

AERODYNAMICS OF A FLUIDIZED BED OF FORESTRY BIOMASS PARTICLES WITH MECHANICAL AGITATION

R. M. MORENO^{†*}, G. ANTOLÍN[‡] and A. REYES[§]

[†] Instituto de Materiales y Procesos Termomecánicos. Universidad Austral de Chile, Casilla 567, Valdivia, CHILE

[‡] Departamento de Ingeniería Química, Universidad de Valladolid, 47011 Valladolid, ESPAÑA

[§] Departamento de Ingeniería Química, Universidad de Santiago de Chile, Casilla 10233, Santiago, CHILE

* Author to whom correspondence should be addressed – email.rm.moreno@uach.cl

Abstract - The aerodynamic behavior of wet forestry biomass particles mechanically shaken in a fluidized bed was analyzed with turning velocity between 0.5 and 2 r.p.s. It was concluded that the agitation exerts an important effect on the fluidization of wet biomass particles. The effect of the agitator is not relevant if the particles have low humidity content. In addition, a methodology based on the Ergun's equation for the calculation of the specific biomass particle surface, with a degree of acceptable correlation ($R^2 > 0.96$) was proposed. For the prediction of the minimum fluidization velocity, a new correlation allowing fitting the experimental values with deviations of $\pm 15\%$ for dry and wet particles, was also proposed.

Keywords - Fluidized bed, Forestry biomass, Agitated fluidized bed

I. INTRODUCTION

Drying is a process where momentum, energy and mass transfer take place simultaneously. The reliability in the design of particle dryers in fluidized bed depends, to a great extent, on the information available on the fluid dynamics of the gas-solid interaction. The determination of drag coefficients for fluidized beds has been objective of many studies up to date. Some of them approached this problem considering the isolated particle and others considered the interaction with other particles, as in the case of a fluidized bed. In general, the theoretical analyses gave good results in particles or systems of regular geometry; in the case of irregular particles and/or turbulent flow, where the energy losses by kinetic effects are relevant in relation to the losses of viscous origin, the empirical analysis from more or less classic procedures prevailed. It has been observed that even the empirical determination of parameters such as the fluidization velocity, is not completely reproducible (Vanecek *et al.*, 1966). Until now, there are not general fundamental studies applicable to any system and still prevails the idea to model particular systems rather than general ones.

The objective of this investigation is to study the aerodynamics in the solid-fluid interaction for a fluidized particle bed of forestry biomass for drying purposes. The study is designed to generate information for the further analysis of the convective heat and mass

transfer between the fluidizing gas and the solids during the process of moisture removal in a fluidized bed with mechanical agitation.

The analysis of the aerodynamics of biomass particles in contact with air, allows to determine the minimum fluidization velocity U_{mf} , such as the particle surface area S_p used in the determination of the convective heat and mass transfer coefficients. In addition, a prediction correlation of fluidization velocities within the range of Reynolds' number between 10 and 250, is proposed. The results are compared with those shown by other authors for fluidized bed systems.

II. THEORETICAL BACKGROUND

In particulated dense or high particle concentration systems, the mechanical, thermal and chemical behavior of a mixture of two or more continuous media have been subject of several studies following the work of Truesdell in the second half of the 50s (Atkin and Craine, 1976). In particular, works applicable to fluidized systems like those of Jackson (1971) and Kuipers *et al.* (1992) among others, have been developed.

Together with the balance equations it is necessary to include the characteristics of medium through constitutive equations. For slow flows of a fluid through a porous body (valid for low Reynolds' numbers), Darcy found that the resistant force between the fluid and a porous medium depends on the superficial velocity $U = \varepsilon u$, considered without the presence of the porous medium. The well-known Darcy's law, for an incompressible flow, is written as:

$$-\nabla P = \frac{\mu_g}{K} U \quad (1)$$

where $P = p + \rho_g gz$ is the modified pressure.

In the case of a large particle fluidized bed as it is the situation of a biomass particle dryer, the pressure gradient in the fluid is governed by the viscous losses and the losses of kinetic energy (creeping-flow and inertial-flow).

Thus, Darcy's law must incorporate the quadratic term and in such case, the global pressure drop in the particle bed Δp , remains as:

$$\frac{\Delta P}{L} = \frac{\mu_g}{K} U + \frac{c\rho_g}{\sqrt{K}} U^2 \quad (2)$$

that is equivalent to the particle beds developed by Ergun (1952)