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Machining Ponderosa Pine and Douglas-Fir

. . . EFFECT OF GROWTH RATE AND DENSITY[1]

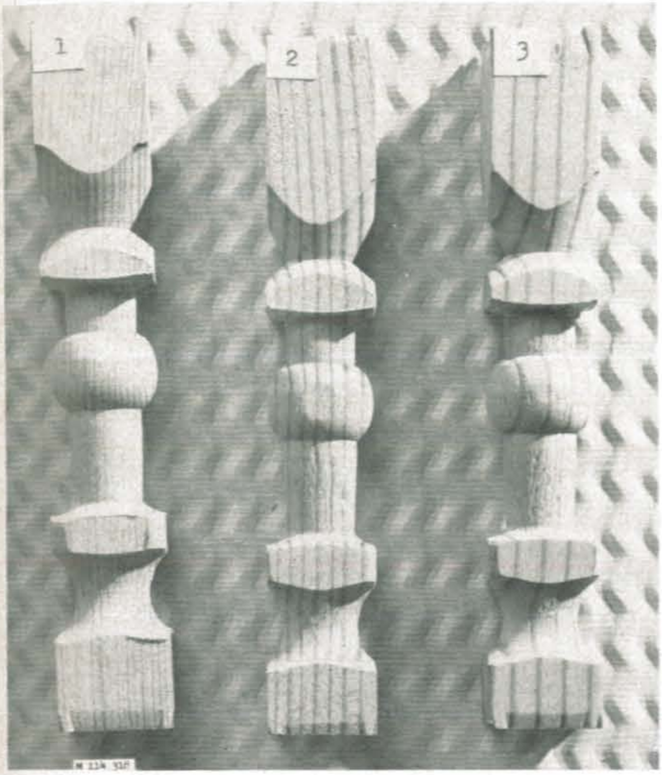

Fig. 2.—Turning samples of ponderosa pine graded 1, 2, and 3 for smoothness of cut.

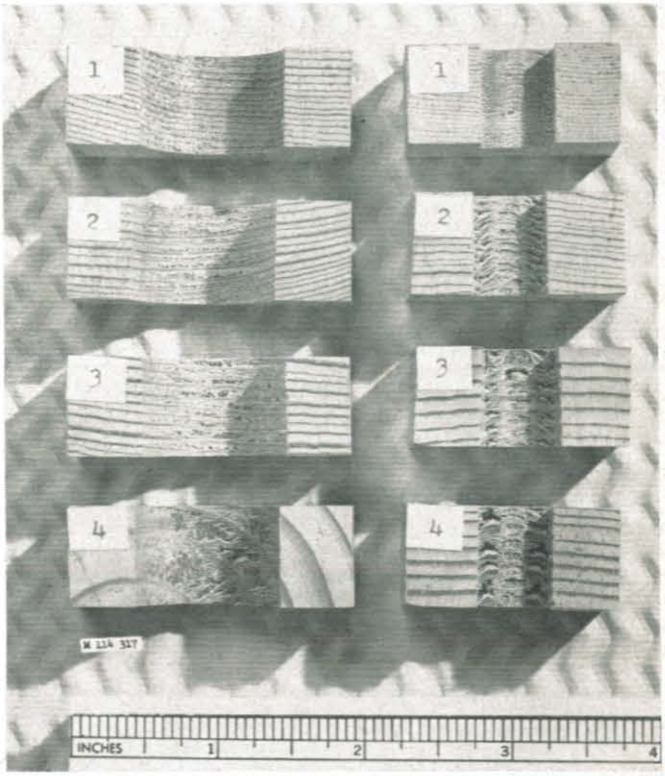

Fig. 3.—Boring and mortising samples of ponderosa pine, showing quality of grades 1 to 4. Note the relationship between number of growth rings and smoothness of cut.

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CLEAR WOOD OF ANY SPECIES may vary widely in its properties, depending upon such things as density, rate of growth, and grain peculiarities. To a large degree, the intended use determines the essential properties that are required. Most fabricated products, such as fixtures, flooring, furniture, and millwork require lumber with good machining properties. Altogether, these products consume yearly over 5 billion board feet of lumber, which is evenly divided between hardwoods and softwoods.

