On the measurement of fiber orientation in fiberboard

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Abstract

An attempt to measure the vertical component of fiber orientation in fiberboard is described. The experiment is based on the obvious reduction of the furnish fiber length which occurs by cutting thin microtome sections of the board parallel to the board plane. Only when no vertical fiber orientation component is present will the fibers contained in these sections have the same average length as the fibers in the board at large. Increasing deviation of fiber alignment from the board plane will result in shorter fiber lengths in the microtome sections.

These relationships could be predicted by computer analysis. The comparison of actual measurement of fiber lengths in microtome sections with fiber lengths estimated by computer for different fiber orientations allowed the estimation of the actual vertical orientation component in a medium-density fiberboard sample. An automatic optical image analyzer coupled to a microscope was used for fiber length measurement.

The sequence of manufacturing steps in the fiberboard process — random deposition of fibers followed by densification in the press — results in a fiber composite in which the individual fibers assume positions of near parallelism relative to the plane of the board (x-y plane), while within such planes their orientation is virtually random.

It has been demonstrated that efforts to align fibers within the x-y plane, either in the x or the y direction, can have dramatic consequences in terms of property modification.[1] It may be assumed that a modification of the fiber orientation out of the x-y plane, that is, the introduction of a vertical z-direction component, would have similar results. It is even probable that such vertical components exist to varying degrees in different types of fiberboard, introduced possibly by the use of very short fibers or by certain characteristics of the fiber depositing equipment. At present, fiber orientation is neither measured, monitored, nor controlled commercially.

The ability to rapidly measure fiber orientation could become an important technological tool which could significantly contribute to improved product performance and better quality control. This paper describes an attempt to use computer simulation and automatic digital image analysis for the measurement of the vertical (z-direction) component of fiber orientation in fiberboard.

Concept of computer model

The computer model was developed to demonstrate the effect of a given z-component on the fiber length distribution in thin sections of board taken from the center of the board and parallel to the board surfaces. The fiberboard will be manufactured at some depth or thickness D and from a fiber furnish which is assumed to have a normal distribution of fiber length. If the fiber length distribution deviates significantly from a normal distribution, then the concept could be modified for the given distribution curve.

Thin sections of thicknesses $T_1, T_2, \ldots$, taken in the x-y plane of this board (Fig. 1) would show exactly the same fiber length distribution as that of the furnish, as long as all fibers were oriented perfectly in the plane of

[1]Talbot, J.W. 1974. Electrically aligned particleboard and fiberboard. *In*: Proc., 8th Particleboard Symp. Pullman, Wash.

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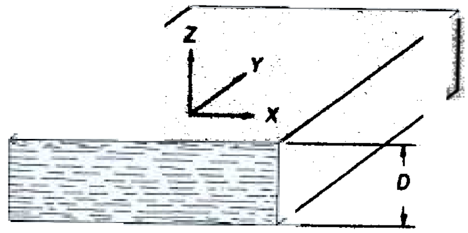

Figure 1. — Fiberboard sample in which the board plane is defined as the x-y plane. The z-direction identifies the direction of the vertical orientation component.

the board (no z-component). If, however, a z-component were introduced, the fiber length distribution in thin sections would differ from that of the furnish and would depend on section thickness, because some fibers would intersect the cutting planes.

The z-component of the fiber orientation is assumed to be an unbiased variation of the fiber alignment about the plane of the board. This means that the average angular fiber inclination out of the x-y plane of the board would always be zero degrees. The positions of fibers in a plus and minus angle relative to the plane of the board would have equal likelihoods of occurring. Thus, the z-component is assumed to be a normal distribution of the angular fiber inclination about the plane of the board. It is characterized by its standard deviation in degrees.

The computer model calculates the fiber length distribution in sections of various thicknesses for any given z-component in terms of the standard deviation in degrees.[2] Actual fiber length measurements on real samples can then be compared with the computer output, and the z-component may be estimated.

