The formation of engine parks of the construction organizations with accounting of energy efficiency and environmental friendliness

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Abstract. Increase in energy efficiency of construction allows reducing costs of technical operation of parks of the equipment and increasing construction energy saving level in general. To achieve these goals, it is offered to apply modern methods of the organization and works, to use the hi-tech construction equipment, and also to form an optimum set of mechanization for construction and installation works. A criterion of optimization is the cost of work. In definition of performance data of the car at the enterprise, its energy efficiency is taken into account, the options are compared, and the optimal set of cars is formed. During the solution of the task, conclusions were formulated, showing that ecological planning and steering together with energy audit on the construction site allow more rational formation of parks of cars, improving ecological component and quality of construction works.

1 Introduction

The purpose of the work - the study of factors affecting the cost structure of construction and installation works carried out with the use of mechanization in today's market. Specific objectives are: improving energy efficiency and environmental performance machine park, the optimization range of construction machines in the organization, the development of proposals to minimize downtime technology and reduce performance time.

Solving of resource-saving issues is one of the most important directions of the modern economic and industry. [1,2] In most cases, energy saving in construction, as a rule, is considered at the design phase of new construction or at the stage of their modernization or reconstruction.[3,4] At the same time, a considerable amount of electricity, heat, fuel and other energy resources are consumed during the construction and installation works, aimed to build new object, and providing the household maintenance of the builders involved in the process. A significant part of these expenses are operating costs on construction machines and mechanisms. For quite some time, manufacturers of modern construction equipment produce hybrid powered construction vehicles , which allows not only to reduce the fuel costs, but also to reduce the noise level andreleases into the environment during their

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work.[5,6] One of the most effective means of energy saving for construction machines with hydraulic of working equipment, are recuperative systems with energy accumulator.[7,8].

In hydraulic excavators "Komatsu HB215LC-1", "Cat 336E H" the kinetic energy recovers and accumulates during braking of rotating superstructure. The accumulated energy from the condenser or nitrogen battery can be used later as supplementary power, to supply elecrto and hydraulic machine installations.

Another example of a constructive approach to energy conservation is the transformation of kinetic energy from braking into electrical current. The regenerative braking system allows stopping the machine without using conventional brakes thereby increasing their resource. Except that the hybrid system allows to save up to 45% of the fuel. [9,10]

Global manufacturers of lifting equipment while developing cargo and cargo-passenger lifts, use energy recovery units when the cab is moving down, and this contributes to the reduction of energy consumption [11, 12]. The use of a frequency electric drive in construction cranes with regenerative module instead of relay-contactor panels, allows significantly reducing electricity consumption. Application of regenerative modules, which replace the resistors in drives with prolonged operation in generator mode, or which have a large braking power, like in lifting and inertia mechanisms, for example, allows to return a part of energy from braking of the electric drive in the supply network.[13]

Except the use of modern construction equipment samples, energy efficiency of construction industry can be achieved by implementation of organizational and technological measures.

2D and 3D automatic control and positioning systems are widely used during preparatory activities, excavation and landscaping works. [14, 15] The use of these systems can significantly reduce the costs and time for the performance of works.

In particular, the Caterpillar Cat D6K2 with 3D Trimble dual GPS system and the Cat 140M AWD motor grader with a robotic total station can automatically lift the knife to unload it basing on analysis of the caterpillar's slip ratio coefficient and manage the planning. [16] This not only allows maximizing the use of the equipment but also reduces the amount of emissions into the atmosphere.

The software of "Virtual Site Solutions" company allows to monitor performance and technical condition, and quickly identify underutilized machines in real time.[17] The integration of these products with 2D and 3D positioning systems, allows to monitor the effectiveness of the use of machines more carefully and to realize their maintenance.

