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TECHNICAL-ECONOMIC RESOURCE OF AGRICULTURAL MACHINERY

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Abstract— The determination of the technical and economic resource (term of service) is a major point of technical operation agricultural machinery (AM). For this purpose they use variety technical and economic indicators. This article presents algorithm for determining the period of service of AM based on the spent funds to purchase (capital losses) and financial resources for the maintenance and repair of technics. Analyzed the impact of individual indicators on the period of service.

Index Terms— Technical and Economic Resource (Term of Service), Agricultural Machinery (AM), Expended Funds

1 INTRODUCTION

According to the standards [1],[2] developed by the American Society of Agricultural Engineers (ASAE), AM used in agricultural production is replaced by the following reasons:

- random failure having such a nature that the recovery of the working capacity is uneconomic;
- AM productivity does not meet the requirements of production;
- morally outdated AM obsolete, as such is considered a technique that is no longer produced by industry and there are no spare parts for its repair or restoration;
- the reliability of the technique is very low (there are unpredictable extended stay due to random failures of different details);
- losses from holding of the next planned repairs lead to increase in relative financial loss of unit performance.

According to the same standard, under the terms of service of agrarian machinery, measured in years, means time interval after which the relative financial losses per unit of performance, calculated for the entire period of service, reaching a minimum and begin to grow. When it is considered that part of the relative financial losses, which includes the amount of capital losses and losses for maintenance and repair throughout the lifetime of agricultural machinery (AM).

2. TECHNO-ECONOMIC ANALYSIS OF THE RELIABILITY OF THE AGRICULTURAL MACHINERY (AM).

Agricultural enginery as a species of AM are a risk technical systems (RTS) and apply to them the same laws of reliability as with other machines - cars, airplanes, helicopters, etc. [3],[4],[8]. Maintenance of technical systems in good technical condition, the timely provision of spare parts and perform repairs and service reflects positively on the terms of service of agrarian machinery [5],[6],[7],[8]. On the other hand, more expensive repairs can make it unprofitable, so that the machine can be taken out of use. For these reasons, technical and economic aspects of the problem are usually considered together.

It is famous model to determine the optimal time for the operation of agricultural machinery based on the theory developed in [9]. This study proposes a new method for determining the terms of service of AM.

The aim is to determine the period of service based on the relative financial loss of unit performance and to analyze the impact of various economic indicators over the duration of this period.

An analysis of the impact of economic indicators over the terms of service of AM. It's definitely effects of inflation, the initial value of the machines and their annual workload. For this purpose, the indicator determining the term of service is calculated in case only one of the indicators and constant values of others.

As a result of this research for determination of the terms of service of agricultural machinery (AM) is presents the following algorithm:

2.1 Determination of the residual value of the machinery at the end of the i-th year.

In accordance with the standard [1] the residual value of the machine is determined by the relationship:

$$S_i = C_0.A.B^i / 100 \quad (1)$$

where:

- C_0 - the initial value of the machinery,
- A,B - factors regulated by [1] and having value shown in the table.1.

With reporting on inflation α [%] formula (1) is written as:

$$S_i = \frac{C_0.A.B^i}{100}.\left(1+\frac{\alpha}{100}\right)^i \quad (2)$$

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Inflation may not be taken into account, assuming that C_0 is the value of a similar new agricultural machinery at the time of the evaluation of the old agrarian available machinery of the same type.

TABLE 1
VALUES OF THE COEFFICIENTS A AND B FOR VARIOUS TYPES OF AGRICULTURAL MACHINERY ACCORDING TO [1].

