Influence of sweep on the efficiency of sawing

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Abstract. The influence of the sweep of logs on the volume yield of sawn timber and the profitability of its production has been investigated by the method of simulation modeling. It is established that when the average sweep varies from 0 to 0.25%, the volume yield is reduced by 1.2 ... 2.9%, the profitability is reduced by 2.7 ... 5.8%. The contribution of the sweep of logs to the deviation of the real volume yield of sawn timber from its calculated value can reach 70 ... 80%.

1. Introduction
The efficiency of a saw mill is greatly influenced by the group sorting of logs according to their diameters [1, 2]. All subsequent technological processes, namely, cutting saw logs, sorting sawn sections, drying sawn timber, processing sawn timber after drying and, as a consequence, harmoniousness and efficiency of the entire production process of a saw mill depend on it [3, 4]. Therefore, the authors [5] defined group sorting of logs according to their thickness as the most important controlled variable for maximizing the efficiency of sawn timber production. The profitability of sawmill production was chosen as the criterion of its optimization [6]. The volume yield of sawn timber is used as a competing optimization criterion and as an indicator of great independent value for evaluating the efficiency of the sawing process. Mathematical models [5] connecting the characteristics of logs and the processes of their cutting with the volume yield and profitability of a saw mill are proposed. Algorithms and programs of simulation studies of the process of sawn timber production with reproduction of real (random) variability of the sizes and shapes of sawn logs, as well as random displacement of logs relative to the center of the saws have been developed [6]. Dependences of the volume yield of sawn timber and the profitability of its production on the amplitude of variation of the log thicknesses, without taking into account the variation in the characteristics of the shape of sawn logs, as well as the random displacement of logs relative to the center of the saws, are investigated [7].

The article continues the series of articles written by the same authors and devoted to the investigation of the influence of probabilistic characteristics of the shape of a log and its orientation relative to saw position on the volume yield of sawn timber and the profitability of its production which was not taken into account in previous works. The subject of the study is the sweep of the logs.

2. Results and Discussion
To establish the general patterns of changes in the efficiency of sawmills in relation to the main technological controllable parameters, that is, group sorting of logs according to thickness, the number
of simultaneously produced thicknesses of boards, grading of lengths of boards, the real (casual) variability of the sizes and shapes of sawed logs as well as their random displacement relative to the center of the saws are taken into account. To do this, we use the method of simulation modeling with multiple reproductions of a set of different values of the original data on the computer. It is believed that ellipticity, sweep and bias relative to the center of saws obey the normal law, and the thickness of the logs obeys an equiprobable distribution law. In the machine experiment, in each sawing schedule "1000 logs are sawn".

The research is carried out on logs of thickness and length of 22 cm / 5.5 m using the sawing schedule number 4: 25 - 150 - 25; 25 - 50/3 - 25, providing a theoretical maximum volume yield of 60.21%; sawing schedule number 5: 25/2 - 100 - 25/2; 25 - 50/3 - 25 with a theoretical maximum volume yield of 58.51%; sawing schedule number 6: 25/2 - 100 - 25/2; 25/3 - 50 - 25/3 with a theoretical maximum volume yield of 57.04% with a length of boards of 1.5 ... 6.3 m with a gradation of 0.3 m, with a share of raw materials costs RMC = 0.8, with a constant basic cost and with a basic profitability of 25%.

The results of the research of the influence of log sweep on the volume yield of sawn timber and the profitability of its production are presented in tables 1 ... 4 and in figures 1 ... 8.

In figures 1 ... 8, the average arithmetic values of logs sweep are plotted along the abscissa. The mean square deviations of the sweep are 1/3 of the arithmetic mean. Thus, the point "0.10" on the abscissa corresponds to a variation from zero to 0.20%, the point "0.20" - from zero to 0.40%, etc. according to the normal sweep law. Sweep refers to a simple sweep (one curve), which is defined as the percentage of the bilge to the length of the log.

