

A STUDY OF THE PROBABILISTIC STATES OF MACHINE-TRACTOR AGGREGATES FOR WHEAT CULTIVATION

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Abstract: This paper applies Markov's theory of stochastic processes (Graph theory) to identify the probability of the machine-tractor aggregate being in each of the machine states adopted by the model. It features a graph of the states of a machine-tractor aggregate (Machine-status) operating in plant growing that allows us to determine the probability of the aggregate being in any of the states considered as basic. It proves that with the increase in the level of reliability of the aggregate, in this case its flawless performance, represented by the non-intermittent operation time indicator (time for trouble-free work), the probability that the aggregate will be in a functional state increases.

Keywords: Agriculture machinery, Machine status, Time for trouble-free work, Graph theory.

1. INTRODUCTION

For the sake of the mathematical explanation of each aggregate in plant agriculture we can present it in the form of a physical system, the state of which changes discretely and continuously over time in a random manner. The process of modifying the aggregate state corresponds to the methods of calculating the operations [1,4,6,7] and can be presented as a sequence of states.

The aim of this study is to determine the probability of the machine-tractor aggregate in the course of the technological operations for wheat farming, being in each of the states adopted in the model using the apparatus of Markov's theory of stochastic processes (Graph theory).

2. EXPOSURE

Figure 1 shows a graph of the states of the aggregate and the possible state transitions are illustrated with arrows.

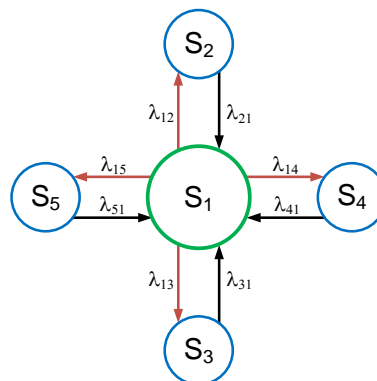


Figure 1. Graph of the states of machine-tractor aggregates

We assume that the aggregate goes from one state to another under the influence of consecutive random events. Generally, the aggregate can be in the following states: - S_1 upright, operating; S_2 - malfunctioning, malfunction to be identified and fixed; S_3 - performing

a turn; S_4 - technological servicing is taking place (e.g. loading consumables or unloading of the grain tank, etc.); S_5 - technological malfunctions are being fixed.

The number of states depends on the type of aggregate, the type of technological process (plowing, sowing, plant protection, fertilizing, spraying, harvesting, etc.), the operation conditions, etc.

The average time for flawless operation (Time for trouble-free work) of the unit is represented by t_1 ; t_2 is the time for search and troubleshooting; t_3 is the time to make a turn; t_4 is the technological maintenance time; t_5 is the time for fixing any technological flaws.

If we know the aggregate's average time of idleness in each of the above states, we can determine the probabilities of the latter by applying Markov's theory of stochastic processes.

In this case, the probability of stopping the aggregate to fix a flaw is α_1 , for making a turn α_2 , for maintenance - α_3 , and the probability $1-(\alpha_1+\alpha_2+\alpha_3)$ will reflect the intensity of transition from one state to another;

$$\lambda_{15} = \frac{1-(\alpha_1+\alpha_2+\alpha_3)}{t_1}; \text{ - Intensity of transition from state } S_1 \text{ to state } S_5;$$

$$\lambda_{12} = \frac{\alpha_1}{t_1}; \text{ - Intensity of transition from state } S_1 \text{ to state } S_2;$$

$$\lambda_{21} = \frac{1}{t_2}; \text{ - Intensity of transition from state } S_2 \text{ to state } S_1;$$

$$\lambda_{14} = \frac{\alpha_3}{t_1}; \text{ - Intensity of transition from state } S_1 \text{ to state } S_4;$$

$$\lambda_{41} = \frac{1}{t_4}; \text{ - Intensity of transition from state } S_4 \text{ to state } S_1;$$

$$\lambda_{13} = \frac{\alpha_2}{t_2}; \text{ - Intensity of transition from state } S_1 \text{ to state } S_3;$$

$$\lambda_{31} = \frac{1}{t_3}; \text{ - Intensity of transition from state } S_3 \text{ to state } S_1;$$

$$\lambda_{51} = \frac{1}{t_5}; \text{ - Intensity of transition from state } S_5 \text{ to state } S_1;$$

$$\left| \begin{aligned} \frac{dP_2}{dt} &= \frac{\alpha_1 P_1}{t_1} - \frac{P_2}{t_2}; \\ \frac{dP_4}{dt} &= \frac{\alpha_3 P_1}{t_1} - \frac{P_4}{t_4}; \\ \frac{dP_3}{dt} &= \frac{\alpha_2 P_1}{t_1} - \frac{P_3}{t_3}; \\ \frac{dP_5}{dt} &= \frac{(1 - \alpha_1 - \alpha_2 - \alpha_3)P}{t_1} - \frac{P_5}{t_5}; \end{aligned} \right. \tag{1}$$

Once selected the state graph, we can determine all probabilistic states as time functions. These probability states satisfy the Kolmogorov - Chapman differential equation and are compiled by a common general rule [1, 6].