Type of Agricultural Machinery	*A*	*B*
Tractors	68	0,92
All types of harvesters	64	0,885
Self-propelled sprayers	56	0,885
Other farming field machines	60	0,885

2.2 Determination of the reduction in value D_i of agricultural technique revaluation at the end of the *i-th* year:

$$D_i = S_{i-1} - S_i \tag{3}$$

2.3 Determining the cumulative reduction in the value *D* of agricultural machinery by the end of the *i-th* year:

$$D = \sum_{i-1}^{n} D_i \tag{4}$$

2.4 Determination of income I_i from the use of machinery

For *i-th* year of operation of agricultural machinery magnitude of income from the use of machinery I_i is equal to the simple percent of annual average rate of capital (interest on the investment associated with the AM):

$$I_i = \frac{b}{100}.\frac{S_i + S_{i-1}}{2} \tag{5}$$

where:

- S_i - is the residual value of the machines after revaluation at the end of *i-th* year,
- S_{i-1} - the residual value of the machinery to revaluation in the *i-th* year.

2.5. Determination of aggregate income *I* from use of the machines by the end of the *i-th* year:

$$I = \sum_{i=1}^{n} I_i \tag{6}$$

2.6 Determination of capital losses C_{cl} from the operation of agricultural machinery

Capital losses do not depend on the performance of AM and intensity of its use [6] and included in case the losses in the value of the machines in their annual revaluation, due to moral wearing and loss of income with capital investments *I*:

$$C_{cl} = D + I \tag{7}$$

2.7. Determination of the technical resource of AM by the end of the exploitation T_{REE} .

Measured in quantity of processed area for a corresponding number of years is carried out in accordance with :

$$T_{REE} = q.i \tag{8}$$

where:

- q *[ha/year]* - the annual production volume is measured in area cultivated for one year,
- i – number of year.

The statistical formula for the technical resource of AM by the end of the exploitation T_{REE} (measured in hours) at follows from [3],[4],[6],[10]:

$$T_{REE} = \int_0^{T_{OTR}} P_{RO}.(\Delta t).dt \tag{9}$$

where:

- P_{RO} (Δt) - the probability of reliable operation of the machine of AM, individual observed time intervals Δt in which it is collected statistical information;
- T_{OTR} - the optimal period of time to perform *i-th* major repairs (MR) and routine repairs (RR) of agricultural machinery.

The probability of reliable operation $P_{RO}(\Delta t)$ of the machine of AM, is given by equation [6],[20]:

$$P_{RO}(\Delta t) = \exp\left[- \int_0^{T_{REE}} \omega(t).dt \right] \tag{10}$$

where:

- $\omega(t)$ - the intensity flow of failures of AM.

2.8 Determination of the loss of technical service (maintenance) and repair C_{TSR}.

According to [1],[2] dependence of accumulated financial losses for technical maintenance and repair C_{TSR} of the time of use of machines for the entire technical resource by the end of the exploitation T_{REE} type:

$$C_{TSR} = C_0.m.\left(\frac{T_{REE}}{10^3} \right)^l \tag{11}$$

where:

- *m,l* - parameters of the regression equation.

Dependence (11) is approximate and is obtained through the use of regression analysis when processing data for the intensity of the flow of failures and the cost of their removal to dispersonal types of agricultural machinery. The experimental values of the parameters *m* and *l* of the regression equation are shown in Table 2 [2].

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2.9 Determination of the terms of service i_{ts},*years*

The terms of service i_{ts},*years* of AM is performed by examining the annual costs C_{ac} of some capital losses C_{cl} and using the formula [8]:

$$C_{ac} = \frac{(C_{cl} + C_{TSR})}{q.i_{ts}}, \$/ha \qquad (12)$$

For a terms of service i_{ts},years of AM accepted amount of years C_{ac}, which corresponds to the minimum value (figures 1÷ 4).

TABLE 2
VALUES OF PARAMETERS M AND L FOR DETERMINING LOSSES OF TECHNICAL SERVICE AND REPAIR C_{TSR} .

