

Increasing productivity of machine-tractor units depending on the influence of the load of the machine operator with maintenance work in the agricultural enterprises of the Omsk region

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Abstract. Increased productivity of machine-tractor units in the conditions of agricultural production is one of the most important and urgent tasks of the engineering and technical service of the agricultural sector. The greatest impact on machine reliability and performance indicators has a timely and good-quality maintenance. Fault tolerance is crucial to ensuring high machine productivity. The amount of maintenance work increases in proportion to the number of hours worked. Inadequate technical maintenance, leading to increased failure rates, reduced productivity and machine operating hours, and higher operating costs. Machine failures and downtime lead to disruptions in agricultural production technology, which leads to delays and loss of crops. This is a main contradiction that is inherent in the actual system of maintenance and use of machines, in the overlapping timing of their performance. Addressing the problem of increasing tractor uptime in the current environment is of particular importance and relevance. This can be achieved by reducing maintenance downtime by intensifying maintenance during the non-stressful period of fieldwork. It is therefore advisable to outsource part of the maintenance and repair work to specialised enterprises, since there, due to their high specialisation and technical equipment, the quality of such work will be higher than on the farm. Tractor uptime can also be improved through greater specialisation and intensification of maintenance operations by shifting them to non-stressful periods of fieldwork. The study proposes and theoretically substantiates the structure of technical service formation in agro-industrial enterprises. The main advantages of the proposed technical service system are discussed.

1 Introduction

Crop yields depend directly on compliance with the agronomic requirements for technological operations and the agronomic timing of these operations. Compliance with agronomic deadlines mainly depends not only on the technical condition of the tractor

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units, but also on the operator's workload in performing complex tractor maintenance tasks that are not typical of him. [1-2]. Concentration and specialisation have the greatest effect in organising maintenance work. The concentration of complex maintenance and repair activities, as well as the greater specialisation of maintenance operations during non-stress periods, allows a sufficient number of highly specialised contractors, thereby improving the quality of work and relieving the operator of much of the maintenance and repair work.

The purpose of the study is to find optimal solutions to increase tractor productivity and uptime by using intensive maintenance methods to reduce downtime during busy periods of fieldwork by specialising maintenance and outsourcing some of the work to maintenance companies.

2 Materials and methods

The main research methods used were direct observation under machinery operating conditions, data from literary sources with an assessment of comparable conditions, as well as data from experiments carried out on farms; mathematical modelling methods and statistical processing of the results were used in processing the experimental data.

3 Results and Discussion

In the current conditions at agricultural companies in the Omsk region, there is a tendency towards a reduction in the number of machine operators, with more than two types of equipment per machine operator. According to the data received, the staffing of machine operators in agricultural enterprises in the Omsk region is 0.222 persons / 100 ha (figure 1), which is insufficient for effective production [3].

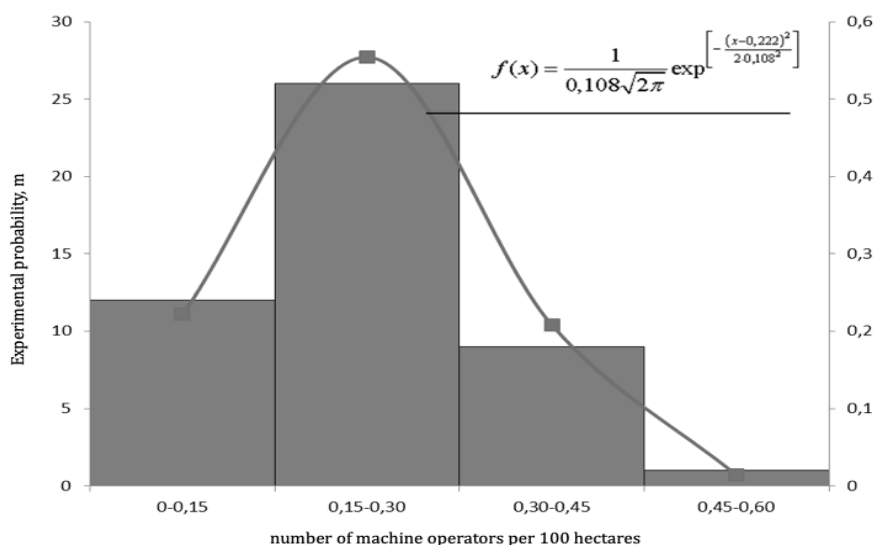


Fig. 1. Normal distribution of staffing of machine operators per 100 ha.

