TEKA. COMMISSION OF MOTORIZATION AND ENERGETICS IN AGRICULTURE – 2012, Vol. 12, No.4, 54-57

Mathematical model of choice of the switcher's optimal operating mode which work on the system of two units on the basis of fuel rate diminishing criterion

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S u m m a r y . In article questions of work optimisation an installation diesel engine-generating are considered. Criterion function of diesel locomotives total expenses by is defined; the equation for calculation of the fuel expense by shunting diesel locomotives which work on system of two units is worked out.
K e y w o r d s . Criterion function, system of two units, fuel expense, shunting diesel locomotive, energy expenses.

INTRODACTION

Experience of the switcher's use, which works by system of two unit's shows that efficiency of their work, can be substantially increased by optimization of the diesel-generator setting operating mode and perfection of control system of locomotive. The choice of optimal operating mode must be based on principles of the complete use of locomotive power and diminishing of expenditure of energy during exploitation [Pappok, Semenido 1962, Stepanov, Dychkov 1968]. For determination of the switcher's optimal operating modes which work on the system of two units it is necessary to analyze the expenses of diesel fuel at implementation of different mobile operations on the whole for a change.

ANALYSIS OF RESEARCHES AND PUBLICATION

Analyzing existent methodologies of determination of fuel rate diesel locomotives we determined that all of it has a substantial defect – it does not take into account operating mode and influence of operating factors on the expense of fuel rate diesel locomotives which work on the system of two units [CT-2421 2000, CT-249 2001, CT-0059 2003].

AIM OF THE ARTICLE

The aim of this paper is determination of the efficiency function of total charges during work of switchers which work on the system of two units for a shift and it limitation and composition the mathematical model for the calculation of fuel rate diesel locomotives which work on the system of two units for a change taking into account time of work on the different modes and change of the modes at implementation of switcher's operations.

EXPOSITION OF BASIC MATERIAL

We executed preliminary estimate of statistical information about the efficiency level of the use of diesel-generator installations of switchers which work on the system of two units [Chernjak, Sazonov, Guschin, Doroshenko, Gatchenko 2006, Gatchenko V.O. 2011] that allows to build the model of rational choice operating mode taking into account actually producible work on the basis of fuel rate diminishing criterion.

As a basis of the model efficiency function we put the total operation cost minimization [Sumtsov, Bragin, Klimenko 2012].

For determination of operating costs of switcher which work on the system of two units during the shift we proposed next function:

$$E = f(B_T, B_{x.x.}, B_{zap}, C_{d.p.}) \to \min, \qquad (1)$$

where: B_T - expenditure of fuel in the mode of traction;

$B_{x.x.}$ - expenditure of fuel in the mode of idling;

B_{zap} - expenditure of fuel rate on the start of diesel;

$C_{d.p.}$ - cost of diesel fuel.

Thus total expenditure of fuel consists of diesel expenditure of fuel in the mode of traction, idling and expenditure on engine start [Kossov, Azarenko, Komaritsky 2007, Osipov, Mironov, Revich 1979].

Fuel engine start in the mode of traction, idling, on the expenditure start:

$$B_T = G_T \cdot \tau_T = \sum_{i=1}^{n} \tau_{pozi} \cdot P_i \cdot g_{ei} \cdot 10^{-3}, \qquad (2)$$

where: G_T - fuel expenditure in the mode of traction, kg;

τ_{pozi} - time of the diesel-generator setting work on position *i* of machinist controller;

P_i - power of diesel on position *i* of machinist controller, kW;

g_{ei} - specific fuel rate on position *i* of machinist controller, g/ kW h.

$$B_{x.x.} = g_{x.x.} \cdot \tau_{x.x.} \qquad (3)$$

where: $g_{x.x.}$ - fuel expenditure in the mode of idling, kg/h;

$\tau_{x.x.}$ - work time in the mode of idling, h.

$$B_{zap} = g^{zap} \cdot n, \qquad (4)$$

g^{zap} - fuel expenditure on the engine start, kg;

n - amount of starts is for a shift.

Then target function:

$$E = \left(\sum G_T \cdot \tau_T + \sum g_{x.x.} \cdot t_{x.x.} + g^{zap} \cdot n\right) \times C_{d.p.} \to \min$$

Limitation:

$$\begin{cases} T_{n.c.} \in -40 \div 40^0 C; \\ T_{o.v.} \in 40 \div 45^0 C; \\ Q \in 0 \div 3000 t. \end{cases}$$

$T_{n.c.}$ - ambient temperature, ^oC;

$T_{o.v.}$ - temperature of diesel cooling water, ^oC;

Q - weight of train, t.

By variables components of target function are operational time in the different modes and amount of starts for a shift [Gatchenko 2011].