Type of Agricultural Machinery	*m*	*l*
Tractors:		
- with two-wheel drive	0,012	2,0
- with four-wheel drive and tracked tractors	0,010	2,0
Tilling machines:		
- plows	0,430	1,8
- disc plows	0,180	1,7
- cultivators	0,220	2,2
Seed drill	0,540	2,1
Harvesters:		
- grain harvesters	0,120	2,1
- beet harvesters	0,190	1,4
Other farming machines:		
- Spray Earth Sprinkler	0,410	1,3
- aircraft (helicopter) sprayers	0,200	1,6

For example determining the terms of service i_{ts},*years* of AM with reliability technical resource for reliable operation.

The results of the calculations of the economic parameters are shown in *Table 3* for *plow Vogel & Noot MS 950* having an initial value C_0=*7263$* in interest *b=8%* on investment related to AM.

In Table. 3 designations are used:

- S_i *[$]* - the residual value of the of the machine,
- D_i *[$]* - reduction in value D_i of agricultural technique revaluation at the end of the *i-th* year,
- *D [$]* - reduction in the value of AM,
- I_i *[$]* - income from the use of machinery,
- *I* [$] - aggregate income from the use of machinery.

The plow was used for the annual processing of soil with an area of *200h*a, i.e. *q = 200 ha/year*.

From table 3 and Figure 1 is determined, the value of the terms of service i_{ts} *= 10 years*. The graphic post on the shape of different colours correspond to the terms of service 10 years and minimum annual cost C_{ac} *= 7,775$* to the processing of *1 ha.*

The impact of inflation is determined by calculation of factor C_{ac} showed at an average annual inflation of α =2% and preserve the value of the other indicators. The result is shown in fig.2.

From this figure appears that the terms of service of AM i_{ts} *= 9 years*. This is due to the increase in capital losses C_{cl} the use of the technique as a result of the increase in inflation.

TABLE 3
RESULTS FROM CALCULATIONS OF ECONOMIC PARAMETERS FOR A SPECIFIC AGRICULTURAL MACHINERY (PLOW VOGEL & NOOT MS 950)

№ y	S_i	D_i	D	I_i	I	C_{ci}	T_{REE}	C_{TSR}	C_{ac}
1	3856,4	3406,1	3406,1	444,7	444,7	3850,9	111,7	116,2	19,8
2	3413,0	443,5	3849,6	290,8	735,5	4585,1	223,5	404,8	12,5
3	3020,4	392,5	4242,1	257,3	992,8	5235,0	335,2	839,8	10,1
4	2673,1	347,4	4589,5	227,8	1220,6	5810,1	446,9	1409,5	9,0
5	2365,7	307,4	4896,9	201,6	1422,2	6319,1	558,7	2106,1	8,4
6	2093,6	272,1	5168,9	178,4	1600,6	6769,5	670,4	2924,3	8,1
7	1852,8	240,8	5409,7	157,9	1758,4	7168,2	782,1	3859,4	7,9
8	1639,8	213,1	5622,8	139,7	1898,2	7520,9	893,9	4908,0	7,8
9	1451,2	188,5	5811,3	123,6	2021,8	7833,1	1005,6	6067,1	7,7
10	1284,3	166,9	5978,3	109,4	2131,2	8109,5	1117,3	7334,0	7,7
11	1136,6	148,0	6126,3	96,8	2228,0	8354,3	1229,1	8706,6	7,8

The impact of annual load is determined by adopting the higher value of the annual production of the machine - 250 ha / year and keeping the other parameters. The result is shown in fig.3. Higher load the machine reduces its terms of service i_{ts}, *= 7 years*. The reason for this is the rapid increase in the cost of maintenance and repair C_{TSR}.

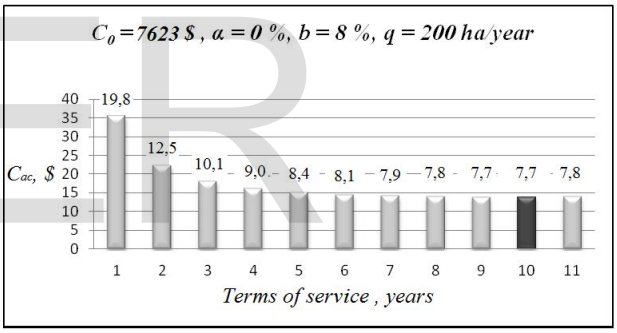

Fig. 1 Determination of the terms of service i_{ts} of AM in certain techno-economic parameters

The impact of the initial value of the machine on the term of service is determined at a higher starting value of *AM – 11173$* and preserve the values of other parameters.

