Use of Fiberboard as Substrate in Floating Engineered Wood Flooring

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Abstract

Because it offers good milling properties, especially for self-locking tongue and groove, medium- and high-density fiberboard (MDF and HDF) have gained acceptance as a substrate in the manufacture of engineered wood flooring (EWF). Depending on the component selected, delamination in the fiberboard or severe cupping deformation have, however, been observed. The aim of this study was to identify key design parameters in EWF made with MDF and HDF substrate, taking into account the density of the fiberboard, the characteristics of the face layer, and the type of backing process selected to meet quality requirements. A sliced face layer led to lower cupping deformation than a sawn face layer. With a sawn face layer, denser HDF provided a better substrate for EWF. The use of melamine-impregnated paper as a backing layer significantly contributed to reduced cupping deformation in all cases.

Among the materials used as a substrate in the manufacture of engineered wood flooring (EWF), medium- and high-density fiberboard (MDF and HDF) offer a special advantage, since their structure permits accurate milling of the tongue and groove, a particularly valuable feature for the self-locking pattern. Floating EWF installation using this type of tongue and groove eliminates the need for costly adhesive and reduces installation time, thereby resulting in a commercial benefit. It represents one way to access the 1×10^9 ft^2 wood flooring market identified in the United States (Anonymous 2006a), of which 52 percent is EWF (Anonymous 2006b).

EWF manufactured in Canada typically uses a sawn face layer (Fig. 1), which gives it the same appearance as solid hardwood flooring. This type of face component develops a high level of strain (Blanchet 2008) and may exceed ultimate stress, causing delamination to occur in the fiberboard substrate.

The objective of this study was to identify key design parameters in EWF made with an HDF substrate, taking into account the density of the fiberboard (MDF and HDF), the characteristics of the face layer, and the type of backing process used to meet quality requirements.

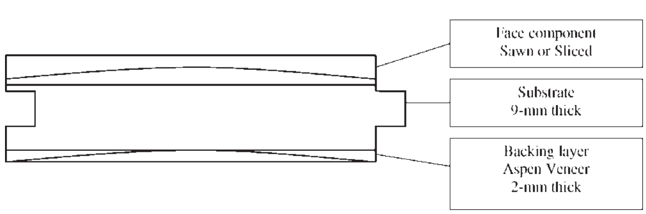

Figure 1.—General view of the EWF construction used in this study.

Materials and Methods

The construction used in this study is presented in Figure 1. In the first experimental design, the face layer consisted of a sawn face component in thicknesses of 2.5, 3, or 4 mm. The fiberboard used as a substrate was manufactured in the FPInnovations pilot plant at three target densities: 775, 875, and 975 kg/m^3. The first is defined as an MDF and the last two as HDF by Suchsland and Woodson (1990). All the specimens made with these face components and substrates included a 2-mm-thick aspen veneer backing layer. Table 1 summarizes this experimental design.

In a second experimental design, the face layer consisted of a sliced veneer in thicknesses of 1, 1.5, or 2.5 mm. Again, the fiberboard substrates were manufactured at three target densities: 775, 875, and 975 kg/m^3. All the specimens made with these face components and substrates included a 2-mm-thick backing layer. Table 2 summarizes this experimental design.

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Table 1.—Experimental design used to compare three HDF substrate densities in EWF constructions based on sawn face components.

Fiberboard density (kg/m^3)	Face component type	Face component thickness (mm)	Backing layer
775 (MDF)	Sawn	2.5	2-mm-thick veneer
		3	2-mm-thick veneer
		4	2-mm-thick veneer
875 (HDF)	Sawn	2.5	2-mm-thick veneer
		3	2-mm-thick veneer
		4	2-mm-thick veneer
975 (HDF)	Sawn	2.5	2-mm-thick veneer
		3	2-mm-thick veneer
		4	2-mm-thick veneer

Table 2.—Experimental design used to compare three HDF substrate densities in EWF constructions based on sliced face components

Fiberboard density (kg/m^3)	Face component type	Face component thickness (mm)	Backing layer
775 (MDF)	Sliced	1	2-mm-thick veneer
		1.5	2-mm-thick veneer
		2.5	2-mm-thick veneer
875 (HDF)	Sliced	1	2-mm-thick veneer
		1.5	2-mm-thick veneer
		2.5	2-mm-thick veneer
975 (HDF)	Sliced	1	2-mm-thick veneer
		1.5	2-mm-thick veneer
		2.5	2-mm-thick veneer

These first two experimental designs involved a 2.5-mm-thick face component. This allowed us to define a third experimental design to compare the effect of the face layer production process (sawn or sliced) on EWF made with a fiberboard substrate. This experimental design is summarized in Table 3.