For determination of operational time in the different modes graph of the states of the system of diesel-locomotive switcher was built, which work on the system of two units and the worked out model for determination of probability of locomotives stay in the different states of the system which is realized in the software product of MATHCAD [Falendish, Ustenko, Gatchenko, Volodarets 2011].

Defining on the developed model probability $P(X_i)$ of being of diesel engines in the different states of count it is possible to calculate the fuel rate in the different modes of diesel-locomotive switcher operations which work on the system of two units for a shift [Gorbunov, Kostyukevich, Kravchenko 2010, Gorbunov, Kostyukevich, Kravchenko, Kovtanets 2010.].

The time of the certain state of the system $\tau(X_i)$

$$\tau(X_i) = P(X_i) \cdot t_{zm}, \qquad (5)$$

$P(X_i)$ - probability of presence in the certain state of the system;

t_{zm} - time of shiftwork.

Total expenditure on operation of diesel-locomotive which works on the system of two units is a function from time of presence in the different states of the system [Kalabuhin, Beletsky 2009, Kalabuhin, Beletsky 2010]:

$$f(\tau(X_i)) = \left[\left(g_{x.x.} \cdot \left(\tau(X_{2,4}) + 2\tau(X_3)\right)\right)\right] +$$
$$+ \left[\tau(X_{5,7}) \cdot \sum_{i=1}^{k} P_i \cdot g_{ei} \cdot P(X_{pozi}^{5,7}) \cdot (1 + k_Q) + g_{x.x} \cdot \theta_j (1 - k_Q)\right] +$$
$$+ \left[2\tau(X_9) \cdot \sum_{i=1}^{k} P_i \cdot g_{ei} \cdot P(X_{pozi}^{9})\right] +$$
$$+ \left[\tau(X_{6,8}) \cdot \sum_{i=1}^{k} \frac{P_i \cdot g_{ei} \cdot P(X_{pozi}^{6,8}) \cdot (1 + k_{PT}) \cdot (1 + k_Q) +}{g_{x.x.} \cdot \tau(X_{6,8}) \cdot (1 - k_{PT}) \cdot (1 - k_Q)}\right] + g^{zap} \cdot n$$

In addition in target function we entered three coefficients $\theta_{j`}$, k_{PT}, k_Q.

Coefficient $\theta_{j`}$ considers switching of operating mode depending on an ambient temperature:

- $j = 1$ *if* $t^0 C \le 0$;
- $j = 2$ *if* $t^0 C > 0$.

Accordingly: $\theta_1 = 1,\ \theta_2 = 2$.

Coefficient k_{PT} considers switching of operating mode depending on temperature diesel cooling water:

- $k_{PT} = 0\ if\ t^0C \le 40\ or\ 40 \le t^0C < 45,\ \uparrow t^0C$;
- $k_{PT} = 1\ if\ t^0C > 40\ or\ 45 \ge t^0C > 40,\ \downarrow t^0C$.

Coefficient k_Q considers switching of operating mode depending on weight of train:

- $k_Q = 0\ if\ Q < 3000\ t$;
- $k_Q = 1\ if\ Q \ge 3000\ t$.

By means of developed mathematical model it is expedient to determine the optimal operating modes of switcher's diesel-locomotive which work on the system of two units, on the criterion of fuel expenditure diminishing.

CONCLUSIONS

1. A certain target function of total expenditure during work of switcher which works on the system of two units for a shift.

2. The restriction of target function on an ambient temperature, to temperature diesel cooling water, to weight of train are imposed

3. On the basis of model for determination of probabilities of presence of diesel locomotives in the different states of the system worked out, an equation for the calculation of expense of fuel by diesel-locomotive switcher which work on the system of two units for a change taking into account time of operation on the different modes and change of the modes at implementation of mobile operations were developed.

4. The calculations of fuel expenses on this model perspective direction of increase of degree of the use of diesel-generator options of mobile diesel engines which work on the system of two units will allow to ground.

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МОДЕЛЬ ВЫБОРА ОПТИМАЛЬНЫХ РЕЖИМОВ РАБОТЫ МАНЕВРОВЫХ ТЕПЛОВОЗОВ, КОТОРЫЕ РАБОТАЮТ ПО СИСТЕМЕ ДВУХ ЕДИНИЦ НА ОСНОВЕ КРИТЕРИЯ СНИЖЕНИЯ РАСХОДА ТОПЛИВА

Анатолий Фалендыш, Виктория Гатченко, Юрий Белецкий

А н н о т а ц и я . В статье рассмотрены вопросы оптимизации работы дизель-генераторной установки. Определена целевая функция суммарных затрат топлива тепловозами, составлено уравнение для расчета расхода топлива маневровыми тепловозами, которые работают по системе двух единиц.
К л ю ч е в ы е с л о в а . Целевая функция, система двух единиц, расход топлива, маневровый тепловоз, затраты энергии.