Then the system of differential equations of the states will look as follows:

The normative condition is:

$$P_1 + P_2 + P_3 + P_4 + P_5 = 1; \tag{2}$$

$$\text{or } \sum_{i=1}^n P_i = 1;$$

When $t \rightarrow \infty$ the system is in stationary mode of operation. In order to calculate the marginal states, the left parts of the differential equations are set equal to zero and the result is a system of linear equations:

$$\begin{cases} \frac{\alpha_1 P_1}{t_1} - \frac{P_2}{t_2} = 0; \\ \frac{\alpha_3 P_1}{t_1} - \frac{P_4}{t_4} = 0; \\ \frac{\alpha_2 P_1}{t_1} - \frac{P_3}{t_3} = 0; \\ \frac{(1 - \alpha_1 - \alpha_2 - \alpha_3)P}{t_1} - \frac{P_5}{t_5} = 0 \\ P_1 + P_2 + P_3 + P_4 + P_5 = 1; \end{cases} \quad (3)$$

where $\alpha_1 = \frac{t_2}{t_2 + t_3 + t_4 + t_5}$, $\alpha_2 = \frac{t_3}{t_2 + t_3 + t_4 + t_5}$, $\alpha_3 = \frac{t_4}{t_2 + t_3 + t_4 + t_5}$;

We solve the system of equations and we find the value of probability P_1 by using the following formula:

$$P_1 = \frac{t_1}{t_1 + \alpha_1 t_2 + \alpha_2 t_3 + \alpha_3 t_4 + (1 - \alpha_1 - \alpha_2 - \alpha_3)t_5}; \quad (4)$$

And then the rest of the probabilities P_1 , P_2 , P_3 , P_4 and P_5 are calculated in the same manner.

P_1 - the probability of MTA being in a workable state, ie state S1 (upright), and then the other probabilities.

P_2 - MTA incapacitated, malfunctions detected and removed.

$$P_2 = \frac{\alpha_1 t_2}{t_1 + \alpha_1 t_2 + \alpha_2 t_3 + \alpha_3 t_4 + (1 - \alpha_1 - \alpha_2 - \alpha_3)t_5} \quad (5)$$

P_3 - MTA performs a turn;

$$P_3 = \frac{\alpha_2 t_3}{t_1 + \alpha_1 t_2 + \alpha_2 t_3 + \alpha_3 t_4 + (1 - \alpha_1 - \alpha_2 - \alpha_3)t_5} \quad (6)$$

P_4 - performing technological service of MTA;

$$P_4 = \frac{\alpha_3 t_4}{t_1 + \alpha_1 t_2 + \alpha_2 t_3 + \alpha_3 t_4 + (1 - \alpha_1 - \alpha_2 - \alpha_3)t_5} \quad (7)$$

P_5 - remove MTA techno malfunctions.

$$P_5 = 1 - (P_1 + P_2 + P_3 + P_4) \quad (8)$$

Figure 2 graphically represents the effect of the change in the flawless Time for trouble-free work t_1 (within $\pm 10\%$ of its average value) on the probabilistic state of the machine P_1 . Therefore, the increase in the level of the reliability of the aggregate, in this case its flawless performance, represented by the non-intermittent operation time indicator.

Figure 3 graphically presents the effect of the changes in the time spent on search and troubleshooting t_2 (within $\pm 10\%$ of its average value) on the probabilistic state of the machine P_1 .

