Modelling for Operator Training in the Manufacturing of Fiberwood Panels: A Proposal for Hot Pressing

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Abstract

A detailed mathematical model of the fiberwood panel manufacturing process is developed to be the core of a digital twin for operator training. This model is able to accurately reproduce variables that cannot be measured directly during the manufacturing. In particular, the evolution of unmeasurable variables along and within the fiber mat (pressure, temperatures) is reproduced during the operation of the hot-pressing process. For this, the main physical and chemical processes taking place in the press are modeled in sufficient detail to evaluate how energy and matter is transported, but with sufficient simplicity for the process model to be easily comprehended by the staff being trained, and with little computational effort, to facilitate "what if" learning approaches. Some simulation results are provided to demonstrate the ability of accurately predicting the process variables in different operating conditions.

Keywords

Fiberwood Panels; Panel Manufacturing; Medium Density Fiberboards (MDF); Operator training; Hot pressing.

1. Introduction

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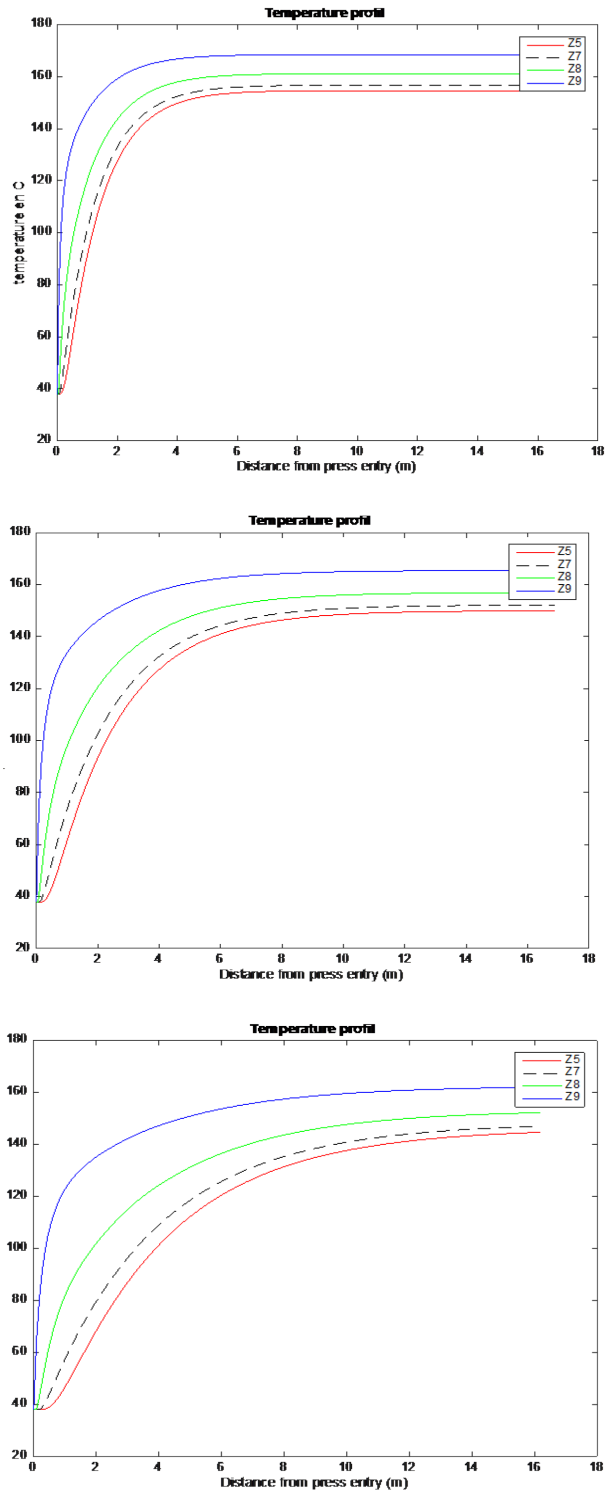

Figure 13: Detail of temperature distribution in the middle section (j=10) using the developed models for three values of mat speed (0.5 m/s, 1.1 m/s and 1.6m/s), at several depths: from the centre (Z5) to the border (Z9)

