Universitatea Transilvania din Brașov

HABILITATION THESIS

SUMMARY

Title: Research în the fields of convective drying and wood biomass

Domain: Mechanical Engineering

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The habilitation thesis entitled ***Research în the fields of convective drying and wood biomass*** showcases the didactic and scientific achievements of its author in the period following the award of the title of Doctor in Technical Sciences/Thermal Machines and Equipment (February 1999) and as associate professor at the Faculty of Mechanical Engineering.

Part (B-i) of the thesis briefly describes the two main research directions approached by the author, namely the analysis of convective wood drying as a combined heat and mass transfer process, and the investigation of thermal conductivity models and correlations between different properties of wood briquettes. The first research direction aimed to continue the previous research carried out during the doctoral studies in the field of heat and mass transfer in the thermal conditioning of wood fiber panels.

The research results presented in the habilitation thesis were published in **5 ISI papers**, in **4 papers** indexed in **International Databases (IDB),** in **4 proceedings** of international conferences and in the scientific report of the research project coordinated by the author. In addition to the research on which the habilitation thesis is based, the author made her contribution in several research areas, such as heat-insulating composite materials (3 ISI papers, 1 IDB paper), dimensional analysis (3 ISI papers), moisture transport in wood (1 IDB paper), aerodynamic resistance in drying chambers (1ISI paper, 4 IDB papers), totalling 13 ISI papers, 16 papers indexed in International Databases and 43 participations in international conferences.

Parts (B-ii) and (B-iii) of the thesis are structured in 6 chapters, describing the main results and contributions of the author in the two research directions.

The first chapter, entitled ***Numerical and experimental analysis of the boundary layer during the drying of capillary-porous materials*** is concerned with the simultaneous momentum, heat and mass transfer in the air boundary layer at the surface of wet materials undergoing convective drying. If the heat and mass transfer during evaporation on the

surface of wet materials is analyzed similarly to the transfer that occurs on the free surface of a liquid, experiments have shown that the processes are similar only as long the temperature of the surface of the wet material remains constant (constant-drying rate period). In order to explain the transfer mechanisms in the boundary layer, the thermodynamics of irreversible processes was applied in the case of a plane wood board. Firstly, a numerical analysis was performed by using the input data of a regular drying schedule. Thus, several characteristics of the boundary layer were obtained, such as: the thickness of the velocity, temperature and vapor concentration boundary layers, the variation of the velocity, temperature and vapor concentration in the boundary layer and their gradients, and the variation of the heat and mass rates along the board. These properties enabled the determination of the phenomenological coefficients described by the thermodynamics of irreversible processes. The numerical results related to the thickness of the boundary layers were validated by the results obtained from experiments performed in a scaled drying kiln.

The research results indicated in this chapter are part of the scientific report of the project PN II–ID–PCE, no. 723/2009, coordinated by the author of the thesis and they also were disseminated in 2 IDB journals and at 2 international conferences.

The second chapter, ***Optimization of wood drying schedules by using the Design of Experiments method***, deals with mathematical models employed to optimize the wood drying process. The TORKSIM software was used to simulate convective drying of spruce with different initial moisture contents in a scaled drying kiln according to several drying schedules. The output data of the simulation were drying time, energy consumption and relative stress. In order to optimize the drying process in regard with minimization of drying time, energy consumption and relative stress, the Response Surface Methodology (RSM) was applied. RSM is a class of Design of Experiments, aimed in this case at finding the optimal combination of air parameters (temperature, velocity and relative humidity) involved

in the drying process. The method can estimate the interaction and quadratic effects of the input variables on responses (output data). The statistical package Design-Expert Software was used for the design of experiments and RSM applications, regression analysis, statistical evaluation of the models, process optimization and graphical presentation of the response surface. The results have shown that the air temperature had the most significant effect on all drying results. Velocity played a minor role. Also, the interaction between temperature and relative humidity on responses was stronger than the other interactions.

The research results presented in this chapter were published in 1 ISI paper and 3 IDB papers.