Experimental procedures

The method outlined above was applied to an experimental medium-density fiberboard manufactured at the Southern Forest Experiment Station laboratory in Pineville, La. The species was sweetgum, refined in a Bauer 418 pressurized refiner. Mats were formed dry and hot-pressed to a board specific gravity of .71 and a thickness of 3/4 inch. Resin content was 8 percent urea-formaldehyde solids.

Smooth microtome sections of various thicknesses were prepared from the board center by a technique that tried to assure near perfect parallelism of section surface and board plane. One-half the thickness of a 1- by 2-inch sample was first removed using a miniature milling machine and fly-cutter to generate a midsection surface parallel to the exterior board surface. After band-sawing into small prisms, 1/4 by 1/4 by 3/8 inch, the original board surface was glued to a wood block held in the microtome vise. The surface of the block had previously been microtomed parallel to the cutting plane generated by the knife.

A small quantity of "instant" glue was applied to the midsection surface and allowed to briefly dry. Sections of the desired thickness were cut, measured, and placed in acetone to remove the "instant" glue. The sections were then macerated in Jeffrey's solution to yield individual fibers.

Fiber length was measured using an automatic optical image analyzer coupled to a microscope.[3] Automatic image analysis, a relatively new technology, employs optical, video, electronic, and computer components to perform measurements and process information from images with minimal user interaction.

For fiber length measurements, it is necessary to prepare slides with a minimum number of crossed or touching fibers as such agglomerates are measured as a single object. Accordingly, an extremely dilute water slurry of macerated fiber was prepared. A vacuum flask equipped with a plastic millipore filter was used to remove the water and deposit fibers on the filter surface. The filter was then pressed fiber side down on a clean glass slide and allowed to dry. When the filter was removed, the fibers remained attached to the slide.

Fiber length was derived by measuring the perimeter of individual fibers and dividing by two. This approach was used since fibers are not perfectly straight and direct measurement of the longest dimension would yield erroneous results. One-half the perimeter tends to slightly overestimate fiber length as the fiber width is included in the measurement. However, the method is more accurate than hand measurement from projections and was deemed sufficient for this initial experiment. Five hundred fibers were measured for each section thickness — the instrument automatically provided the mean, standard deviation, and frequency distribution histogram. The histograms were slightly skewed toward the shorter lengths. Other anatomical elements (vessels) and extremely fine material were excluded from the measurements by introducing a detection threshold.

The measured furnish fiber length distribution in terms of average and standard deviation and the section thicknesses were introduced as inputs into the previously described computer analysis. The computer then calculated fiber length distributions for these same thicknesses and for assumed standard deviations of the fiber inclination (z-component) ranging from 2 to 32 degrees (Fig. 2). The computer 'measured' 500 fibers in each section.

Results

The results of the fiber length measurements by image analyzer are summarized in Table 1. Each row represents the average of three different areas of the board (1,500 observations). A graphic illustration is shown in Figure 3. This relationship can be fitted with a straight line when a reciprocal scale is used for both variables. The fitted curve in Figure 3 was derived by this method.

[2]The computer program was developed by the Applications Programming Service (A. Johanson) of Michigan State University Computer Laboratory. For further information contact the senior author.

[3]McMillin, C.W. 1982. Application of automatic image analysis to wood science. Wood Sci. 14(3):97-105.

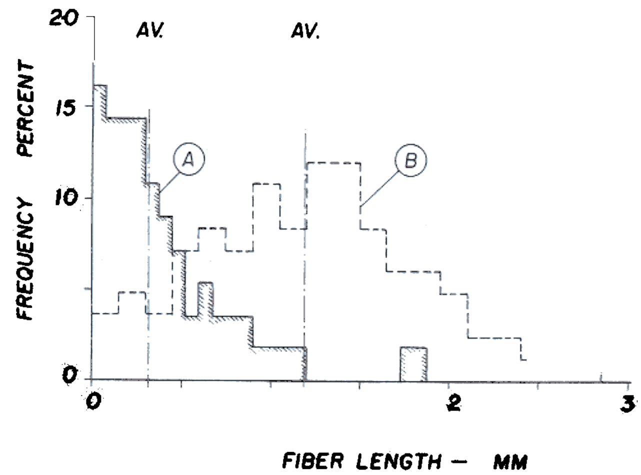

Figure 2. — Examples of fiber length distributions as 'measured' by computer in sections of two different thicknesses of fiberboard with an average furnish fiber length of 1.3 mm and a standard deviation of +/− .57 mm.

