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TENSION WOOD IN OVERCUP OAK

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TENSION WOOD IN OVERCUP OAK

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Introduction

Tension wood is characterized by the presence of peculiar gelatinous fibers that are physically and chemically different from typical wood fibers. When these gelatinous fibers are treated with certain biological dyes and reagents they are easily identifiable microscopically by their swelling and by the stain in part of the secondary wall.

Tests made at the U. S. Forest Products Laboratory and elsewhere, have shown that excessive longitudinal shrinkage is correlated with the presence of relatively large numbers of gelatinous fibers (5, 8).[2] Differential shrinkage caused by irregular distributions of the gelatinous fibers within a board sets up internal stresses that lead to bowing, crooking, and twisting of the board (1, 6), and frequently is associated with collapse.

This is an analysis of the relation of gelatinous fibers and percentage of fibrous area (including both typical and gelatinous fibers) to longitudinal shrinkage in overcup oak (*Quercus lyrata* Walt.).

Materials and Methods

This project originated because overcup oak veneer showed considerable edgewise crook during a veneer slicing test that was made in cooperation with the Southern Forest Experiment Station.[3] Examinations of the backboards of the quarter-sliced flitches indicated the presence of tension wood. Because of their extreme fuzziness, suspected areas were marked on each backboard.

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[1]Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[2]Underlined numbers in parentheses refer to literature cited references at the end of this report.

[3]The logs were obtained through the cooperation of the Southern Forest Experiment Station and the Chicago Mill and Lumber Company.

A total of 53 longitudinal shrinkage samples was cut across the full width of the backboards. These samples approximately 9.5 inches in length, came from four flitches taken from two trees. A total of 46 samples was finally selected for straightness of grain and freedom from other visible defects. The samples were taken from areas in the backboards suspected to contain tension wood.

The total longitudinal shrinkage that occurred as the wood dried from the green to the ovendry condition was determined for all samples to the nearest 0.001 inch with a dial micrometer. Longitudinal shrinkage was calculated as a percentage of the length of the specimens while green.

The comparative numbers of gelatinous fibers were determined by microscopical examination of microtome sections. These were taken from a block 3/4-inch long that had been cut along the grain from each longitudinal shrinkage sample. Each block was split into four approximately equal pieces. These four pieces were boiled in distilled water and stored in 70 percent alcohol until cross sections about 15 microns thick were cut. Thus, the sections from the four pieces represented the entire cross section of each longitudinal shrinkage specimen. One microtome section from each piece was treated with a temporary staining reagent, chloriodide of zinc (5), and microscopically examined immediately. From a second section of the same piece a permanent slide was made, using safranin as the staining reagent.

To estimate the comparative number of gelatinous fibers in each transverse section examined, a frequency distribution system was used (5, 8). A numerical value represented the frequency of the gelatinous fibers, such as occasional, scattered, abundant, or solid groups. To replace the visual estimate of distribution of the gelatinous fibers, a refinement was attempted. In order to increase the accuracy of this estimation, a microscope ocular equipped with crosshairs was used to divide the field of view into four quadrants. Beginning at one corner of the section and slowly traversing the entire field, it was possible to determine by count the total number of quadrants (T) in the entire cross section. By the same process, it was possible to determine the number of complete quadrants occupied by gelatinous fibers (G) for each frequency class. The quotient of these numbers (G ÷ T) gave the decimal value for the distribution.

The product of the frequency and distribution values was then calculated to express the comparative number of gelatinous fibers per unit area for each microtome section examined. The average of the four pieces gave the numerical value for the entire cross section of each longitudinal shrinkage sample.

The percentage of fibrous area, which includes scattered strands of parenchyma, can be estimated because the thick-walled fibers of oak appear as aggregations on the transverse surface (3). With a photographic enlarger set at a constant magnification, photomicrographs were made directly from the permanent slides stained with safranin. From these photomicrographs (figs. 1 and 2), the percentage of fibrous area, which included both typical and gelatinous fibers, was determined by planimetering these areas. The average of the four sections equaled the percentage of fibrous area for the entire cross section of each longitudinal shrinkage sample.

As an assist in analyzing the data, two simple regressions were set up to determine the relation of number of gelatinous fibers to longitudinal shrinkage and the relation of percentage of fibrous area to longitudinal shrinkage. Then, using the factors of the two simple regressions, a multiple regression problem was set up.

