EFFECT OF THICKNESS OF MICROTOME SECTIONS ON THEIR TENSILE PROPERTIES

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ABSTRACT

Tangential microtome sections of loblolly pine of varying thickness (earlywood from 0.00300 inch to 0.01150 inch, latewood from 0.00150 to 0.00730 inches) were sliced, using two different slicing arrangements. All microtome sections were tested wet in tension. The results demonstrate that irrespective of the slicing arrangement, a high degree of association exists between tensile properties (tensile strength, tensile stiffness) and thickness of microtome sections.

Previous work by Biblis (1969) demonstrated that tensile properties of either earlywood or latewood zones of loblolly pine (*Pinus taeda* L.) obtained from microtome sections 100 μm in thickness were approximately one-half of the values obtained from modified ASTM Standard tensile specimens for the same zone. Two factors were listed that could have caused this reduction in values of properties of microspecimens: (a) longitudinally and/or obliquely cut fibers on either side of the microspecimens, and (b) permanent deformations produced during slicing. Kloot (1952), who first tested microtome wood sections in tension, questioned the effect of cut tracheids on the tensile strength and on the nature and occurrence of failures. Kloot specifically questioned the ability of cut fibers to carry proportional loads and stated that "the effective cross section of the specimen is in doubt and thus also is the computed maximum tensile stress." Kisser and Junger (1952), Dinwoodie (1966), Keith and Côté (1968), and Hartler (1969) have shown that certain cutting defects can occur during slicing microtome sections. Frequency an intensity of these defects depend on the slicing technique. Kennedy and Chan's data (1970) show that when the number of induced slicing defects (slip planes) exceed certain limits, tensile properties are reduced significantly when compared to those microspecimens with relatively few slicing defects.

This paper presents results of a study that investigates primarily the first suggested reducing factor, i.e. thickness of microtome sections. Sectioning of microspecimens, however, was performed by two techniques, one that induces a minimum number of "slip lines" and another that is known to produce an excessive number of slicing defects.

EXPERIMENTAL PROCEDURE

A 42-year-old loblolly pine was selected and used for this study. All tested material was obtained from the first (bottom) 8-ft log. Three cross sections (discs) 6 inches along the grain were taken, one from each end and one from the middle of the log. Immediately after cutting, the discs were immersed in water and kept refrigerated at 35 ± 1 F until slicing and testing. All tests were completed within two weeks.

Since the main objective of this study was to determine whether there exists an effect of thickness of microtome sections on their tensile properties, the following requirements were considered for selecting growth zones for testing: (a) width of growth zone had to be wide enough to provide several replications of series of microspecimens with varying thicknesses, and (b) growth zones had to be relatively free of resin canals.

Inasmuch as the effect of thickness of microspecimens on their tensile properties was to be investigated on microspecimens sliced by two different techniques, an attempt was made to obtain matched material (adjacent small blocks) from each growth zone selected for testing. The frequency and distribution of resin canals, however,

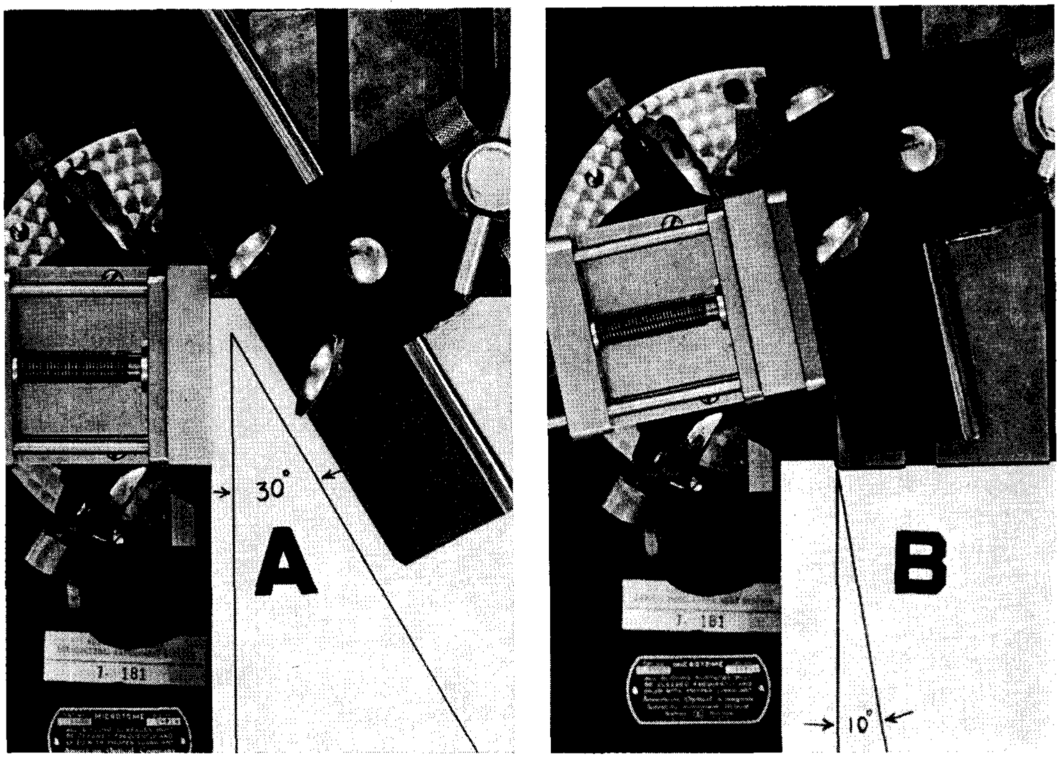

FIG. 1. Cutting arrangements A and B used for slicing microtome sections.

allowed such matching for only one earlywood and two latewood zones.

