In view of the impossibility of obtain such equipments for economic reasons, in 2011, Tannous and Silva (2012) have decided to seek alternatives to solve many research problems concerning biomass particles in the Laboratory of Particle Technology and Multiphase Processes at University of Campinas. This laboratory has experience in educational software development (Rimoli, Assis, & Tannous, 2006; Maranesi & Tannous, 2009; Tannous & Rocha, 2012; Tannous & Santos, 2012).

DEVELOPMENT OF APOGEO® SOFTWARE

General Information

APOGEO® (Particles and Geometric Shapes Analyzer) software was developed for students and professionals in different area of expertise (e.g: chemistry; physics; and chemical, mechanical and food engineers). It is based on image processing techniques in order to transform pixels in computational objects. This software was registered in National Institute of Industrial Property-Brazil (nº 13085-6) by Tannous and Silva in 2012.

The software can quantify the major and minor axes correlating with two or three dimensions of particles (e.g.: woods, coconut fiber, sugarcane bagasse, rice husk) to obtain their sphericity. The particles can be associated with different geometries such as: spherical, parallelepiped rectangular, cylinder, oblate and prolate spheroids, and irregular. The results are presented in histograms and tables and can be saved in a spreadsheet (Excel file, OpenOffice Calc file).

APOGEO Minimum Requirements

APOGEO was developed on personal computer sufficiently supplied with memory and processing of operational systems. The hardware chosen was: processor of 800 MHz, 1 GB of RAM memory, monitor of 15," mouse, keyboard and Java Runtime Environment version 1.6.0 or higher.

Methodology Applied

Particle Selection and Recognition

The development of APOGEO software for mapping images requires that it be able to manage with clustering and pattern recognition. Notwithstanding, it has to manage with both filters to improve image quality, like ensure a valid background and impurities on the image plane. According to Starck, Murtagh, and Fadili (2010), the technique of sparse matrices is an efficient solution to solve these problems. This approach is widely used to identify the size and shape of minerals through images by microscopy.

Therefore, using this mathematical technique, it became possible to approach our research of pattern recognition as a problem of sparse matrix assembly. After that, the new task was to transform these sparse matrix computational objects in an easy access and of the manipulation. One solution was found using the recommendation by Cormen, Leiserson, Rivest, and Stein (2002), concerning on the isolation of particles and save them into data structures.

The results of this technique were satisfactory, since it became easy to manipulate the data. In terms