Structural Variation

In transverse microscopical sections of overcup oak containing solid concentrations of gelatinous fibers stained with safranin and fast green, the gelatinous layer was frequently detached from the remainder of the secondary wall. In the upper half of figure 3 the gelatinous layers are detached from the secondary wall, while in the lower half of the figure, showing typical fibers, the secondary wall is intact. This suggests that the gelatinous layer is loosely attached to the remainder of the secondary wall.

The gelatinous fibers of overcup oak showed a structural variation that has not been hitherto observed in other species of hardwood, such as cottonwood, mahogany, and other oaks. The innermost part of the secondary wall in some of the oak fibers did not react to either the fast green dye or chloriodide of zinc reagent (fig. 4). In these fibers the gelatinous layer did not extend to the inner boundary of the secondary wall, as it usually does in the other hardwoods when gelatinous fibers are present. This structural variation is in accord with a report by Jutte (2) in which he proposes some modification of the present description of gelatinous fibers. He describes gelatinous fibers as possessing a secondary wall built up entirely or in part of one or more unlignified layers, which may have no fixed position in the secondary wall.

The entire central layer of the secondary wall was essentially unlignified in many fibers of the overcup oak and also some fibers had only a part of the secondary wall unlignified as described above. In addition, some wholly gelatinous central layers of these secondary walls showed concentric lines, which implied some separation within that layer even though differential staining was not observed. The typical fibers, those without a gelatinous layer, did not show any separation within the secondary wall.

Results and Discussion

Microtome sections were extremely difficult to cut from the overcup oak because of staining and dulling of the microtome knife. Unless the knife was cleaned after every few sections, the stain, which was deep purple in color, was impossible to remove unless emery paper was used.

The gelatinous fibers were found frequently; of the 184 microtome sections analyzed, only 26 were without any gelatinous fibers. The values for the number of gelatinous fibers for all the samples are shown in table 1.

The percentages of fibrous area for the entire transverse section of each longitudinal shrinkage sample also are shown in table 1. Figure 1, with a total fibrous area of about 20 percent, and figure 2, with a total area of 65 percent, illustrate extremes in total fibrous area where some scattered parenchyma cells are included.

The longitudinal shrinkage (table 1) of 21 samples was appreciably above the usual range of longitudinal shrinkage, namely 0.1 to 0.3 percent of the green dimension (4). The greatest longitudinal shrinkage encountered in this study was 0.895 percent and the least was 0.074 percent.

Highly significant simple correlations were found between the number of gelatinous fibers (X_1) and longitudinal shrinkage (Y), and between percentage of fibrous area (X_2) and longitudinal shrinkage. These are, respectively, $r_{y.1} = 0.7490$ and $r_{y.2} = -0.3933$. A significant correlation was not found ($r_{1.2} = 0.0389$) between the comparative number of gelatinous fibers and percentage of fibrous area.

Graphs relating regressions of longitudinal shrinkage to number of gelatinous fibers and longitudinal shrinkage to the percentage of fibrous area are shown in figures 5 and 6. From the regression equations it can be assumed that, for every increase of 10 in the comparative number of gelatinous fibers, there is a corresponding increase of 0.214 percent in longitudinal shrinkage. From the regression equation shown in Figure 6 it can be assumed that, for every increase of 10 percent in fibrous area, the longitudinal shrinkage decreases 0.096 percent. That is, average increase in longitudinal shrinkage with additional numbers of gelatinous fibers was greater than the average decrease with additional fibrous area.

From table 1 it is noted that an area of low fibrous percentage and high in number of gelatinous fibers produces the highest longitudinal shrinkage. This may be due to the combined effect of gelatinous fibers and the longitudinal shrinkage of the tracheids, which comprise perhaps an equal or greater area than the fibers.