Section	A	B
Section thickness (mm)	.10	.96
Assumed z-component (degrees)	32.0	2.0
Avg. sect. fiber length (mm)	.314	1.184
Stand. deviation (mm)	.012	.025
Number of fibers 'measured'	500.0	500.0

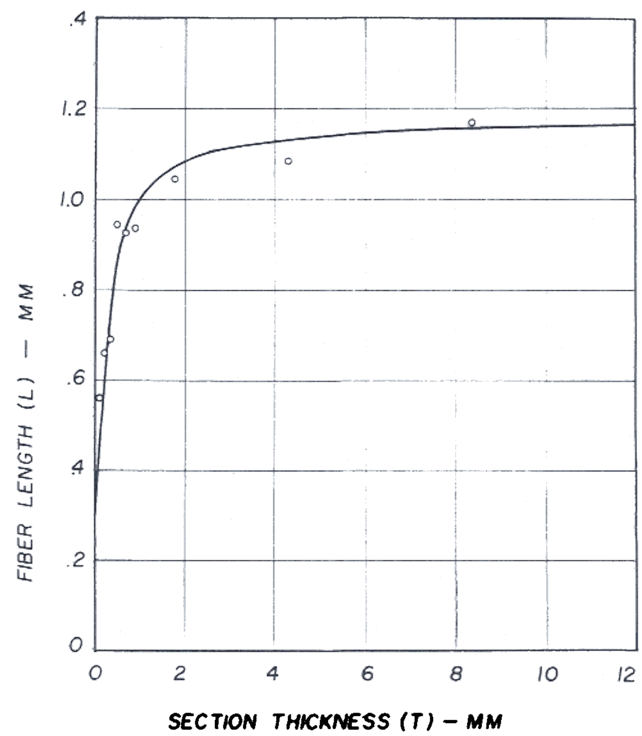

Figure 3. — Relationship between microtome section thickness, T, and average fiber length, L, as measured by image analyzer.

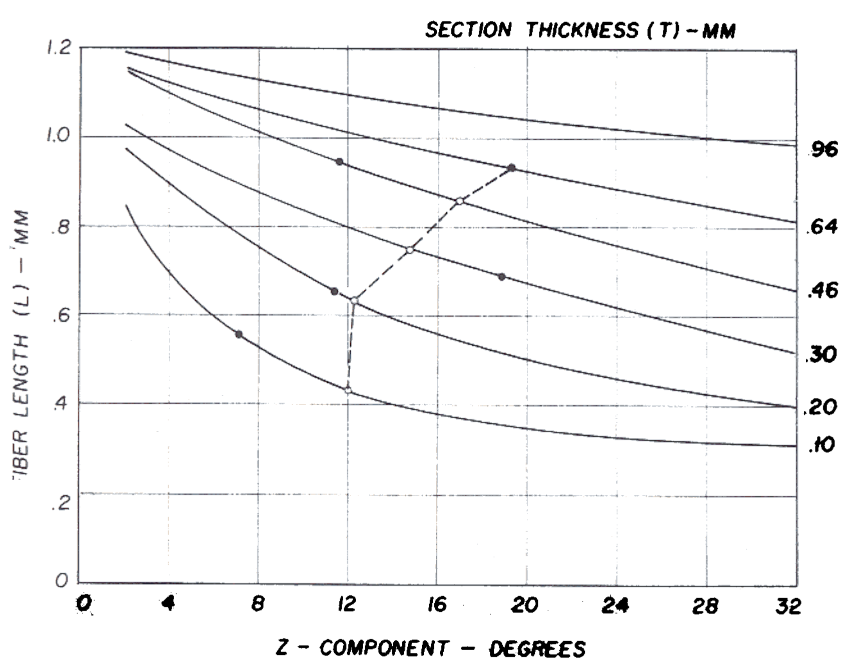

Figure 4. — Result of computer simulation showing relationship between section thickness, T, the z-component in degrees, and the average fiber length, L. The dotted line and the individual measurements are experimental results from Figure 3.

