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Operational control of energy consumptions of reclamation machines

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Abstract. The article presents the results of theoretical and experimental studies of the effectiveness of the application of a new method of operational control over the consumption of fuel and lubricants (POL) of construction and reclamation machines using GIS technologies. Operational control over the consumption of fuels and lubricants is necessary to place orders for their purchase on stock exchanges, to manage the route of refueling vehicles between construction sites and to assess the continuity of the machines at the construction site. Remote sensing of the work of the organization's construction machines will allow you to quickly manage the processes of their transfer from facility to facility, as well as to monitor the timing of specific work (production assignment) by these machines, units and teams.

1. Introduction

The problem of operational control of the rational and efficient use of fuel and energy resources at the present stage of economic and social development of the national economy of Uzbekistan is one of the most urgent.

An important link in solving the national problem of saving fuel and energy resources is the operational metering of consumption, rational and economical use of fuel and lubricants for the operation of reclamation machines in repair and restoration and reclamation work. The effective use of these materials for the operation of reclamation machines should be controlled and ensured by the use of scientifically based, operational methods and progressive rates of fuel and lubricants consumption, determining their actual online consumption, and the needs at all levels of production management.

The accumulated experience in the operation of foreign-made land reclamation machines with JPS navigators and on-board computers makes it possible to develop innovative methods of operational control of fuel consumption rates for specific brands of machines and mechanisms in the branches of the Ministry of Water Resources of Uzbekistan, made it possible to prepare this article, which is generalizing and of a kind guiding the further specification of the rationing of fuel consumption in various directions and levels of planning [1].

2. Method

The main components of the regulation of fuel consumption are fuel consumption per unit of time, at the rated power of the engine, the standard integral coefficient (K), which takes into account the peculiarities of loading the engine of machines during operation. The individual rate of fuel consumption

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per unit of working time of the machine H_t, kg / machine-h, is determined by the formula [1,2]

$$H_т = g_v \cdot N_e \cdot K \cdot 10^{-3} \quad (1)$$

where g_v is the specific fuel consumption at the rated engine power of the reclamation machine, g / kW · h (taken according to the operating documents for the engine or determined empirically in production conditions, the actual specific fuel consumption in the modes of machine use) [2,3];
N_e is the rated power of the engine of the machine, kW (taken according to the data of the operating documents of the machine);
K is the integral standard coefficient of change in fuel consumption depending on the engine load modes of the machine (hereinafter - the integral coefficient); 10-3 is the conversion factor from grams to kilograms.
The value of the integral coefficient is determined by the formula, [4,5]:

$$K = K_{tz} \cdot K_v \cdot K_m \cdot K_{tm} \cdot K_i \quad (2)$$

Where, K_{tz} - coefficient that takes into account the fuel consumption for starting and warming up the engine, as well as shift maintenance of machines, K_ (tz) = 1.03 for all machines;
K_v - engine utilization factor over time (in the absence of actual values determined in real operating conditions, it is taken according to Table A.1 of Appendix 3);
K_m is the engine power utilization factor (in the absence of actual values determined in real operating conditions, it is taken according to Table A.1 of Appendix 3);
K_{tm} - coefficient taking into account the change in fuel consumption depending on the degree of use of engine power (expressed by the coefficient Km), is determined according to Table A.2 of Appendix 3;
K_i- coefficient taking into account engine wear is determined according to Table A.3 of Appendix 3
Notes:
1. The coefficients are developed on the basis of data on actual fuel consumption when construction and land reclamation machines perform certain volumes of work.
2. Recalculation of individual fuel consumption rates from kg / engine-h to l / engine-h is carried out according to the formula:

$$H_t\ (l/(\text{mach.h})) = H_t\,(\text{kg}/(\text{mach.h})) \cdot K \quad (3)$$

where K = 1.2 for diesel fuel.

3. To convert power, expressed in kilowatts (kW), into horsepower (hp), use the coefficient 1.36 A, horsepower in kW - 0.735.
4. If it is necessary to recalculate the consumption in the standard fuel, the caloric equivalent E, equal to 1.45 for diesel fuel, is used.

