CONTINUUM MODELING OF ENGINEERING CONSTANTS OF ORIENTED STRANDBOARD

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(Received January 2002)

ABSTRACT

A two-dimensional model to predict engineering constants of oriented strandboard (OSB) was developed using a continuum theory. The orthotropic flake properties, flake alignment distribution, and panel shelling ratio (as measured by flake weight ratio, FWR, between face layer and entire board) for three-layer OSB were considered in the model.

The two-term cosine probability density function (PDF) provided an effective way to describe flake alignment distributions for both single and three-layer OSB based on flake angle measurements from the panel top surface. The parameters that define the PDF varied with percent alignment (PA) and FWR. The continuum model, combined with flake alignment PDFs, predicted general trends of changes in OSB's engineering constants including Young's moduli, shear modulus, Poisson ratio, and linear expansion (LE) coefficients. The predicted values Young's moduli and LE along the two major directions compared well with experimental data for selected board structures. The three-dimensional mesh plots on various properties allow examining the trend of change of each property as a function of PA and FWR, which can be used to optimize OSB's engineering performance.

The continuum model provides a comprehensive analytical solution for the prediction of two-dimensional engineering constants of OSB, which is the basis for future modeling on OSB's void structure.

Keywords: Flake alignment distribution, in-plane modulus, laminate modeling, linear expansion coefficient, structural panel.

INTRODUCTION

Considerable amount of work has been done to correlate mechanical and swelling properties of structural oriented strandboard (OSB) to various processing variables including board density, resin content, and flake alignment level (Kelly 1977; Geimer 1979; Wu 1999). Establishment of quantitative relationships among the variables is typically limited to empirical modeling of experimental data collected from extensive laboratory testing. This is probably due to the fact that the orthotropy of the constituent oriented strand matrix considerably increases the complexity of the mechanical analysis. Attempts have been made to develop theoretical models for the prediction of elastic constants and linear expansion (LE) of OSB (Hunt and Suddarth 1974; Shaler and Blankenhorn 1990; Xu and Suchsland 1997; Xu 2000; Barnes 2000; Lee and Wu 2002). However, flakes as orthotropic planar components, flake alignment distribution (FAD), thermal/mechanical modification of flake properties, panel shelling ratio (as measured by flake weight ratio, FWR, − weight proportion of flakes in the face layer

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Wood and Fiber Science, 35(1), 2003, pp. 24–40

TABLE 3. *Model parameters of the probability density function at various PAs and FWRs obtained by simulation analysis.*

FWR	Percent alignment (%)									
	0	10	20	30	40	60	60	70	80	84
					Parameter a_1					
1.0	−0.003	0.215	0.434	0.654	0.873	1.092	1.311	1.531	1.772	1.837
0.7	0.101	0.180	0.258	0.337	0.416	0.495	0.573	0.652	0.730	0.762
0.4	0.116	0.054	−0.01	−0.07	−1.13	−0.19	−0.26	−0.32	−0.38	−0.40
0.0	−0.04	−0.25	−0.50	−0.75	−1.00	−1.25	−1.59	−1.74	−1.99	−2.09
					Parameter a_2					
1.0	0.052	0.082	0.142	0.232	0.352	0.502	0.682	0.892	1.132	1.236
0.7	0.186	0.216	0.276	0.366	0.486	0.636	0.816	1.026	1.266	1.371
0.4	0.205	0.235	0.295	0.385	0.505	0.655	0.835	1.045	1.285	1.389
0.0	0.052	0.082	0.142	0.232	0.352	0.502	0.682	0.892	1.132	1.236

els of PA and FWR are summarized in Table 3 for both single- and three-layer boards.

The shape parameters predicted by Eq. (16) are plotted in three-dimensional graphs in Fig. 5 in comparison with the original data fitted from measurements on the panel surface. Parameter a_1 (Fig. 5a) increased with increases of PA and FWR. Its relationship with FWR is linear, but becomes significantly curvilinear at higher PA. Parameter a_2 (Fig. 5b) increased with increases of PA, similar to a_1. It had a symmetric relationship with FWR with peak values along the FWR = 0.5 line. This symmetric characteristics of the a_2-FWR relationship directly influenced the trend of the predicted shear modulus-FWR relationship shown later in the paper.

Simulated probability density.—Flake alignment probability densities as a function of alignment angle and PA (or FWR) were simulated using Eq. (1) with a_1 and a_2 defined by Eq. (16). Typical probability density data in relation with PA and alignment angle from 0 to 1.57 radians are shown in Fig. 6a. Along Side A (PA = 0%), the probability density was equal to a constant ($1/\pi$) at all flake alignment angles, indicating a uniform flake alignment distribution. Along Side B, the density decreased from its maximum value as flake alignment angle increased. This was due to the fact that most flakes were aligned towards the MD. As PA increased, the probability density increased in the MD (Side C), and decreased in the CD (Side D). With PA > 60%, the probability densities at flake angles $\theta > 0.628$ radians were close to zero, indicating that few flakes were aligned at these directions. The slightly upward trends of the density values in the corner range defined by Sides B and C were due to the nature of the PDF (Eq. (1)). This indicates the limitation of the two-term cosine PDF, which are further discussed later in this section.

Typical variations of probability densities as a function of FWR and alignment angle are shown in Fig. 6b. The trend was anti-symmetric with respect to the line at FWR = 0.5 due to the nature of three-layer OSB with the cross-aligned flakes. Along Side A (FWR = 0), the density increased with increases in the flake alignment angle. The opposite is true along Side B (FWR = 1.0). Along Side C (θ = 0), the probability density was the lowest when FWR = 0 (core layer only), and it increased with the increase of FWR, and reached maximum at FWR = 1.0. The opposite trend is seen along Side D (θ = 1.57 radians). The prediction of such a stereoscopic change in flake alignment distributions as affected by two major variables (PA and FWR) is helpful for optimizing the process variables related to control OSB engineering properties.

Limitation.—The shape parameters a_1 and a_2 are subjected to limits to ensure that no negative probabilities are generated. As shown in Fig. 6a, the distribution narrows from Side A