Dependence of saw timber volume output and production efficiency on logs ellipticity

V V Ogurtsov, D N Dereviannykh, E V Kargina and I S Matveeva

Reshetnev Siberian State University of Science and Technologies, Krasnoyarsk, 660037, Russian Federation
E-mail: vogurtsov@mail.ru

Abstract. We investigated the effect of the log ellipticity on the volume output of timber and production efficiency by means of simulation. The degree of ellipticity influence on the forecasting of timber production economic indicators accuracy is shown. We have found out that when the average ellipticity from 0 to 6 mm, so the volumetric output is reduced by about 1 %, and profitability decreases by 0.8...2.3 %.

1. Introduction
The authors have analyzed and explained in their papers [1-6] the possibility of improving the economic efficiency of sawmills by optimizing the fractional sorting of logs in thickness. We took saw timber volume output and production efficiency as competing criteria of optimality. Mathematical models that connect the characteristics of logs and the processes of their cutting with the saw timber volume output and the profitability of a sawmill have been developed. Algorithms and programs for imitation studies of the production process for saw timber have been developed. Dependencies of profitability and volume output of saw timber on the fractional sorting of sawlogs in thickness are determined without taking into account the random variation of the curvature and log ellipticity, and also without taking into account their spontaneous displacement relative to the saw mill.

This article is the first one in a cycle of articles concerning the influence of probabilistic characteristics of a log shape and log's orientation on the saw timber volume output and the production efficiency that were not taken into account in previous works.

2. Results and Discussion
In order to understand what affects the efficiency of the sawmill enterprises, we need to take into account the main technologically controlled parameters; this includes the fractional sorting of logs by thickness, the number of simultaneously produced thicknesses of boards and gradation of board lengths. The real (random) variability of sizes and shapes of sawed logs and their random displacement relative to the center of the saw mill depend on those parameters. For this simulation we used method with multiple playback on the computer with different values in the source data. It is supposed that the ellipticity, curvature and displacement of the saw mill from the center follow usual rules, and the log thickness follows the equally possible distributive law. In the experiment every saw mill has 1000 sawn logs.

Research is being conducted on the logs of a thickness and length at 22 cm / 5.5 m, saw mill used #4: 25 – 150 – 25; 25 – 50/3 – 25, providing the theoretical maximum volumetric output 60.21 %;
saw mill #5: 25/2-100-25/2; 50/3-25-25 with a theoretical maximum volume output 58.51%; saw mill #6: 25/2 – 100 – 25/2; 25/3 – 50 – 25/3 the theoretical maximum of volumetric output is 57.04 % when the length of the boards is 1.5...6.3 m with a step of 0.3 m, the proportion of commodity costs equals 0.8, while the permanent base cost and the underlying profitability of 25%.

The results of the study of the log ellipticity influence on the saw timber volume output and the production efficiency are presented in tables 1 to 3 and figures 1 to 6.

In the figures, the x-axis deposit the average value of log ellipticity. Average quadratic deviation of ellipticity is equal to 1/3 of the average values. Thus, the point "2" on the x-axis corresponds to the variation of the ellipticity according to the normal law of zero to 4 mm, and the point "4" corresponds from zero to 8 mm, etc. The ellipticity refers to the difference between the maximum and average diameter or polprasert between the maximum and minimum diameter of the apical end of a log.

Table 1. Saw timber volume output and production efficiency in amplitude (ddmax) of varying log thicknesses in 2.5 mm.

| Ellipticity, mm at ddmax=2.5 | Profitability, % | Volume output, % |
|-----------------------------|------------------|------------------|
| Saw mill 4                  | Saw mill 5       | Saw mill 6       | Saw mill 4 | Saw mill 5 | Saw mill 6 |
| 0                           | 2.8              | 0.4              | -2         | 60.14      | 58.68      | 57.30      |
| 2                           | 2.4              | -0.1             | -2.5       | 59.91      | 58.41      | 57.01      |
| 4                           | 2                | -0.6             | -3         | 59.62      | 58.12      | 56.72      |
| 6                           | 1.4              | -1.1             | -3.8       | 59.32      | 57.82      | 56.29      |
| 8                           | 0.8              | -1.7             | -4.8       | 58.97      | 57.46      | 55.71      |
| 10                          | 0                | -2.5             | -6         | 58.48      | 56.99      | 55.01      |

Figure 1. Dependence of the profitability on the log ellipticity in the amplitude of thicknesses variation of 2.5 mm.
Figure 2. Dependence of the saw timber volume output from the logs ellipticity in the amplitude of thicknesses variation of 2.5 mm.