A fourth experimental design was used to compare four backing options: (1) no backing, (2) 2-mm-thick aspen veneer, (3) melamine-impregnated paper, and (4) foil (FoilSpec from CDM paper–based foil). The veneer was bonded with the same polyvinyl acetate (PVA) as the face components (see below), while the melamine paper and foil were bonded in industry according to standard practice. The substrate selected was an HDF with a target density of 875 kg/m^3. Table 4 summarizes this experimental design.

Table 3.—Experimental design used to compare the effect of the two face component manufacturing processes.

Fiberboard density (kg/m^3)	Face component type	Face component thickness (mm)	Backing layer
775 (MDF)	Sawn	2.5	2-mm-thick veneer
	Sliced	2.5	2-mm-thick veneer
875 (HDF)	Sawn	2.5	2-mm-thick veneer
	Sliced	2.5	2-mm-thick veneer
975 (HDF)	Sawn	2.5	2-mm-thick veneer
	Sliced	2.5	2-mm-thick veneer

Table 4.—Experimental design used to compare the effect of different backing layers.

HDF density (kg/m^3)	Face component type	Face component thickness (mm)	Backing layer
875	Sawn	2.5	None
		2.5	2-mm-thick veneer
		2.5	Melamine-impregnated paper
		2.5	Foil
	Sliced	2.5	None
		2.5	2-mm-thick veneer
		2.5	Melamine-impregnated paper
		2.5	Foil

In all the tests, sugar maple was the wood species used in the face layer, which was bonded to the substrate with a Type-II PVA adhesive from Hexion Specialty Chemicals WB 956LP. Throughout the EWF manufacturing process, all components and specimens were kept in a conditioning room at 20°C and 50 percent relative humidity (RH) to prevent distortion. All the specimens were varnished with an industrial coating system provided by Canlak. Coating was an ultraviolet-cured polyurethane high-solid content varnish. All data were analyzed with SAS statistical software.

All the test specimens were milled to a tongue-and-groove pattern for floating installation, the final width of the strips being 82.5 mm (3¼ in.). Thirteen EWF strips were installed on cement board (Permabase) bases. The different constructions were then evaluated for performance when subjected to RH variations. They were placed in a conditioning room kept at 20°C and 20 percent RH for 3 weeks, and then at 20°C and 80 percent RH for another 3 weeks. These conditions represent average winter and summer temperature and RH conditions in a northeastern American house. Cupping deformation was tracked throughout each conditioning phase according to the following schedule: days 0, 1, 2, 3, 5, 7, 14, and 21. For each specimen, cupping deformation values were plotted as a function of time, and deformation amplitude was determined as defined in Figure 2. The methodology used to

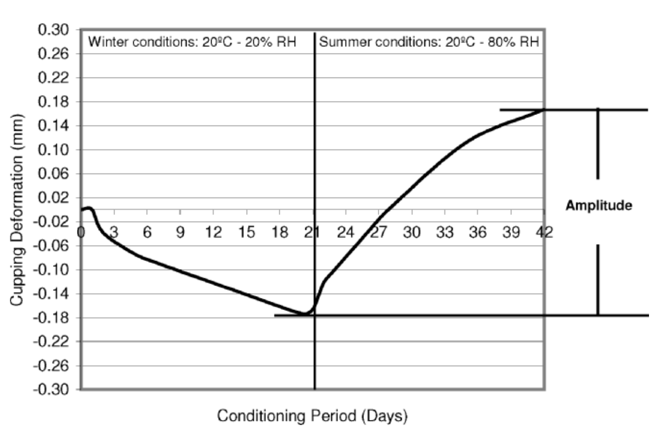

Figure 2.—Typical curve of cupping deformation as a function of time and conditioning room conditions. Cupping amplitude is defined as the difference between maximum cupping under summer conditions and minimum cupping under winter conditions.

Table 5.—ANOVA results on cupping amplitude in constructions using sawn face components, three face component thicknesses, and three fiberboard densities.

