THE EFFECT OF SPIRAL GRAIN ON THE STRENGTH OF WOOD

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The occurrence of spiral or cork-screw grained trees has long been a subject of interest to foresters. Many theories have been advanced to account for the phenomenon and experiments are now under way to determine if it is inheritable.

Severe spiral grain has been recognized by many as disqualifying timber for uses in which strength and resistance to shock are important. However, many timber producers and users, while recognizing as defects knots, pitch pockets, rot, shakes, severe checks, and cross grain resulting from mismanufacture, have entirely neglected spiral grain as a source of danger or weakness except perhaps in extreme cases.

It has long been observed in the testing laboratory that spiral grain is as weakening as other forms of cross grain and it has been considered more dangerous because of the probability of its passing unnoticed or not being recognized as a source of weakness. It had not been possible previous to the war to carry out tests to give a quantitative measure of the effect of spiral or other forms of cross grain, but when the problem of specifying material for use in airplane construction arose, it soon became apparent that more exact knowledge of the effect of deviations of the grain of wood from parallelism with the edges or axis of the piece was needed. In order to secure such information a series of tests was made on Sitka spruce, Douglas fir, and white ash, at the Forest Products Laboratory. These tests go a long way in clarifying cross grain and spiral grain as defects and, because of the depreciating influence of these defects upon the strength properties of the wood and the frequency with which spiral grain occurs in many stands, indicate that their control is a subject worthy of study by the silviculturists.

Before proceeding to further discussion of these tests, it is desirable to have exact definitions of some of the factors to be treated.

The term "cross grain" covers all instances in which the direction of the wood fibers deviates from straightness or is not parallel to the axis of the piece. Considering the fact that the trunk of a tree is made