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For the more exacting uses, growth rate and specific gravity have a significant effect on the machining properties of ponderosa pine and Douglas-fir, with the number of rings per inch being especially important.

This paper deals with the relationships between the machining properties of ponderosa pine and Douglas-fir and their density and growth rate.

Test Results

Table 1 summarizes the results of machining tests on ponderosa pine. Since the two sets of material are practically the same in specific gravity but vary widely in number of rings per inch, the difference in results can be attributed almost wholly to the ring factor.

In the case of planing, the direction of cut was parallel to the grain; in order to show any significant difference in the results obtained, it was finally necessary to do part of the planing with sharp knives and part with dull knives. The remaining operations cut across the grain rather than parallel to it, and are therefore more severe tests than planing. In all four instances the slow-grown material machined better than the fast-grown material.

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[1] A contributed paper received March 1959.
[2] Maintained at Madison, Wis. in cooperation with the University of Wisconsin.

Table 1.--Percent of defect-free samples in machining tests of ponderosa pine

Machining operation	Fast-grown[1] wood	Slow-grown[2] wood
	Percent	Percent
Planing, sharp knives....	91	94
Planing, dull knives.....	65	85
Shaping, end grain.......	15	89
Turning..................	0	36
Boring...................	4	38
Mortising................	0	11

[1]Average specific gravity 0.42; average number of rings per inch 8.

[2]Average specific gravity 0.44; average number of rings per inch 28.

Table 2.--Percentages of grades 1 and 2 samples in machining tests of Douglas-fir

Machining operation	Fast-grown[1] material	Slow-grown[2] material
	Percent	Percent
Planing, sharp knives....	48	75
Shaping, end grain.......	55	100
Turning..................	22	33
Boring...................	20	85
Mortising................	30	50

[1]Mean Number of rings per inch 9; mean specific gravity 0.48.

[2]Mean number of rings per inch 21; mean specific gravity 0.52.

...e 3.--Specific gravity and growth rate of material for machining tests

Species	Source of material	Specific gravity[1] Minimum	Specific gravity[1] Maximum	Specific gravity[1] Mean	Rings per inch Minimum	Rings per inch Maximum	Rings per inch Mean
Ponderosa pine	Challenge, Calif.	0.31	0.55	0.42	2	20	8
Do.	Stock[2]	.36	.54	.44	10	40	28
Do.	Medford, Oreg.	.46	.55	.48	6	20	15
Douglas-fir	Oakridge, Oreg.	.38	.63	.50	4	40	16
Do.	......do.......[3]			.48			9
Do.	......do.......[4]			.52			21
Do.	......do.......[5]			.45			12
Do.	......do.......[6]			.55			19

[1]Based on weight when oven dry and volume when green.

[2]Stock lumber from unknown source.

[3]Fast-grown material.

[4]Slow-grown material.

[5]Lighter weight group

[6]Heavier group.

The results of machining tests on Douglas-fir are summarized in Table 2. Douglas-fir does not machine as well as ponderosa pine, and relatively few defect-free samples were obtained. Comparisons were therefore based on percentages of grade 1 (defect-free) samples and grade 2 samples (those only slightly defective) in order to show relationships more plainly. In Douglas-fir, the two lots are somewhat further apart in mean specific gravity than in ponderosa pine. Although Tables 1 and 2 are not directly comparable, the trends are parallel; that is, in all the operations the slow-grown material machined better than fast-grown material of approximately the same specific gravity.

Test Material

Ponderosa Pine: Three different sources of ponderosa pine were represented. As shown in Table 3, they differed significantly in specific gravity and more especially in rate of growth. Two earlier Forest Products Laboratory investigations gave mean specific gravities of 0.41 and 0.42 for a large number of samples. On this basis, the fast-grown material from Challenge, Calif., was about average specific gravity; the stock material was slightly above average; and the samples from Medford, Oreg., were substantially above average.

Douglas Fir: All Douglas-fir test material came from 28 trees grown in the vicinity of Oakridge, Oreg. The samples were selected to represent the ranges in density and in number of growth rings per inch of the test material. The mean specific gravity of all samples was 0.50, as compared with the 0.48 value for this species.

