Increasing energy efficiency level of building production based on applying modern mechanization facilities

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Abstract. Building industry in a present day going through the hard times. Machine and mechanism exploitation cost, on a field of construction and installation works, takes a substantial part in total building construction expenses. There is a necessity to elaborate high efficient method, which allows not only to increase production, but also to reduce direct costs during machine fleet exploitation, and to increase its energy efficiency. In order to achieve the goal we plan to use modern methods of work production, hi-tech and energy saving machine tools and technologies, and use of optimal mechanization sets. As the optimization criteria there are exploitation prime cost and set efficiency. During actual task-solving process we made a conclusion, which shows that mechanization works, energy audit with production juxtaposition, prime prices and costs for energy resources allow to make complex machine fleet supply, improve ecological level and increase construction and installation work quality.

1. Introduction

Building industry in a present day is going through the hard times. Machine and mechanism exploitation cost, on a field of construction and installation works, takes a substantial part in total building construction expenses. In current article, we solve the task of cost reducing for the technical machine exploitation and increasing energy saving while construction works. To the goal achievement we plan to use modern methods of work production, hi-tech and energy saving machine tools and technologies, and use of optimal mechanization sets. As optimization criterion we use prime cost and sets productivity. During actual task-solving process we made a conclusion, which show that mechanization works energy audit with production juxtaposition, prime prices and costs for energy resources allow to make complex machine fleet supply, improve ecological level and increase construction and installation work quality.

2. Materials and Methods

Resource saving tasks is the most actual question of modern economy and industry. Majority cases of energy saving in construction industry, as a rule, are considered on a stage of building project, modernization or reconstruction.

Also during production of construction and installation works aimed to object construction while household supply of participate builders, a lot of electro energy, warm, fuel and other resources are expended. The substantial part of the coasts is for construction machines and mechanisms.

While choosing of mechanization sets for construction and installation works one use for machines following demands:

1. High efficiency and reliability;
2. Availability of machines under time and in sufficient quantity;

3. Minimum, relevant cost price of machine-hour.

Technic production depends of different criterion and production conditions. There are numerous articles dedicated to production increasing and machine efficiency provision [1, 2].

Generally building organizations are aware that without using modern, efficient machines it's impossible to get rival advantage on building market. At the same time machine fleet update and modernization are irregular. In big regions of the country efficient machines by foreign and domestic production, with under 5-10 years life time are used. In a small regions organization, there are exploitation of different ages machines fleet frequently with over time exploitation period, which requires extra attention [3, 4].

There is necessary to elaborate high efficient method, which allowed not only production increase, but to reduce direct costs while machine fleet exploitation, and to increase its energy efficiency.

3. Results

As an optimization criteria there are exploitation prime cost and set efficiency.

$$c = \sum_{i=1}^{n} c_i \quad (1)$$

$$P = \sum_{i=1}^{n} p_i \quad (2)$$

Average machine efficiency is determined:

$$\overline{p_i} = \frac{\sum_{j=1}^{n} P_{ij} * k_{ti} * k_{vi} * k_{ri}}{n} \quad (3)$$

where P_{ij} - productivity of *i* machine on *j* object; k_{ti} - coefficient, which account temperature influence on the works cost rise; k_{vi} - coefficient, which account machine age on the exploitation costs; k_{vi} - coefficient, which account exploitation condition influence and work structure.

One of the way of reducing prime cost is increasing matching productivity by reducing technological operations amount. In a field of building and construction technics main trend of efficiency increasing is using 2D and 3D-systems of automatic control and positioning.

In 2008 Topcon made market presentation of leveling system named 3DMC2 for bulldozers and graders, which significantly increase of possible machine speed without losing heap and positioning accuracy. Depending on the set it reaches by complexing of laser or GNSS-changes with inertial bloc based on gyroscopes and accelerometers. After several years company Leica first, and later Trimble also expended thee systems by inertial blocs. [5]

Besides that, by the virtue of additional operation part position observation facilities and quality of received surface in real time mode production regulation depending on the environment became possible. In particularly - Caterpillar machines: bulldozer Cat D6K2 with 3D Trimble dual GPS and motor grader Cat 140M AWD with robotic tacheometer can pick up knife for its discharging based on analysis of slipping track and planning implement. Its help not only to use machines with maximal efficiency, but also help to prevent premature deterioration and reduce atmosphere emissions quantity.

Allying modern automatization systems of work production, in particular – earthen, allow to reduce technological operation amount, which lead to productivity increasing, machine working hours reducing, and then enlarge resource before repairs and TS, which extremely important while machine fleet with over-standard period of exploitation. [6]

Virtual Site Solutions program facilities allow to check in real-time mode technical state, productivity and detect insufficiently loaded machines. [7] This product integration with 2D and 3D positioning systems allowed to monitor matching efficiency and make its technical service. Among Russian manufactures SCAUT system could be registered which works based on satellite GPS and GLONASS technologies.

During calculations, the mean-square deviation for productivity and prime cost are determined, also results comparison of implementation of plan improving organization and technological actions with established in company. .

$$s_p = \sqrt{\frac{\sum_{i=1}^{n}(p-\overline{p_i})^2}{n}} \quad (4)$$

$$s_c = \sqrt{\frac{\sum_{i=1}^{n}(c-\overline{c_i})^2}{n}} \quad (5)$$

Define variations coefficient:

$$k_v = \frac{\sum_{i=1}^{n}(p-\overline{p}_i)^2}{p_i^2*(n-1)} \quad (6)$$

If it under set value 0.1-0.2 – machines are takes get into the calculation.

