Engelmann spruce, which is coming on the market in increasing volume nowadays, is relatively new to many woodworkers. Information on its machining properties is needed to facilitate its use.

This report covers a series of machining tests that were made with Engelmann spruce and two associated species, Douglas-fir and ponderosa pine. Fifty clear samples of each species were used in each test. Planing, shaping, and turning were investigated.

Results obtained with the Engelmann spruce varied considerably according to the conditions under which the work was done. In the tests described here, the spruce was consistently below ponderosa pine in machining properties. On the other hand, it was somewhat better than Douglas-fir. If proper precautions are taken, the machining properties of Engelmann spruce may be considered adequate for all ordinary uses.

Planing

Next to sawing, planing is the most important woodworking operation. Nearly every piece of lumber is planed before final use, if only as a sizing operation.

Quality of planing is determined by the occurrence and the seriousness of such machining defects as raised grain, fuzzy grain, chipped grain, and chip marks. The above defects are greatly influenced by some of the variables in machine operation. Cutting angles, feed rate, and cutter-head speeds, depth of cut, and number of knife cuts per inch, for instance, all affect the results. The effect of the above variables was determined by a series of runs under different operating conditions. After each run, the samples were carefully examined, piece by piece, for planing defects and the results recorded.
The tests were made with a modern molder having a 4-knife cutterhead with a 6-1/2-inch cutting circle. Only straight knives were used, and the results are believed to be applicable within limits to other planer-type machines.

Comparative Planing Properties

Ponderosa pine planed much better under any of the conditions of the test than either Engelmann spruce or Douglas-fir. The spruce, however, gave somewhat better results than the fir.

The most common planing defects in spruce were fuzzy grain and raised grain, especially when the wood was not thoroughly seasoned. Although they affect more or less appearance, moderate amounts of these defects are not seriously objectionable in boards and dimension lumber, which are the principal uses for spruce. Of course, for exacting uses like finish, raised grain and fuzzy grain would be very strictly limited.

Feed Rates and Cutterhead Speeds

Runs were made at the following combinations of feed rates and cutterhead speeds:

<table>
<thead>
<tr>
<th>Feed Rate</th>
<th>Cutterhead Speed</th>
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<tbody>
<tr>
<td>F. p. m.</td>
<td>R. p. m.</td>
</tr>
<tr>
<td>60</td>
<td>3,600</td>
</tr>
<tr>
<td>80</td>
<td>4,800</td>
</tr>
<tr>
<td>90</td>
<td>5,400</td>
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<tr>
<td>100</td>
<td>6,000</td>
</tr>
<tr>
<td>120</td>
<td>7,200</td>
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</table>

With a 4-knife cutterhead, each of the above combinations gave 20 knife cuts per inch. The results were substantially the same for all combinations. The fastest combination, 120 feet per minute at 7,200 revolutions per minute, did as good work as the slowest combination, 60 feet per minute at 3,600 revolutions per minute, and doubled the output of the machine. Within the limits of this study at least, feed rates and cutterhead speeds have a negligible effect on quality of planing, provided the number of knife cuts per inch is constant.
Number of Knife Cuts per Inch

One of the most important planing factors is the number of knife cuts per inch. Eight to ten cuts may pass in the common grades, but about twice as many may be required to meet satisfactory standards for finish. Test runs at 6, 8, 10, 12, 16, and 20 knife cuts per inch showed a rapid improvement up to about 12 cuts, and a slower improvement beyond that point. Four times as many defect-free pieces were produced with 20 knife cuts as with 6.

The theoretical number of knife cuts per inch can be computed from the following formula:

\[
\text{R.p.m. of cutterhead} \times \text{No. of knives in head} = \left( \frac{\text{feed rate in feet per minute}}{12} \right) = \text{No. of knife cuts per inch}
\]

This is the number of knife cuts produced if each knife is doing its share of the work. The theoretical number of knife cuts per inch (as determined above) and the actual number (as determined visually) do not always agree. The usual reason is that the knives do not project uniformly from the cutterhead and, therefore, do not cut uniformly. This can be remedied, in modern machines at least, by jointing the knives in the head.

Cutting Angles

Runs were made at cutting angles of 10°, 20°, 30°, and 40°. With the test material dried to 6 percent moisture content, the 30° angle proved to be definitely the best. With 20-percent test material, the 20° angle was best. For general all-around use with average air-dried material, the 30° angle is probably preferable. Either of these angles will apparently do a satisfactory job, provided other conditions are right.

Moisture Content

Tests were made at two moisture contents, 6 percent and 20 percent. The former was much the better, especially as regards raised grain and fuzzy grain. Most of the spruce going to market is no doubt planed at some moisture content between these two extremes. These tests, however, indicate plainly that 20 percent moisture content is too high for best planing results.

Depth of Cut

Runs were made with four different depths of cut, 1/32 inch, 2/32 inch, 3/32 inch, and 4/32 inch. Within these limits, the shallower the cut, the better the results. The 1/32-inch cut gave much better results than the 2/32 inch, which in turn was significantly better than 3/32 inch. There was very little difference between results at the two heavier cuts. Where the best quality of finish is needed, a light finishing cut, if practical, is to be desired.

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Shaping properties affect the utility of a wood for core stock. Tests were made using the same three softwoods at 6 percent moisture content on a spindle shaper running at 7,200 revolutions per minute. Little difficulty was encountered with side grain cuts on any of the woods. All of them, however, developed more or less tearouts on end grain cuts. Ponderosa pine gave the best results, while Engelmann spruce was somewhat poorer and Douglas-fir considerably poorer.

Turning

A series of turning tests was made as one indication of the general machinability of Engelmann spruce. A modified back-knife lathe was used, turning at 2,200 revolutions per minute, with test material at 6 percent moisture content.

Ponderosa pine was much the better of the three softwoods, with Engelmann spruce in second place and Douglas-fir a close third. The chief trouble with the Engelmann spruce was a tendency to develop a slightly rough or fuzzy surface, a condition that can usually be remedied by a tumbling operation. The Douglas-fir was more subject to chipping or breaking where the turning had fine detail.

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