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ORIGINAL

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Comparison of the pressing behaviour of wood particleboard and strawboard

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Abstract To improve the understanding of strawboard manufacturing processes, mat pressing behaviour of wood particleboard and strawboard bonded with urea formaldehyde resins were experimentally investigated and compared in terms of mat compressibility, transverse permeability, mat pressure, core temperature, core gas pressure and vertical density profile. The results have shown that straw particles are much more compressible and therefore require less platen pressure for pressing. Compared to wood particle and refined straw particle mats, hammer milled straw mats have low permeability and subsequently show high core gas pressure and high maximum core temperature during hot pressing, in addition to large differential densities between surface and core layers in the final pressed boards. It is recommended that a slower press closing rate and longer press opening time be used to develop the strawboard pressing schedule.

Introduction

Strawboard is a relatively new composite product made from wheat or rice straws. During the manufacturing processes, straws may be hammer-milled into particles and/or refined into fibres. Due to high surface inorganic content, effective bonding between straw furnishes usually requires uses of Methylene diphenyl diisocyonate (MDI) resins. Many studies have shown that good performance can be achieved with strawboard (e.g. Grigoriou 2000). Strawboard can be used to substitute such wood products as particleboard and medium density fibreboard (MDF). The strawboard product can be very attractive in regions or countries where wood resources are scarce and agricultural fibres are readily available (Bowyer and Stockmann 2001). However, strawboard has yet

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to gain broad commercial production largely due to technical difficulties in processing straw furnishes which seem characteristically different from wood particles and fibres.

One technical challenge in manufacturing strawboard is pressing. As in wood composites, pressing is a key operation in manufacturing strawboard. During pressing, heat and pressure are applied to consolidate the mats and cure the resin. Not only is the productivity governed by pressing time, the physical and mechanical properties of the final products are also largely dependent upon how the mats are densified and how well the resin is cured. The hot pressing operation is very complex because significant changes in heat, moisture, deformation and curing take place simultaneously in a short processing time (e.g. Humphrey and Bolton 1989; Dai et al. 2000). The pressing behaviour of strawboard was studied in this paper by comparing its properties with the better-known wood particleboard. While the general goal of this study was to improve the understanding of hot pressing behaviour of strawboard, the specific objectives were:

1. To experimentally investigate the consolidation and permeability of strawboard as compared to wood particleboard, and
2. To characterize mat temperature, internal gas pressure and vertical density profile of strawboard and particleboard during hot pressing.

Materials and methods

Three types of furnish were made from wheat straw. They were split straw strands, straw particles from a hammer mill, and straw particles (fibres) refined under atmospheric pressure. For comparison, fine wood particles were also acquired from a particleboard mill.

Mats of straw furnish and wood particles were pressed using a 250 mm×250 mm cold press which was mounted on a universal mechanical testing system. Compression tests were conducted to determine the stress-strain relationships of the furnish mats under loading and unloading conditions.

Hot pressing tests were conducted using resinated furnish mats to reveal the hot pressing behaviour and make composite panels. Two panels (900 mm×900 mm×11 mm) were made from each of the three furnishes, i.e. hammer milled straw particles, refined straw particles, and wood particles. UF resin was used at a 9% level and mat moisture content was measured at 8% on an oven dry basis before pressing. Sensing probes were used to detect both temperature and gas pressure inside mats during pressing. Mat pressure and displacement were automatically controlled and measured using a computerized system.

To determine the permeability, disc specimens (50 mm diameter × 5 mm thick) were cut from the laboratory panels and from commercial particleboard. These specimens were subjected to a steady-state unidirectional air flow system (Fig. 1). The air pressure and the flow rate were recorded for each test. The permeability was then calculated based on Darcy's law.