Another direction of reducing energy consumption and the saving of energy resources is the use of modern diagnostic complexes and organizational measures aimed at maintaining the equipment in good working order. [18, 19, 20]

At the same time, in the current realities of economic and foreign policy, Russian building companies face an acute shortage in modern construction techniques and technologies. In order to maintain their competitiveness in the global market and to prevent the backlog from foreign companies, it is necessary to develop an integrated approach to the formation and operation of machine parks of construction organizations, taking into account the reduction in the cost of production of works, the possibility of renewing and increasing the level of energy savings in the manufacture of construction and installation works.

2 Methods

Mathematical modeling was taken as the basis of the research methodology. In constructing a mathematical model, we are guided by the following principles:

- The mathematical model should cover all the factors affecting the performance indicators of construction equipment set, but at the same time it should have a single optimization criterion for forming the fleet of the vehicles.

- In addition to assessment of factors which affects on indicators of technical operation of the equipment, mathematical model should take into account and allow to enter other parameters into the system, such as the location of objects, the economic situation in the region in the field of sales, leasing and maintenance of machinery, the possibility of attracting equipment from outside, etc.
- While creating a mathematical model it is necessary to have a clear division of subtasks depending on the level of their importance from the fundamental to the subordinate.

In the process of solving the problem of completion of construction equipment fleet there is a need to build a multistage hierarchical system of interrelated mathematical models.

With this solution, it is possible to take into account the main features and the interconnections arising during the design stage, and at the same time it allows to explore individual models. The total costs for the maintenance of construction equipment, according to their energy efficiency, were taken as optimization criteria:

$$Z_{\mathrm{ud}} = s * \left(1 + \frac{F}{V} * \frac{r}{100}\right) + \sum_{i=1}^{n} \frac{R_i}{W_i} \quad (1)$$

where s - cost of work, rub; F - average annual cost of fixed assets and working capitals, rubles; V - annual turnover of the construction organization, rub; r- internal rate of return of capital; Ri - annual costs for maintenance and operation of the i-th machine, rub; Ri – annual costs for maintenance and operation of the i-th machine, rub; Wi – estimated remaining useful life of the i-th machine, year; n – is the number of machines of this type, pcs.

The annual cost of maintenance and operation of machines is given by the following formula:

$$\mathrm{R_i} = \mathrm{S_t} + \mathrm{S_d} + \mathrm{S_n} \quad (2)$$

where S_t - the cost of transportation of the machine to the place of work, rub; S_d - costs for maintenance and repair of the machine, rub; S_n – energy costs, rub.

The costs of maintenance and repair were determined by taking into account the probabilistic coefficients which depends on the term of operation and work conditions of the equipment. Determining the impact of the above criterias was based on statistical processing of reliability indicators and productivity of machinery in construction organizations [21]

$$\mathrm{S_d} = \mathrm{S_s} * \mathrm{y_{ti}} * \mathrm{y_{vi}} * \mathrm{y_{ri}} \quad (3)$$

where Ss – average costs for maintenance and repair of this type of machines , rub; yti- coefficient, which takes into account the temperature influence on the rise of works costs; yvi- coefficient which takes into account the influence of the equipment age on operation cost; yri - coefficient which takes into account the influence of the operating conditions and work structure.

The coefficient that takes into account the influence of temperature on the rise of construction and installation works cost, is determined on the basis of calculating the dependence of the change in the total costs on the work performed by the machine, depending on the natural and climatic conditions. The simplest method is to compare repair and maintenance costs with the temperature and time of the year.

The coefficient which takes into account the useful life of the equipment, is determined on the failure rate, time spent for maintenance and while waiting the equipment to be repaired, and also taking into account financial losses as a result of a sudden failure of equipment at the facility.

The coefficient that takes into account the structure of work was determined on the basis of percent of workload of the construction machine while performing the specified amount

of work, as well as the speed of changing attachments or units. The best indicators in this criterion are shown by multifunctional machines with a high level of computerization and the possibility to choose the operation parameters of the equipment.