Source	Degrees of freedom	F value	Pr > F
Model	8	11.00	<0.0001
Error	90		
Density (D)	2	29.93	<0.0001
Face component thickness (T)	2	9.63	0.0002
$D \times T$	4	2.22	0.0732

Table 6.—ANOVA results on cupping amplitude in constructions using sliced face components, three face component thicknesses, and three fiberboard densities.

Source	Degrees of freedom	F value	Pr > F
Model	8	29.46	<0.0001
Error	90		
Density (D)	2	3.06	0.0517
Face component thickness (T)	2	109.62	<0.0001
$D \times T$	4	2.58	0.0426

measure cupping deformation is described in detail in Blanchet et al. (2003).

Results

Table 5 presents the analysis of variance (ANOVA) results for the first experimental design, which considered the effects of the thickness of a sawn face component and the density of the fiberboard (MDF or HDF) substrate on cupping deformation in EWF. Both face thickness and fiberboard density were found to be highly significant ($\alpha = 0.01$), but the interaction between these parameters was not significant. The fiberboard density with the highest F value in the model appeared to be the main parameter to control cupping deformation, so this parameter should be considered in the selection of an MDF or HDF substrate. The second parameter that should be considered is the thickness of the face component. The tests indicated that cupping deformation increased with thicker face components. These observations are in line with those reported in Blanchet et al. (2006) and Blanchet (2008).

As relates to cupping amplitude, Figure 3 clearly shows the effect of substrate density and face layer thickness. According to this graph, and within the limits of this study, the best EWF construction made with a sawn face component was that combining the highest HDF density and the thinnest face layer possible.

Table 6 presents the ANOVA results for the second experimental design, which considered the effects of the thickness of a sliced face layer and the density of the fiberboard substrate on cupping deformation in EWF. The analysis revealed that the thickness of the face component was highly significant ($\alpha = 0.01$) where interaction of the face layer thickness and substrate density was significant at a level of $\alpha = 0.05$. The density of the fiberboard substrate itself was not significant. This observation suggests that the selection of HDF as a substrate in EWF made with a sliced face component is not as important as for EWF made with a sawn face component. The interaction means that fiberboard density should be considered but the thickness of the sliced face component is by far the parameter with the highest F value and should therefore drive the design process when a sliced face is used.

A closer look at the deformation amplitude results (Fig. 4) for the different substrate densities with a sliced face component indicates that density impacted positively on deformation when the face layer reached 2.5 mm. This is an extreme thickness for a sliced face layer, and the slicing process may lead to excessive wood checking. On this basis, and taking into account the observations shown in Figure 5, manufacturing an EWF product combining a fiberboard substrate and a 2.5-mm-thick sliced-wood face component is not recommended. Within the limits of this study, the density of the fiberboard (MDF or HDF) substrate face layer thickness was the only driver in cupping deformation.

To compare EWF constructions made with different fiberboard densities and face component production types

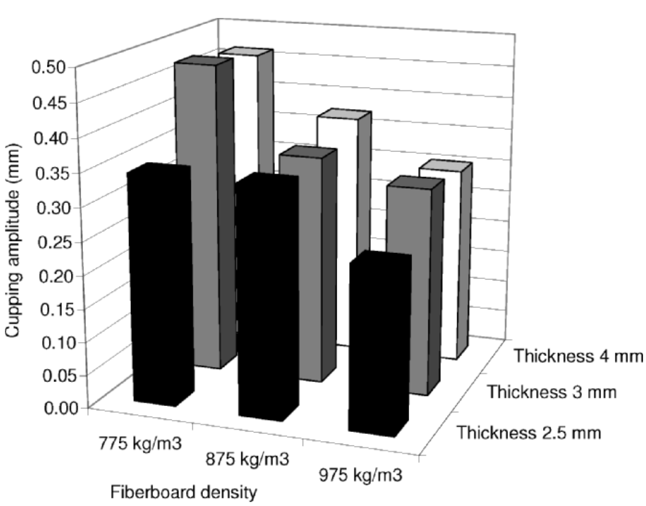

Figure 3.—Average cupping amplitude in EWF constructions as a function of the thickness of the sawn face component and three fiberboard substrate densities.