Based on information provided by the Ministry of Agriculture and Food of the Omsk region, the renewal of agricultural machinery in farms in the Omsk region has been extremely slow (Figure 2). The average age of tractors is 26.2 years, which indicates their poor technical condition [4-5].

To maintain tractors in a technically good condition, they require in accordance with GOST 207-2009 "Tractors and agricultural machinery. Maintenance" complete and quality maintenance. There are several main reasons why it is impossible to carry out it in a modern agricultural enterprise:

- Insufficient staffing, both as mechanics and maintenance workers.
- The lack of maintenance material and technical base to service agricultural enterprises [6-9].

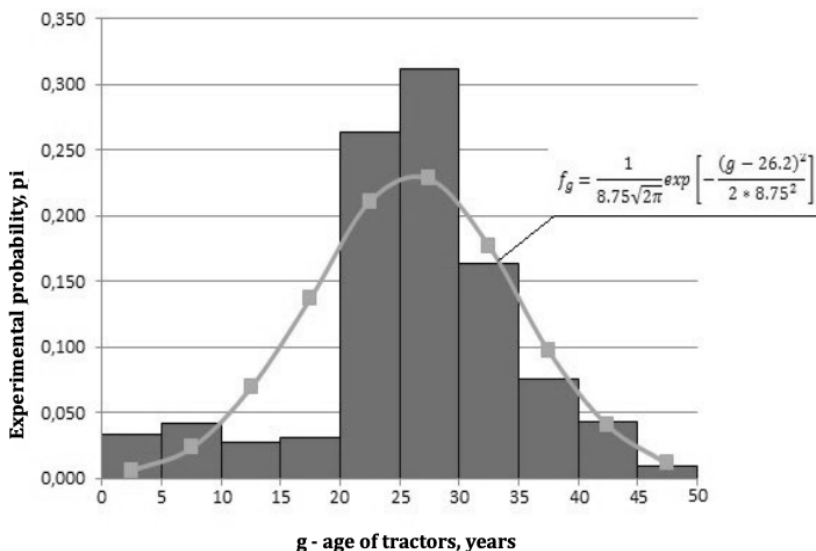


Fig. 2. Normal distribution: average age of tractors on farms in the Omsk region.

As a result, the maintenance and repair of agricultural machinery is performed directly by the machine operator, resulting in an excessive load on the machine operator for the maintenance and repair of agricultural machinery (Figure 3), distracting him from the main types of work, accordingly poor quality of their performance.

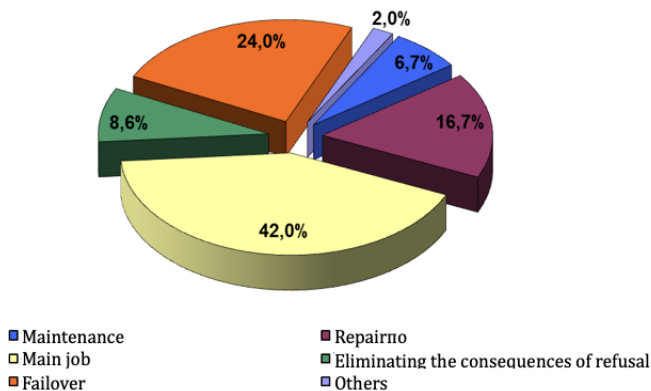


Fig. 3. Diagram of the employment of the machine operator during the year.

More than half of the working time the machine operator is engaged in machine maintenance and repair work and the elimination of the consequences of refusals. This leads to inadequate and incomplete maintenance, repairs and the elimination of the consequences of refusals, which affects the technical condition of the equipment [10-12].

During busy periods of agricultural fieldwork, the machine operator is under stress. He must perform his main job and at the same time participate in the maintenance and repair of agricultural machinery, which has a significant affect on the performance of the machine and tractor units, the compliance with the agronomic deadlines of the technological operations. At the same time, the average age of machine operators in the Omsk region is around 50 years, and their overload leads to an increase in the frequency and severity of injuries, as well as a reduction in average life expectancy. While according to Rosstat the average life expectancy of men in the Omsk region in 2020 is 66.9 years, according to independent sources the average life expectancy of machine operators in the Omsk region does not exceed 65 years.

The completeness and quality of maintenance, as well as the productivity of the machine and tractor units, depend above all on the operator's maintenance workload, the concentration and specialisation of the operations performed [13].

There is therefore a need, first and foremost, to relieve the operator of the excessive burden of tractor maintenance and repair work by outsourcing some of the work to specialised service companies [14-15].