A multiple regression of longitudinal shrinkage based on the independent variables of comparative numbers of gelatinous fibers and percentage of fibrous area showed some interesting trends. The test of significance (7) of each variable on longitudinal shrinkage, while holding the other variable constant (partial regression), gave highly significant results.

$$\text{for } b'_{Y1.2} : t = 9.846$$

$$\text{for } b'_{Y2.1} : t = 5.437$$

where Y is longitudinal shrinkage, 1 the comparative numbers of gelatinous fibers, and 2 the percentage of fibrous area. These t values are significant at the 1 percent level. The multiple regression equation computed from the above data is:

$$Y = 0.5555 + 0.0219X_1 - 0.0103X_2$$

The relations between one variable and two others operating jointly is shown in a three-dimensional graph (fig. 7). From this graph it is readily apparent that in each of the fibrous area classes, longitudinal shrinkage increases in linear relation to additional numbers of gelatinous fibers. Conversely, in each of the gelatinous fiber classes, longitudinal shrinkage decreases with additional fibrous area.

Conclusions

Gelatinous fibers, which characterize tension wood, were found throughout suspected areas in the backboards from quarter-sliced flitches of overcup oak. Microscopical examination and determination of the relation of comparative numbers of gelatinous fibers and percent fibrous area to longitudinal shrinkage led to the following conclusions:

1. Gelatinous fibers were found in almost all parts of overcup oak boards suspected of having tension wood.

2. A weak attachment between the gelatinous layer and the remaining part of the secondary wall was revealed after staining with safranin and fast green.

3. The overcup oak showed variations in some of the gelatinous fibers such as the fibers whose layers did not extend to the inner boundary of the fiber wall as had been observed in some other hardwoods.

4. Almost half of the samples had a longitudinal shrinkage exceeding the usual range, namely 0.1 to 0.3 percent of the green dimension.

5. Statistical analyses of the data show that both gelatinous fibers and percentage of fibrous area jointly affect the longitudinal shrinkage in overcup oak. In each of the fibrous area classes, longitudinal shrinkage increases in linear relation to the additional numbers of gelatinous fibers. In each of the gelatinous fiber classes, longitudinal shrinkage decreases with additional percentages of fibrous area.

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Table 1.--Longitudinal shrinkage, percent fibrous area, and comparative numbers of gelatinous fibers for test specimens from two overcup oak trees

Designation of sample	Longitudinal shrinkage[1]	Fibrous area[2]	Comparative numbers of gelatinous fibers[3]
	Percent	Percent	
Tree No. 166			
1-3-2	0.232	34.87	16.42
1-3-3	.505	36.55	26.42
1-3-4	.600	32.78	19.82
1-3-5	.705	28.72	17.50
1-3-6	.726	33.77	20.12
1-3-7	.895	26.31	18.55
1-3-8	.863	33.21	19.92
1-3-9	.811	39.34	24.82
1-3-10	.695	27.54	15.87
1-4-11	.168	41.34	0.20
1-4-12	.147	35.13	.90
1-4-13	.200	32.39	.44
1-4-14	.211	31.52	3.25
1-4-15	.463	28.37	3.28
1-4-16	.495	29.73	13.62
1-4-17	.705	29.86	16.28
1-4-18	.432	18.20	3.42
1-4-19	.705	20.68	14.52
Tree No. 167			
2-4-21	.200	49.68	17.22
2-4-22	.200	57.46	13.58
2-4-25	.570	46.34	26.55
2-4-26	.337	42.00	14.08
2-4-27	.368	51.10	14.60
2-4-28	.210	49.16	8.88
2-4-29	.537	50.62	11.78
2-4-30	.421	55.54	10.60
2-4-31	.589	51.81	21.00
2-4-35	.348	50.81	11.38
2-4-36	.190	53.03	14.70
2-4-37	.442	53.96	25.82

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Table 1.--Longitudinal shrinkage, percent fibrous area, and comparative numbers of gelatinous fibers for test specimens from two overcup oak trees (continued)

Designation of sample	Longitudinal shrinkage[1]	Fibrous area[2]	Comparative numbers of gelatinous fibers[3]
	Percent	Percent	
Tree No. 167			
2-4-38	0.242	50.10	11.78
2-4-39	.211	46.90	10.12
2-4-40	.253	56.40	9.45
2-4-41	.411	38.94	13.40
2-4-42	.705	44.34	24.00
2-4-43	.716	52.07	24.55
2-1-44	.084	48.79	2.88
2-1-45	.084	42.02	1.22
2-1-46	.074	44.99	.10
2-1-47	.095	39.39	----
2-1-48	.126	35.48	1.38
2-1-49	.105	47.72	2.80
2-1-50	.137	52.53	.88
2-1-51	.137	42.04	.05
2-1-52	.242	39.63	----
2-1-53	.147	45.12	----

[1]Based on green dimension.