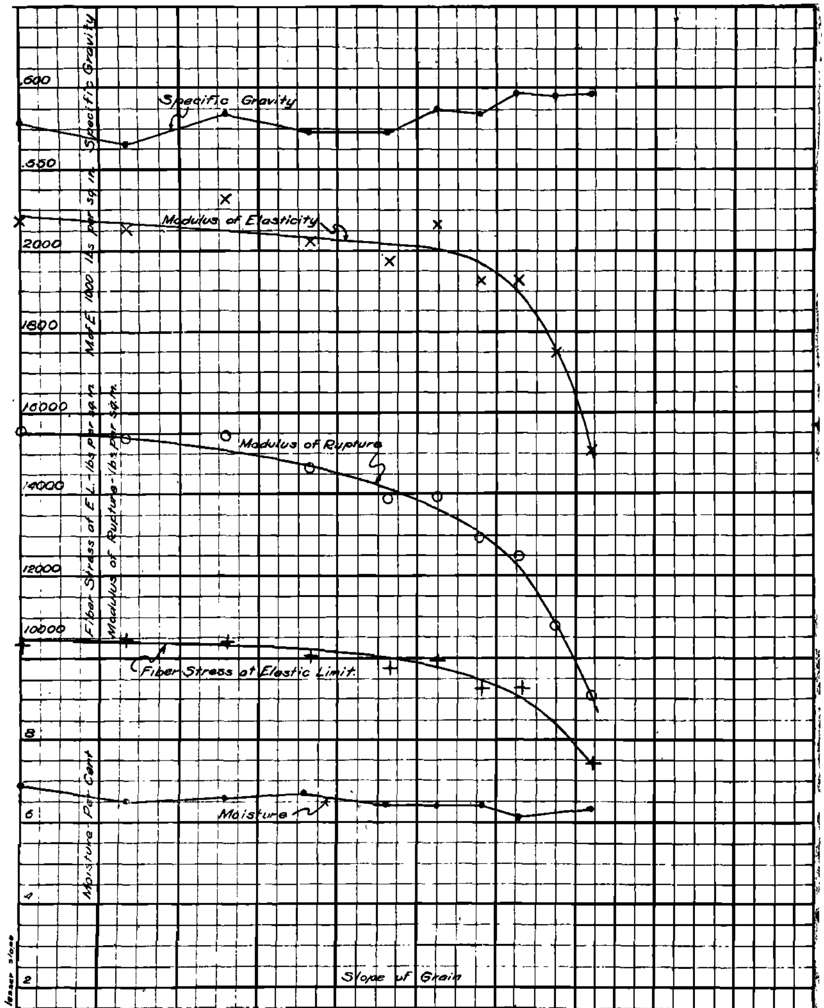

Fig. 1.—Effect of spiral and diagonal grain on fiber stress at elastic limit, modulus of rupture, and modulus of elasticity in static bending. White ash.

up of wood fibers arranged in annual layers it is evident that there are two principal ways in which cross grain may occur.

(*a*) The annual layers may not be parallel to the axis of the piece. This results in *diagonal grain.* Diagonal grain is most readily determined by inspection on quarter-sawed surfaces, that is, surfaces which are radial to the direction of the annual growth rings.

(*b*) The wood fibers instead of being vertical in the tree may wind around it in a cork-screw curve or spiral. This is *natural spiral grain.* If a piece from a tree which is free from natural spiral grain is cut in such a manner that the wood fibers as observed on a flat-sawed face are not parallel to the axis of the piece a phenomenon somewhat similar to natural spiral grain is produced and the piece may be said to be *artificially spiral-grained.*

In order to correlate cross grain in timber with its strength properties, it is necessary to have some measure of the cross grain. This is furnished by the angle between the direction of the fibers and the edge of the piece. This angle is usually expressed as a *slope,* for instance 1 *in* 15, or 1 *to* 15, means that in a distance of 15 inches the grain deviates 1 inch from the edge of the piece.

Because of the difficulty of getting comparable material with ***natural spiral grain*** of various slopes, tests were made on sticks containing *artificial spiral grain.* The standard size of stick for these tests was 2 by 2 by 48 inches. Sticks from each plank were made straight-grained and with various slopes of spiral or diagonal grain. This provided specimens which were inherently similar except for the different slopes of grain. Approximately one-half of the sticks of each slope of grain were tested in static bending and the remainder in impact bending. Following the bending tests a piece for test in compression parallel to grain was cut from each stick of ash whenever sufficient uninjured material remained. Tests were made on about 1,800 sticks of Sitka spruce, 900 of Douglas fir, and about 1,800 of commercial white ash.[1]

Sticks were cut with as near as possible predetermined slopes of grain but in order to avoid mistakes in slope classification all sticks were examined after test and the slopes of both diagonal and spiral grain at the point of failure determined. When a piece had both

[1] This material is termed commercial white ash because although the exact species were not known it was all from species classified in the market as white ash.

spiral and diagonal grain the two slopes were combined to get the true or absolute slope of grain. As spiral grain appears in the tangential plane or surface and diagonal grain in the radial plane the absolute or combined slope is computed by taking the square root of the sum of the squares of the slopes of spiral and diagonal grain. As a specific example

