# OPTIMIZATION OF THE STRUCTURE AND COMPOSITION OF TECHNOLOGICAL COMPLEXES FOR HARVESTING GRAIN CROPS BY ENERGY COSTS

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**ABSTRACT**

A model has been developed for optimizing the structure and composition of technology of technological complexes for harvesting grain crops by energy costs, taking into account the likely nature of their interaction. The problems of technical re-equipment of agricultural producers are being solved by the introduction of energy-saving technologies for growing and harvesting grain crops.

**Keywords**: technological complex, grain crops, structure and composition, harvester, transport, harvesting, energy consumption, optimization criterion, energy saving, model, probable state.

## INTRODUCTION

The technologies of plant production that we inherited from the past are costly. In order to achieve the greatest efficiency of agricultural production, it is necessary to introduce energy-saving technologies. Nowadays is a market economy with its fierce competition. If we continue to advance traditional consumption technologies, it will soon be that the expected result (increase in productivity, gross output, quality and lower cost of production), we will never receive. Crop production is one of the most profitable types of agricultural business – 110% profitability may be the norm for crop production. Norm but not the limit. Production costs "eats" a significant portion of the profit under the traditional model of plant growing. Successful producer is the one who collects the best harvest at the lowest cost (Kravchuk and Miller, 2009).

## THE STATEMENT OF THE PROBLEM

For agriculture in Ukraine there is a problem of increasing the efficiency of energy use. All technologies of agricultural production are estimated by economic indicators (given costs, profitability, etc.) and labor costs. However, in modern conditions, this is not enough, since these indicators have significant fluctuations and are determined by the pricing policy. Therefore, technological processes and complexes of machines are estimated taking into account energy costs for the production of each type of agricultural products. This enables us to evaluate both the applied and new technologies as well as their prospects from the point of view of the specific energy consumption per unit of cultivated products (D. Domuschi, pers. commun.).

## ANALYSIS OF RECENT RESEARCH AND PUBLICATIONS

An analysis of the current state of mechanization of harvesting of grain crops in Ukraine reveals its low efficiency. The statistical data indicate a constant tendency of reducing the total number of combines in the fleet, increasing the share of defective machines, aging of the fleet, and increasing the average load on the combine, increasing the time of harvesting and loss of grain from falling off (Dumenko and Boyko, 2011).

Ukraine is lagging behind the leading countries of the world 3-6 times in terms of technical maintenance of harvesting operations, and on providing grain per capita we are at the level of the beginning of the last century. The livestock dropped almost twice, which drastically reduced the need for fodder grain and roughage (straw). Orders for new equipment dropped below the expected level, which led to a reduction in its industrial production. The role of state mechanisms of agricultural management has further weakened, the form of equipment leasing changed, and the volume of use of various harvesting technologies deformed towards the less-operational, less resource-intensive and productive technologies in terms of gross collections of grain. Almost ceased the existence of industrial seed production. However, machine and tractor stations (MTS)'s role in the harvest campaign has increased slightly, and import of foreign machinery has increased (Dumenko, 2010a).

In many documents and materials of the state and regional level, the position of grain production and technical support to the agro industrial complex (including harvesting of grain) in Ukraine is assessed as critical (Dumenko, 2010b).

The development of a promising strategy for the development of mechanization of harvesting of grain crops concerns a class of problems of forecasting the development of macro systems, whose functioning depends on the interaction of the set of external and internal factors. Modernization or creation the new resource intensive grain harvesting equipment according to its purpose and scale of production cannot be considered in isolation from the general state of agro industrial complex, the effectiveness of mechanisms of state policy and social order for agricultural products (Kravchuk and Miller, 2009).

The comparative technical and economic assessment of modern combines shows that domestic technology, which is much cheaper than other foreign machinery, in terms of complex specific indicators of the technical level is slightly inferior to it. Significant lag is still observed for reliability, design and comfort (Enakiev et al., 2016).

## PURPOSE OF RESEARCHES

Improving the efficiency of the use of machine-transport complexes (MTC) in harvesting grain cereal crops by reducing material and energy costs.

## MATERIALS AND METHODS

The main indicator characterizing the efficiency of machine-transport systems and takes into account, to a large extent, the agronomic and structural factors, are the energy costs per unit of work. Energy analysis allows assessing existing and planned systems, their prospects in terms of energy efficiency and opens up the possibility of purposefully developing new and improving existing systems. In the study of the work of machinery of harvesting machine-transport complexes, the main criterion for assessing the efficiency of their work, taking into account the results of studies, is the minimum total energy consumption for harvesting grain crops per unit area ΣE, MJ/ha is the function of the purpose of this research (D. Domuschi, pers. commun.):

$$\sum E = \frac{\left[\sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{l} X_{ijk}\, E_{IJ} + \sum_{i=1}^{m}\sum_{k=1}^{l} X_{ijk} E_{l} + \sum_{l=1}^{t} X_{ijk} Q_S\, E_{cf}\right]}{\Omega} \to \min \qquad (1)$$

where $X_{ijk}$ – the volume of work performed by all means of the i-th type on the j- th production process in the kth period, ha;

$E_{ij}$ – total energy consumption by type i on the j-th process, MJ/ha;

$E_l$ – the cost of living labor, MJ/ha;

$Q_S$ –standard rate of fuel consumption per unit area, kg/ha;

$E_{cf}$ – energy equivalent of complex fuel, MJ/kg;

Ω – the volume of performed works, ha.