To measure the vertical density profiles, three 50 mm×50 mm samples were cut from each board. Their air dry densities were determined using the gravimetric method first. The samples were then scanned across their thickness

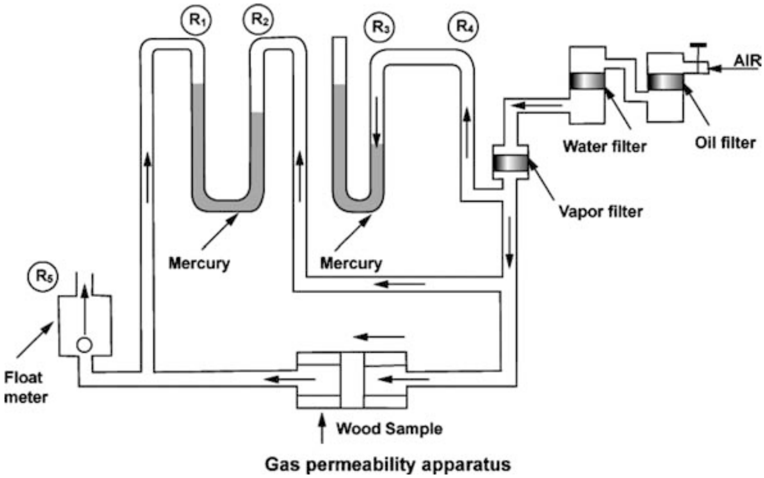

Fig. 1 Permeability testing apparatus

directions using a standard X-ray scanner. The scanning results were calibrated based on the sample average densities to generate the profiles of layered density averages.

Results and discussion

Material characteristics

Furnish geometry

Table 1 reveals the size distributions of wood particles, hammer milled straw and refined straw particles. Both wood particles and hammer milled straw particles contain some coarse particles with little fine particles, whereas the distribution of refined straw seems to be more uniform. Hammer milled straw particles are coarsest and contain almost no dust. Another geometric feature of straw particles, especially the hammer milled particles, is that they are very much like mini-flakes, which are thin and flat, as opposed to the cubic shape of wood particles. The flake-like shape can result in low gas permeability in densified or semi-densified straw mats.

Table 1 Analysis of particle size in terms of percentage on screen

Screen size	Wood particleboard	Hammermill straw	Refined straw
20[a]	31.94	23.40	6.14
40	39.24	51.65	26.75
50	10.33	12.86	16.87
100	10.81	10.90	28.07
200	4.66	1.20	13.40
325	0.30	0	3.99
Dust	2.72	0	4.78

[a]Aperture number in 25 mm length

Table 2 Comparing bulk density of mats made of straw and wood particles

	Wood particleboard	Hammer milled straw	Refined straw
Mat thickness (mm)	20.52 (0.72)	42.58 (1.31)	34.47 (0.66)
Bulk density (g/cm^3)	0.24 (0.008)	0.12 (0.006)	0.15 (0.006)

Values in brackets are standard deviations with three replicate measurements

Mat bulk density

Table 2 lists the bulk density of mats of wood particles, hammer milled straw and refined straw particles. Without any pressing, wood particle mats are much denser than straw particles. This, plus the fact that straw is waxy on surfaces, can lead to practical problems in maintaining the mat integrity for strawboard during transportation from the former to the press. Such problems are not alleviated unfortunately by the use of MDI resin which has poor tacking properties. Therefore, pre-pressing may be necessary during commercial production of strawboard, especially hammer milled straw particleboard.

Compressibility

Figure 2 compares the compression behaviour between mats of wood particles, hammer-milled straw and refined straw particles. It is apparent that the wood particles are the most difficult to compress while refined straw is the most compressible. Under the same pressure, the mats of straw particle or fibre are denser than those of wood particle. In other words, strawboard requires lower pressure than wood particleboard of the same density.

Permeability

Figure 3 compares the permeability of solid wood, hammer milled straw mats (panels), refined straw mats and wood particle mats. Wood permeability in the