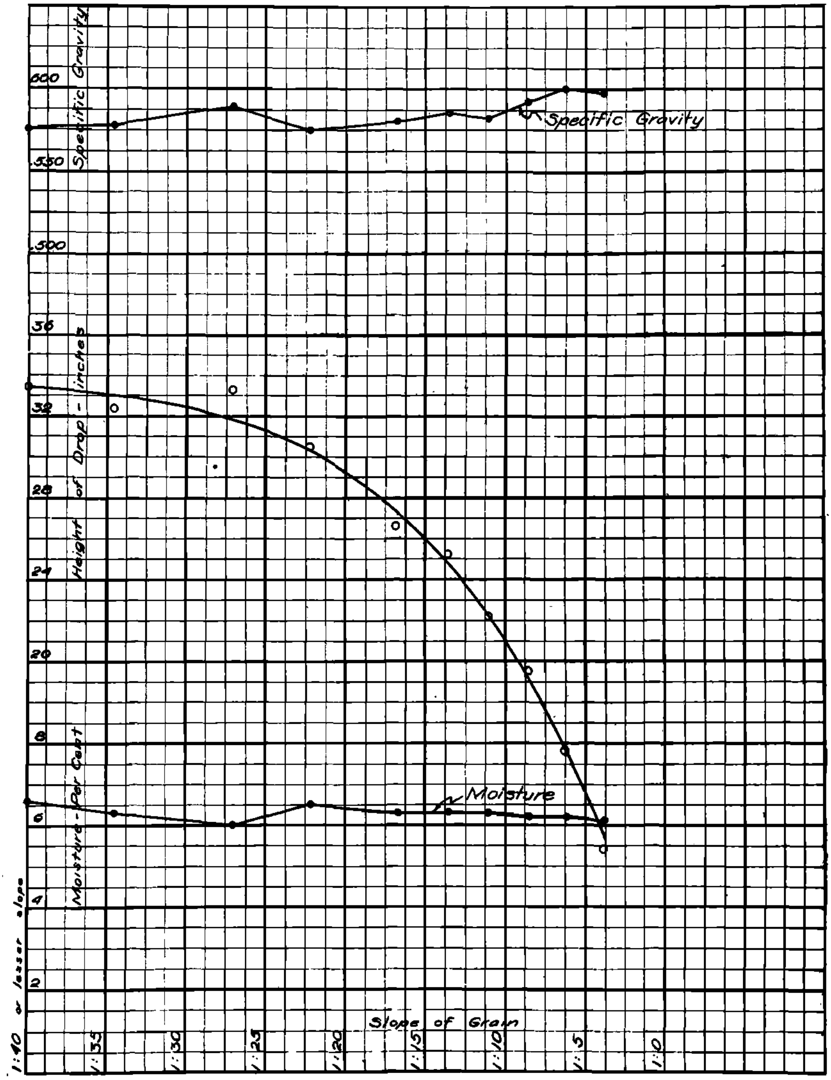

Fig. 2.—Effect of spiral and diagonal grain on maximum drop. White ash.

of this computation assume a test piece has slopes of 1 to 10 and 1 to 15. For computation of absolute slope these ratios are converted into decimals and are equivalent to .10 and .067, respectively. Squaring these and extracting the square root, gives .12 which expressed as a ratio equals 1 to 8.3.

In correlating the data, all the sticks with slopes of grain between certain limits as 1 to 30 and 1 to 39.9, 1 to 25 and 1 to 29.9, 1 to 20 and 1 to 24.9, etc., were averaged together with respect to strength properties and slopes. All sticks with slopes not greater than 1 to 40 were averaged together and treated as if they were straight-grained.

The average values of strength property and slope were plotted in diagrams such as figures 1, 2, and 3, in which specific gravity and moisture content were also plotted. These figures were for white ash only but the curves showing the relation of strength properties to slope of grain are not essentially different for the other species.

Figure 4 presents a comparison of the three species with respect to the influence of slope of grain on a combination of important strength properties. The maximum difference between the three curves does not exceed 3 per cent until a slope in excess of 1 to 12.5 is reached, thus indicating that in the aggregate the three species are practically alike with respect to the relation of slope of grain to strength properties.

Table 1 shows the percentage by which material with the various slopes of grain falls below straight-grained material in various strength properties.

Inspection of the figures and table shows that compressive strength is but little affected until quite steep slopes of grain (1 to 10 or greater) is reached. Modulus of elasticity—stiffness—is more affected and begins to suffer a really appreciable decrease at a slope of 1 to 15. Modulus of rupture—strength in bending—decreases even more rapidly and has about 10 per cent deficiency at a 1 to 20 slope and nearly 20 per cent at 1 to 15. The most pronounced effect is on work to maximum load and maximum drop—both measures of shock-resisting ability—which are considerably deficient even at a slope of 1 to 25 and decrease very rapidly as slope of grain increases.