[2]Planimetered area of each cross section

[3]Calculated from the frequency and distribution of gelatinous fibers as estimated by microscopical examination. Average of the quartered sections.

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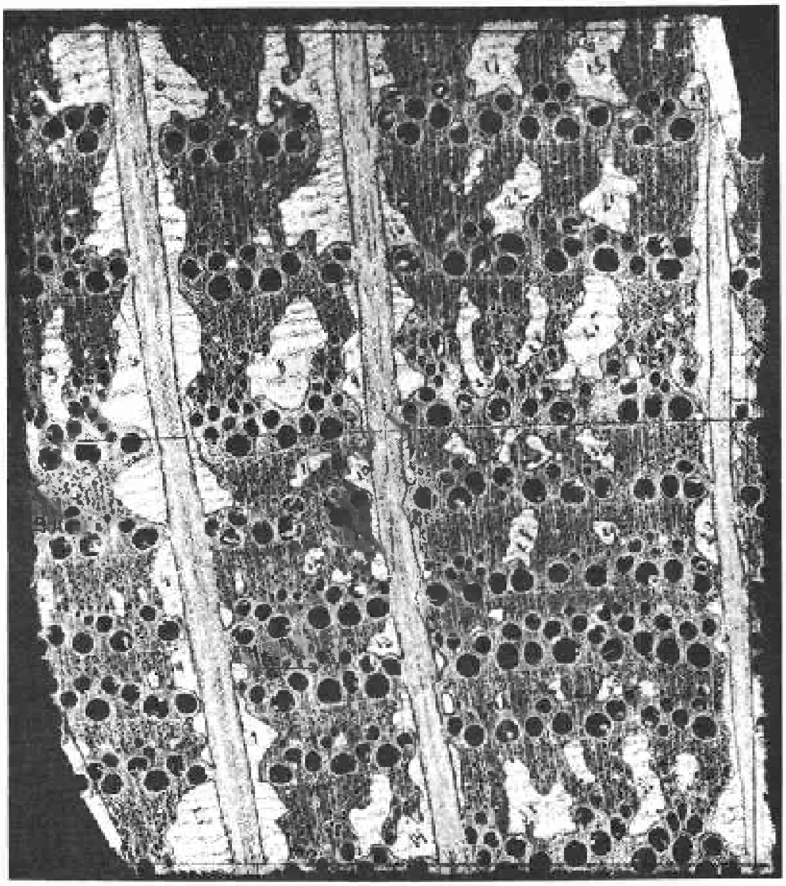

Figure 1.--A safranin-stained cross section of overcup oak showing about 20 percent of the area made up of thick-walled fibers.

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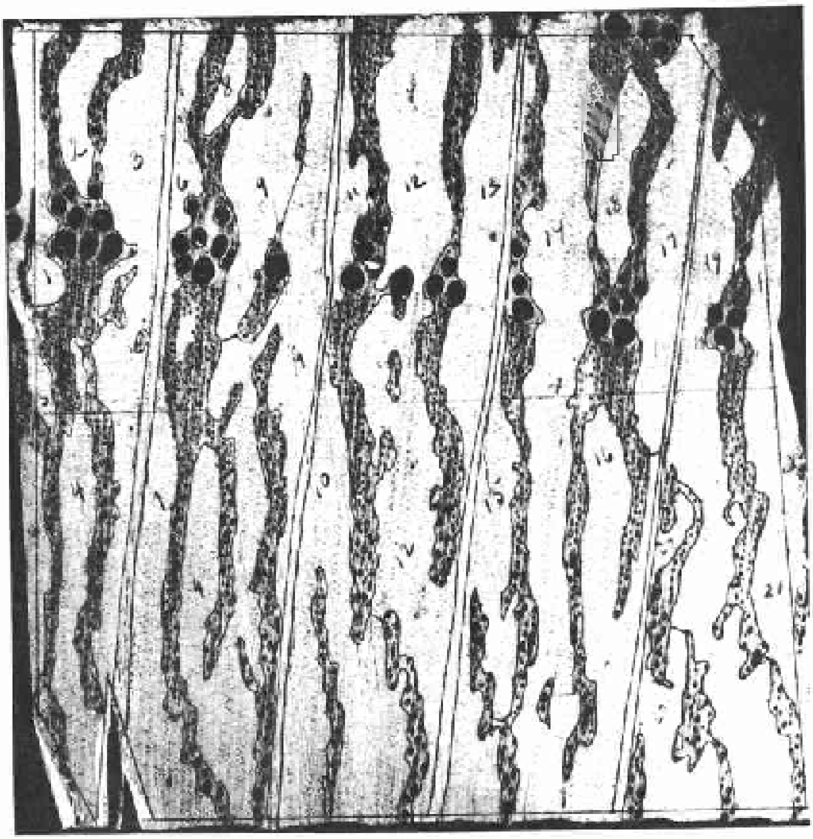