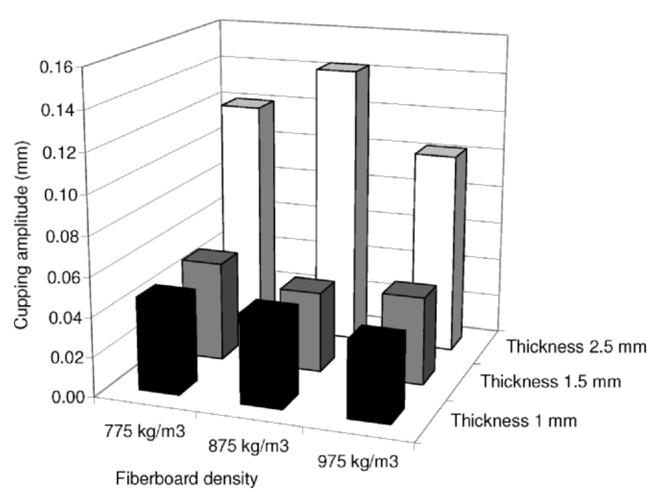

Figure 4.—Average cupping amplitude in EWF constructions as a function of the thickness of the sliced face component and three fiberboard substrate densities.

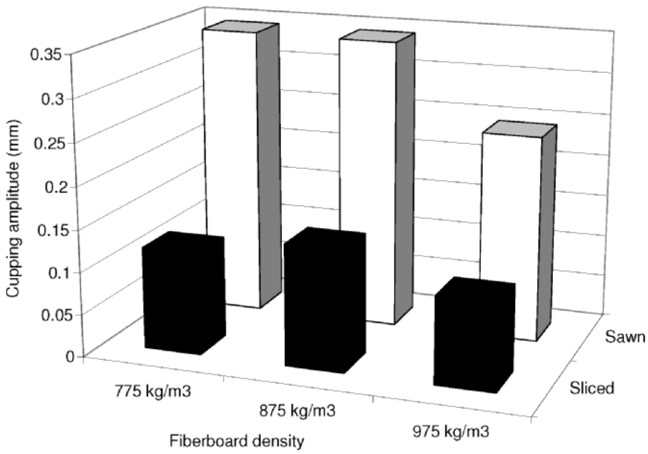

Figure 5.—Average cupping amplitude in EWF constructions as a function of sawn or sliced face components of a constant thickness and three fiberboard substrate densities.

(sawn vs. sliced), a third experimental design compared specimens consisting of a 2.5-mm-thick face component produced by sawing and slicing processes glued onto fiberboard substrates at three different densities (MDF and HDF) (Table 3). The corresponding ANOVA results are shown in Table 7. The process selected to obtain the face component, sawing or slicing, proved highly significant ($\alpha = 0.01$). Similar results were obtained by Blanchet (2008) for various glued-down EWF constructions. In fact, the choice of a face layer manufacturing process has such an important F value that it should be the starting point in the design of HDF substrate-based EWF. At a 2.5-mm face layer thickness, fiberboard density was also significant ($\alpha = 0.05$) for both the sawn and sliced face components. The effect of the process is well illustrated in Figure 5, where EWF cupping amplitude for a sliced face layer is roughly one-third of what it is with a sawn face layer.

Table 7.—ANOVA table used to assess the effects of the face component manufacturing process and fiberboard substrate density.

Source	Degrees of freedom	F value	Pr > F
Model	5	26.74	<0.0001
Error	60		
Density (D)	2	6.14	0.0037
Process (P)	1	117.51	<0.0001
$D \times P$	2	1.94	0.1521

Table 8.—ANOVA table used to assess the effects of the backing layer type and the face component manufacturing process.

Source	Degrees of freedom	F value	Pr > F
Model	7	31.20	<0.0001
Error	80		
Process (P)	1	193.23	<0.0001
Backing (B)	3	5.98	0.0010
$P \times B$	3	2.41	0.0733

Table 9.—Duncan comparison test on the effects of the backing layer type on cupping deformation in EWF constructions using sawn and sliced components.

Backing type	Average value	Duncan grouping	
Sawn face component—HDF substrate density, 875 kg/m^3			
No backing	0.310	A	
2-mm-thick veneer	0.343	A	
Foil	0.321	A	
Melamine-impregnated paper	0.249		B
Sliced face component—HDF substrate density, 875 kg/m^3			
No backing	0.179	A	
2-mm-thick veneer	0.143	A	B
Foil	0.141	A	B
Melamine-impregnated paper	0.120		B