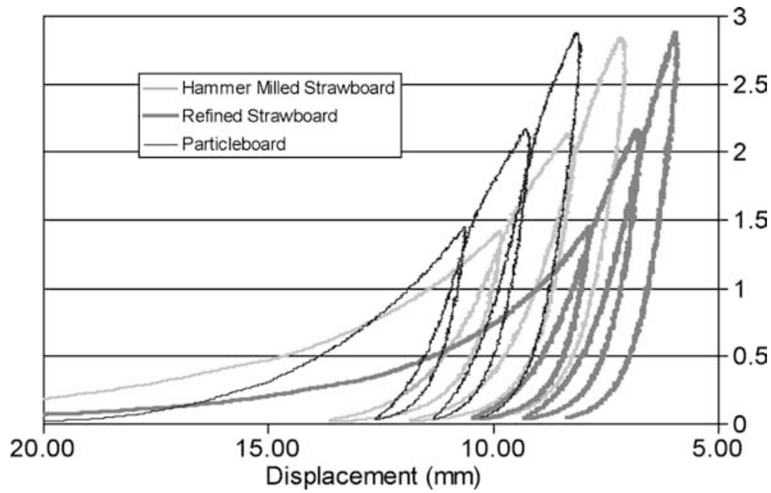

Fig. 2 Compression behaviour of wood and straw particle mats

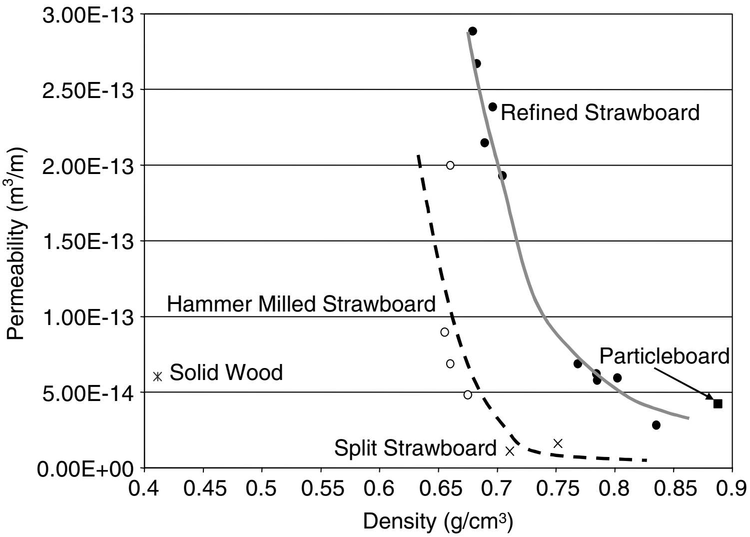

Fig. 3 The relationships of transverse permeability and density for typical solid wood, wood particleboard and strawboard

transverse to grain direction is very low. Mats of wood furnish such as OSB strands and particles are much more permeable than solid wood due to high percentage of voids formed between the furnish (Dai and Steiner 1993). However, as mat density increases during pressing, permeability dramatically decreases. When wood particles are pressed into a composite panel, the mat permeability seems to be more or less the same as solid wood although the panel is much denser (Fig. 6).

The relationships between mat permeability and density are generally exponential (Humphrey and Bolton 1989). In this regard, the permeability-density relationship of refined straw mats seems to follow the same exponential curve as wood furnish mats, whereas permeability of the hammer milled straw and split straw follows another curve. At the same density, the permeability of hammer milled straw and split straw mats appear to be significantly lower than that of refined straw or wood furnish.

Hot pressing behaviour

Mat pressure

All mats were compressed using the same pressing schedule in which the press platens were closed in 60 s using two rates and then held for 240 s before switching to pressure control for a 40-s opening. Figure 4 compares the observed and predicted variations of mat pressure during hot pressing between straw particles and wood particles. The maximum pressure is significantly lower for straw particles than wood, because the straw is much more compressible as indicated from the cold pressing tests (Fig. 2). Consequently, the relaxed mat pressure is also lower for straw. In addition, refined straw particles seem to require even lower pressure for the press than hammer milled particles.