Figure 2. --A safranin-stained cross section of overcup oak showing about 65 percent of the area made up of thick-walled fibers.

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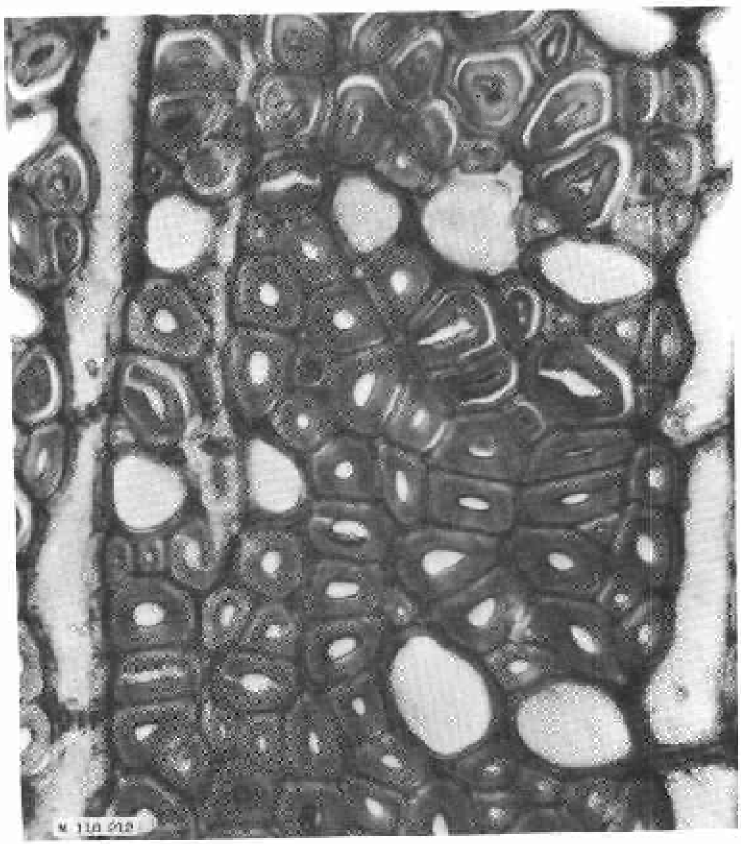

Figure 3. --Gelatinous fibers in upper half and typical fibers in lower half of photomicrograph. Note: the gelatinous layers are pulled away from the remaining part of the secondary wall while walls of the typical fibers are intact. 880X.

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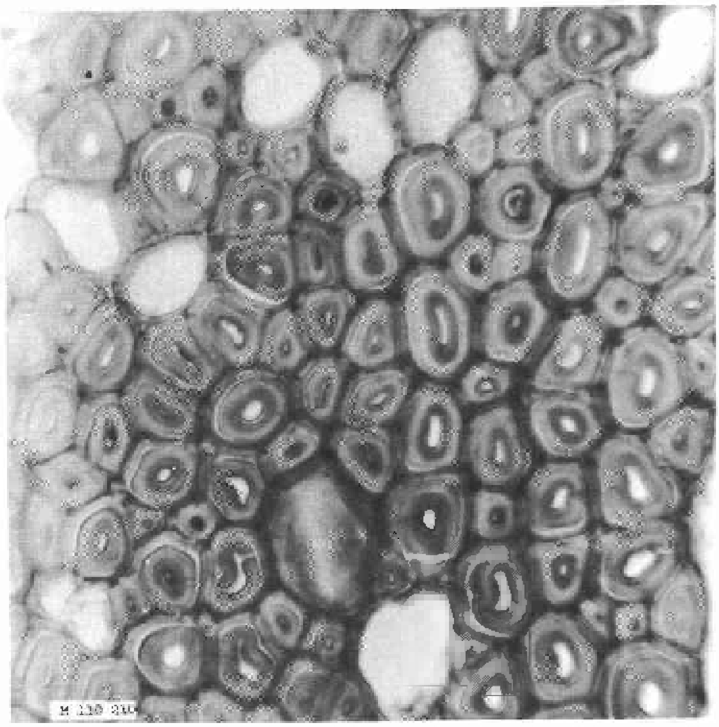

