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Management and optimization of mobile machine store

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Abstract
In the article is presented the results of studies on the development of methods for managing and optimizing the mobile machine stores, taking into account the main factors affecting the level of fuel reserves and fuel tank capacity of a mobile agricultural machine. It has been established that the lowest total costs for maintaining fuel reserves and organizing refueling as well as the optimal fuel tank capacity can be obtained using a model for regulating the level of fuel reserves with a constant dose of refueling during operational (continuous) monitoring.

Keywords: Fuel supply, refueling point, fuel tank, simply car, maximum power, specific fuel consumption, correlation coefficient, optimal refueling dose, fuel tank capacity

Introduction
Due to the deficite of fuel in recent years, the task of regulating and optimizing reserves has become urgent, not only in oil depots and refueling points, but in the fuel tanks of mobile machines.
From the point of view, management [1] the fuel tank store of a mobile machine (tractor, car, combine harvester, etc.) is a warehouse designed to store fuel supplies. Until now, studies have not been conducted to justify the capacity of the fuel tank, factors that affect it have not been studied much. The absence of a method for substantiating the optimal capacity leads to the fact that in practice machine operators put additional tanks on the machine in order to increase fuel reserves and thereby reduce the likelihood and downtime of the machine when refueling.
The aim of current work is to develop a method for managing and optimizing the stock of mobile cars, taking into account the main factors affecting the level of fuel reserves and the fuel tank capacity of an agricultural tractor.
To establish the influence of various factors on the capacity of the fuel tank, the technical indicators and parameters of domestic tractors and automobiles were processed and analyzed (table 1).

Table 1: Relationship between fuel tank capacity and technical indicators of tractors and cars

Index	Correlation Coefficient	Equalization of link
Tractors		
Constructive weight T,	0,89	V_δ=40,3-15
Rated engine power, kW	0,82	V_δ=1,62N+1,0
Nominal hourly fuel consumption, kg / h	0,74	V_δ=10,5G_z+25
Cars		
Total weight, t	0,91	V_δ=15,2M+30
Maximal power kW	0,86	V_δ=2,1N-60
Hourly fuel consumption, l / h		
diesel	0,34	V_δ=12,5G_{ch}+100
petrol	0,78	V_δ=14,5G_{ch} - 25
Specific fuel consumption, l / 100 km		
diesel	0,33	V_δ=8,1q-40
petrol	0,62	V_δ=6,2q-5

An analysis of the found correlation coefficients and communication equations showed that there is a direct correlation between the fuel tank capacity Vδ, hourly fuel consumption G_c, engine power N, vehicle weight M and specific fuel consumption q per 100 km of run. Observations showed that the time of complete consumption of diesel fuel from the tank of various tractors (at a nominal hourly consumption) is in the range of 6.3 ... 12.3 hours (an average of 9.2 hours), of cars - 6.2.. .31.7 hours (average 14.3 hours).

The level of fuel store in the tank at the beginning of the shift is determined by the formula:

$$V_{p+1}=V_p+d_{zap}-G_p. \qquad (1)$$

where: Vp + 1, Vp - the level of fuel reserves at the beginning of (n +1) -and *p*.- shift, t;

d_{zap} - dose of fueling for *p* - shift, t;

G_p - fuel consumption from the tank for n - shift, t.

Equation (1) is widely used in practice for accounting and analyzing the consumption of petroleum products during the operation of tractors, automobiles, combines and other machines. This equation is indispensable for optimizing fuel reserves by simulation, which can be used to find the optimal fuel tank capacity.

In general, the fuel tank capacity of a machine is:

$$V_\delta= \frac{V_{max}}{\rho \cdot f} \qquad (2)$$

where: V_{max}- maximum fuel supply in the tank of the machine, t;

ρ - fuel density, t / m3;

f - tank capacity utilization coefficient.

The maximum fuel supply depends on the model used to regulate the level of reserves in this machine.

Consider the two main models for regulating the level of fuel reserves in the car.