Determination of energy resources on work execution by a set of construction equipment is made according to the formula:

$$S_n = \sum_{i=1}^{n} q_i * y_i * l_n \quad (4)$$

where qi- rate consumption of energy resources; yi- is the load factor of the power equipment; ln – average weighted cost of energy

The load factor can be determined depending on the soil group, the conditions of production (temperature and humidity conditions, water saturation of soils, etc.) resulted in the energy audit during execution. At the initial stage, it can be taken equal to 1, then the calculation will be made only on the basis of petrol, oil and lubricants consumption standards.

In the calculation of this indicator, it is necessary to consider the long-term prospects of using modern models of energy-saving equipment, as well as the possibility of its modernization.

The selection of the optimal composition for construction equipment fleet, is made basing on the projected workload, after the determination of the coefficients for each type of machine. Existing software tools and techniques are used, to solve the transport problem. Meanwhile during the selection process it's possible to impose restrictions on priority factors (cost, productivity, energy consumption.) and get the most optimal sets.

In addition to the economic effect, the use of energy-efficient sets makes it possible to improve the environmental perspective of construction and installation works and preserve the environment of the surrounding areas.

In the course of calculations, the root mean square deviation is determined, based on the resulted costs, and also comparison of the results of the implementation of planned activities, aimed at improvement of organizational and technological processes with prevailing activities in the organization.

Basing on a comparison of different variants of machine parks and methods of works, it is possible to manage the complete set, and operational control of the construction organization

In the analysis of efficiency of the applied decisions it is necessary to consider also effect of cutting-down of duration of construction:

$$D = \varepsilon_n \cdot (k_n \cdot t_n - k_p \cdot t_p) \quad (5)$$

where εn– standard effectiveness ratio of investments, kn and kp– the amount of capital investments, average during construction, in construction of object on norms and on the project; tn and tp– construction duration respectively on norms and on the project, years.

For works where systems automation are applied improvement of use of working hours, cutting-down of its losses and eventually increase in productivity of work of workers is provided. The increase in productivity of work at drop of intra replaceable losses of working hours:

$$W = \left(\frac{100 - q_{n2}}{100 - q_{n1}} - 1\right) \cdot 100 \quad (6)$$

where W - increase in productivity of work, %; qn1 and qn2 – losses of working hours before implementation of actions, %.

The reduction of labor expenses caused by increase in productivity of work:

$$D_w = q_s \cdot \frac{W}{100 + W} \quad (7)$$

where qs - labor costs of construction of object on estimate norms, are accepted on the local estimate in the people - h

3 Results

During the analysis of structure of machine parks in the construction industry of the Vladimir region, a share of machines with an over-standard lifespan were obtained (Fig. 1).

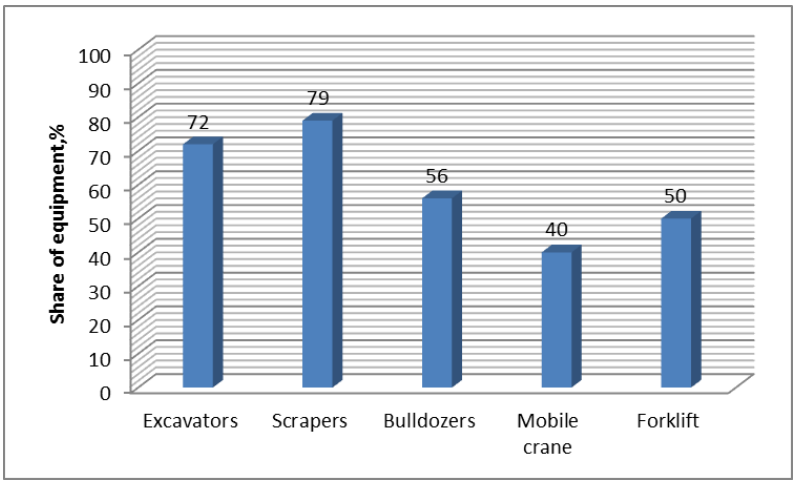

Fig. 1. Proportions of the equipment with an over-standard lifespan.