Figure 4. --Solid concentration of peculiar gelatinous fibers in overcup oak showing innermost dark part of the secondary wall differentially stained as compared to the light-colored gelatinous layer. 880X.

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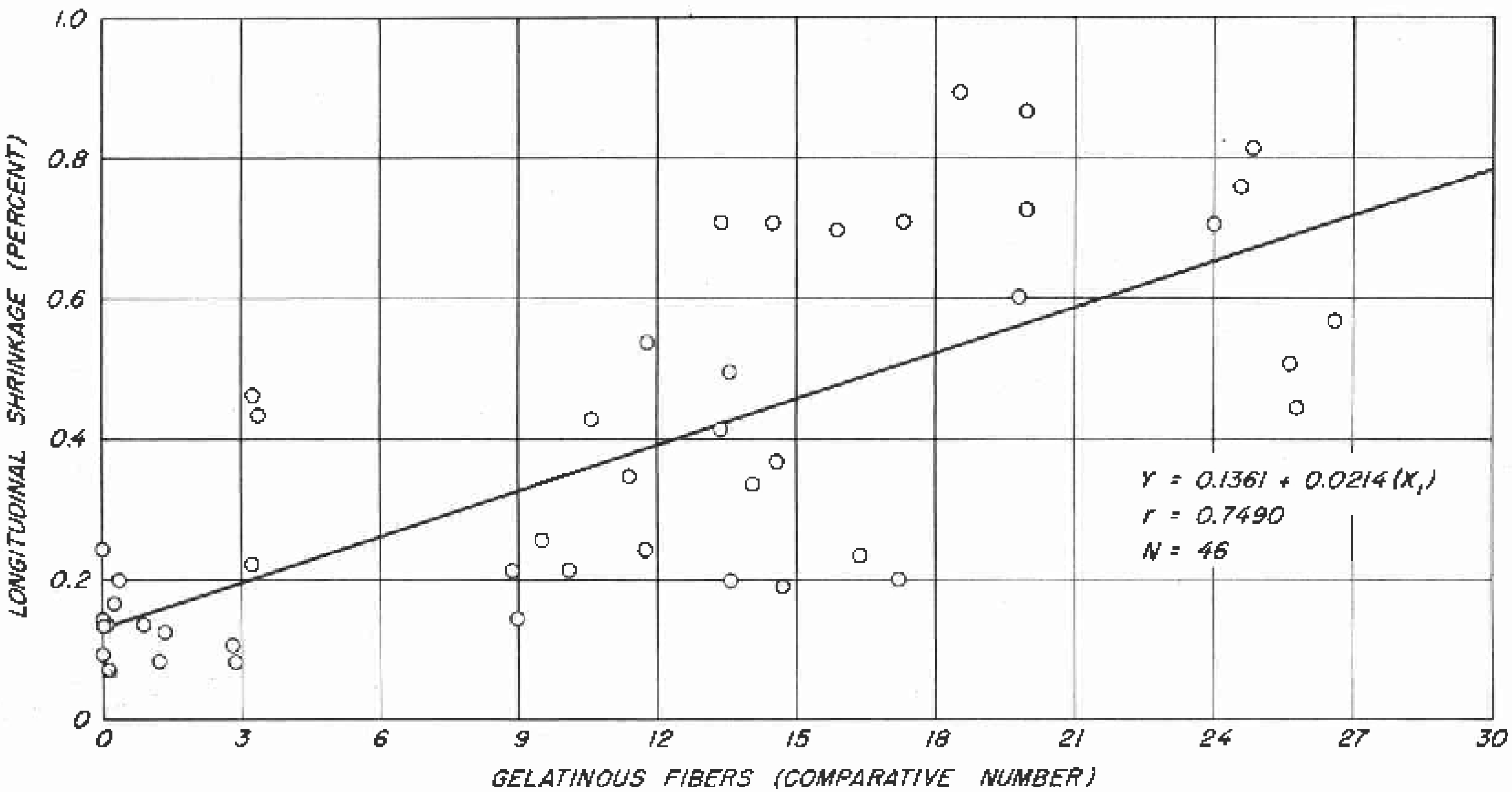

Figure 5. --Relation of longitudinal shrinkage on comparative numbers of gelatinous fibers for overcup oak.