The next phase is comparison of work duration with required (by the customer or according to the work production list). Wherein machines, work duration of such is above required indicators, are excluded from the calculations. If work duration is not hard limited, then in output data sign «random» duration and all machines get into the calculations.

$$N_j^{pl} - N_{ij} \geq 0 \quad (7)$$

where N_j^{pl} - planed work duration on *j* object, days; N_{ij}- calculated work duration performed *i* machine on *j* object, days

One more direction in a field of improving building organizations machine fleet is applying high-tech equipment rigging by recuperation system, energy accumulation and hybrid power plants.

4. Discussion

Modern building machines constructors have been produce for long machines with hybrid facilities which allowed not only reduce fuel costs, but reduce noise level and emissions into the environment while work. [8, 9]. One of the most efficient way of energy saving in building machine with hydraulic drive of work equipment is recuperative systems with energy accumulator.

On hydraulic one-bucket excavator such systems can be divided into following groups:

1) Mechanical
- with counterweight;
- with spring-loaded or torsion accumulators;

2) Thermal:
- with thermal accumulators;

3) Hydraulic:
- with hydro-accumulators;
- with additional hydraulic pump and hydro-motors;

4) Combined:
- with electro-hydro-aggregates.

In hydraulic excavators Komatsu HB215LC-1, Cat 336EH kinetic energy redeemed and accumulates while braking of rotatable superstructure. Energy stockpiled from capacitor or nitrogen accumulator could be used after in quality of additional energy for supplying electromotor of rotate mechanism, or for supplying motor-generator, works as electromotor and which add above 60 h.p. to the ICE, and which actuate gears hydro pumps.

One another way of energy save is conversion of braking kinetic energy to electricity. Diesel-electric gear is used in large career machines quite long time ago. Such type gear development got new impulse with the advent of electro control systems. Recuperate braking system allow to stop machine without general brakes use, which increases its resource. Besides, hybrid system allows to save above 45% of fuel. [10, 11]

World hoisting equipment constructors have been producing quite long-time cargo and cargo-and-passenger hoist supplied by energy recuperation while cabin down movement mechanism, which reduce energy expansion. [12, 13]

Electro-frequent gear applying with recuperation model instead of relay-contact surfaces allow to significantly reduce electro energy consumption.

While using of traditional panel, above 70 % of expended energy could be spend to air warming, not only while cargo descent, but also while cargo lifting.

Established practice of frequent electro gear based on process in which electro energy, generated by engine while cargo lifting or inertial braking mechanism, transmitted to the braking blocks resistance and transformed into thermal. There are some limitations in such braking way. Braking resistor connects to each frequency converter, which increase electro gear cost and reduce weight-and-size equipment indicators.

Braking energy, except for lose in electro gear elements, stands out like thermal upon braking resistor, which lead to its significant warming and irrational use of electro energy.

As alternative of such irrational energy use is applying of recuperation modules, which replaces resistors in gears with long time work in general mode or without high braking power, such as, for example, in lifting and inertial mechanisms. In such case braking electro gear energy return to supplying chain.

Frequent electro gear with recuperation module allows:

1. Get energy saving (as braking energy could be directed to other mechanisms, total energy consumption is reducing, and extra energy is returned to supplying chain);
2. Exclude irrational energy consumption for air warming;
3. Reduce electro equipment weight and space it occupies;
4. Reduce working hours amount of equipment service. [14]

Of course, modern equipment models with high exploitation qualities has a heightened price, but in situation of energy resources price rising its long-term using shall allow to get new level in a field of energy saving and CIW performing.

Energy expenses for work performing by building machines could be calculated according to the formula:

$$E = \sum_{i=1}^{n} E_i * n_{ij} * K_{pi} \quad (8)$$

Where E_j - energy consumption norm; K_{pi} - functioning coefficient of power equipment.

Functioning coefficient could be determined depending on the soil group, work production conditions (temperature-humidity conditions, soil water saturation etc.) because of energy audit while working process. On a first stage, it could be set equal 1, then calculation will be produce according to the fuel consumption rates.

After indicators definition task solution of machine selection for work performing is produces. For these goals, existing methodic and program facilities could be used. Wherein constraints for prime factors (cost price, productivity, energy consumption) could be set and it allowed to get the most optimal kits.

Besides of economic effect, energy effective sets applying allows to improve ecological constituent of construction and installation works and save of adjoin environment.

5. Conclusions

Russian building machines models in present are not possible to compete with foreign machines due to limited nomenclature, low production and technical support quality.

But if one use of foreign experience in a field of construction and installation work automatization and apply modern control systems for the technical state, energy and resource-saving, it could be possible, from the one side, to extend period of exploitation of existing machine fleet, from another side make «renewal» and collect work experience with applying energy efficient technologies.

With rising currency prices and as result, rise in price of exploitation and acquiring Europe models, construction machines park renewal takes a strategy value. Investments inserted in machine building, will lead to increasing population employment, production resurgence in main states industries and as result reduce import dependency. Besides strategic partnership could be machine building of Belarus Republic and China.

1. Comprehensive evaluation of machine sets, organization and technological measures allowed to evaluate and select machine sets for major indicators.
2. Applying of modern technologies and machines could significantly increase competitiveness of building companies.
3. Methodic use allows to perfume energy audit of work mechanization and production comparison, prime cost and energy resources consumptions.

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