Two latewood and four earlywood zones were selected to be sectioned by one technique, while one earlywood zone and three latewood zones were selected for sectioning by the second technique. Small rectangular blocks were cut that included the zones to be sliced. These blocks were 2.25 inches in length longitudinally, 0.40 inch in width tangentially and 0.70–1.00 inch in depth radially. Care was taken in machining the blocks to have true tangential and radial sides. For slicing microspecimens, each rectangular block was attached securely to an A. O. Spencer No. 860 slicing microtome with one tangential surface facing the knife. A new microtome knife 250 mm long with 32° bevel angle was used for slicing at a clearance angle of approximately 9°. Each block was oriented so that the true tangential plane would be parallel to the plane formed by the moving knife edge. This was done to minimize the number of cut fibers on the tangential surfaces of microspecimens. The two cutting arrangements employed for cutting microspecimens are shown in Fig. 1. Cutting set A, in which the grain direction of the block is parallel to the direction of the knife movement but forms an angle of 30° with the knife edge, represents a slicing arrangement producing a significant number of "slicing defects" as shown by Dinwoodie (1966), Keith and Côté (1968), Kennedy and Chan (1970). Cutting set B, in which the grain direction of the block is parallel to the knife edge but forms an angle of 10° with the direction of knife movement, represents a slicing arrangement producing an insignificant number of "slicing defects," as shown by the same investigators.

For each selected growth zone, microtome sections were cut in four thicknesses alternatively in series extending throughout the zone as shown in Figs. 2 and 3. Thick-

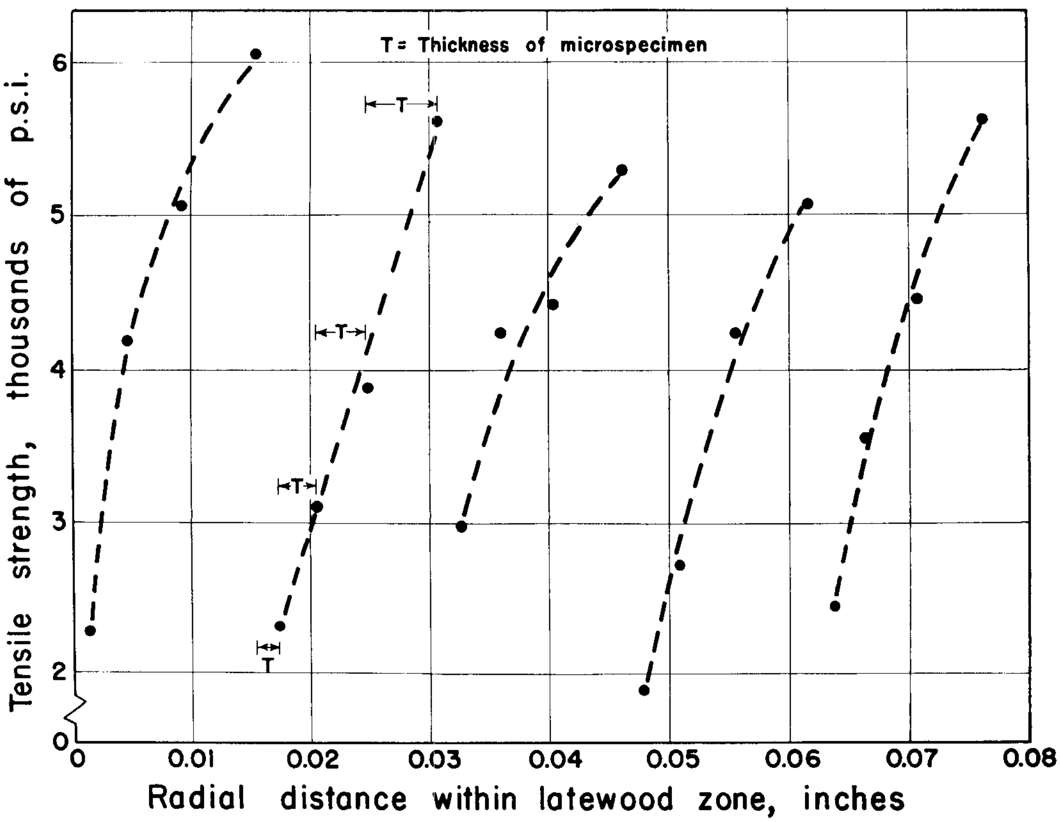

FIG. 2. Relationships between tensile strength and thickness of microtome sections sectioned with slicing arrangement A. Sections were sliced in four thicknesses alternatively in series extending throughout the latewood zone of 36th growth ring.

ness of earlywood microtome sections varied from 0.00300 to 0.01150 inch, while latewood sections varied from 0.00150 to 0.00730 inch. These minimum and maximum thickness limits for sections of each zone were established by preliminary sectioning. Microtome sections of loblolly pine exceeding these limits were found either damaged and/or of nonuniform thickness.

Actual microtensile specimens were punched from microtome sections using a rectangular die 2 inches by ¼ inch attached to a ½-ton arbor press. Before punching, care was taken to ensure parallel alignment of the long axis of the die to the grain of microtome sections. Prior to testing, minimum thickness of each water-saturated microtensile specimen was measured with a dial indicator sensitive to 0.00005 inch at 5-g pressure.

