Particle Shape Analysis Using Digital Image Processing

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INTRODUCTION

The fluidization technology has been closely related to traditional processes, such as petrochemical, pharmaceutical, polymer, food, and incineration (Kunii & Levenspiel, 1991). In these processes, the characterization of solid particles is vital to obtain higher efficiencies and lower process costs. Recently, many clean energy processes (e.g.: mechanical processes, pyrolysis, combustion, and gasification) involving biomass (non-woody and woody plants, and organic wastes) need fundamental parameters to understand energy conversion (physical, chemical, thermal and biological) in obtaining bio-fuels (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; Tannous e Lourenço, 2015).

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 contents of cellulose, hemicellulose and lignin. Mandø and Rosendahl (2010), and also, Tannous, Lam, Sokhansanj, and Grace (2013) reviewed fundamental definitions for solid particles such as mean diameter and shape.

Different definitions have been presented in the literature to calculate shape factors of solid particles based on two-dimensional (2D) and three-dimensional (3D) analyses. Depending on the shape, two-dimension representations may be insufficient to represent the true particle shapes (Zavala, 2012; Rodriguez, Edeskär, & Knutsson, 2013; Tannous, Lam, Sokhansanj, & Grace, 2013). The geometry of biomass particles is complex because it depends of the type of raw material and process applied changing 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 chapter will discuss new software, Particles and Geometric Shapes Analyzer (APOGEO) aiming the determination of major and minor axes, aspect ratio and sphericity of solid particles (mainly biomass) for four different definitions by image processing without any manual work. This software was developed to reach users from academy and industry.

BACKGROUND

The influence of biomass particle shapes cannot be ignored in particle transportation, mixing and fluidization processes. Various particle shapes result in different particle surface areas, in 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. The authors observed that there is no agreement

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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 spherical 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 needed 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 equipments 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; Nikon E200 and ImagemJ software, DOMAS Digital Imaging System from Fiber and Particle Engineering Laboratory (University of Oulu), and Eyecon™ from Innopharma Labs. 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 results is dependent on the skill and experience of the operator, and also 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 through of development of their own software to obtain the shape and sphericity of these kind of particles. 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 to reach professionals in different area of expertise (e.g: chemist; physicist; and chemical, mechanical and food engineers). It is based on image processing technique in order to transform pixels in computational objects. This software was published in the National Institute of Industrial Property-Brazil (nº 13085-6) by Tannous and Silva (2012).

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

Minimum Hardware Requirements

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