If the number of cars of the same brand (model) in the park of a construction organization is more than ten, then it is recommended to organize a check of the calculated rate (fuel consumption per 1 machine hour of machine operation) by determining the actual fuel consumption [6,7,8]. Based on the results of such a check, the calculation rate can be adjusted. The results of calculating the individual rates of fuel consumption of cars in Table 1.
Individual fuel consumption rates can be increased or decreased depending on the specific operating conditions, which are taken into account using correction factors (Di) that increase or decrease the initial value of the fuel consumption rate (Table 2).
Individual fuel consumption rates increase under the influence of the factors shown in Table Individual fuel consumption rates are reduced:
- in a time-based mode of using machines with interruptions exceeding those established by the technology of work;
- replacing the engine with an engine with a lower control fuel consumption or less power

Table 1. The individual rates of fuel consumption of cars

Machine name	Machine brand	Motor characteristic			
		Diesel	Power Ne, kW	Specific fuel consumption g_vg / kWh	Engine utilization over time
1	2	3	4	5	6
Single-bucket hydraulic excavator	GLG205C	D	108	220	0.90
	GLG225C	D	108	220	0.90
	GLG925LL	D	115	227	0.90
	JYL210E	D	108	220	0.90
	JY210E	D	126	220	0.90
	JY230E	D	126	220	0.90
	JY230ELD	D	126	220	0.90
	JY230ELB	D	126	220	0.90
	HXW230LC	D	124	220	0.90
	JY623ELD	D	120	220	0.90
	XE215CLL	D	106,5	220	0.90
	XE260CLL	D	128,5	220	0.90
	EK1860	D	90,5	220	0.90
	EK2027	D	132	220	0.90
Bulldozers	TY-160	D	120	210	0.86
	E-9.01 KBR-1-01	D	123	220	0.86
	GLGB-160	D	120	220	0.86
	YTO-140	D	115	220	0.86
	SD-16	D	120	224	0.86
	T-9.01	D	110	230	0.86

In the presence of several increasing (decreasing) factors, the individual rate of fuel consumption is set taking into account the sum or difference of the allowances expressed by the generalized correction factor (D), equal to:

$$D = \sum_{i=1}^{n} (\pm D_i) \quad (4)$$

The adjusted value of the individual fuel consumption rate H_{th} is determined by the formula:

$$H_{th} = H_t(1 + D) \quad (5)$$

For vehicles on an automobile chassis (truck cranes, drilling rigs, concrete pumps, etc.), the fuel consumption rate is determined only for the operation of the equipment, and the fuel consumption rate for the vehicle chassis mileage is taken in accordance with the basic (linear) rates of gasoline (diesel fuel) consumption of the vehicle, taking into account specific working conditions. To implement GIS technologies in the mechanization of land reclamation, the following is required: land reclamation and construction equipment, onboard computers, precision positioning devices on the ground (GPS receivers), technical systems and measuring complexes, remote sensing devices for construction sites and machines (Figure 1) [9,10,11].

Table 2. The initial value of the fuel consumption rate

Factors that increase the individual fuel consumption rate	Correction factor value (D_i) no more	
Running in a new car	D_1	0.05
Operation after overhaul	D_2	0.05
Inside garage costs, hauls, maintenance and repairs (except capital), storage of cars	D_3	0.05-0.08
Practical training and internship of personnel	D_4	0.10
Cramped working conditions	D_5	0.10
Transportation of goods requiring reduced travel speeds	D_6	0.10
Work in difficult road conditions during the period of seasonal thaw and increased snow drifts	D_7	0.10
Work in mountainous areas at an altitude above sea level, m: from 500 to 1500 from 1501 to 2001 from 2001 to 3000 St. 3000	D_8	 0.05 0.10 0.20 0.30
Work in winter (with an average daily air temperature below 0 ° C): in the southern regions of the country * in the northern regions of the country * in areas of the north and areas equated to them *	D_9	 0.05 0.15 0.20
* Limit values of winter surcharges to fuel consumption rates in the Republic of Karakalpakstan and regions of Uzbekistan are given in Appendix 4.		
Note - For machines running on diesel fuel, equipped with starting carburetor engines, the gasoline consumption for starting is 3% in the summer and 4.5% in the winter of the individual diesel consumption rate.		