An Instron Testing Machine (Model TT-D-L) was used for testing the microspecimens. Each microspecimen was securely gripped with rubberfaced jaws at a span of 1.25 inches and tested with a movable head speed of 0.01 inch/min. The test was conducted at 72 F. During tests, microspecimens were kept saturated by a continuous flow of a thin water film over both surfaces. Total elongation of the 1.25-inch span was recorded simultaneously with the corresponding load on a chart of an X-Y recorder.

With few exceptions, all microtome sections developed failures within the spans away from the grips. The majority of microspecimens developed failures within

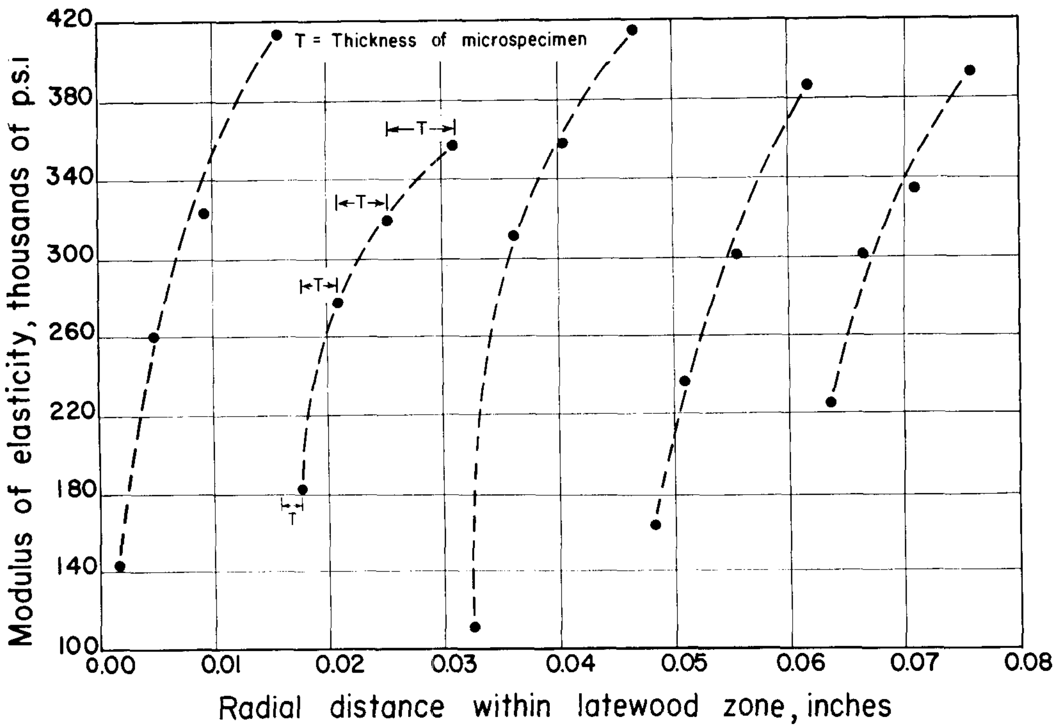

Fig. 3. Relationships between modulus of elasticity and thickness of microtome sections sectioned with slicing arrangement A. Sections were sliced in four thicknesses alternatively in series extending throughout the latewood zone of 36th growth ring.

the middle one-half of spans. A number of failures also developed approximately ⅛ inch from the grips. There was no relationship between location of failures and thickness of microspecimens. The location of failure also was independent of growth zone type. The applied pressure at grips was sufficient to prevent slippage in the rubber jaws.

RESULTS AND DISCUSSION

Results of tensile properties in relation to thickness of microspecimens of certain zones tested are shown in Figs. 2–9. Results of microspecimens sectioned with slicing arrangement A are shown in Figs. 2–4, while test results of microspecimens sectioned with slicing arrangement B are shown in Figs. 5–9. An attempt was made to establish a relationship between each tensile property and corresponding thickness of microspecimen for each growth zone tested. Two regression equations were fitted for each set of data, one linear and the other curvilinear (second order polynomial). The better fit of the two was investigated with an analysis of variance and F-test and presented with each set of data. Table I and II present, in summary, equations for best fitted regressions, correlation coefficients, and number of microspecimen sectioned with slicing arrangements A and B, respectively.

The high values of the correlation coefficients of the relationships between the dependent and independent variables tested demonstrate without any doubt that irrespective of the slicing arrangement, a high degree of association exists between tensile properties (tensile strength and tensile stiffness) and thickness of microtome sections.

The reduction in tensile properties with reduction in thickness of microspecimens