Table 1. Volume yield of sawn timber and profitability of production with variation amplitude (ddmax) of log thicknesses of 2.5 mm.

| Sweep, % at ddmax=2,5 mm | SAWING, % | Volumetric yield, % |
|--------------------------|-----------|---------------------|
|                          | Sawing schedule 4 | Sawing schedule 5 | Sawing schedule 6 |
|                          | Sawing schedule 4 | Sawing schedule 5 | Sawing schedule 6 |
| 0.00                     | 2,8        | 0,4                | -2                  | 60,138 | 58,68  | 57,299 |
| 0.05                     | 2,1        | -0,4               | -2,8               | 59,7   | 58,25  | 56,86  |
| 0.10                     | 1,4        | -1,1               | -4,3               | 59,27  | 57,82  | 55,97  |
| 0.15                     | 0,3        | -2,2               | -5                 | 58,63  | 57,204 | 55,579 |
| 0.20                     | -0,7       | -2,9               | -5,1               | 58,08  | 56,76  | 55,48  |
| 0.25                     | -2,1       | -3,4               | -5,2               | 57,234 | 56,46  | 55,45  |

Figure 1. Dependence of profitability on the sweep of logs with variation amplitude of their thicknesses of 2.5 mm
Figure 2. Dependence of the volume yield of sawn timber on the sweep of logs with variation amplitude of their thicknesses of 2.5 mm.

Table 2. Volume yield of sawn timber and profitability of production at variation amplitude of log thicknesses of 10 mm.

| Sweep, % at ddmax=10 mm | Profitability, % | Volume yield, % |
|------------------------|------------------|-----------------|
|                        | Sawing schedule 4 | Sawing schedule 5 | Sawing schedule 6 | Sawing schedule 4 | Sawing schedule 5 | Sawing schedule 6 |
| 0                      | 22.7             | 20.8            | 17               | 58.94            | 58.09             | 56.37            |
| 0.05                   | 21.8             | 19.9            | 15.8             | 58.49            | 57.65             | 55.75            |
| 0.1                    | 20.5             | 18.7            | 14.9             | 57.9             | 57.09             | 55.35            |
| 0.15                   | 19.4             | 17.6            | 14.4             | 57.37            | 56.56             | 55.09            |
| 0.2                    | 18.4             | 17.0            | 13.9             | 56.89            | 56.26             | 54.86            |
| 0.25                   | 17.2             | 16.5            | 13.5             | 56.32            | 56.05             | 54.68            |

Figure 3. Dependence of profitability on the sweep of logs with variation amplitude of their thicknesses of 20 mm.
Figure 4. Dependence of profitability on the sweep of logs with variation amplitude of their thicknesses of 10 mm.

Figure 5. Dependence of the volume yield of sawn timber on the sweep of logs with variation amplitude of their thicknesses of 10 mm.

Table 3. Volume yield of sawn timber and profitability of production with variation amplitude of log thicknesses of 20 mm.

| Sweep, % at dmax=20 mm | Profitability, % | Volume yield, % |
|------------------------|-----------------|-----------------|
|                        | Sawing schedule | Sawing schedule | Sawing schedule | Sawing schedule | Sawing schedule | Sawing schedule |
|                        | 4               | 5               | 6               | 4               | 5               | 6               |
| 0                      | 25              | 24,6            | 20,6            | 58,00           | 57,67           | 55,98           |
| 0,05                   | 23,9            | 23,5            | 19,6            | 57,50           | 57,19           | 55,53           |
| 0,1                    | 22,9            | 22,6            | 18,9            | 57,04           | 56,74           | 55,22           |
| 0,15                   | 22,2            | 21,9            | 18,4            | 56,69           | 56,41           | 54,98           |
| 0,2                    | 21,3            | 21,3            | 18,0            | 56,30           | 56,17           | 54,79           |
| 0,25                   | 20,4            | 20,9            | 17,7            | 55,88           | 55,95           | 54,63           |
Figure 6. Dependence of the volume yield of sawn timber on the sweep of logs with variation amplitude of their thicknesses of 20 mm.

Table 4. Volume yield of sawn timber and profitability of production at variation amplitude of log thicknesses of 30 mm.

| Sweep, % at ddmax=30 mm | Profitability, % | Volume yield, % |
|-------------------------|------------------|-----------------|
|                         | Sawing schedule 4 | Sawing schedule 5 | Sawing schedule 6 | Sawing schedule 4 | Sawing schedule 5 | Sawing schedule 6 |
| 0                       | 24,3             | 25,7            | 21,8             | 56,89             | 57,33             | 55,77            |
| 0,05                    | 23,5             | 24,9            | 21               | 56,51             | 56,95             | 55,39            |
| 0,1                     | 22,7             | 24,2            | 20,3             | 56,14             | 56,62             | 55,11            |
| 0,15                    | 22,2             | 23,6            | 19,9             | 55,90             | 56,36             | 54,90            |
| 0,2                     | 21,6             | 23,2            | 19,5             | 55,62             | 56,18             | 54,73            |
| 0,25                    | 20,4             | 22,7            | 19,1             | 55,09             | 55,97             | 54,54            |