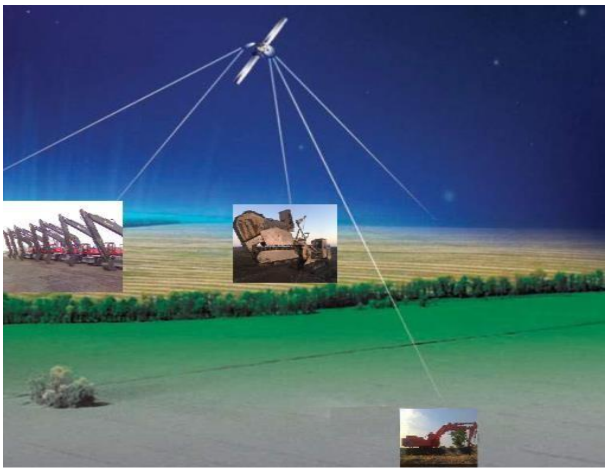

Figure 1. Remote sensing of construction machines

An important part of the technology of operational control over the consumption of fuels and lubricants for construction and reclamation machines is software that automatically maintains the spatial-attribute data of the card index of construction sites (Figure 2), as well as the generation, optimization and implementation of optimal parameters of construction technological processes. This stage of GIS technologies implementation complex mechanization and automation of water management work is the least developed today. However, part of this stage, such as specialized geographic information systems, is constantly being improved, and connections to existing satellite systems (Russia, USA, etc.).

3. Discussion

An example of calculating an individual fuel consumption rate for a GLG225C excavator equipped with a new 6BTA5.9-C173 diesel engine [12,13,14,15].
3, [1]);
Initial data:

- specific fuel consumption $g_e = 220$ g / kWh [1];
- rated motor power according to the passport or operating instructions $N_e = 108$ kW [6,7];
- engine wear is estimated at 0-30% [1].

Selection of coefficients [1]:
coefficient of use of the engine over time $K_v = 0.86$ (taken according to Table A.1, Appendix
engine power utilization factor Km = 0.8 (taken according to Table A.1, Appendix 3, [1]); coefficient taking into account the change in fuel consumption depending on the use of the engine in terms of power $K_{t.m} = 1.02$ (taken according to Table 2, Appendix 3, [1]);
engine wear factor $K_i = 1.0$ (taken according to Table A.3, Appendix 3 [1]).
Determine the individual fuel consumption rate HT for the 6BTA5.9-C173 engine $H_t = 1{,}03 g_e \cdot N_e \cdot K_v \cdot K_m \cdot K_{tm} \cdot K_i \cdot 10^{-3} = 1.03 \times 108 \times 220 \times 0.86 \times 0.8 \times 1.02 \times 1.0 \times 10^{-3} = 17.17$ kg / machine-h;
We clarify the individual rate of fuel consumption in accordance with the operating conditions according to table 2 [1]:
-season - winter, place of work - foothill zones of Andijan ($D_9 = 0.15$ [1]);
-transportation of goods requiring reduced speeds ($D_6 = 0.1$ [1]);
- Severe road conditions ($D_7 = 0.10$ [1]).
$H_{ty} = H_t \times (1 + D_6 + D_7 + D_9) = 17.17 \cdot (1 + 0.1 + 0.1 + 0.15) = 23.18$ kg / machine h.