Table 2. Saw timber volume output and production efficiency in amplitude (ddmax) of varying log thicknesses in 2.5 mm.

| Ellipticity, mm at ddmax=2.5 mm | Profitability, % | Volume output, % |
|---------------------------------|-----------------|------------------|
|                                 | Saw mill 4  | Saw mill 5  | Saw mill 6  | Saw mill 4  | Saw mill 5  | Saw mill 6  |
| 0                               | 22.7       | 20.8       | 17           | 58.94      | 58.09      | 56.37       |
| 2                               | 22.1       | 20.1       | 16.3         | 58.67      | 57.76      | 56.03       |
| 4                               | 21.3       | 19.4       | 15.5         | 58.35      | 57.40      | 55.64       |
| 6                               | 20.5       | 18.5       | 14.7         | 57.99      | 56.96      | 55.22       |
| 8                               | 19.7       | 17.4       | 13.6         | 57.57      | 56.45      | 54.69       |
| 10                              | 18.7       | 16.1       | 12.4         | 57.09      | 55.84      | 54.14       |

Figure 3. Dependence of the profitability on the log ellipticity in the amplitude of thicknesses variation of 10 mm.
Figure 4. Dependence of the saw timber volume output on the ellipticity of logs in the amplitude of thicknesses variation of 10 mm.

Table 3. Saw timber volume output and production efficiency in amplitude (ddmax) of varying log thicknesses in 30 mm.

| Ellipticity, in mm at ddmax=30 mm | Profitability, % | Volume output, % |
|-----------------------------------|-----------------|-----------------|
|                                   | Saw mill 4 | Saw mill 5 | Saw mill 6 | Saw mill 4 | Saw mill 5 | Saw mill 6 |
| 0                                 | 24.3       | 25.7       | 21.8       | 56.89      | 57.33      | 55.77      |
| 2                                 | 23.7       | 25.0       | 21.1       | 56.59      | 57.02      | 55.47      |
| 4                                 | 23         | 24.2       | 20.5       | 56.28      | 56.66      | 55.16      |
| 6                                 | 23.5       | 23.6       | 19.7       | 56.12      | 56.26      | 54.83      |
| 8                                 | 22.7       | 22.9       | 19         | 55.74      | 56.04      | 54.50      |
| 10                                | 21.9       | 22.2       | 18.2       | 55.37      | 55.72      | 54.14      |

Figure 5. Dependence of the profitability on the log ellipticity in the amplitude of thicknesses variation of 30 mm.
Figures 2, 4 and 6 show that saw timber volume output from logs of 22 cm / 5.5 m decreases with increasing linear ellipticity (with sufficiently high determination coefficients: from 0.965 to 0.999). The reduction in volumetric output depends on the log thickness variation amplitude in the sawing lot and saw mill. If you change the average value of ellipticity from 0 to 10 mm with a variation from 0 to 20 mm volumetric output is reduced by 1.5 to 2.3 percent. When the average ellipticity changes from 0 to 6 mm, most characteristic of logs with thickness of 22 cm, the volumetric output is reduced by 0.8...1.2 %. Such a reduction should be mentioned as significant.

Figures 1, 3 and 5 show that production efficiency and saw timber volume output from logs of 22 cm / 5.5 m decreases with increasing linear ellipticity (with determination coefficients from 0.915 to 0.999). Reducing volume of profitability approximately equally depends on the amplitude varying log thicknesses and saw mill. If you change the average value of ellipticity from 0 to 10 mm with a variation from 0 to 20 mm volumetric output is reduced by 2.4 to 4.7 %. When the average ellipticity changes from 0 to 6 mm then profitability is reduced by 0.8...2.3 %. This decline in profitability is quite significant and therefore a factor of log ellipticity must be considered when forecasting the economic indicators of a sawmill.

Comparing the pattern of reduction in saw timber volume output and production efficiency due to the log ellipticity, we see that they are very similar. The reason is that ellipticity reduces the profitability only through the reduction in saw timber volume output.

3. Conclusion
Investigation of the effect of log ellipticity on the saw timber volume output and the production efficiency allow to make the following conclusions:
1. The decrease in saw timber volume output from the log ellipticity with dimensions of 22 cm / 5.5 m should be recognized significant. When the average ellipticity changes from 0 to 6 mm then profitability is reduced by 1 %.
2. The influence of the log ellipticity on the deviation of the saw timber volume output from the calculation of its value is about 10 %. The contribution of other causes will be described in the following papers of the authors.
3. The production efficiency of sawn timber is highly dependent on the log ellipticity with dimensions of 22 cm / 5.5 m. When the average ellipticity changes from 0 to 6 mm then profitability is reduced by 0.8...2.3 %.
4. In the next step, the influence of ellipticity on the dependence of the production efficiency of sawn timber from the amplitude variation of the thickness of the logs, which is used as the objective function when searching for optimal external sorting logs by diameter.
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