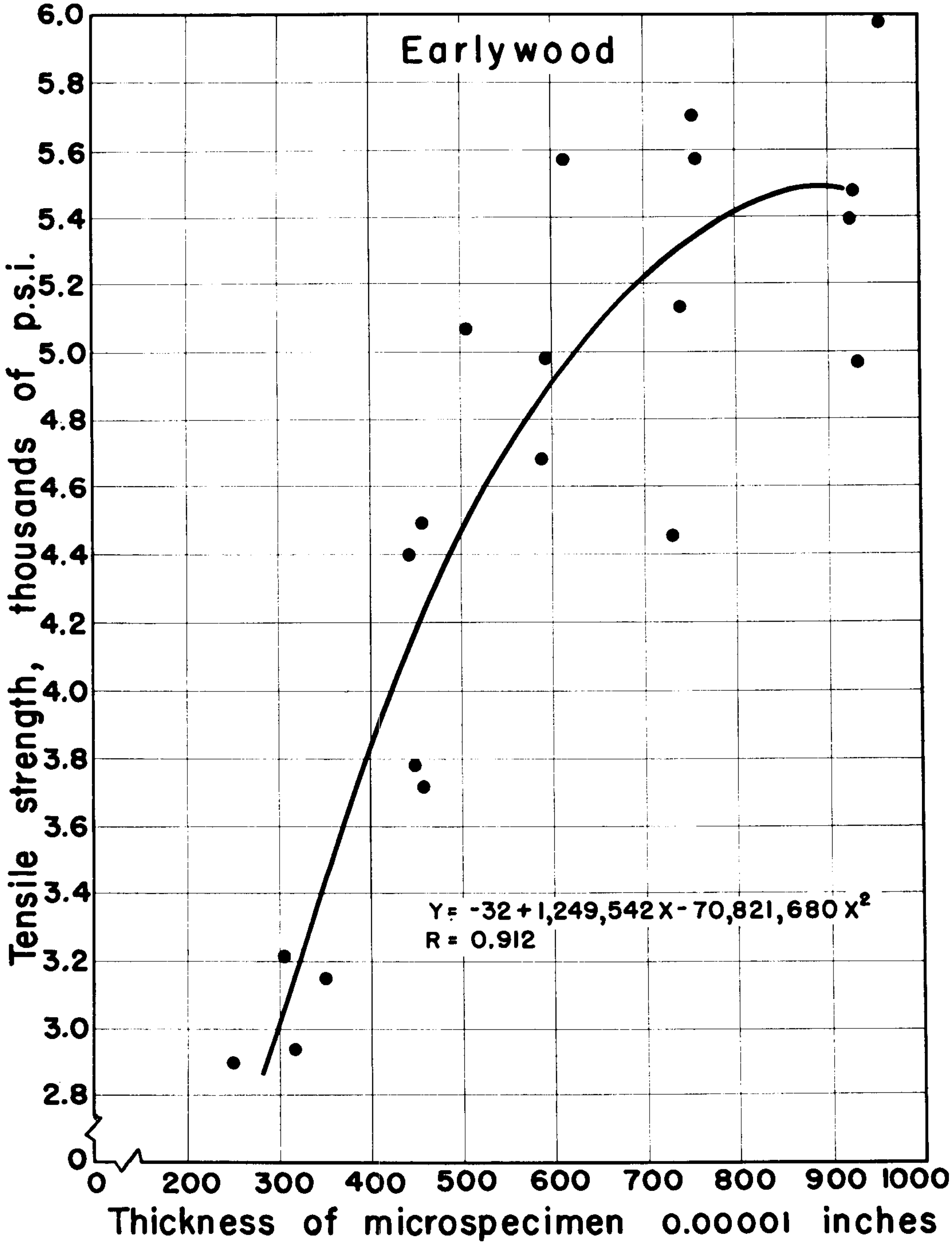

FIG. 4. Relationship between tensile strength and thickness of earlywood microtome sections (30th ring) sliced with arrangement A.