Fig. 1 shows that construction organizations desperately need to renovate their construction machines. The current situation does not allow to compete in the construction market and does not provide an opportunity to modernize the technology of construction and installation works.

As a result of analysis of the structure and the amount of financial expenses on works execution it was revealed that:

- The level of automatic positioning use in the production of excavation works does not exceed 2%.
- The expenses on maintenance and repair of construction equipment are around 40% of the cost of machine-hour.
- The amount of energy costs which ensure the work of machines and mechanisms, as well as execution technological operations, is up to 20% of total costs.

4 Discussion

Unlike the works considering durability of construction and road cars on the basis of mathematical modeling and an optimum resource of systems [18, 19] the conducted researches have shown need of more careful accounting of the factors influencing energy efficiency of construction and functionality of the construction equipment.

There are works recommending an integrated approach for operation of construction cars when, the equipment, doesn't manage to become outdated morally if intensively to operate them [20]. But in the regional organizations where the speed of updating of parks isn't sufficient, they are hardly applicable.

After the fleets of construction equipment were completed by the proposed method in leading construction organizations of the region, the share of energy costs decreased up to

15%, maintenance and repair up to 25%. Projected percentage increase of the equipment's output will be 10%.

The economic effect of the proposed solutions is achieved through solving the following questions:

- quantitative optimization of the machinery park, based on the required volume of work and the use of multifunctional machines;
- qualitative renewal of the machinery park due to the released units of equipment;
- increasing the readiness of technical level, according to various factors;
- reducing the downtime of the machinery fleet during the repair and maintenance;
- reduction of the works cost due to the use of energy-saving equipment and technologies (Fig. 2).

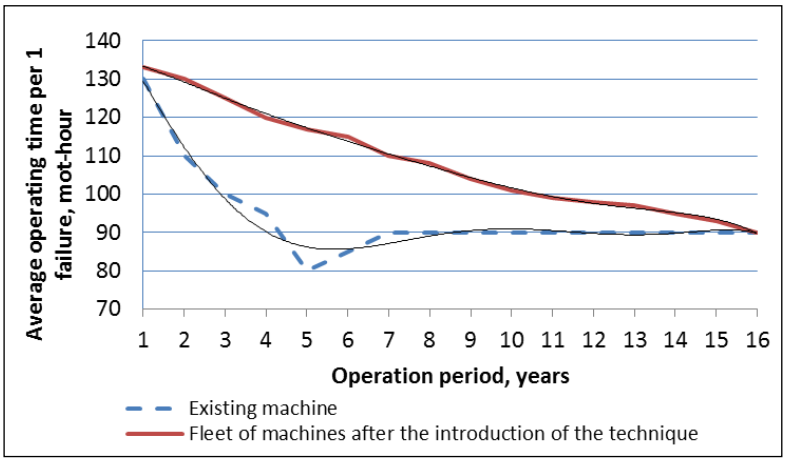

Fig. 2. Distribution of failures in excavators.

5 Conclusions

The suggested technique allows minimizing losses from downtime due to the lack of work front, as well as downtime caused due to failures under the influence of various factors. This is achieved by better consideration of each individual impact factor per unit of equipment. The use of foreign experience in the field of automation of construction and installation works and implementation of the newest systems for monitoring after technical condition, energy and resource saving, let us on the one hand, to "prolong life" of the existing machinery parks, and on the other, to make the "rejuvenation" and accumulate experience in using energy-efficient technologies. Due to the investments in domestic machinery and capital construction, it is possible to reduce import dependence and increase the competitiveness of domestic companies. Due to investments in domestic mechanical engineering and capital construction, it is possible to reduce import dependence and increase the competitiveness of domestic companies.

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