The optimum structure and composition of the harvesting machine-transport complexes, the way of organization of maintenance and maintenance in different conditions is determined by the minimum target function (1) with allowable yield losses. When minimizing the purpose of the function, one must adhere to a number of restrictions:

1. All estimated unknown values should be positive:

$$X_{ijk}>0; \quad i=1,2,...,m; \quad j=1,2,...,n; \quad k=1,2,...l. \qquad (2)$$

2. The volume of work on each of the production processes Ωi must be performed completely in the established agro technical terms, that is:

$$\sum_{j=1}^{n} \sum_{k=1}^{l} x_{ijk} = \Omega_i \qquad (3)$$

The summation of "K" here goes within those periods from $l_1$ to $l_2$, during which agrotechnics foresee the implementation of the i - th process.

3. The costs of live labor should ensure the implementation of the volume of the

i-th production process and the K-th period in the established agro technical terms:

$$\sum_{j=1}^{n}\sum_{k=1}^{l} E_l < n_i \qquad (4)$$

where $n_i$ - the number of employees available to the farm for this type of work, people

4. The fuel consumption $Q_j$ should not exceed the normative values $Q_S$:

$Q_j < Q_S$. Total (total) energy consumption by means of j-th type is determined by the formula:

$$E_{ij} = \left[\frac{\alpha_{tm} W_t}{100}\right]\frac{A_t+R_t}{L_t} + \left[\frac{\alpha_{wm} W_w}{100}\right]\frac{A_w+R_w}{L_w}, \qquad (5)$$

where $\alpha_{tm}$, $\alpha_{wm}$ – energy unit of weight according to traction and working machine, MJ/kg;

$W_t$, $W_w$ – weight of traction and working machines, kg;

$A_t$, $A_w$ – norms of depreciation for traction and working machines, percent;

$R_t$, $R_w$ – rates of deductions for repair and maintenance according to traction and working machines, percent;

$L_t$, $L_w$ – annual load of traction and working machines, hour.

Expenditures of live labour energy $E_l$, MJ/ha:

$$E_l = \frac{(n_m\alpha_m + n_a\alpha_a)}{P_e} \qquad (6)$$

where $n_m$, $n_д$ – the number of main and auxiliary workers participating in the MTC, people;

$\alpha_m$, $\alpha_a$ – corresponding energy equivalents of labor costs, MJ/people-year ;

$P_e$ – operating efficiency MTC, ha/hour.

Direct energy consumption of fuel $E_{cf}$, MJ/ha:

$$E_{cf} = \alpha_{cf} Q_{cf}, \qquad (7)$$

where $\alpha_{cf}$ – energy equivalent of fuel consumption, MJ/kg;

$Q_{cf}$ – fuel consumption per unit area, kg/ha.

When comparing MTC in grain harvesting, it is necessary to identify differentially the coefficients of energy cost efficiency:

– coefficient of energy efficiency of costs of technological means $K_{eт}$:

$$K_{eт} = E^p_{ij} / E^b_{ij} \qquad (8)$$

– coefficient of energy efficiency of labor costs $K_{el}$:

$$K_{el} = E^p_l / E^b_l \qquad (9)$$

– coefficient of energy efficiency of direct energy consumption $K_{ed}$:

$$K_{ed} = E^p_{cf} / E^b_{cf} \qquad (10)$$

– coefficient of energy efficiency of expenses when applying the proposed complex in comparison with the base one $K_{ee}$:

$$K_{ee} = \frac{E^p_{ij} + E^p_l + E^p_{cf}}{E^b_{ij} + E^b_l + E^b_{cf}} \qquad (11)$$

The calculation of the comparative economic effect from the introduction of the recommended MTC per unit area was determined by the formula:

$$E_{ra} = \sum E_b - \sum E_p, \qquad (12)$$

where $\sum E_b$, $\sum E_p$ - total energy costs in the base and projected composition of the MTC.

## RESULT OF RESERCH

In order to calculate the comparative estimation of energy costs for the basic and projected machine-transport systems, the following technologies of harvesting of grain crops were used: direct harvesting without straw shredding and separate harvesting. For these technologies, according to the methodology of the Ukrainian Research Institute for the Productivity of the Agro-Industrial Complex of the Ministry of Agrarian Policy of Ukraine "Norms for the Cost of Living and In determined Labor for the Production of Grain Crops", technological maps were developed for harvesting winter wheat. All technologies were developed for such production conditions: growing area - 1300 hectares; yield of main products - 4,6 t/ha; yields of by-products - 4,6 t/ha. Normative crop losses of 3%; harvesting time at full ripeness of grain - 7 days (Vitvytskyy et al., 2010).