As a result of these tests, it has been recommended to the War and Navy Departments and to aircraft manufacturers that slopes of grain in excess of 1 to 20 should not be permitted in highly stressed parts. The advisability of restricting the slope of grain to 1 in 20 as now provided in grading rules for select structural southern yellow pine and Nos. 1 and 2 structural Douglas fir is confirmed by the tests.

In view of the showing of these tests and of the fact that in so many of the uses of timber strength and shock resistance are of great importance, it is apparent that the exercise of considerable effort to discover and overcome if possible the causes of spiral grain in tree

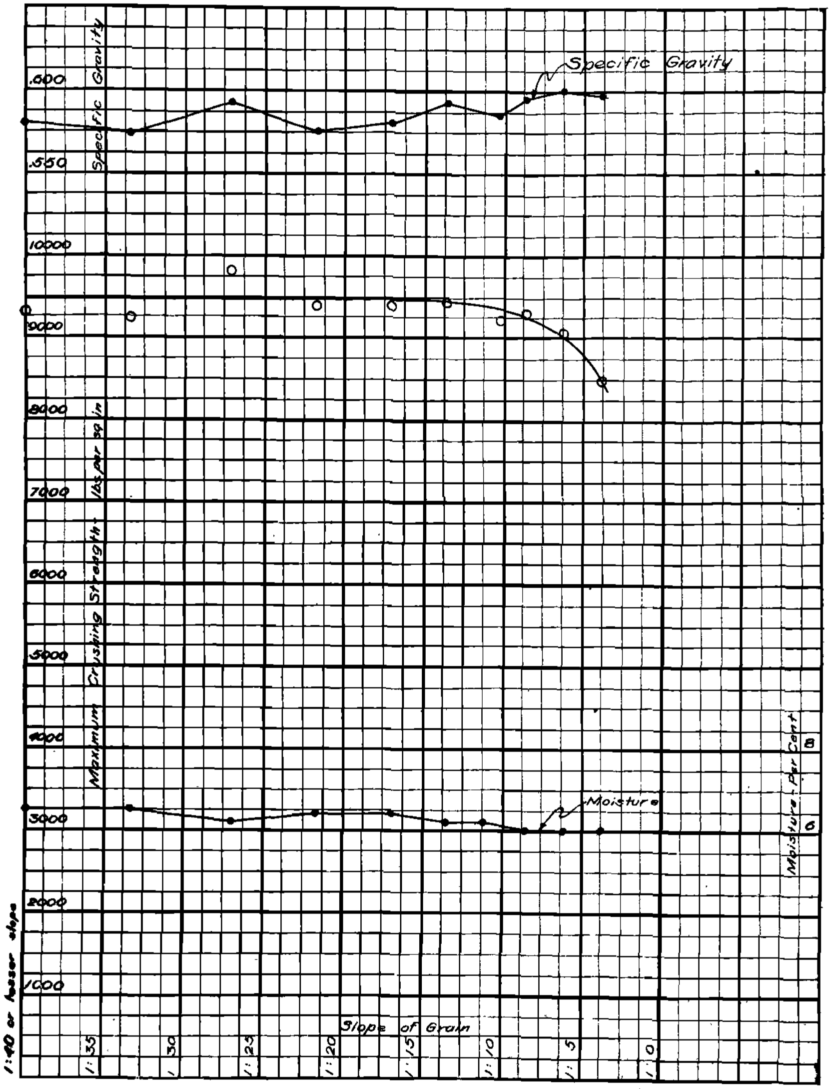

Fig. 3.—Effect of spiral and diagonal grain on maximum crushing strength. White ash.

growth is justified. It has been observed that in some stands and some localities, the presence of spiral grain is so large that stumpage values are heavily depreciated. The production of trees with straight trunks free from irregular and spiral grain will reflect to the credit of American silviculture by contributing very materially to the financial stability of the rotation and by promoting economy in forest production.