Model with constant dose of filling. Stock level control is carried out using the order point V_z. As soon as the stock level reaches V_z, an application is submitted for the refueling dose d_z, which is constant during the production period (month, quarter, year). The order point is calculated by the formula:

$$V_z=S+G_z(t_d+\frac{t_s}{2}) \qquad (3)$$

Where

S - insurance fuel supply, t;

t_d - fuel delivery delay time, h;

t_s - the frequency of monitoring the level of fuel in the tank, h

The maximum fuel supply in the tank of the machine depends on the delivery delay time t_d:

at constant t_d - Vmax = S + dz (4)

at random t_d - Vmax = V_z + dz (5)

The fuel safety stock is determined as follows:

$$S = (\lambda_{G_{ch}}- 1)\ G_{ch}\ (t_d +\frac{t_s}{2}); \qquad (6)$$

where: $\lambda_{G_{ch}}$ is the coefficient of non-uniformity of hourly fuel consumption from the tank of the machine (maximum to average ratio).

In the operational (continuous) control of the fuel supply level in the tank of the machine, the calculation according to formulas (3) and (6) is carried out at t_s = o

Model with variable dose refueling. The insurance and maximum fuel reserve is calculated by the formulas:

$$S = (\lambda_G-1)\ Gh\ (t_d + t_s); \qquad (7)$$

$$Vmax = S + G_{ch}\ (t_d - t_s); \qquad (8)$$

Periodically, through the interval t_s at the time of monitoring the level of reserves, the dose of fueling the tank is determined:

$$d_{zi} =V_{max} -V_i + G_{ch}\cdot t_d \qquad (9)$$

Where: Vi is the fuel supply level at the time of control, t. In the theory of inventory management, this model is called the model with the maximum level of stock, i.e. periodically the stock is replenished to the maximum level.

The greater the capacity of the fuel tank of the machine, the greater the fuel supply the machine can take and the lower the cost of organizing its refueling during the production period. But an increase in the level of fuel supply and fuel tank capacity leads to an increase in the mass of the machine and the cost of maintaining it. These contradictions indicate the need to find the optimal fuel reserves, i.e. fuel tank capacity in the car. During optimization, the average level of fuel reserves during the production period is taken (Figure 1). The optimization criterion is the minimum of reduced costs 3:

$$3=3_{xr}+3_{oz}=[(L_t+K_{n\ st})(S+ \frac{d_z}{2}) + L_t(S+d_z)K_b+L_{oz}\frac{Q_g}{dz}] \rightarrow min \qquad (10)$$

Where,

Zxr, Zoz sum/year - costs for storage, fuel reserves in the car and organizing refueling sum/year;

Lt - unit cost of storing fuel reserves, sum / t year;

Kn - coefficient of efficiency of capital investments in stocks, 1/year;

s_t - fuel price, sum/t;

K_b - coefficient taking into account the own mass of the fuel tank (the ratio of the mass of the tank to the mass of fuel);

L_{oz} - the cost of the organization of the refueling, not depending on the dose of the refueling, cm;

Q- annual fuel consumption per machine, so‘m / year.

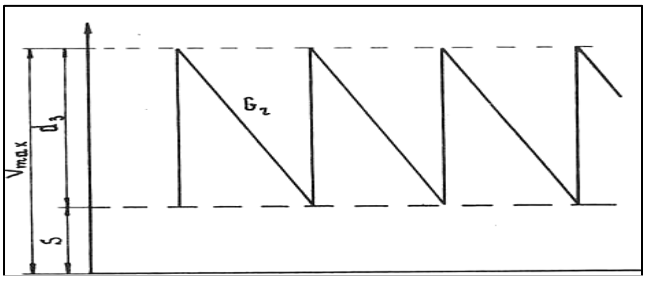

Fig 1: To determine the level of fuel reserves in the tank of a mobile car.