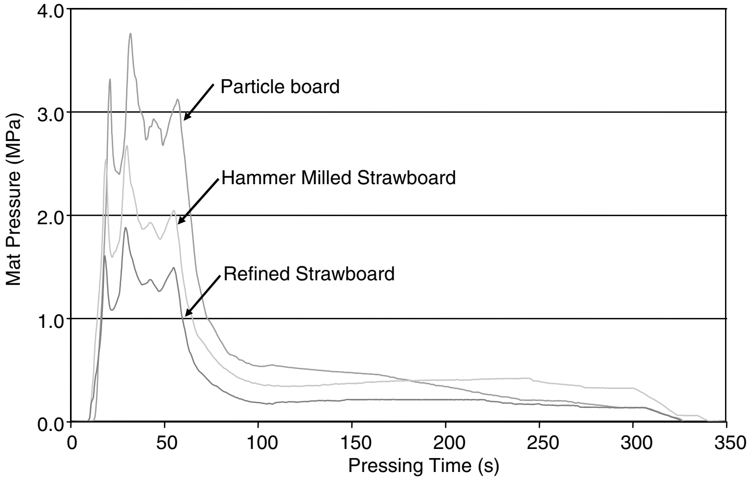

Fig. 4 Variations of mat pressure as a function of time during hot pressing.

Core temperature

The variations in core temperature are similar for wood particle mats and refined straw particle mats (Fig. 5). The core temperatures of wood particle mat rise faster than hammer milled straw mats but are lower towards the later stage of pressing. The slow increase and high maximum temperature with hammer milled straw mats are attributed to their low permeability according to the preceding discussion (Fig. 3). Lower permeability leads to slower convection heat flow from surface to core, and less lateral gas/steam escape to the atmosphere and thus less heat loss, which can result in higher end temperature inside the mat.

Gas pressure

Figure 6 shows the variations in core gas/steam pressure during pressing. A significant difference exists between hammer milled straw, refined straw and wood particles. The internal gas pressures are more or less the same for both refined straw and wood particles. However, the internal gas pressure for hammer milled straw is twice as high. The difference in gas pressure is likely due to permeability. The model predicts that as hammer milled straw is less permeable, the gas generated inside the mat is harder to escape and therefore leads to higher pressure. The higher core gas pressure can cause delamination in the panel upon press opening. Therefore, the degassing or decompression period should be prolonged.

Vertical density profile

Figure 7 depicts a typical vertical density profile for refined strawboard which is very close to that of wood particleboard, despite the large difference in mat compressibility. This means that mat compressibility is not a controlling factor of density profile. Table 3 shows the face and core densities from the vertical density profile data for all three types of boards. Again, the density variations

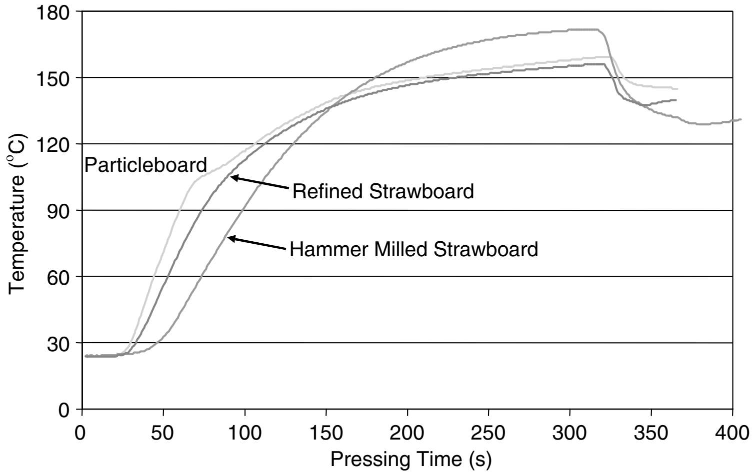

Fig. 5 Variations of core mat temperature as a function of time during hot pressing