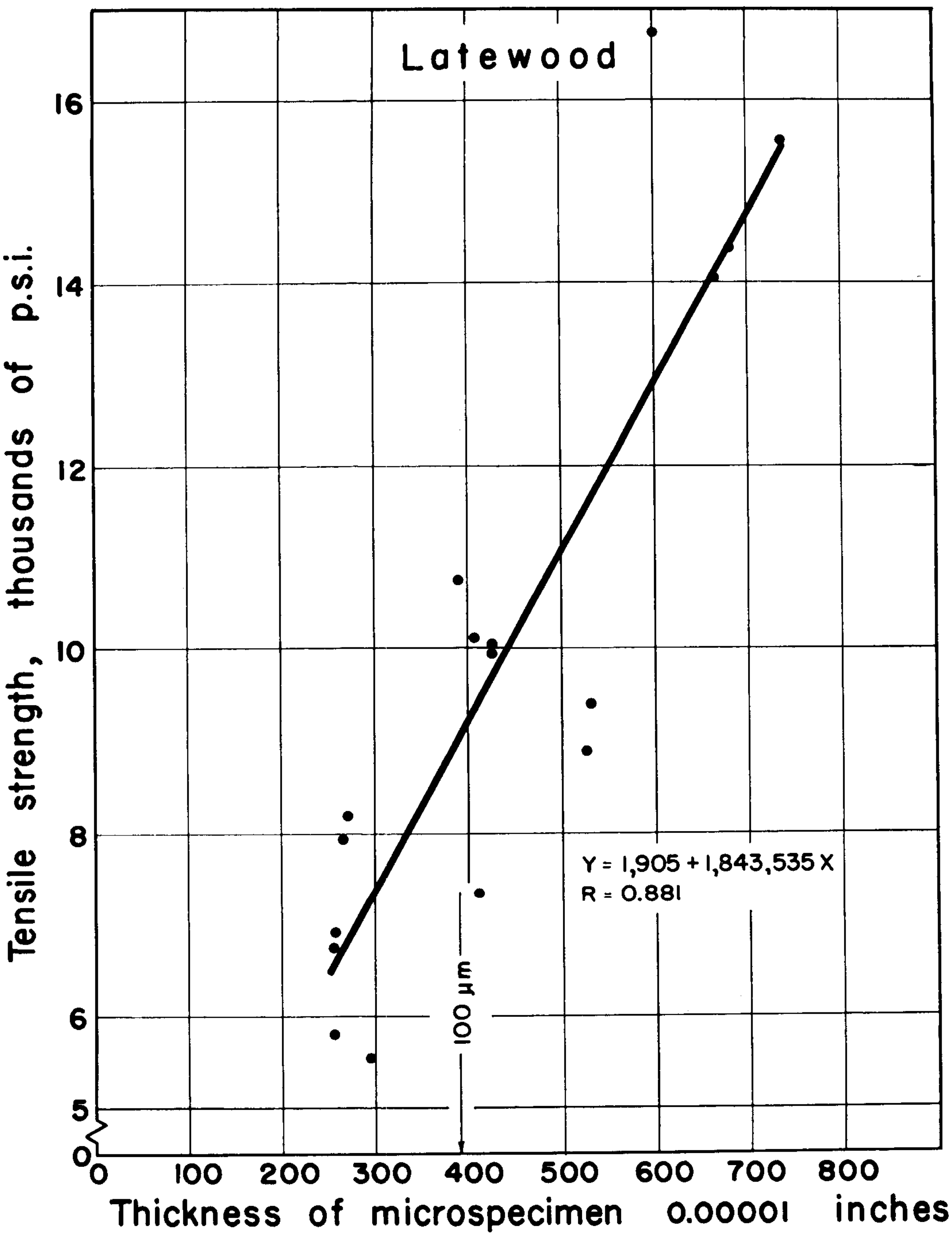

FIG. 5. Relationship between tensile strength and thickness of latewood microtome sections (36th ring) sliced with arrangement B.

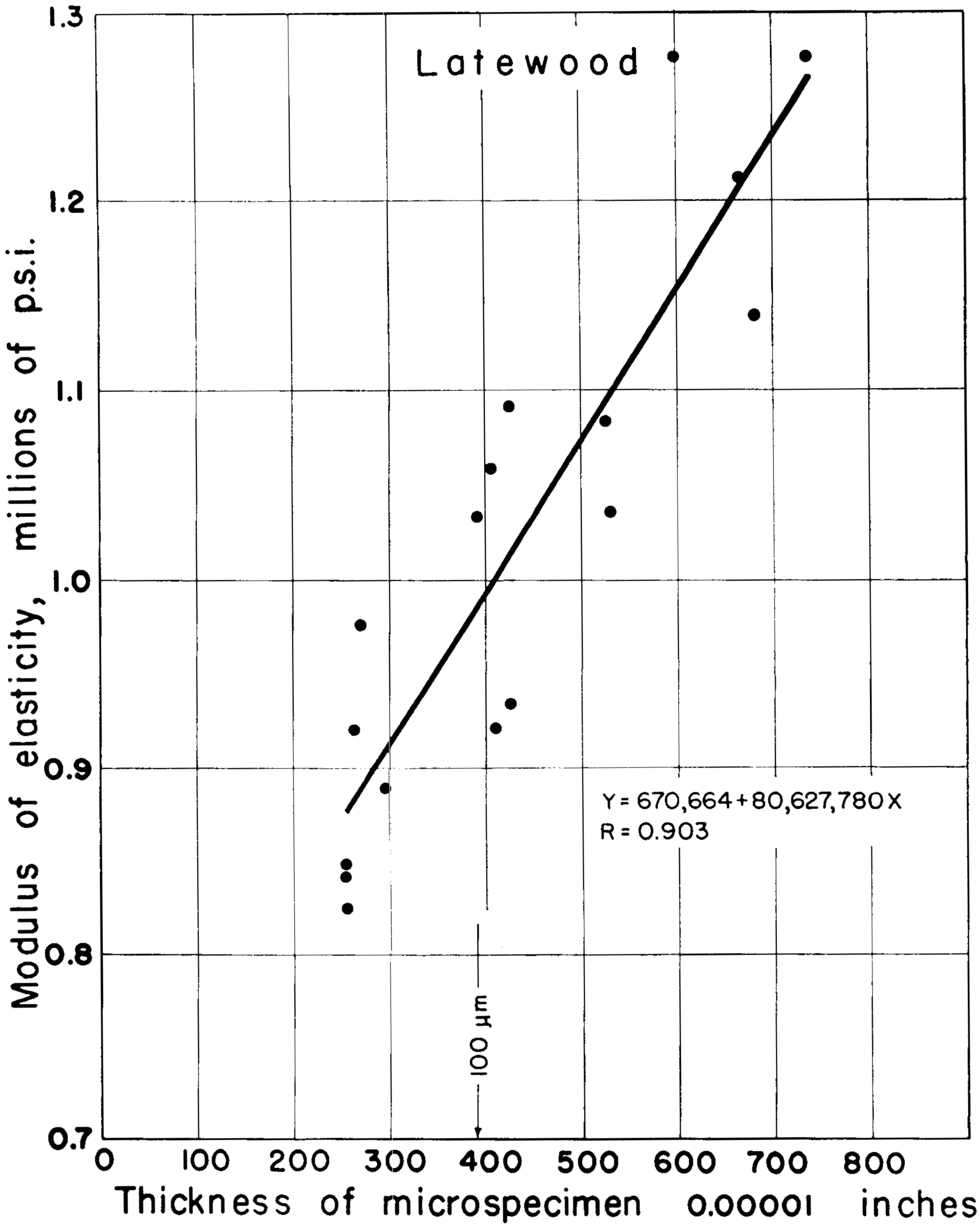

FIG. 6. Relationship between modulus of elasticity and thickness of latewood microtome sections (36th ring) sliced with arrangement B.