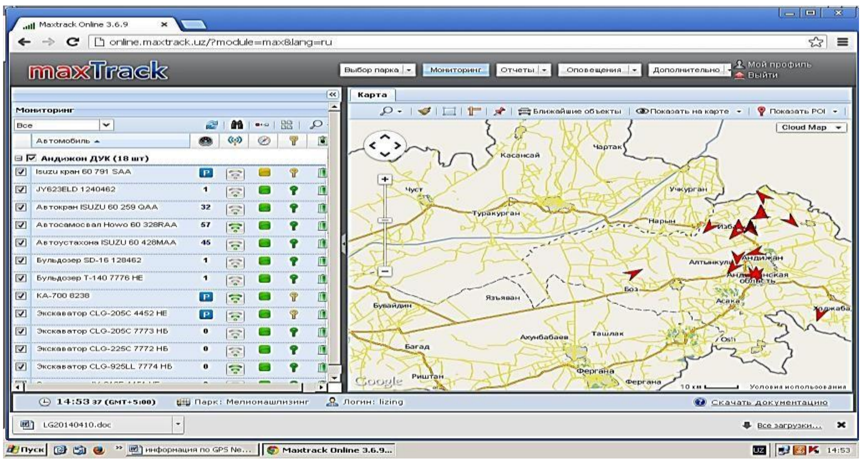

Figure 2. Automated maintenance of spatially-attribute data of land reclamation machines at construction sites

To determine Hт.y in liters we use the conversion factor (in accordance with the notes to 5.2.1 [1]): H_{ty} 1 = 23.18 kg / machine-h = 23.18 × 1.21 = 28.05 l / machine-h.
We determine the individual rate of fuel consumption HT for the 6BTA5.9-C173 engine of the GLG225C excavator for one shift.

The development of the economy of the Republic of Karakalpakstan and the regions forming a single system of the country's water management complex and subject to the impact of global climatic changes and the functional specifics of domestic socio-economic concepts are aimed at shaping the fundamental economic growth of cluster agriculture and all sectors of the national economy [16].

However, highlighting the constituent components in the sectoral structure, it should be noted that it is the water management construction production that historically forms the natural basis for the development of most regional economies, in connection with which this growth in a broad sense can be characterized as the driving force of many sectors of the national economy of the republic. This explains the steadily increased interest in theoretical and practical problems of the potential and real contribution of the water sector to the economic growth of other regional socio-economic systems. The development of local water management is a prerequisite for the industrialization of all sectors of agriculture, and it is practically impossible to raise and modernize the industrial, infrastructural and service sectors of agriculture without the modernization of this complex as a base for advanced growth. This actualizes the theoretical, methodological and applied basis of the essential perception of agro economic growth as the dominant engine of the systemic development of the economic complex of the regions of Uzbekistan.

Table 3. Hourly accounting of intra-shift use of excavators at sites

Период отчета			From 01.05.2019 00:00:00 to 31.01.2020 23:59:59										
Total data period (number of shifts)													
Excavators mark	State number	Garage room	Capacity Bucket m^3	amount shifts	duration shifts, hours	Clean work		Prepared Job		Technological breaks		Plain	
						%	hours	%	hours	%	hours	%	hours
1	2	3	4	5	6	7	8	9	10	11	12	13	14
CLG205C	4452HB	01-2008	0,8	93	762,6	75	571,95	12	91,512	1	7,626	3	22
CLG205C	7773HB	02-2008	0,8	165	1353	76	1028,28	14	189,42	9	121,77	1	13
CLG225C	7772HB	05-2008	0,65	225	1845	73	1346,85	13	239,85	9	166,05	5	90
CLG925LL	7774HB	03-2008	0,5	200	1640	75	1230	13	213,2	11	180,4	1	16
JY230ELD	7775HB	06-2008	0,5	172	1410,4	74	1043,696	12	169,248	11	155,144	3	42
JY230E	7776HB	04-2008	0,5	164	1344,8	73	981,704	12	161,376	12	161,376	3	39

Table 4. Accounting for fuel consumption in the types of work performed by excavators at Sites

Excavators mark	State numbe	Clean work			Preparatory final work			Technological breaks			Simple (forced)		
		hours	norm	Consum-ption	hours	norm	Con-sum-ption	hours	norm	Consum-ption	hours	norm	Consum-ption
1	2	3	4	5	6	7	8	9	10	11	12	13	14
CLG205C	4452HB	571,95	28,05	16042,1	91,512	17	1555,7	7,626	22,4	170,8	22	17	374
CLG205C	7773HB	1028,28	28,05	28843,3	189,42	17	3232,1	121,77	22,4	2727,6	13	17	221
CLG225C	7772HB	1346,85	28,05	37779,1	239,85	16,9	4053,4	166,05	22,4	3719,5	90	16,9	1521
CLG925LL	7774HB	1230	25,7	31611	213,2	15,4	3283,3	180,4	21	3788,4	16	15,4	246,4
JY230ELD	7775HB	1043,696	26,5	27657,9	169,248	15,9	2691,1	155,144	21,2	3289,1	42	15,9	667,8
JY230E	7776HB	981,704	26,5	26015,1	161,376	15,9	2565,8	161,376	21,2	3421,2	39	15,9	585
The amount of fuel consumption, 206061.7 liters				167948,5			17381,4			17116,6			3615,2

In the development of the water industry, it is important to introduce the achievements of science and technology into automated accounting and the continuous provision of reclamation technology with fuels and lubricants [17].

