UDC 634.0.30

D. V. Klokov, PhD (Engineering), assistant professor (BSTU);
I. V. Turlay, PhD (Engineering), assistant professor (BSTU)

MODELS OF FOREST MACHINES BASED ON RELIABILITY

A new model of forestry systems taking into account technical and technological failures at various stages of work is proposed, the formulas to determine the effectiveness of systems according to the criteria determining the probabilities of states with rational parameters of operation (flow rate of raw materials, their processing and repair of equipment) are offered.

Introduction. In today's timber industry almost all forest machinery and equipment are strongly influenced by natural factors, and production factors, that is why they work with a margin. Accordingly, the models and rational solutions should be based on the given conditions. [1]

Main part. The solution for the system with a margin of m units is shown in Fig. 1.

$$P_0 = \left[1 + \frac{\lambda_1}{\mu_1} + \frac{\lambda_2}{\mu_2}\frac{\lambda_1}{\mu_1} + \left(\frac{1}{2} + \frac{\lambda_2}{\mu_2}\right)\sum_{i=2}^{m+2}\left(\frac{1}{2}\right)^{i-2}\left(\frac{\lambda_1}{\mu_1}\right)^{i}\right]^{-1};$$

$$P_i = \left(\frac{1}{2}\right)^{i-1}\left(\frac{\lambda_1}{\mu_1}\right)^{i} P_0,\ P_{i1} = P_{i2} = \frac{\lambda_2}{\mu_2} P_i.$$

Consider the model of functioning system of the three production systems with a margin of 2 per production unit (Fig. 2).

Here S_0 – free state of a system, the processing of items of work is not conducted; S_1 – one production system processes the subject of work, two systems are free; S_{11} – the state of the technical failure of the operating production system, occurred in the state S_1; S_2 – two production systems provide the processing of items of work, one is free; S_{21} – state of technical failure of one of the working production systems occurred in the state S_2; S_{22} – status of the technical failure of two operating production systems occurred in the state S_2; $S_{3,4,5}$ – all three production systems provide the processing items of work; $S_{31,\ 41,51}$ – state of the technical failure of one of the production systems occurred in the state $S_{3,\ 4,5}$; $S_{32,\ 42,52}$ – state of technical failure of the two production systems so occurred in the state $S_{3,4,5}$; $S_{33,\ 43,53}$ – state of technical failure of all the three production systems occurred in the state $S_{3,\ 4,5}$.

The parameters in the model are the same.

Mathematical model of the functioning system is a system of equations:

$$\frac{dP_0}{dt} = -\lambda_1 P_0 + \mu_1 P_1;\ \frac{dP_1}{dt} = -(\lambda_1 + \lambda_2 + \mu_1) P_1 + $$
$$+ \lambda_1 P_0 + \mu_2 P_{11} + 2\mu_1 P_2;\ \frac{dP_{11}}{dt} = \mu_2 P_{11} + \lambda_2 P_1;$$
$$\frac{dP_2}{dt} = -(\lambda_1 + 3\lambda_2 + 2\mu_1) P_1 + \lambda_1 P_1 + \mu_2 P_{21} +$$
$$+ 2\mu_2 P_{22} + 3\mu_1 P_3;\ \frac{dP_{21}}{dt} = -\mu_2 P_{21} + \lambda_2 P_2;$$
$$\frac{dP_{12}}{dt} = -2\mu_2 P_{22} + 2\lambda_2 P_2;\ \frac{dP_3}{dt} = -(\lambda_1 + 6\lambda_2 + 3\mu_1)\times$$
$$\times P_3 + \lambda_1 P_2 + \mu_2 P_{31} + 2\mu_2 P_{32} + 3\mu_2 P_{33} + 3\mu_1 P_4;$$
$$\frac{dP_{31}}{dt} = -\mu_2 P_{31} + \lambda_2 P_3;\ \frac{dP_{32}}{dt} = -2\mu_2 P_{32} + 2\lambda_2 P_3;$$
$$\frac{dP_{33}}{dt} = -3\mu_2 P_{33} + 3\lambda_2 P_3;\ \frac{dP_4}{dt} = -(\lambda_1 + 6\lambda_2 + 3\mu_1)\times$$
$$\times P_4 + \lambda_1 P_3 + \mu_2 P_{41} + 2\mu_2 P_{42} + 3\mu_2 P_{43} + 3\mu_1 P_5;$$
$$\frac{dP_{41}}{dt} = -\mu_2 P_{41} + \lambda_2 P_4;\ \frac{dP_{42}}{dt} = -2\mu_2 P_{42} + 2\lambda_2 P_4;$$
$$\frac{dP_{43}}{dt} = -3\mu_2 P_{43} + 3\lambda_2 P_4;\ \frac{dP_5}{dt} = -(6\lambda_2 + 3\mu_1) P_5 +$$
$$+ \lambda_1 P_4 + \mu_2 P_{51} + 2\mu_2 P_{52} + 3\mu_2 P_{53};\ \frac{dP_{51}}{dt} = -\mu_2 P_{51} + \lambda_2 P_5;$$
$$\frac{dP_{52}}{dt} = -2\mu_2 P_{52} + 2\lambda_2 P_5;\ \frac{dP_{53}}{dt} = -3\mu_2 P_{53} + 3\lambda_2 P_5.$$