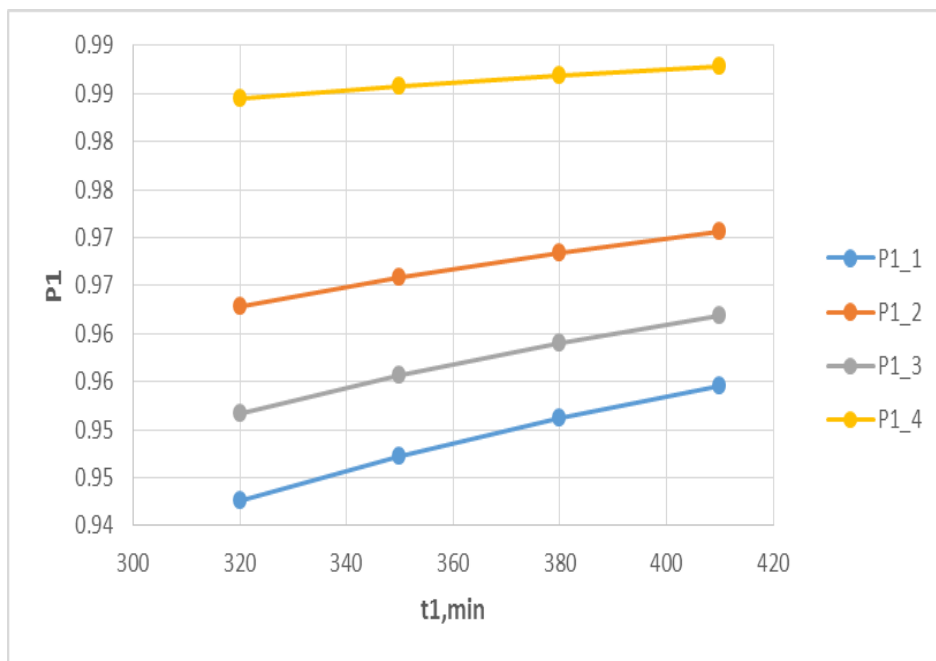


Figure 2. Effect of flawless non-intermittent operation time t_1 on P_1

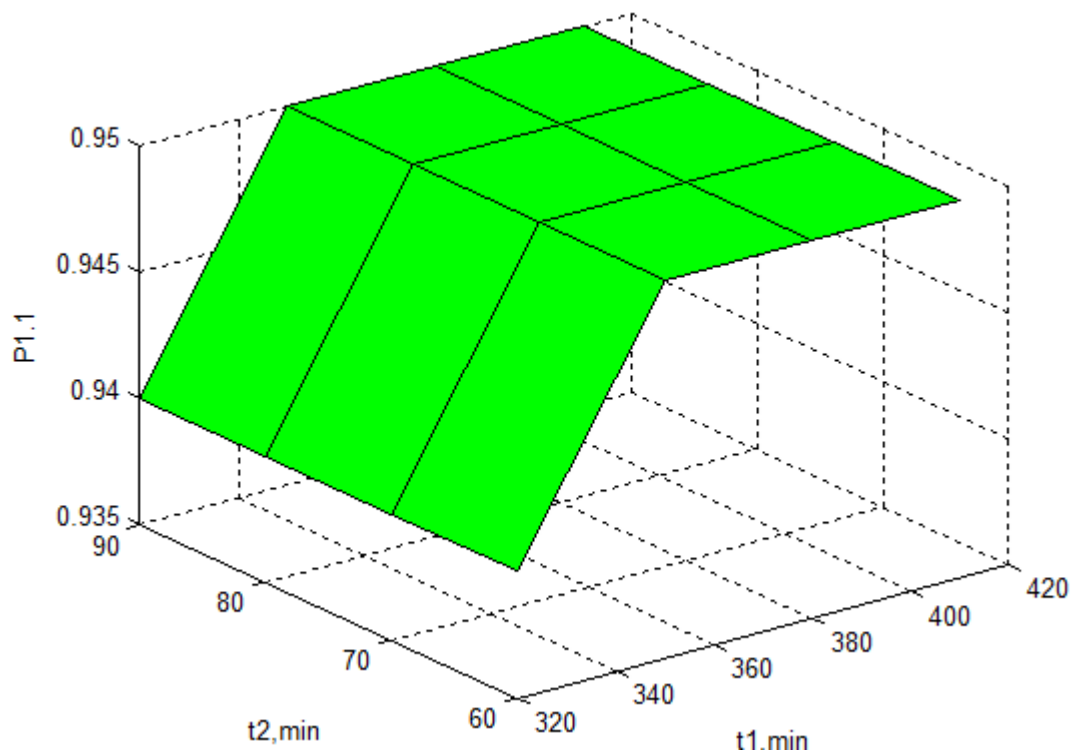


Figure 3. Changes in the probability of the unit being in a workable condition depending on the uninterrupted operation time t_1 and the search and troubleshooting t_2

3. CONCLUSION

- This paper introduces a graph of the states of a machine-tractor unit operating in plant growing, which allows to determine the probability of the aggregate being in any of the states considered as basic.
- It proves that the increase in the level of reliability of an aggregate, in this case its flawless performance, presented by the non-intermittent operation time indicator (time for trouble-free work), increases the probability of the aggregate being in a functional state.
- A correlation has been established between the probability that the unit is in an operational condition and the times for flawless non-intermittent operation t_1 and for searching and troubleshooting t_2 .

4. ACKNOWLEDGMENTS

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