TABLE 1. — *Results of fiber length measurements on medium-density fiberboard.*

Section thickness (mm)	Fiber length	
	Mean (mm)	Std. dev. (mm)
.10		
.20		
.30		
.46		
.64		
.89		
1.78		
4.32		
8.38		
Furnish		

Figure 4 shows a family of curves representing the result of the computer simulation for this furnish. The solid data points are those values obtained with the image analyzer. The dotted line is the fitted curve in Figure 3. If the fitted curve would transform into a vertical line in Figure 4, the horizontal scale would then indicate identical z-components for all measured sections.

Figure 5 allows some estimation of the sensitivity of the described method. It was constructed as follows:

- The intersection of three vertical lines (10, 20, and 30 degrees) with the section thickness lines in Figure 4 were plotted over reciprocal scales of fiber length and section thickness.
- The plots were fitted with straight lines. The correlation coefficients between $1/T$ and $1/L$ were .974, .995, and .999, respectively.
- From the regression equations of the three lines, data points were computed and used to draw the three broken curves in Figure 5.

Also shown in Figure 5 are the measured values and a portion of the fitted curve from Figure 3, the real fiberboard.

It may be estimated that the z-component of this medium-density fiberboard is between 10 and 20 degrees. Assuming that the average is 15 degrees, this would mean that 68 percent of all fibers have a fiber angle between + 15 degrees and − 15 degrees, and that 32 percent of all fibers have larger fiber angles.

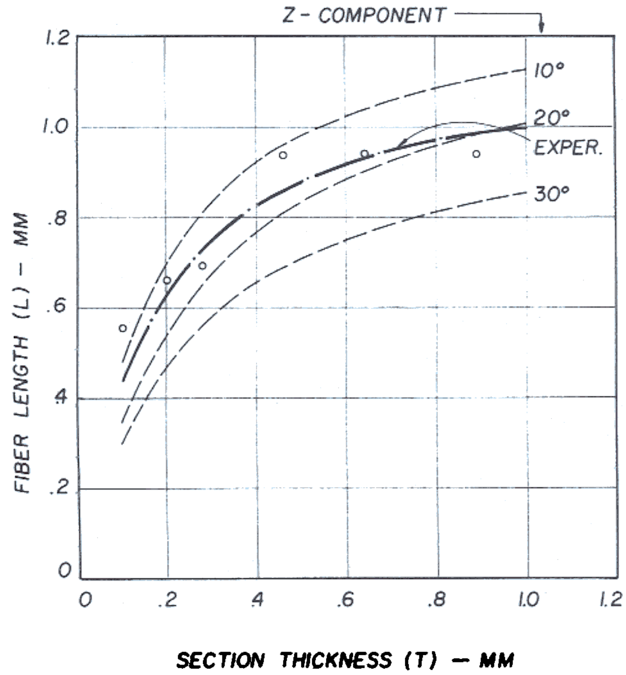

Figure 5. — Comparison of computer simulation with experimental results. Dotted lines are result of computer simulation, heavy curve is fitted to experimental results.

Conclusions

The following conclusions may be reached:

1. The combination of computer simulation and computer controlled measurement equipment promises to be an important tool which may be applied to the solution of some basic technological problems, inaccessible to more conventional laboratory methods.
2. The described method was capable of establishing the presence of a vertical component of fiber orientation in medium-density fiberboard.
3. The sensitivity of the described method appears to be less than adequate to produce the kind of discrimination necessary for practical work. However, both the computer simulation model as well as the measurement technique provide considerable opportunity for refinement.