The solution of equivalent linear system of equations is the following:

$$P_0 = \left[1 + \frac{\lambda_1}{\mu_1}\left(1 + \frac{\lambda_2}{\mu_2}\right) + \frac{\lambda_1^2}{\mu_1^2}\left(\frac{1}{2} + \frac{\lambda_2}{\mu_2}\right) + \right]^{-1} +$$
$$+ \left[\frac{1}{2}\left(\frac{1}{3} + \frac{\lambda_2}{\mu_2}\right)\left(\frac{\lambda_1^3}{\mu_1^3} + \frac{1}{3}\frac{\lambda_1^4}{\mu_1^4} + \frac{1}{9}\frac{\lambda_1^5}{\mu_1^5}\right)\right]^{-1};$$

$$P_1 = \frac{\lambda_1}{\mu_1} P_0;\ P_{11} = \frac{\lambda_2}{\mu_2}\frac{\lambda_1}{\mu_1} P_0;\ P_2 = \frac{1}{2}\frac{\lambda_1^2}{\mu_1^2} P_0;$$

$$P_{21} = P_{22} = \frac{1}{2}\frac{\lambda_2}{\mu_2}\frac{\lambda_1^2}{\mu_1^2} P;\ P_3 = \frac{1}{6}\frac{\lambda_1^3}{\mu_1^3} P_0;$$

$$P_{31} = P_{32} = P_{33} = \frac{1}{6}\frac{\lambda_2}{\mu_2}\frac{\lambda_1^3}{\mu_1^3} P_0;$$

$$P_4 = \frac{1}{18}\frac{\lambda_1^4}{\mu_1^4} P_0;\ P_{41} = P_{42} = P_{43} = \frac{1}{18}\frac{\lambda_2}{\mu_2}\frac{\lambda_1^4}{\mu_1^4} P;$$

$$P_5 = \frac{1}{54}\frac{\lambda_1^5}{\mu_1^5} P_0;\ P_{51} = P_{52} = P_{53} = \frac{1}{54}\frac{\lambda_2}{\mu_2}\frac{\lambda_1^5}{\mu_1^5} P_0.$$

Generalizing these results, we obtain the solution for a system with a margin of m production units (Fig. 3).

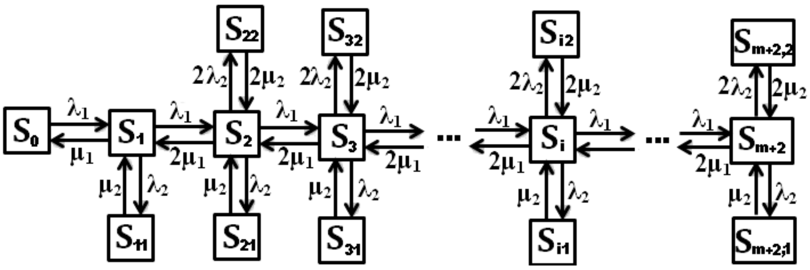

Fig.1. Labeled state graph of the three production systems
with a margin of *m* per production unit