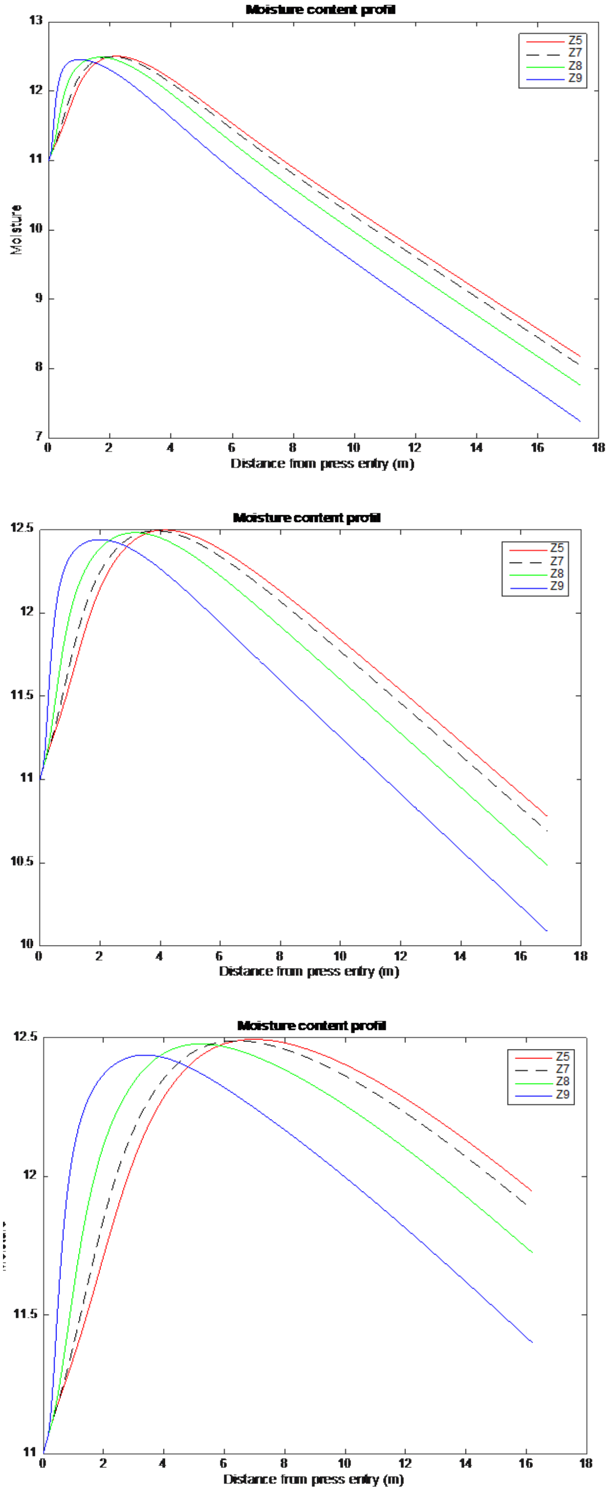

Figure 14: Detail of humidity evolution in the middle section (*j*=10) using the developed models for three values of mat speed (0.6 m/s, 1.1 m/s and 1.6m/s), at several depths: from the center (Z5) to the border (Z9)

2. CONCLUSIONS

This paper has shown how it is possible to accurately simulate the pressing process in wood panel manufacturing to reproduce different operating conditions that can be used for staff training. For this, a detailed model of the hot pressing in fiberwood panel manufacturing has been developed. This model considers the evolution of unmeasurable variables within the three dimensions of the mat in order to reproduce the operation of the process. The modeling has focused on developing models that are simple to simulate, but which provide sufficient precision for understanding the evolution of unmeasured variables. For this, the main process (pressing) is modeled, focusing on the mass and energy transfer processes, evaluating in detail how energy and matter is transported through the process, while affecting pressure, temperatures, humidity, etc., in terms of the parameters that can be obtained through laboratory experiments. Thus, the trade-off between the complexity and precision of the model is addressed by selecting equations that give sufficient precision for graphical representations, but which can easily be comprehended by staff to be trained, as well as updated for different factories. This is demonstrated by simulating the models for different values of a main parameter (mat speed).

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List of symbols

C_p: the specific heat [J/Kg/K]
E: Arrhenius activation energy [J/mol]
E: Modulus of Elasticity (MOE) [Pa]
E_{de}: MOE of delayed-elastic strain component [Pa]
E_{el}: MOE of elastic strain component [Pa]
E_{pmf}: coefficient of plastic and micro-fracture strain component [Pa]
F_{ev}: mass of the evaporated water [Kg/s/m^3]
F_g: total flow of gas [kg/m^2/s]
ΔH_r: resin polycondensation enthalpy [J/Kg]
K: thermal conductivity [W/m/K]
K_0: Arrhenius collision frequency [s^{-1}]
K_g: permeability of the board to the gas phase [m^2]
M : Molecular weight [Kg/mol]
P_n: is the total gas pressure [Pa]
P_{sat}: saturated pressure [Pa]
Q_l: heat of desorption [J/Kg]
Q_r: heat of the polycondensation reaction [J/Kg]
R: gas constant [8.31432 J/mol/K]
T: temperature [K]
λ: vaporization heat of water [J/Kg]
v_c: press speed [m/s]
V_{de}: viscosity of delayed elastic strain component [Pa.s]
v_g: gas velocity [m/s]
v_r: relative velocity of the gas phase
V_{vi}: viscosity of viscous strain component [Pa.s]
y_r: resin content in weight [-]
Δl: change in thickness [m]
ε: porosity [-]
λ: vaporization heat
μ_g: is the viscosity of the gas in [Ns/m^2].
ρ: material density [Kg/m^3]
ρ_g: density of the gas [Kg/m3]
ρ_s: density of the dry fibre [Kg/m3]
σ: stress applied externally by the press [Pa]