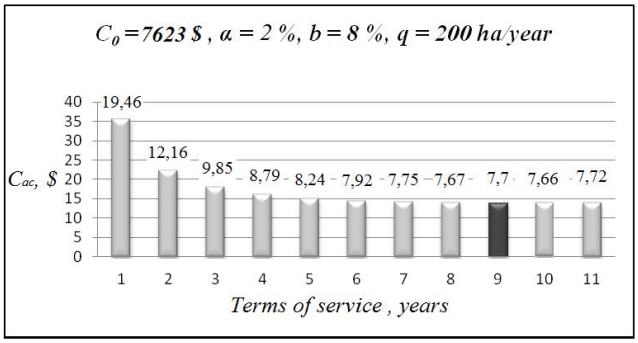

Fig. 2 Determination of the inflation α =2% on the term of service i_{ts}

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The results presented in fig.4 suggests that the period of service is *10 years*, with an initial value of C_0=*7263$*.

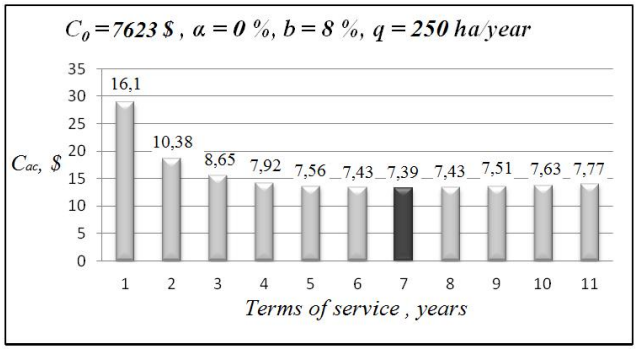

Fig. 3 The impact of annual load *q = 250 ha/year* of AM on the term of service i_{ts}

Therefore, the initial value of the machine does not affect the term of service. The value of the index of the term of service i_{ts} is changed from by increasing the annual load of AM due to the rapid increase in the cost for repairs, representing economic elements of reliability.

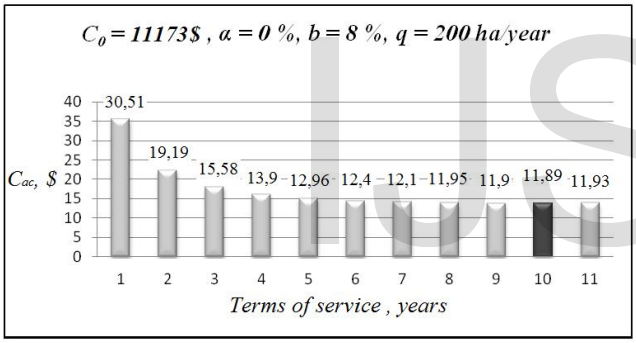

Fig. 4 The impact of C_0 - the initial value of the machinery the term of service i_{ts}

3. RESULTS

The indicator C_{ac} that determined the term of service i_{ts} of AM includes capital losses C_{cl}, repair costs C_{TSR} and loading machines (i_{ts} . q). For its part, the cost of repair also depends on the load (equation 11). From Fig. 1-4 it was noted that the determining factor for the current value of the term of service of one AM is its annual load as their technical-management solution by its users.

4. CONCLUSIONS

As the conclusions of the papers should indicate the following:

1. Increasing economic inflation, reduces the duration of use of agricultural machinery, due to increased capital losses on its use.
2. Increasing the annual load of the machines leads to a reduction of their term of service, due to the rapid increase in the cost of maintenance and repair (elements of reliability).

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