A feature of water management construction is the scattering of objects over large areas and remoteness from settlements, therefore, it includes preparatory and final work every shift, as a rule, the duration is determined according to established standards as a percentage of the time (labor) norm. As an exception, it is allowed to adopt a standard for FWD based on the results of normative observations with a detailed justification of the accepted FWD value. Rest and personal needs determine the amount of time spent according to established standards as a percentage of the time (labor) norm or by analogy with these standards with a proper justification. The amount of technological breaks (P_{tp}) is projected as a percentage of the time (labor) norm based on the results of the analysis of normative observations

In the presence of technological breaks, which can be partially used by workers for rest, the standards for this time are reduced by half the size of the breaks so that the time for rest and personal needs is at least 5%. In those cases when, according to the existing conditions, it is not possible for the worker to use the technological break for rest, then the standards for rest and personal needs should be set in full.

These features make it possible to quickly distribute the standard duration of the work shift – 8,2 hours, for the "clean work", for the "preparatory final work", for the "technological breaks" and for the "forced downtime" due to organizational shortcomings.

The "clean work" time is 75-85% of the duration of the work shift and for the period of work of a link of six hydraulic excavators from 05/01/2019, 00:00:00, to 01/31/2020, 23:59:59 is equal to 6202.48 hours. Fuel consumption for the "clean work" period is 138.8 tons [18,19].

The time for "preparatory and final work" consists of two parts, the first part at the beginning of the shift and is about 4% of the duration of the shift, 0.25 hours, the second part at the end of the shift is also about 5%. The total duration of "preparatory and final works" for a link of 6 excavators is 1064.6 hours, and fuel consumption is 14.3 tons. As part of the "preparatory final work" provides for starting and warming up the engine, moving cars on their own at the beginning of the shift from the parking lot to the place of work and at the end of the shift from the place of work to the parking place at a distance of excavators up to 100 m.

"Technological breaks" - in terms of duration, taking into account the time for rest and the personal needs of six drivers and assistants is 792.4 hours and from 05/01/2019 00:00:00 to 01/31/2020 23:59:59 fuel consumption is 14, 2 tons. "Technological breaks" include the time for refueling the machine with fuel at a distance of up to 30 m by hand; technological shifts, moving the excavator from one face to another, and breaks due to bad weather conditions, etc.

Expenses for "forced downtime" up to a maximum of 2% due to shortcomings in the organization of the material and technical supply of the construction site. In the period of operation from 05/01/2019, 00:00:00, to 01/31/2020, 23:59:59, the costs will be 98.1 hours of working time and the fuel consumption will be 2.98 tons [20,21].

Operational control of the fuel consumption of reclamation machines can be carried out according to the readings of the JPS navigator, on-board computer, receiving SMS signals on the engine hours of the engine by shift, by ten days, monthly, etc.

4. Conclusions

1. The well-known technological methods of delivering a construction machine to the object, excavating soil into the dump, moving excavators along the face, idle movements have been analyzed, their parameters and quality indicators in the production of repair and construction work have been determined, a set of machines and working bodies for autonomous performance of technological operations has been determined.
2. Using the capabilities of a GPS navigator and computer programs for the logical programming of excavation using excavators.
3. A general objective function has been obtained for the remote determination of the fuel demand to optimize the number of working machines and obtain a minimum fuel cost and compensation for damages due to disruption of the work schedule.
4. A complete algorithm of the probabilistic simulation model of the objective function has been developed to determine the composition of machines and their technological parameters. The adequacy of the simulation results to the data of statistical observations was checked; the relative simulation error did not exceed 5%.

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