Table 8 presents the ANOVA results for the assessment of the impact of the backing layer and the face component production type on the cupping deformation of EWF made with an HDF (density = 875 kg/m^3) substrate. As previously, the face component manufacturing process was highly significant ($\alpha = 0.01$) but the use of a backing layer also proved highly significant ($\alpha = 0.01$). In order to further clarify the effect of the backing layer, two Duncan multiple comparison tests were performed on the data for both sawn and sliced face layers (Table 9; Fig. 6). As shown in the table, melamine-impregnated paper helps to decrease the cupping in the construction setup using a sawn face component. In fact, the use of a backing layer under a sawn component had a positive impact. Blanchet et al. (2003, 2006) also determined that the use of a backing layer was significant but as a secondary order design lever. In fact, the modulus of elasticity and thickness were identified as primary design levers for various glued-down EWF constructions in that study. The results of the present study show that a melamine paper backing may have greater effect

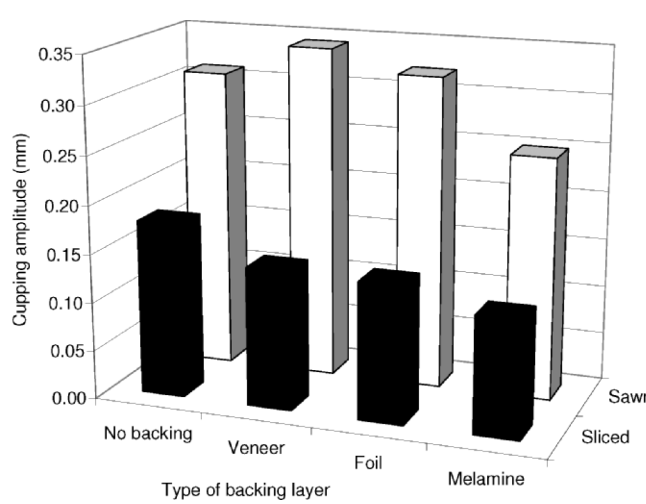

Figure 6.—Average cupping amplitude in EWF constructions as a function of sawn or sliced face components of a constant thickness, a constant fiberboard substrate density, and four backing strategies.

on HDF-based floating EWF systems than stated in previous studies (Blanchet et al. 2003, 2006).

In the constructions using a sliced face component, all the backing types had a positive effect on the cupping observed (Group B). The performance of EWF specimens using a veneer or a foil was comparable to that of specimens with no backing (Group A). With the use of a melamine-impregnated paper, cupping deformation decreased by 33 percent when compared with specimens without any backing layer. This may be explained by the high stiffness of polymerized melamine-impregnated paper compared with that of veneer and foil. It is worth noting that melamine-impregnated paper was also the cheapest of the backing materials considered ($0.068/ft^2), followed by foil ($0.080/ft^2) and 2-mm-thick aspen veneer ($0.130/ft^2).

Conclusions

The use of fiberboard as a substrate in the manufacture of EWF is gaining acceptance in the industry. The aim of this study was to assess the effects of the different components in MDF- and HDF-based products in order to improve performance and design. The study covered 2.5-, 3-, and 4-mm-thick sawn face components, as well as 1-, 2-, and 2.5-mm-thick sliced face components. It also included three fiberboard substrate densities (775, 875, and 975 kg/m^3) and four backing strategies (no backing layer, 2-mm-thick aspen veneer, foil, and melamine-impregnated paper).

A first conclusion from the study was that, in the design of a fiberboard-based EWF product, the type of face layer manufacturing process should be the first decision, since it will affect the choice of the other components. Sliced face components led to lower cupping deformation in the finished product. It should be noted, however, that thick sliced veneers are known to develop microchecks that can be visible in the product when installed. This suggests that a sliced face layer should preferably be thinner than 2.5 mm in thickness. At this thickness level ($<$2.5 mm), the density of the fiberboard had no effect on cupping (could range from 775 to 975 kg/m^3). The use of a backing layer will complete the design and decrease cupping deformation accordingly. Backing layers consisting of 2-mm-thick aspen veneer, foil, or melamine-impregnated paper were found to decrease cupping by 20 percent, 21 percent, and 33 percent, respectively, as compared with constructions without backing.

A sawn face layer will generate a higher level of cupping deformation (up to three times more than a sliced component), a thinner face layer inducing a lower degree of cupping deformation. Fiberboard density selection will also be critical. The higher the density, the lower cupping deformation will be. Selecting a high-density substrate may, however, lead to supply difficulties, since HDF with a density of 975 kg/m^3 is considered a specialty product.

Acknowledgments

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