In the third chapter of the thesis, ***The study of the occurrence of cracks during drying by assessing the moisture distribution in wood***, the solution of the coupled heat and mass transfer equations is used to find the hygrometric Kirpichev number that describes the occurrence of superficial cracks during the first drying period at the maximum drying intensity. A small value of the Kirpichev number indicates a low internal resistance to moisture diffusion, while an increased value, a high resistance to diffusion. It is also a measure of internal stress that creates the conditions for the occurrence of cracks. Since the moisture flow rate depends on the drying schedule (velocity, temperature and relative humidity of air), there is a relation between Kirpichev number and the air properties during this drying period. To avoid the occurrence of cracks, the air properties must be selected so that the Kirpichev number is lower than the critical (maximum) number. In order to apply this method, pine wood samples with different initial moisture contents were submitted to five drying schedules simulated with the TORKSIM software. Thus, the variation of the moisture content in time, the average temperature and the average moisture content of wood were obtained. Then, the variation of the Kirpichev number in time was found by numerical modelling for the five drying schedules. A correlation was also established between the Kirpichev number and the relative stress determined from the simulation.

The research results indicated in this chapter are part of the scientific report of the project PN II–ID–PCE, no. 723/2009 and they also were disseminated in 1 ISI journal and at 1 international conference.

The fourth chapter is entitled ***Effective thermal conductivity of wood biomass under the form of briquettes***. The research described in this chapter refers to three electrical resistive-circuit models that were analysed in order to determine the effective transverse (series and parallel) and effective longitudinal thermal conductivity of wood briquettes. The models applied are different for the moisture content below the equlibrium moisture content (EMC) and above EMC. For the latter moisture content range, new relations were developed in order to determine the effective transverse thermal conductivity of combined wood cells in series and parallel circuits. Experiments were performed on briquettes with the moisture content ranging from 0% to 22.7%, dry basis. They showed that the increase in the moisture content above EMC determined both the swelling of the wood fiber and the increase in briquettes voids, which affected the effective thermal conductivity. Also, the experiments and models indicated that the effective thermal conductivity of briquettes increased, as well as the density of the briquettes, when the moisture content increased from 0% to EMC. EMC was determined to have a mean value of 5.95%. When the moisture content increased from EMC to the maximum moisture content (22.7%), both thermal conductivity and density decreased. Experimental results of thermal conductivity were very close to the results of the transverse resistive models.

The proposed models which were used to determine the effective thermal conductivity of briquettes are included in 1 ISI paper.

The fifth chapter of the thesis is ***The relation between porosity and roughness of wood briquettes***. Porosity is one of the important properties used in analysing the combustion of briquettes. The first aim of the research undertaken to determine the porosity of briquettes was to show the applicability of the relations of wood porosity to briquettes. It also aimed to

find correlations among a measurable quantity, such as roughness, and a calculated quantity, namely porosity. According to several studies conducted on wood, both porosity and roughness parameters are properties that depend on density. Therefore, the research performed on briquettes revealed correlations between the following properties: porosity and density, roughness and density, and roughness and porosity. Porosity was calculated with three methods indicated in the literature on wood, while density was determined by three different experiments (two stereometric methods and a liquid displacement method). The research concluded that the estimation of the porosity of briquettes by assessing the surface quality can be performed if the roughness parameter *Rk*+*Rpk*+*Rvk* is measured, followed very closely by the *Ra* parameter. Very strong correlations with roughness were obtained when the porosity was calculated using the three methods, and the density was measured by one of the stereometric methods.

The correlations indicated in this chapter were reported in 1 ISI paper and at 1 international conference.

Chapter 6, ***The study of physical, thermal and mechanical properties of briquettes made of blends of wood species***, deals with the analysis of different properties of blends of beech and bamboo wood particles, in various amounts, compressed into briquettes. Accordingly, the following properties of briquettes were measured: density by using a stereometric method, the higher and lower heating values by using calorimetry, ash content by calcination, specific heat and thermal conductivity based on the transient line heat source method, and the breaking strength by compressing the briquettes. Even if beech wood is the most common solid fuel, the research carried out on briquettes has shown that the addition of bamboo particles enhances the analysed physical, chemical, thermal and mechanical properties.

The research undertaken in the field of the properties of wood briquettes was reported in 1 ISI paper.

Part (B-iv) of the thesis deals with the plans for the author's career evolution and development. Chapter 7 presents the academic evolution of the author of the habilitation thesis, consisting in education, didactic and scientific activities, while Chapter 8 describes the development plan of the author's didactic career in correlation with the directions of her future scientific research.