Specialised technical service enterprises with a more modern material and technical base, the provision of highly skilled personnel for repair and maintenance, a high level of specialisation and concentration of repair and maintenance work, perform the transferred maintenance and repair work more qualitatively, in compliance with all maintenance rules. As the result will be increased equipment reliability and reduced failure rates. Up to 30% increase in MTBF and up to 40% increase in MTBF. Figures 4 and 5 show data on MTBF and MTBF for two tractor brands under different conditions of tractor maintenance and repair organisation.

With the proposed form of organisation of technical service of machine-tractor fleet, the share of working time of a machine operator for main job will reach 73%, and time spent on maintenance, repair and elimination of consequences of refusal will be reduced to 25% (Figure 6).

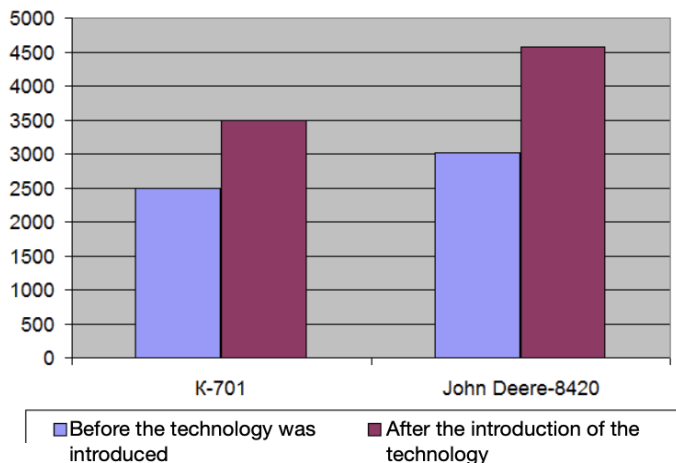


Fig. 4. Tractor Reliability - MTBF, hours.

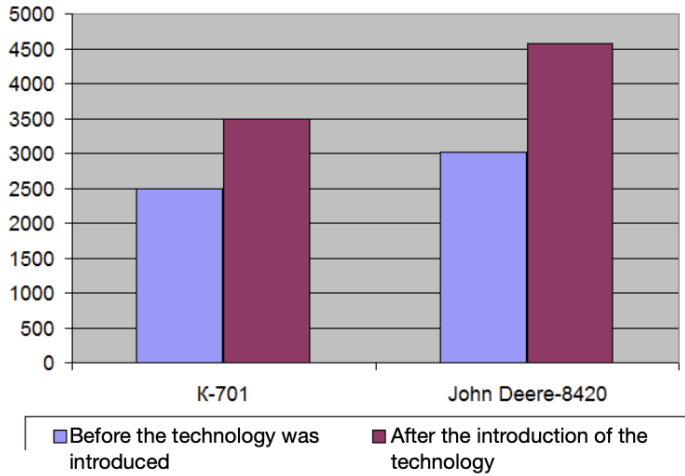


Fig. 5. Tractor Reliability - Inter-repair MTBF, h.

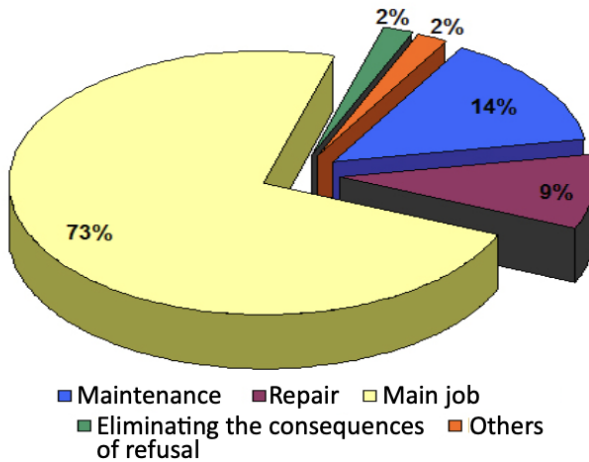


Fig. 6. Diagram of mechanic's employment during the year.

On the basis of research it is determined that increasing the share of machine operator's working time for main job and increasing the reliability of agricultural machinery, according to dependencies (1,2) allows increasing the actual productivity of machine-tractor units by 14% due to increasing the coefficient of machinery use and reducing the components accompanying pure work time.

$$W_f = W_j \times k_{ti} = W_j \frac{T_p}{T_p + T + T + T} \tag{1}$$

Where k_{ti} – the coefficient of technical use; T_p – pure running time of the j-th machine, h; T_{to} – time for all types of maintenance, h; T_{rem} – time related to repairs, including the rectification of failures, h; T_{dop} – additional associated waiting time, transport and other costs of maintenance, fault rectification and repair.

$$W_f = W_j \frac{(T_p + \Delta T_p)}{(T_p + \Delta T_p) + (T - \Delta T) + (T - \Delta T) + (T - \Delta T)} \quad (2)$$

Where ΔT_p – increased machine uptime due to the elimination of complex maintenance activities, as well as reduced downtime for faults and repairs during busy periods of major agricultural work; $\Delta T_{to}, \Delta T_{rem}, \Delta T_{dop}$ – reduced maintenance, fault and repair times and associated costs (transport, waiting times).