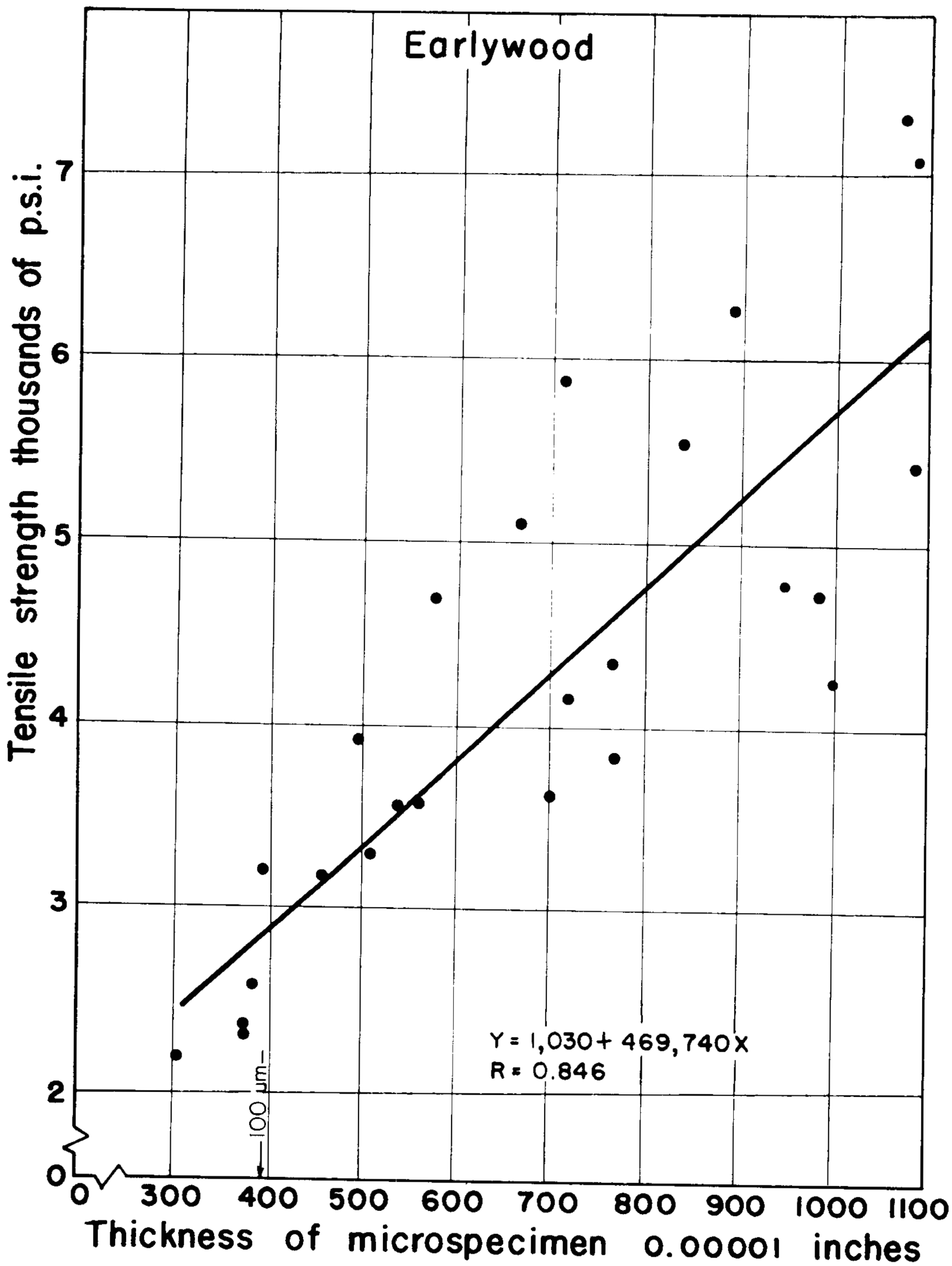

FIG. 7. Relationship between tensile strength and thickness of earlywood microtome sections (30th ring) sliced with arrangement B.