To determine the effect of growth rate upon machining properties, the samples were divided into fast-grown and slow-grown groups and tested separately. The effect of specific gravity upon machining properties was also tested with light and heavy samples of Douglas-fir. Results of tests are given in Table 3.

Test Procedure

The tests included planing, shaping, turning, boring, and mortising. The procedures followed, which have been in use at the Forest Products Laboratory for some time, are described in detail in Laboratory Report No. 2108, "Development of Methods for Evaluating the Machining Properties of Wood and Wood-Base Materials."

Samples of both ponderosa pine and Douglas-fir were graded after each machining operation on a 5-grade scale based on smoothness of cut. Grade 1 represented perfect, or practically perfect, machine work, and grade 5 represented a reject quality. These grades are illustrated in Figures 1, 2, and 3.

Planing

Next to sawing, planing is the commonest and most important workworking operation. The direction of cut in planing is parallel to the grain, which makes it a less severe test than operations that cut across the grain.

Ponderosa Pine: Table 4 compares the results when planing fast-grown and slow-grown ponderosa pine of about equal density, first with sharp knives and then with dull ones. With sharp knives, the difference in results was too small to be significant; dull knives, however, made the test more severe. The slow-grown pine made a much better showing, producing 86 percent of defect-free samples as compared to 65 percent for the fast-grown material.

Douglas-Fir: In Douglas-fir, the effect of growth rate upon planing was quite evident even with sharp knives. The slower-grown wood, with a mean of 21 rings per inch, produced 50 percent more good samples than the faster grown portion that had a mean of 9 rings per inch. Densities of both groups were relatively close together with 0.48 for the fast-grown portion and 0.52 for the slow-grown group.

Among the group separated on the basis of specific gravity, the heavier samples (mean specific gravity of 0.55) gave 16 percent more good samples than the lighter ones (mean specific gravity of 0.45). It is questionable how much of this difference is due to variation in density alone, because the heavy specimens averaged 19 rings per inch, as compared with 12 rings for the lighter lot.

Shaping

Ponderosa Pine: Side-grain cuts failed to reveal significant differences in ponderosa pine. With end-grain cuts, which are a more severe test, the yield of high-grade samples increased rapidly as the number of rings per inch increased, as shown in Table 5. Specific gravity alone appeared to have a minor influence on results. The grades referred to in Table 5 are illustrated in Figure 1.

Douglas-Fir: Although the average quality of machined surfaces was poorer in Douglas-fir than in ponderosa pine, the trends were similar. Again the influence of density appears to be small and effect of growth rate to be important. The slow-grown samples yielded twice as many good surfaces as those from fast-grown wood.

Turning

Ponderosa Pine: Turning typically involves cuts at various angles to the grain rather than parallel to it. In turning, as in shaping, the slow-grown pine gave much better results than the fast-grown material, as shown in Table 6. Figure 2 illustrates the pattern used and the turning grades referred to in Table 6. The turnings in each of these three grades were weighed collectively, and they showed a definite trend toward better work at the higher specific gravities. Taking the average weight of turnings of the poorest grade (No. 3) as a base of 100, the No. 2 turnings averaged 111, and the No. 1 turnings averaged 125.

Douglas-Fir: Although the slow-grown wood turned noticeably better than the fast-grown, rate of growth did not affect results nearly as much in Douglas-fir as in ponderosa pine. Within the range covered by these samples at least, density had little effect on the results. The weakness of Douglas-fir in this test was in detail and sharp edges that might not count in many sorts of turnings.

Boring and Mortising

Ponderosa Pine: Flat-grained samples were used in tests of the boring and mortising properties of ponderosa pine; therefore the direction of cut was perpendicular to the rings. In both of these operations, the lot that was slightly heavier but slower grown gave much better results than the lighter, faster grown material. These two lots of test material were of so nearly the same density that the difference in results can be attributed almost entirely to differences in rate of growth.

Table 7 compares the results of tests on the boring and mortising properties of the two lots of samples. Figure 3 illustrates the quality of the different grades as well as the consistent relationship that was found between rate of growth and smoothness of cut.

