Composites Science and Technology 157 (2018) 40–47

Contents lists available at ScienceDirect

Composites Science and Technology

journal homepage: http://www.elsevier.com/locate/compscitech

Hot-pressing composite curling deformation characteristics of plastic film-reinforced pliable decorative sliced veneer

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ARTICLE INFO

Article history:
Received 30 June 2017
Received in revised form
27 December 2017
Accepted 13 January 2018
Available online 2 February 2018

Keywords:
Plastic film
Decorative sliced veneer
Plastic film reinforced pliable decorative sliced veneer
Curling deformation
Finite element analysis

ABSTRACT

The new type of plastic-film-reinforced pliable decorative sliced veneer (PRPDSV) is a green product that features remarkable water resistance, no glue penetration, easy operation, low cost, good environmental protection, and no formaldehyde release. However, curling deformation under high-temperature hot-pressing is a bottleneck in the industrial development of this product. The relationship among hot-pressing temperature, thickness of decorative sliced veneer and plastic film, and type of decorative sliced veneer and curling deformation was studied through calculating experimental and theoretical models to explore the factors that influence the curling deformation of PRPDSV under hot-pressing. The nonlinear finite element analysis method was used for the first time to establish the elastic-plastic finite element simulation model of the PRPDSV composite. A comparison of the results obtained through the job visualization model and the experimental results indicated the reliability of the established model. Results showed that the hot-pressing temperature had a remarkable effect on the curling deformation of PRPDSV. As the hot-pressing temperature increased, the curvature radius of the curling deformation decreased and the curling degree gradually increased. The curling deformation was small when the ratio of the thickness of decorative sliced veneer was greater than that of the plastic film. The decorative sliced veneer with dense wood pores and other cellular tissues presented slight curling deformation from the hot-pressing composite.

1. Introduction

The high-speed development of the economy and continuous progress in the material standards of living have increased the development of furniture and interior decoration industries, as well as the demand for wooden decorative materials [1,2]. This trend has intensified the contradictions between supply and demand for natural precious timber [3,4]. Pliable decorative sliced veneer emerged to improve the added value of wood products and the use of precious trees as wood. In particular, the new type of plastic-film-reinforced pliable decorative sliced veneer (PRPDSV) we invented has broad market prospects because of its advantages, including remarkable pliability, no glue penetration, good water resistance, and no sizing in the processes of preparation and facing. These features, especially the latter, greatly simplify the production process, improve the production efficiency, save on production cost, and avoid the release of free formaldehyde [5,6].

PRPDSV is a mechanical meshing structure formed by the permeation of plastic film into the pliable decorative sliced veneer via high-temperature hot-pressing and fusion [7]. The plastic film and decorative sliced veneer are relatively thin and have different thermal expansion coefficients (the former is approximately 10 times bigger than the latter). The processes of high-temperature hot-pressing synthesis and unloading and cooling to room temperature cause a significant difference in the shrinkage displacement of decorative sliced veneer and plastic film. Such difference easily causes the curling deformation of pliable decorative sliced veneer to occur toward the side of the plastic film [7–10]. Curling deformation is an important index to judge product quality because it affects the subsequent improvement of the veneering effect and reduces production efficiency [11–13]. Thus, it is one of the key technical problems in the industrial production and application of PRPDSV [14–18].

In this work, an experimental study on the hot-pressing synthesis preparation of PRPDSV was conducted to explore the factors that influence curling deformation. The nonlinear finite element

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https://doi.org/10.1016/j.compscitech.2018.01.028

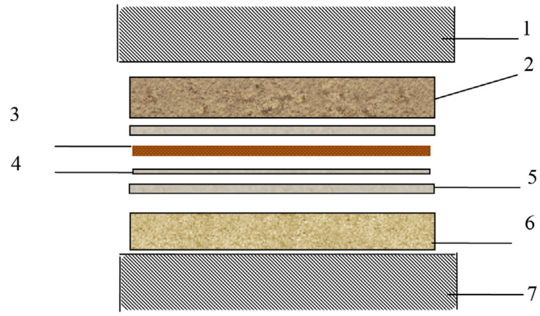

Fig. 1. Modified polyethylene film and decorative veneer hot-pressing assembly.

method called ABAQUS was used to establish the mechanical simulation model of the hot-pressing composite curling deformation of PRPDSV. The comparative analysis of the solution and the experimental results show that the hot-pressing temperature, the thickness ratio of the materials, and the type of decorative sliced veneer have different degrees of effect on curling deformation. These results provide technical guidance to solving the curling deformation of products and promote the industrial production of PRPDSV.