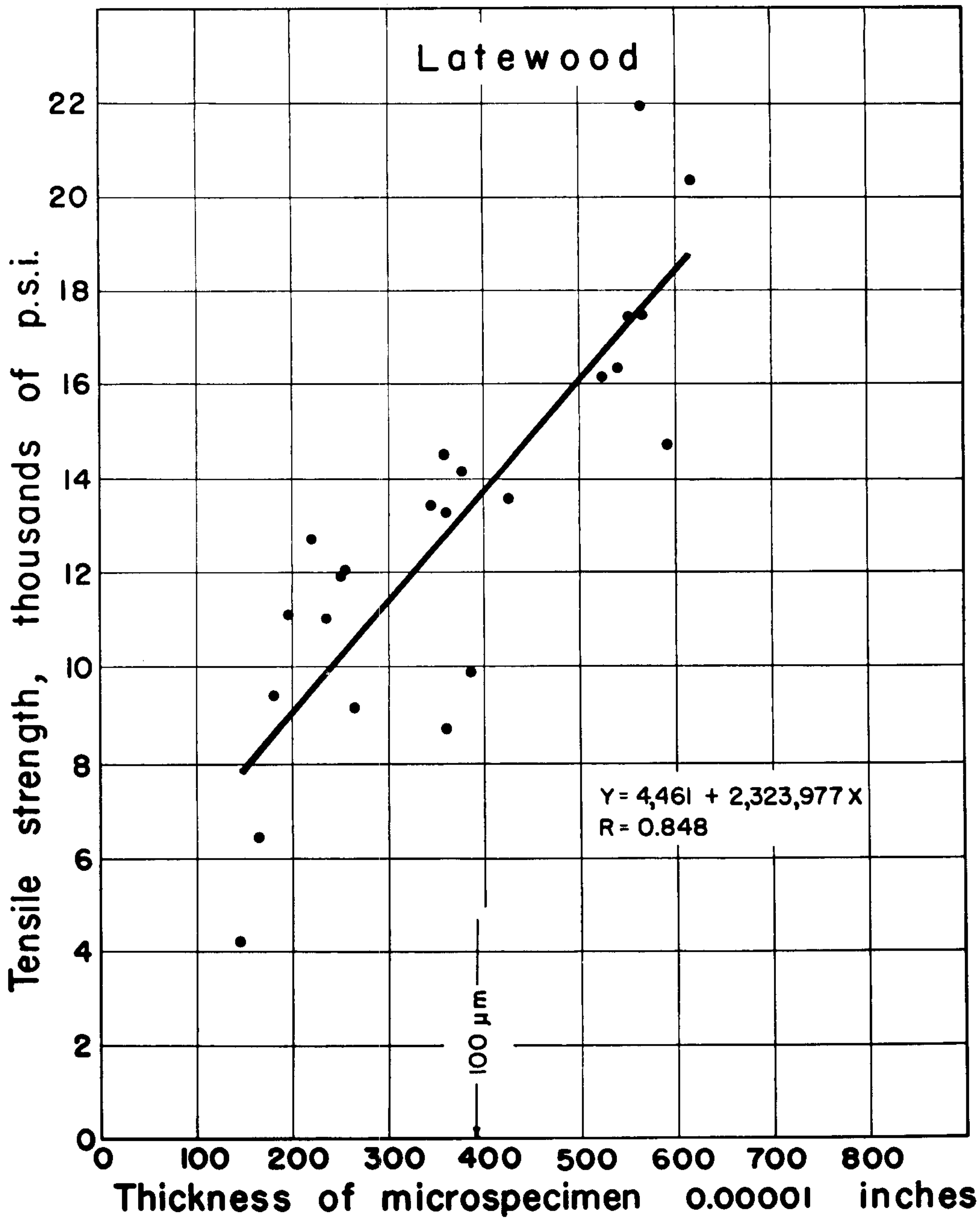

FIG. 8. Relationship between tensile strength and thickness of latewood microtome sections (34th ring) sliced with arrangement B.

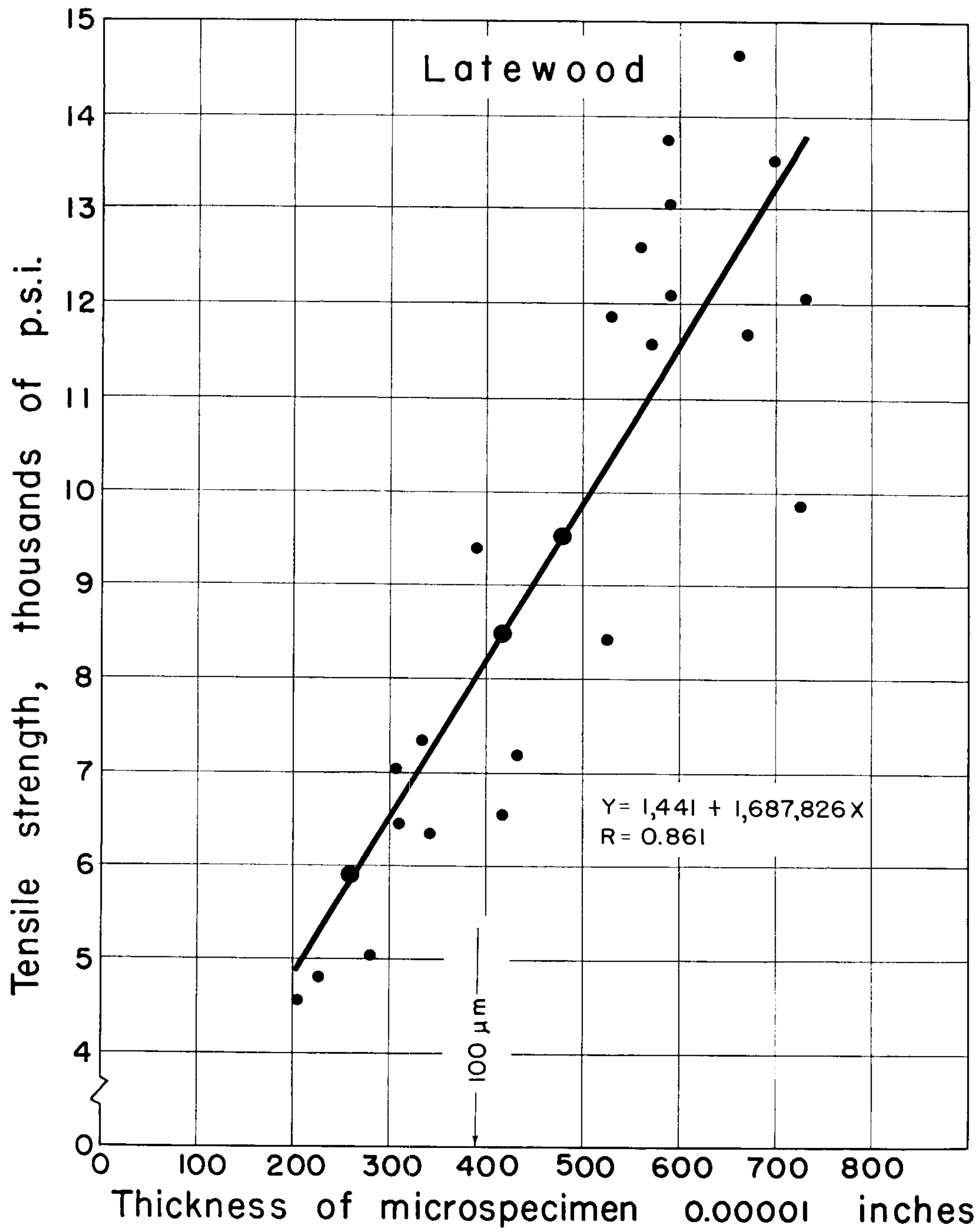

FIG. 9. Relationship between tensile strength and latewood microtome sections (30th ring) sliced with arrangement B.