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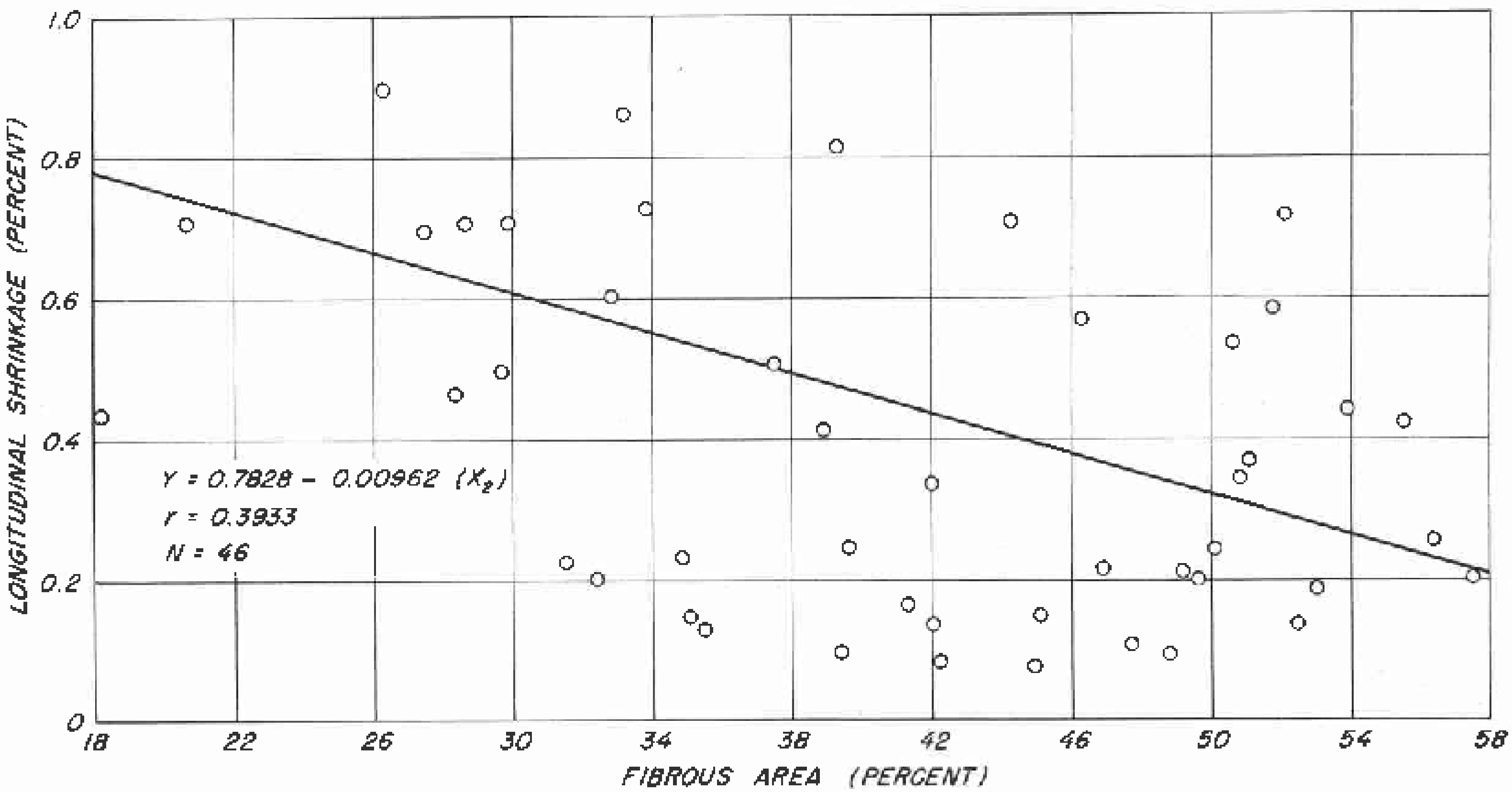

Figure 6. --Relation of longitudinal shrinkage on percentage of fibrous area for overcup oak.

