8th. World Congress on Computational Mechanics (WCCM8)
5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 – July 5, 2008
Venice, Italy

THERMAL DAMAGE AND COOLING EFECTS ON MODELLED BOND STRENGTH MAPPINGS IN BIO-COMPOSITE MATERIALS DURING THEIR CONSOLIDATION

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Key Words: *Bio-composites, pressing simulation, adhesion mapping, thermal damage, thermal properties, ABES technique.*

ABSTRACT

Physical mechanisms operative within bio-composite materials during their consolidation (hot pressing) are broadly characterized in the paper as: 1) heat and moisture transfer with phase change and vapour convection, 2) hygro-thermo viscoelastic micro-stress relaxation and associated densification, and 3) adhesive polymerization leading to inter-particle bond strength development. These are highly linked mechanisms and interact in three space dimensions and time as composites gain integrity. Their interaction has been modelled deterministically using carefully measured material properties and well defined boundary conditions [1,2]. This approach is being used to optimize the production efficiency and properties of conventional composites (such structural building products), but also is providing a platform for new product and process innovation.

Adhesion kinetics data have now been incorporated within the composite pressing simulation model, and thermally driven spatial (3-D) distributions of localised micro-structural bond strength predicted during pressing of a range furnish types in both conventional and continuous presses. The ABES (Automated Bonding Evaluation System) technique has been used to provide input data by quantifying the effect of temperature on isothermal bond strength development rates of miniature amino resin-to-wood test bonds. The ABES has further been used to quantify the rate of thermal damage (bond strength reduction kinetics), and these data (Fig. 1) have also been incorporated into the simulation. Significant reductions in bond strength (damage) of material near the platen-composite interface are predicted (Fig. 2). This finding may have a major impact on product performance (particularly bending stiffness) and highlights the need to modify pressing cycles and adhesive formulations accordingly.

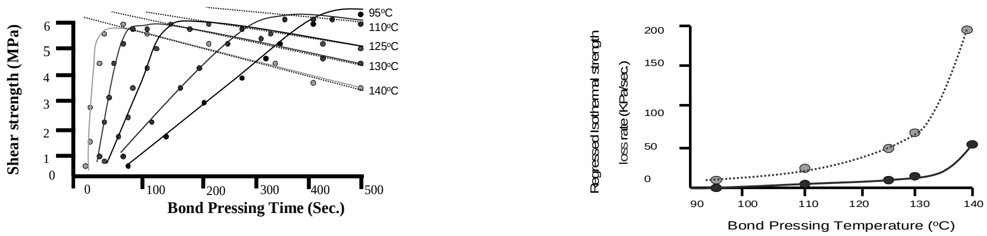

Figure 1. Isothermal ABES strength development plots for UF adhesive, showing thermal damage at high temperatures (left) and regressed rates of development (right upper curve) and decline (lower curve)

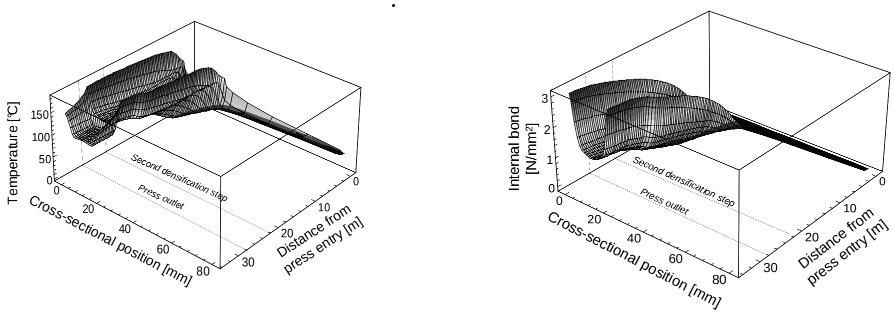

Figure 2. Simulated temperature (industrially verified) and derived bond strength distributions through the thickness of a UF bonded wood fiber composite (MDF) as it passes through a continuous press running at 160°C (initial mc of 8% and final density of 650 kg m^{-3}). *****

Further, Tg (glass transition temperatures) of phenolic adhesive bonds have been quantified as a function of adhesive cure by employing the rapid cooling function of the ABES instrument (Fig. 3). Significant strength enhancement may be affected for partially cured bonds by cooling them below their transient Tg. Pressing technologies in which vapour is vented from composite products *before* press opening has been incorporated into the simulation models. Rapid adiabatic cooling has been predicted together with associated bond strength increases*****. Findings suggest there is considerable potential for reductions in pressing time with such technologies and appropriately formulated adhesives.

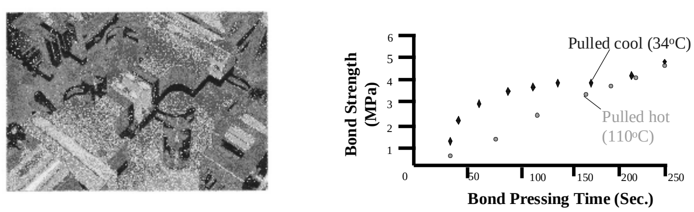

Figure 3. The cooling device on ABES and some typical cooling effects on test bonds (PF adhesive-to-maple bonds) *****

REFERENCES

[1] P.E. Humphrey and A.J. Bolton. "The hot pressing of dry-formed wood based composites. Part II. A simulation model for heat and moisture transfer." *Holzforschung*, Vol. **43**(3), pp.199-206, (1989).

[2] H. Thoemen and P.E. Humphrey. "Modelling the continuous pressing process for wood-based composites", *Wood and Fiber Science*, Vol. **35**(3), pp. 456-468, (2003).

***PLEASE NOTE**: New adhesion mappings (showing the combined effects of thermal damage and panel cooling) will be incorporated in the final paper.