Solving equation (10) regarding the refueling dose dz we obtain its optimal value: with operational (continuous) control of stock levels (dz = const)

$$d_{z\,opt} = \sqrt{\frac{2L_{oz}Q_{ch}}{L_t(2K_b+1)+K_nS_t}} \quad (11)$$

with periodic control of the stock level (dz = const)

$$d_{z\,opt} = \sqrt{\frac{2L_{oz}Q_{ch}}{\lambda_G[L_t(K_b+1)+K_nS_t]+L_t-K_b}} \quad (12)$$

with periodic monitoring of the stock level (dz = const)

$$d_{z\,opt} = \sqrt{\frac{2L_{oz}Q_{ch}}{2\lambda_G[L_t(K_b+1)+K_nS_t]-K_nS_t}} \quad (13)$$

It should be noted that with (uniform hourly fuel consumption) formulas (11) and (12) are identical.
Annual fuel consumption per machine is equal to:

$$Q_g = 0{,}001\ G_{ch}\ T\ Z \quad (14)$$

Where: T- is the standard operating time of the machine during the year, h;
Z- is the load factor of the machine (Z = 0.5 ... 0.9).
The value of L_{oz} when refueling a machine at a stationary point (SPR) is found by the formula:

$$L_{oz} = S_m\left(\frac{2R_cP_c}{V_m} + t_{oj} + t_{oz}\right) \quad (15)$$

Where
S_m - The cost of maintaining the machine, cm / h;
R_c - The average distance of the vehicle to SPR, km;
P_c - The likelihood of a car driving for refueling;
V_m- Average vehicle transport speed, km / h;
t_{oj}- Average waiting time for refueling, h;
t_{oz} - Preparatory-final time (entrance-departure of the machine, turning on/off the column, opening-closing the cap of the neck of the tank, registration of accounting documents). h.

If the car does not make a run associated with refueling, Rc = 0 is taken in formula (15). Such a case is possible during single-shift operation, when the car returns to the parking lot at the end of the shift and the SPR is located next to the parking lot.
When refueling vehicles with mobile units, the L_{oz} value is equal to:

$$L_{oz} = S_{mz}\left(\frac{R_{mz}}{V_{mz}} + t_{pz}\right) + S_m(t_{oj} + t_{pz}) \quad (16)$$

Where
S_{mz}- The cost of maintaining a mobile refueling unit, sum / h;
R_{mz}-Average travel distance of a mobile refueling unit to a car, km;
V_{mz}- Average technical speed of a mobile refueling unit, km/h.

The average wait time is calculated by the method of [2].
Substituting (11) and (12) into expressions (4) and (5), and (13) into expression (8), we obtain the optimal maximum fuel supply level, and then, using formula (2), we find the optimal fuel tank capacity cars.
For example, we determine the optimal $d_{z\ opt}$, $V_{max\ opt}$, $V_{\delta\ opt}$ for the VT-150 tractor with the following initial data:
C_m = 2.4 thousand sum / h, Pc = 2km, Pc = 0.5,
Q_{ch} = 15t / year, = 1.5, λ_G = 11.2 kg / h, t_{oj} = 0.02 h, t_{oz} = 0.025 h,
V_m = 11.2 km / h, K_b = 0.5, K_n = 0.15 1 / year, L_t = 500 sum/year, s_T = 68 thousand sum. The tractor is refueled at a stationary refueling point.
Optimum fuel reserves and fuel tank capacity of tractor VT-150

Table 2: The lowest total costs for maintaining fuel reserves and organizing refueling

Index	Model with Constant Refueling: Operational Control of stocks	Model with Constant Refueling: Periodic Control	Model with Variable Refueling Dose
1	2	3	4
The cost of organizing a refueling thousand sum	540,0	540,0	540,0
Optimum fueling dose, t	0,127	0,108	0,084
Safety stock of fuel, t	0,002	0,030	0,056
Point of order, t	0,0065	0,512	-
Optimal maximum stock, t			
with constant	0,129	0,138	0,168
with random	0,134	0,159	0,168
Optimum fuel tank capacity, l			
with constant t_d	160	170	208
with random t_d	165	196	208
Total bringing of expenditure for the storage of fuel reserves in the car and the organization of reduelling thousand sum/year	129,4	152,4	180,8

Conclusions
The calculation results showed (Table 2) that the lowest total costs for maintaining fuel reserves and organizing refueling as well as the optimal fuel tank capacity can be obtained using a model for regulating the level of fuel reserves with a constant dose of refueling during operational (continuous) monitoring.

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