THERMAL BEHAVIOUR OF FOREST BIOMASS DRYING IN A MECHANICALLY AGITATED FLUIDIZED BED

R. M. MORENO[1*], G. ANTOLÍN[2] and A. REYES[3]

[1]*Instituto de Materiales y Procesos Termomecánicos Universidad Austral de Chile, Casilla 567, Valdivia, CHILE*
[2]*Departamento de Ingeniería Química. Universidad de Valladolid, 47011 Valladolid, ESPAÑA*
[1]*Departamento de Ingeniería Química. Universidad de Santiago de Chile, Casilla 10233, Santiago, CHILE*
* *Author to whom correspondence should be addressed.*

Abstract — **The results obtained in the analysis of the thermal behaviour of a forest biomass fluidized bed dryer with mechanical agitation, are reported. The study is carried out in a pilot size experimental equipment in batch operation. By means of Taguchi's techniques the specific consumption of energy and the rates of evaporation of water and production of dry biomass are analyzed based on the control factors (agitation speed, temperature of operation, superficial velocity and product load into the dryer). As noise factor the initial moisture content of the biomass was considered. The results of the study reveal that the drying process is obtained with a specific consumption of energy of 3040 kJ/kg and a thermal efficiency of 80%.**

Keywords— **Fluidized bed, Forestry Biomass, Particles Drying, Taguchi's method.**

I. INTRODUCTION

Nowadays the drying forest biomass particles has great importance due to the use given to this raw material in the manufacture of particle board, pellets, briquettes, as well as in the processes of combustion and gasification of biomass (Zabaniotou, 2000; Pang, 2000; Herguido *et al*., 1992; Olazar *et al*., 2000). Due to the high consumption of energy required during drying, an important variable to optimize is the thermal efficiency which is closely related to the specific consumption of caloric energy of the process (Snezhkin and Khavin, 1997).

At present the use of units of fluidized bed for particle drying has been increased due to the multiple advantages that this technology offers. Nevertheless, the forest biomass has the problem of high agglomeration of solids when they have a high moisture content (Moreno and Rios, 2002). For such a reason, diverse alternatives have been studied to improve the fluidization process showing that for particles between 1 and 4 mm the best system is a fluidized bed with mechanical agitation (Moreno *et al*., 2006). The objectives of this study are the analysis of the caloric energy consumption and the rate of water evaporation in the process of forest biomass drying in a mechanically shaken fluidized bed. Additionally, the behavior of the dryer in terms of the rate of production of dry biomass, is analyzed.

In this work the Design of Experiments of Taguchi's methodology is used as tool for the analysis of the behavior of the biomass dryer. In addition to the analysis of variance (ANOVA), the optimization incorporates a Signal/Noise analysis, using the Signal-to-Noise ratios (*S/N*), which allows to find the control factors levels of the process which guarantee that the variable to optimize is less sensible to the variations caused by the noise factor and therefore giving robustness to the process.

II. THEORETICAL BACKGROUND

A. Specific Background

The useful heat-flux in a drying process is the one used for warming up the wet product and for evaporating part of the contained water in the material and it is represented as:

$$\dot{Q}_{\acute{u}} = M_0 C_{p,0}\frac{dT_p}{dt} + M_0 w C_{H_2O}\frac{dT_{H_2O}}{dt} + M_0 h_{fg}\left(-\frac{dw}{dt}\right) \quad (1)$$

Bearing in mind that in the particulate material, the solid and liquid phases are in thermodynamic equilibrium then the temperatures of the water and the particle are equal so:

$$\dot{Q}_{\acute{u}} = M_0\left[C_{p,bs}\frac{dT_p}{dt} + h_{fg}\left(-\frac{dw}{dt}\right)\right] \quad (2)$$

Moreover, the energy flow used in the process corresponds to the sensible heat used in the heating unit to increase the air temperature from environmental temperature to operation temperature. Thus,

$$\dot{Q}_c = \dot{m}_g\, C_g (T_{g,i} - T_0) \quad (3)$$

and thermal efficiency of the process can be expressed as:

$$\eta(t) = \frac{M_0\left[C_{p,bs}\frac{dT_p}{dt} + h_{fg}\left(-\frac{dw}{dt}\right)\right]}{\dot{m}_g\, C_g (T_{g,i} - T_0)}100 \quad (4)$$

This efficiency varies with time as a consequence of the drying kinetics represented by the changing rates of moisture content and temperature of the particles in the dryer, dw/dt and dT_p/dt, respectively.

Another definition of efficiency is given by Vanecek *et al*. (1966), who say that the degree of heat utilization is given by $(T_{g,i}-T_p)/T_{g,i}$ and they show that the specific consumption of energy is decreased by the choice of high entrance temperatures of the gas fluidizing $T_{g,i}$.