2. Experimental materials and method

2.1. Materials and equipment

Decorative sliced veneers from *Quercus coccinea*, *Tectona grandis*, *Pterocarpus indicus* Willd, and *Fraxinus mandshurica*, with specifications of 250 × 250 mm and 12% moisture content, and low-density polyethylene (LDPE) film 250 × 250 mm in size and with 0.92 g/cm^3 density, were compounded through a hot-pressing machine (Zhuoshang Type G-12) to produce PRPDSV under different hot-pressing conditions.

2.2. Preparation of PRPDSV

As Fig. 1 shows, the decorative sliced veneer was compounded to an LDPE film to form the composite slab. Then, anti-sticking polytetrafluoroethylene (PTFE) plates were added on the upper and lower surfaces of the composite slab, and a steel plate was placed under the undersurface to buffer and level. The following thermal pressure composite was conducted according to the experimental design conditions, and the pressure of the composite (plastic/veneer) samples was relieved for natural cooling and drying. Finally, the PRPDSV was taken off from the PTFE plates [7].

2.3. Experimental design

2.3.1. Influence of hot-pressing temperature on curling deformation

The *Q. coccinea* decorative veneer and LDPE film composite slab was hot-pressed at 1.0 MPa for 120 s and at hot-pressing temperatures of 120 °C, 125 °C, 130 °C, 135 °C, 140 °C, 145 °C, 150 °C, 155 °C, 160 °C, and 165 °C to measure the curling deformation of PRPDSV under different hot-pressing temperatures. Each experimental condition was tested thrice, and the results were averaged.

2.3.2. Influence of material thickness ratio on curling deformation

The LDPE film with 0.02, 0.03, 0.04, and 0.05 mm thickness and *Q. coccinea* decorative veneer with 0.2, 0.3, 0.4, and 0.5 mm thickness were selected. Their composite slab was hot-pressed at 1.0 MPa for 120 s and at a hot-pressing temperature of 120 °C [7] to measure and discuss the influence of their thickness ratios on the curling characteristics of PRPDSV. Each experimental condition was tested thrice, and the results were averaged.

2.3.3. Influence of decorative sliced veneer species on curling deformation

Commonly used ring and scattered hole wood sliced decorative veneers, such as *Tectona grandis*, *Q. coccinea*, *Pterocarpus indicus Willd, and Fraxinus mandshurica*, were selected and the material parameters such as density, thermal expansion coefficient, and elastic modulus were measured, as Table 1 shows, initially to explore the curling deformation situation of different kinds of decorative veneers for PRPDSV.

Wood density can be tested based on the international standard ISO 3131:1975. The sample size was 20 × 20 × 20 mm and the accuracy and moisture content of sample preparation were carried out according to the standard ISO 3129:1975.

The thermal expansion coefficient was tested using the differential based on the standard ASTM D696:2003. The diameter and length of the sample based on the UBD universal dilatometer were 3 mm and 50 mm, respectively.

The tangential and horizontal elastic modules were tested with reference to ISO 13061-4-2014: The physical and mechanical properties of wood-Test methods for small clear wood specimens - Part 4: Determination of modulus of elasticity in static bending.

The tangential and horizontal Poisson's ratio was tested in accordance with the optical measuring method of ISO 527-1.

2.4. Curling measurement and characterization

In the existing evaluation system of the curling degree of composite materials, the maximum warping deformation is generally used for judgment [17]. The curling degree of PRPDSV is defined by the curvature radius *R*, as shown in Fig. 2. (a) Shows that when the curling degree is huge and more than a half circle, the curvature radius is equal to the radius of the circle. Fig. 2(b) shows that when the curling degree is relatively small and less than a half circle, the curvature radius *R* can be calculated by Formulas (1)–(3) through the arc length *C*, the chord length *L* and the central angleθ. A horizontal–vertical slab structure should be manufactured to test and calculate the curvature radius of the flexible decorative veneer

Table 1
Material characteristic parameters of decorative veneer and LDPE film.

Species	Destiny (g/cm^3)	Coefficient of thermal expansion ($\times 10^{-6}$/K)	Tangential Poisson ratio	Horizontal Poisson ratio	Tangential elastic module (MPa)	Horizontal elastic modulus (MPa)
Tectona grandis	0.72	6.2	0.309	1.051	500	1000
Q.coccinea	0.74	7.6	0.302	1.027	570	1140
Pterocarpus indicus Willd	0.93	8.4	0.298	1.013	700	1300
Fraxinus mandshurica	0.65	5.4	0.318	1.082	460	920
LDPE film	0.92	86.2	0.431	0.431	216	216