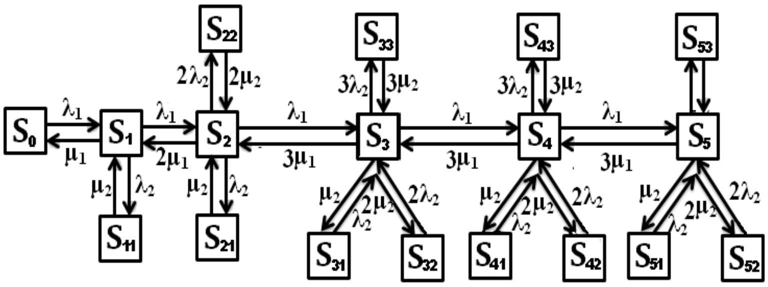

Fig.2. Labeled state graph of the three production systems
with a margin of 2 per production unit

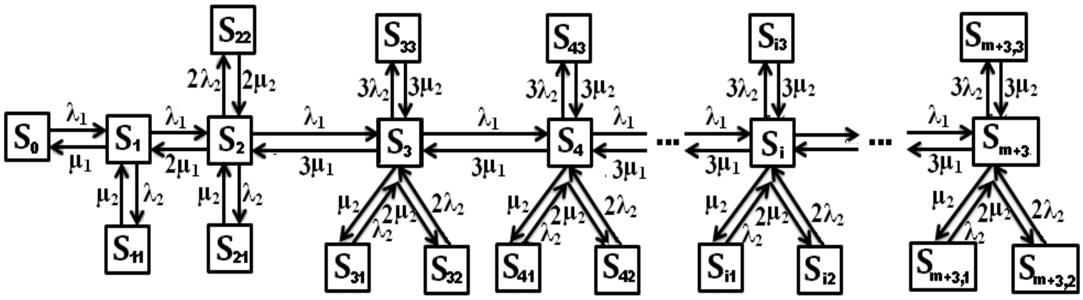

Fig.3. Labeled state graph of the three production systems
with a margin of 2 per production unit

$$P_0 = \left[1 + \frac{\lambda_1}{\mu_1}\left(1 + \frac{\lambda_2}{\mu_2}\right) + \left(\frac{\lambda_1}{\mu_1}\right)^2 \left(\frac{1}{2} + \frac{\lambda_2}{\mu_2}\right)\right]^{-1} +$$

$$+\left[+\frac{1}{2}\left(\frac{1}{3} + \frac{\lambda_2}{\mu_2}\right)\sum_{i=3}^{m+3}\left(\frac{1}{3}\right)^{i-3}\left(\frac{\lambda_1}{\mu_1}\right)^i\right]^{-1};$$

$$P_1 = \frac{\lambda_1}{\mu_1}P; \quad P_{11} = \frac{\lambda_2}{\mu_2}\frac{\lambda_1}{\mu_1}P_0; \quad P_2 = \frac{1}{2}\frac{\lambda_1^2}{\mu_1^2}P_0;$$

$$P_{21} = P_{22} = \frac{1}{2}\frac{\lambda_2}{\mu_2}\frac{\lambda_1^2}{\mu_1^2}P_0; \quad P_i = \frac{1}{2}\left(\frac{1}{3}\right)^{i-2}\left(\frac{\lambda_1}{\mu_1}\right)^i P_0;$$

$$P_{i1} = P_{i2} = P_{i3} = \frac{\lambda_2}{\mu_2}P_i; \quad i = 3, 4, \ldots, m+3.$$

Conclusion. In practical terms, the elaborated models allow at the given characteristics of the machinery and equipment to get the rational modes of supply of raw materials for processing and maintenance of equipment in case of technical failure. This will increase the productivity of the equipment without significant financial costs.

References

1. Игнатенко, В. В. Моделирование и оптимизация процессов лесозаготовок: учеб. пособие для студентов специальностей лесотехнического профиля / В. В. Игнатенко, И. В. Турлай, А. С. Федоренчик. – Минск: БГТУ, 2004. – 180 с.

Received 16.03.2012