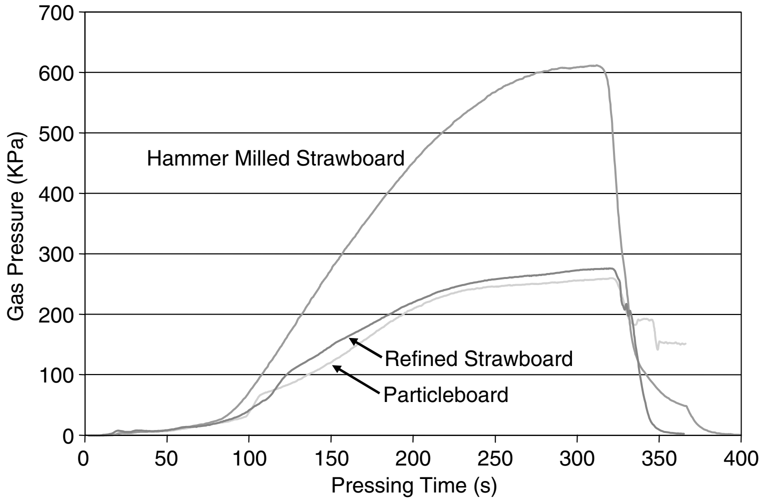

Fig. 6 Variations of core gas pressure as a function of time during hot pressing

are very similar for refined strawboard and wood particleboard. However, the face to core density variations are much greater in hammermilled strawboard in which the maximum densities are greater and minimum densities are lower. The lower core density can cause problems in the internal bond strength. According to the Dai et al. (2000) model, the greater density variation in hammermilled strawboard is due to lower mat permeability.

Pressing strategies

In the development of optimum pressing schedule for strawboard, at least two factors need to be considered. Firstly, straw particles are much more com-

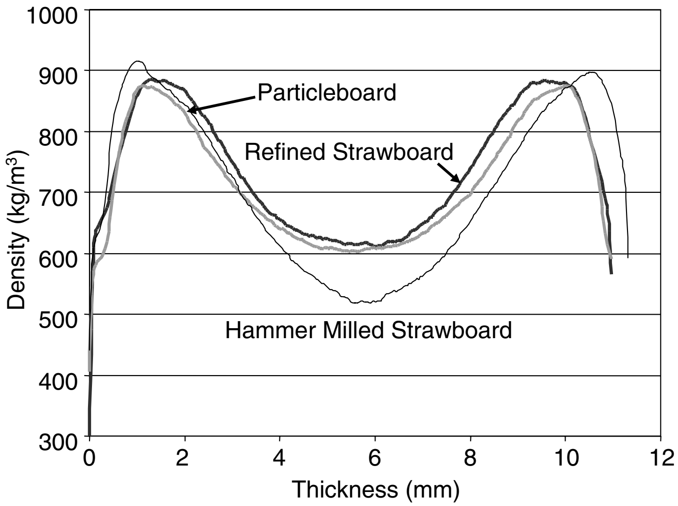

Fig. 7 Typical vertical density profiles for wood particleboard and strawboard

Table 3 Comparing vertical density distributions between strawboard and wood particleboard

	Wood particleboard	Hammer milled strawboard	Refined strawboard
Average density (g/cm^3)	0.78 (0.03)	0.72 (0.03)	0.90 (0.04)
Face/average density ratio	1.22 (0.01)	1.29 (0.02)	1.22 (0.01)
Core/average density ratio	0.84 (0.02)	0.77 (0.05)	0.86 (0.02)

Values in brackets are standard deviations with nine replicate measurements

pressible and thus need significantly lower pressure for press closing. Secondly, hammer milled straw particles are less permeable than wood and refined straw particles/fibres; therefore, press closing rate should be slower in order to prevent the core density from being too low. Also, to avoid delamination associated with high core gas pressure, press opening period should be prolonged.

Conclusions

Compared to wood particles, straw particles are unique in terms of their geometric shapes and size distributions. Hammermilled straw particles in particular are flake-like and contain little dust. The bulk densities of straw particle mats are lower. This, along with their waxy surfaces, may cause handling problems in maintaining mat integrity for strawboard production. With regard to pressing, straw particles are much more compressible and therefore require less platen pressure during press closing. Due to their flake-like shape and impermeable surface property, the permeability of hammer milled straw particle mats is significantly lower than that of wood particle and refined straw mats. Compared to wood particle and refined straw particle mats, hammer milled straw mats have lower permeability and subsequently show higher core gas pressure, higher maximum core temperature, and larger differential densities between surface and core layers. It is recommended that slower press closing rates and longer press opening times be used to develop the strawboard pressing schedule. It should be noted that the findings are related only to UF bonded boards because the use of other resins, e.g. MDI, may lead to different results.

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