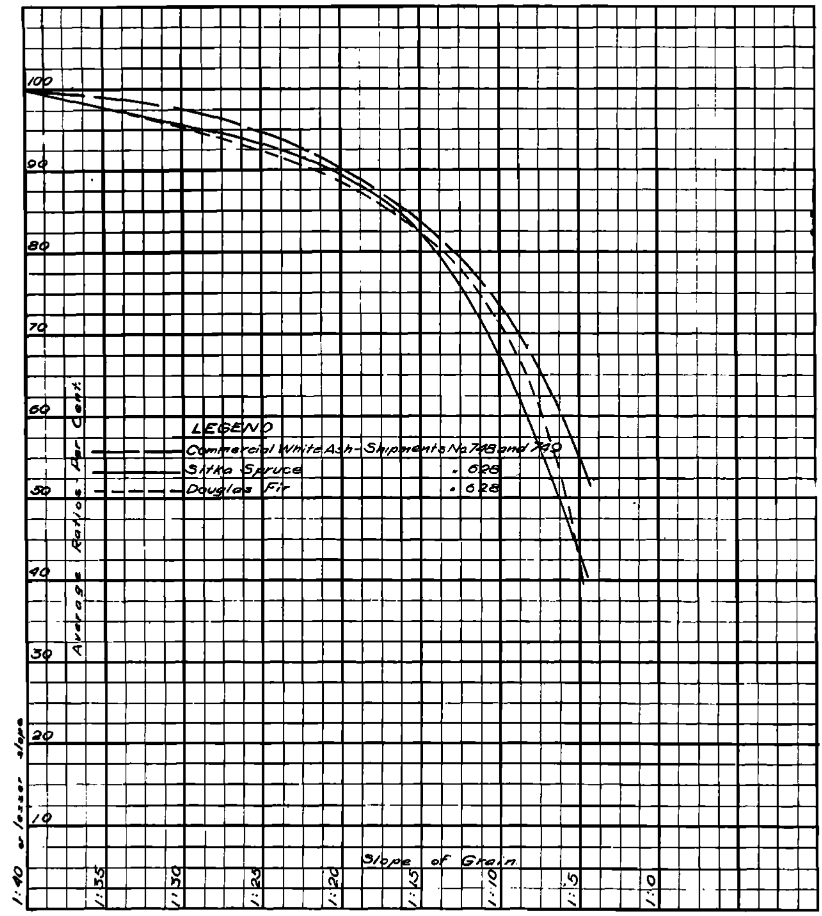

Fig. 4.—Composite curves showing the effect of spiral and diagonal grain on modulus of rupture, modulus of elasticity, work to maximum load, and maximum drop. White ash, Sitka spruce, and Douglas fir.

TABLE 1.—*Average Percentage Deficiency in Strength Properties of Spiral and Diagonal Grained Material of Various Slopes with Respect to Straight-Grained Material.*

Slope of grain	Static bending			Impact bending	Compression parallel to grain
	Modulus of rupture	Modulus of elasticity	Work to maximum load	Maximum drop	Maximum crushing strength
White ash—					
1:25	4	2	9	6	0
1:20	6	3	17	12	0
1:15	11	4	27	22	0
1:10	18	7	43	37	1
1:5	36	22	61	59	7
Sitka spruce—					
1:25	2	2	14	8	..
1:20	4	4	21	13	..
1:15	8	7	33	22	..
1:10	17	13	55	45	..
1:5	44	36	76	69	..
Douglas fir—					
1:25	7	4	17	1	..
1:20	10	6	24	4	..
1:15	15	8	34	13	..
1:10	25	14	46	31	..
1:5	54	40	68	65	..
Average for three species—					
1:25	4	3	13	5	..
1:20	7	4	21	10	..
1:15	11	6	31	19	..
1:10	19	11	48	38	..
1:5	45	33	68	64	..