TABLE I. *Regression equations and correlation coefficients between thickness and tensile properties of microtome sections sectioned with slicing arrangement A.*

Growth zone	Tensile strength—Thickness	R	n
36 Latewood	$y = 1{,}166 + 743{,}579\ X$	0.939	20
30 Latewood	$y = 1{,}060 + 884{,}170\ X$	0.861	12
30 Earlywood	$y = -32 + 1{,}249{,}542\ X - (7.082)10^8\ X^2$	0.912	20
25 Earlywood	$y = 1{,}830 + 221{,}217\ X$	0.769	15
24 Earlywood	$y = 2{,}325 + 190{,}455\ X$	0.726	10
23 Earlywood	$y = 2{,}595 + 253{,}843\ X$	0.762	9
	Modulus of elasticity—Thickness		
36 Latewood	$y = -63{,}375 + (1.185)10^8\ X - (8.401)10^9\ X^2$	0.952	20
30 Latewood	$y = 132{,}480 + 45{,}561{,}620\ X$	0.825	12
30 Earlywood	$y = 63{,}668 + (2.963)10^7\ X - (1.701)10^9\ X^2$	0.816	20
25 Earlywood	$y = 73{,}360 + 2{,}928{,}500\ X$	0.754	15
24 Earlywood	$y = 80{,}670 + 5{,}239{,}857\ X$	0.710	10
23 Earlywood	$y = 78{,}446 + 6{,}301{,}090\ X$	0.841	9

may be attributed to the effect of cut tracheids, which are always present as a result of the sectioning process. It is obvious that the cut tracheids on either side of microspecimens do not carry a load proportional to their cross section. As the thickness of microspecimens decreases, the ratio of cross section area of uncut tracheids to those cut decreases and so do the tensile properties. Wood microtome sections of earlywood and latewood, of any possible thickness, represent mechanically damaged samples of that particular zone, and their tensile properties are reduced. The degree of reduction depends on the thickness of the microspecimen in relation to cross section dimensions of its anatomical elements and the sectioning arrangement of the microtome.

The variation in tensile properties of microspecimens of the same thickness from the same zone may be attributed to anatomical differences and in varying cross section area of cut tracheid walls.

The regression equations between tensile properties and thicknesses of microspecimens of a particular earlywood zone have either different form or slope from the corresponding regression equation of the latewood zone of the same growth ring. This suggests that no single correction factor can be applied to all values of microspecimens, representing the entire growth ring, for an adjustment of tensile properties to represent the distribution of true properties of the ring.

Tensile properties obtained from latewood microspecimens sectioned with slicing arrangement A (Figs. 2 and 3) are considerably lower than corresponding properties of microspecimens of same thickness and zone sectioned with slicing arrangement B (Figs. 5 and 6). The lower

TABLE II. *Regression equations and correlation coefficients between thickness and tensile properties of microtome sections sectioned with slicing arrangement B.*

Growth zone	Tensile strength—Thickness	R	n
36 Latewood	$y = 1{,}905 + 1{,}843{,}535\ X$	0.881	17
34 Latewood	$y = 4{,}461 + 2{,}323{,}977\ X$	0.848	23
30 Latewood	$y = 1{,}441 + 1{,}687{,}826\ X$	0.861	25
30 Earlywood	$y = 1{,}030 + 469{,}740\ X$	0.846	25
	Modulus of elasticity—Thickness		
36 Latewood	$y = 670{,}664 + 80{,}627{,}780\ X$	0.903	17
30 Latewood	$y = 582{,}621 + 16{,}762{,}070\ X$	0.603	25
30 Earlywood	$y = 127{,}955 + 16{,}762{,}070\ X$	0.695	25

tensile properties of microspecimens sectioned with arrangement A were expected since it is known that sectioning arrangement A produces a considerably larger number of slicing defects.

Differences in tensile properties of earlywood microspecimens sectioned with arrangements A and B are less substantial (Figs. 4 and 7). This smaller discrepancy in the earlywood zone may be explained by the fact that cross-sectional dimensions of earlywood tracheids are of such a size that the damage caused by the slicing arrangement A is inflicted largely on the already damaged surfaces of cut tracheids.

The tensile properties of microtome sections of maximum thickness, sliced with the cutting arrangement B that minimizes slicing defects, are approximately one-half of corresponding tensile values obtained by Biblis (1969) for unmatched tensile specimens, the width of each encompassing an entire seasonal growth zone.

CONCLUSIONS

1) The high values of the correlation coefficients of the relationships between the dependent and independent variables tested demonstrate that irrespective of the slicing arrangement, a high degree of association exists between tensile properties (tensile strength, tensile stiffness) and thickness of microtome sections.

2) The microtome sectioning arrangement, which is known to produce a large number of slicing defects (slip lines), affects considerably the tensile properties of latewood microspecimens. The effect of this slicing arrangement on the tensile properties of earlywood microspecimens is small.

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