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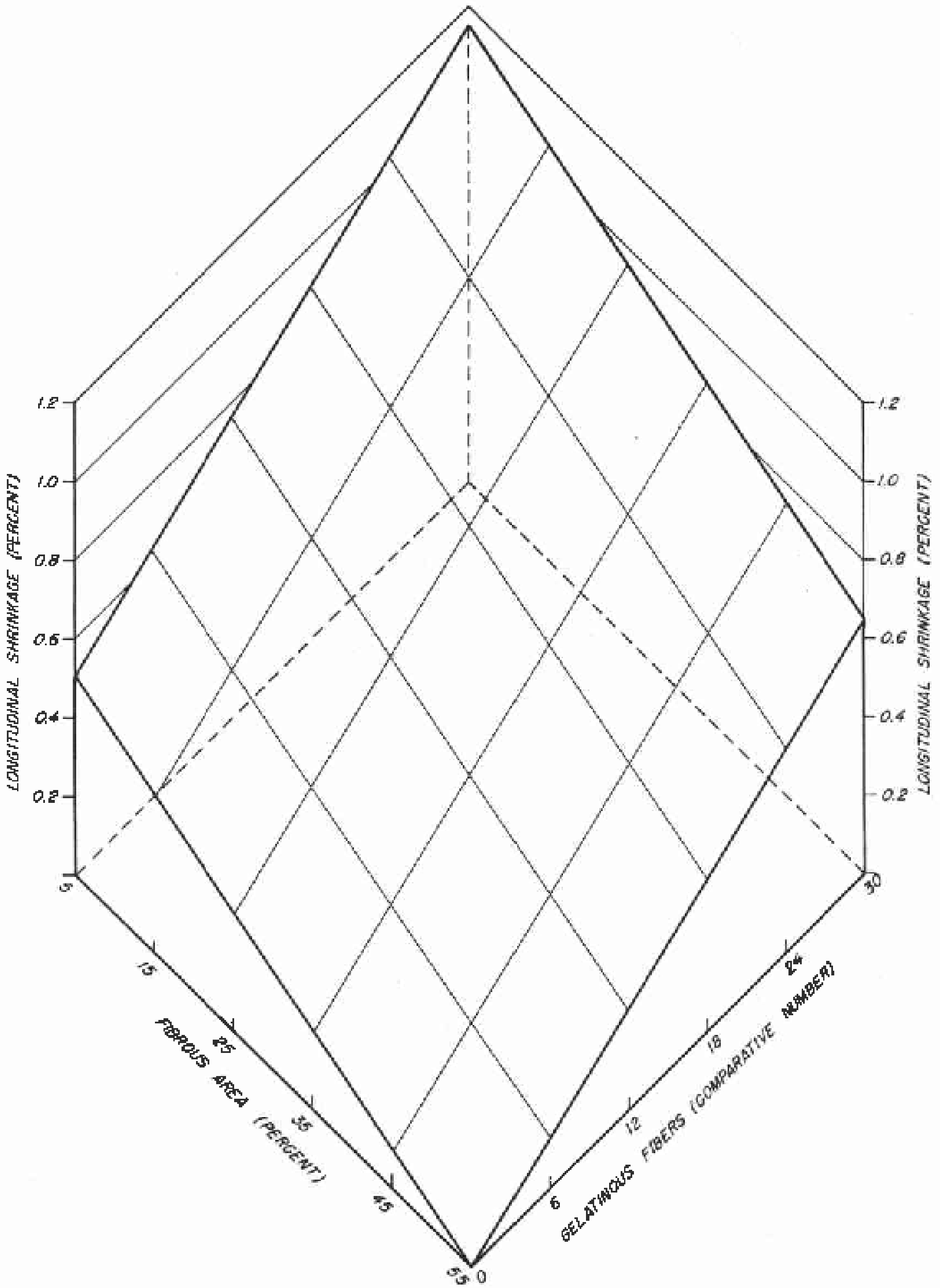

Figure 7. --A three-dimensional graph showing the combined effects of gelatinous fibers and percentage of fibrous area on longitudinal shrinkage in overcup oak.

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