Figure 7. Dependence of profitability on the sweep of logs with variation amplitude of their thicknesses of 30 mm.
From figures 2 ... 8 it can be seen that the volume yield of boards from logs of 22 cm / 5.5 m decreases with increasing sweep either by a linear or a quadratic law (with sufficiently high determination coefficients: from 0.945 to 0.999). The magnitude of the decrease in the volume yield depends on the amplitude of variation in the thickness of the logs and on the position of saws. When the average sweep value changes from 0 to 0.25% with a range of variation from 0 to 0.50%, the volume yield for № 4 sawing schedule is reduced by 2.9% at variation amplitude of the log thickness of 2.5 mm, for № 5 sawing schedule it is reduced by 2.2%, and for № 6 - by 1.8%. With the amplitude variation of log thicknesses of 30 mm, the decrease in the volume yield is 1.8: 1.4: 1.2%, respectively. It is easy to see that even a small sweep of logs (up to 0.25%) leads to a significant decrease in the volume yield of sawn timber (up to 2.9%). Moreover, the more efficient the sawing schedule and the higher the accuracy of log selection according to thickness are, the more the sweep reduces the volume yield.

It can be seen from figures 1 ... 7 that the profitability, as well as the volume output of boards from logs of 22 cm / 5.5 m, decreases with increasing sweep either by a linear or a quadratic law (with coefficients of determination from 0.952 to 0.999). Moreover, the quadratic dependence is observed with a very accurate group timber sorting according to thickness (up to ± 5 mm) and low quality of the sawing schedule (№ 6). The magnitude of the decline in profitability depends on the amplitude of variation in the thickness of logs in a sawing lot and on the position of saws. When the average sweep value varies from 0 to 0.25% with a range of variation from 0 to 0.50%, the profitability for № 4 sawing schedule decreases by 5.8% if the amplitude variation of the log thickness in the sawing lot is 5 mm; for sawing schedule № 5 it decreases by 4.2%, and for sawing schedule № 6 - by 3.5%. If an amplitude variation of log thicknesses is 30 mm, the profitability decrease is 3.9: 3.0: 2.7%, respectively. It should be noted that even a small sweep of logs (up to 0.25%) leads to a significant decrease in profitability of sawn timber production (up to 5.8%). Moreover, the more effective the sawing schedule and the higher the accuracy of log selection according to thickness are, the more the sweep reduces the profitability of timber production.

Comparing the patterns of decrease in the volume yield of sawn timber and the profitability of its production, caused by the sweep of the logs, we see that they are also similar, as well as due to ellipticity. This is explained by the fact that sweep as well as ellipticity reduces profitability only through a decrease in the volume yield of sawn timber.

3. Conclusion
The study of the influence of the sweep of logs on the volume yield of sawn timber and the profitability of its production makes it possible to draw the following conclusions:
1. Reducing the volume yield of sawn timber because of the sweep of logs measuring 22 cm / 5.5 m should be recognized as very significant. When the average sweep varies from 0 to 0.25% (with a range of variation from 0 to 0.50%), the volume yield is reduced by 1.2 ... 2.9%. If we take into account that the real sweep of the logs varies from 0 to 2%, then we can expect a decrease in volume yield by 5 ... 12%.

2. The expected contribution of the log sweep to the deviation of the real volume yield of sawn timber from its calculated value can reach 70 ... 80% (the contribution of ellipticity is about 10% [5]). The contribution of other causes will be described in the following papers of the authors.

3. Profitability of timber production is highly dependent on the sweep of logs measuring 22 cm / 5.5 m. When the average sweep changes from 0 to 0.25%, the profitability decreases by 2.7 ... 5.8% (ellipticity decreases by 0.8 ... 2.3% [5]).

4. At the next stage, the influence of sweep on the dependence of the profitability of sawn wood production on the amplitude of variation in log thickness will be investigated, which is used as an objective function in the search for the optimal sorting of log by diameters.

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