From expression (3) it is possible to extract the time of agricultural work:

$$T_{cx.r} = T_r + T_{mo} + T_{otk} + T_{rem} + T_{tr} + T_{oz} \quad (3)$$

As can be seen, the main reserve for increasing the productivity of agricultural machinery is to reduce the components associated with pure working time (T_p).

Studies have established a correlation between equipment utilisation and maintenance time (Figure 7).

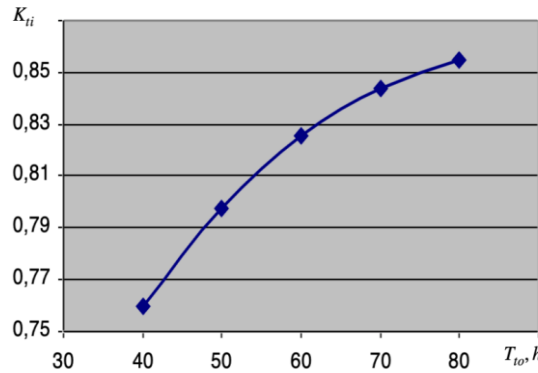


Fig. 7. Dependence of machinery utilisation factor k_{ti} on maintenance time T_{to} .

The dependence of the actual productivity of a machine-tractor unit on the coefficient of technical use has been established on the example of two agricultural enterprises of the Omsk region (Figures 8 and 9). With an increasing ratio of technical utilisation, the actual change productivity of the machine and tractor units increases by 14% and the quality of the field work is improved.

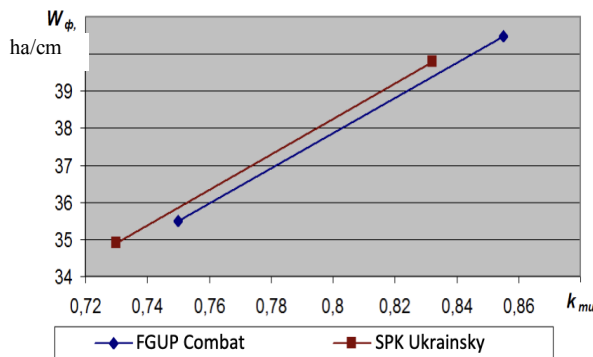


Fig. 8. Productivity of the tractor-machine unit when sowing cereals.

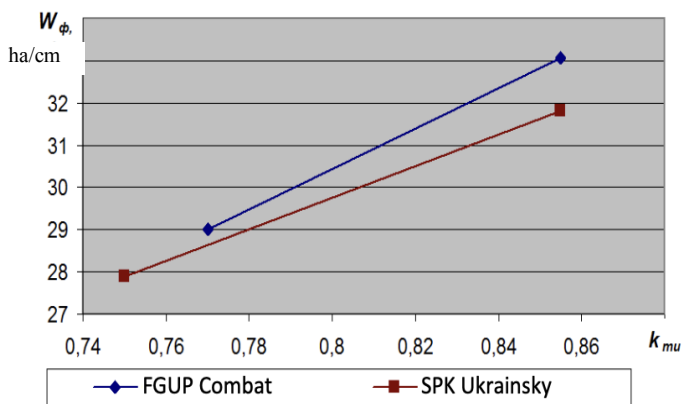


Fig. 9. The performance of the machine-tractor when plowing plowing.

4 Conclusion

The following conclusions can be drawn based on the above study:

The transfer of complex maintenance work to specialised service companies will relieve the machine operator from participating in maintenance operations (maintenance 2, maintenance 3) and increase tractor reliability, as well as reduce the number of failures. A machine operator will spend about 73% of his working time on main job. Exemption of the machine operator from the complex maintenance operation will allow:

- Increase the productivity of machine and tractor units by 14%.
- Improve the quality of fieldwork by increasing the reliability of equipment.
- The MTBF is increased by 30%.
- 40% longer overhaul intervals.
- Injury and disability rates in agricultural enterprises are falling.

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