*In the direct combine harvesting*, the Don-1500B harvesters were used for harvesting - twelve units. The grain was transported by trucks CamAZ-55102 with trailers GBK-8527 in quantity - 12 units. Each harvester was serviced by a personal vehicle. Straw - non-grain products were pulled to the edge of the field with the unit T-150K-05-09 +VTU-10 - 8 units and transported for tricking the unit - MTZ-80 + 2PTS-4-887A - 24 units. Straw throwing - unit YUMZ-6AKL + PF-0,5B - 8 units.

*At separate collection,* the ratio of the area of harvesting in a separate and direct way - 40% and 60%. To mow down the rolls and the selection of rolls, four combines - Don-1500B, harvester ZBH-6, pick-up - PL-150 in quantity - 4 units were used. Direct harvesting - Don-1500B - 8 units, vehicles - CamAZ-55102 + GBK-8527- 8 units. Straw is pushed to the edge of the field and drowned at the edge of the field. Quantity and composition of aggregates, as in the first technology. The energy assessment of the efficiency of the MTC was determined for the recommended and existing on-farm options for the availability of equipment and organization of the process of harvesting. Comparative analysis of the energy intensity of a unit of production - 1 t grain grains of cereals of the basic and recommended variants is determined by the formula 1. The results of calculations for the energy performance of the MTC are summarized in table 1.

**Table1 Comprehensive energy intensity of harvesting and transport operations**

| Energy expenditure | Basic equipment MTC | | The proposed equipment warehouse MTC | | Energy equivalent | Total energy costs, MJ/t | |
|---|---|---|---|---|---|---|---|
| | | | | | | Options | |
| | Energy facilities | Working machines | Energy facilities | Working machines | | Base | Offered |
| On the main means: Combine, MJ / kg | SC-5M | | Don-1500B | | 86,4 | 1600,6 | 1002,2 |
| Needle, MJ / kg | SC-5M | ZBN-5 | Don-1500B | ZBN-6A | 75,4 | 113,1 | 74,0 |
| Pick up trailer, MJ/ kg | SC-5M | Pick-up - PL-150 | Don-1500B | Pick-up - PL-150 | 75,4 | 33,5 | 21,0 |
| Vehicles, MJ / kg | GAZ-53B | - | CamAZ-55102 | GKB - 8527 | 86,4 | 756,0 | 593,2 |
| Tractors | MTZ-80 | 2PTS-4-887 | T-150K-05-09 | VTU -10 | 86,4 | 680,4 | 419,3 |
| | YUMZ-6L | PF-0,5 | MTZ-800 | PF-0,5 | 75,4 | 593,8 | 453,2 |
| On the reverse side means: Fuel and lubricants, MJ /kg | - | - | - | - | 52,8 | 274,6 | 256,0 |
| Living labor MJ/ human year: combiner | - | - | - | - | 1,90 | 1,23 | 0,67 |
| tractor driver | - | - | - | - | 1,26 | 0,41 | 0,22 |
| the driver | - | - | - | - | 1,50 | 0,54 | 0,30 |
| auxiliary staff | - | - | - | - | 0,60 | 0,10 | 0,10 |
| **Total:** | | | | | | **4054,3** | **2820,5** |

Comparison of options by the end result shows that the recommended variant is more effective than the base one. The magnitude of the effect is 4054,3–2820,5 = 1233,8 MJ/t. A differentiated assessment of comparable harvesting machine-transport complexes for specific labor costs and material and energy resources is given in table 2.

**Table 2 Differentiated assessment of machine - transport complexes**

| Name indicators | Unit measurement | Marking | Options | |
|---|---|---|---|---|
| | | | basic ones | projecting |
| Energy efficiency factor, including cost: | - | $K_{ee}$ | 1,00 | 0,74 |
| - the technical facilities | - | $K_{er}$ | 1,00 | 0,76 |
| - live labor | - | $K_{el}$ | 1,00 | 0,54 |
| - direct energy | - | $K_{ed}$ | 1,00 | 0,93 |
| Combine harvest performance | ha / hours | $P_{teh}$ | 1,76 | 2,20 |

## CONCLUSIONS

1. The model of estimation of energy costs of equipment of harvesting machine-transport complexes is developed, which allows optimizing the structure and composition of harvesting machines and vehicles taking into account the probable nature of their interaction.
2. Differential consideration of material and energy expenditures makes it possible to assess in large measure the need for material and energy resources to collect the entire volume of planned products and compare this demand with the actual availability, so the recommended variant of the composition of MTC is more efficient than the base at 1233,8 MJ/t.
3. The recommended composition of machinery of transport systems will increase the efficiency of the process of harvesting grain cereal crops with the energy consumption of technical equipment by 24%, live labor - 46%, fuel and lubricants - 7%, and overall efficiency by 26,0%.

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