Douglas-Fir: The slow-grown Douglas-fir with a mean of 21 rings per inch and a specific gravity of 0.52 gave four times as many grade 1 and 2 holes in boring as did the fast-grown Douglas-fir with 9 rings per inch and a mean specific gravity of 0.48. In mortising, the difference in favor of the slow-grown material, though less pronounced, was still substantial.

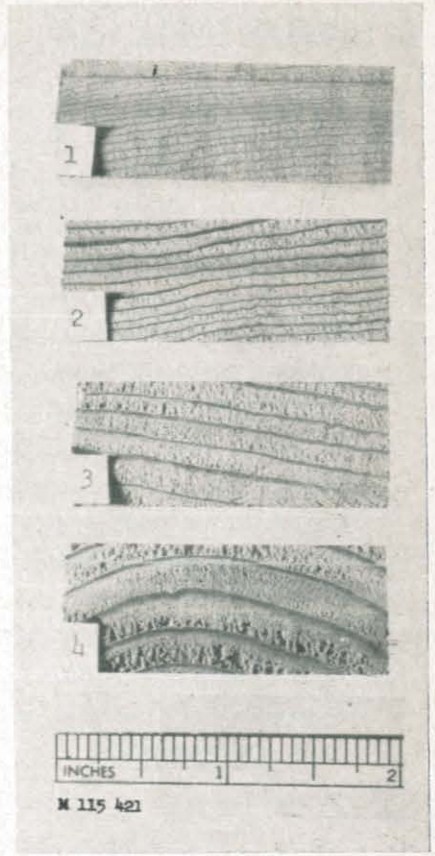

Fig. 1.—End-grain cuts in ponderosa pine, showing samples graded 1 to 4 on the basis of machinability.

Conclusions

Although the amount of test material was not large enough to exclude all effects of interrelationships, the following conclusions are believed to be justified:

Both the number of rings per inch and the specific gravity of a given sample of ponderosa pine or Douglas-fir affect its machining properties to a degree that is highly significant, at least for the more exacting uses.

In ponderosa pine and Douglas-fir, the number of rings per inch has more effect on the machining properties than does specific gravity.

Table 4.--Planing properties of ponderosa pine samples from different sources

Source of material	Condition of knives	Mean specific gravity	Mean number of rings	Defect-free	Chipped grain	Fuzzy grain	Raised grain
				Percent	Percent	Percent	Percent
Challenge, Calif.	Sharp	0.42	8	91	9	0	0
Stock[1]	Sharp	.44	28	94	6	0	0
Challenge, Calif.	Dull	.42	8	65	22	13	0
Stock[1]	Dull	.44	28	86	6	0	8

[1]Stock lumber from unknown source.

Table 5.--Shaping properties of ponderosa pine from different sources

Source of material	Mean specific gravity	Mean number of rings per inch	Grades in end-grain shaping			
			No. 1	No. 2	No. 3	No. 4
			Percent	Percent	Percent	Percent
Challenge, Calif.	0.42	8	8	19	64	9
Medford, Oreg.	.48	15	50	40	10	0
Stock[1]	.44	28	89	11	0	0

[1]Stock lumber from unknown source.

Table 6.--Turning properties of ponderosa pine from different sources

Source of material	Mean specific gravity	Mean number of rings per inch	Grade of turnings			
			No. 1	No. 2	No. 3	No. 4
			Percent	Percent	Percent	Percent
Challenge, Calif.	0.42	8	0	18	82	0
Medford, Oreg.	.48	15	30	70	0	0
Stock[1]	.44	28	36	56	8	0

[1]Stock lumber from unknown source.

Table 7.--Boring and mortising properties of ponderosa pine from different sources

Source of material	Mean specific gravity	Mean number of rings	Grade of holes and mortises			
			No. 1	No. 2	No. 3	No. 4
			Percent	Percent	Percent	Percent
BORING						
Challenge, Calif.	0.42	8	4	63	31	2
Stock[1]	.44	28	38	41	21	0
MORTISING						
Challenge, Calif.	.42	8	0	13	39	48
Stock[1]	.44	28	11	47	42	0

[1]Stock lumber from unknown source.