Diesel-locomotive switcher's modernisation by hybrid transmission of power

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Summary. The questions of diesel locomotive's modernization with a hybrid transmission and workings out of model of definition necessary for power consumption of the energy store and power-plant power which are established on it are considered in the article.
Keywords. switcher, hybrid transmission, model, power consumption, energy store, power-plant.

INTRODACTION

Power of diesel locomotives during exploitation changes in wide limits. It goes out from many observations that a loading of locomotives power-plant depends on the polygon of exploitation and never exceeds a value 0,5 [Kossov, Azarenko, Komaritsky 2007, Kossov, Azarenko, Kornev, Komarnitskiy 2008]. It means that middle service rating of locomotives power-plant average is not more than half from her capacity.

If we set the energy store of sufficient capacity on a locomotive, then the set power of power-plant can be reduced in two times and anymore without harm for implementation of hauling work [CT-2421 2000, CT-249 2001, CT-0059 2003].

Storage batteries, condensers of high capacity, can be used in quality of possible energy stores, gyroscopic vehicles [Gulia 1980]. The power intensity of store on a locomotive is limited to gravimetric, by volume and cost descriptions.

Therefore determination of minimum power intensity of store, which is needed for implementation of certain type of locomotives work, is expedient.

RESEARCH OBJECT

Development of technical decisions in relation to modernization of mobile diesel engine by the hybrid transmission of power and determination for it of necessary power-hungriness of store of energy and power of power-plant.

BASIC MATERIAL

Application of energy store in the locomotive hauling network - is one of ways of the cost of fuel cutting on traction in the whole world [Falendish, Volodarets 2010, Golubenko, Mogila, Nozhenko 2007]. It is most actual for a locomotive power which works in the pulse-mode, for example: motor carriage rolling stocks, shunting engines.

In a table 1 comparative description over of hybrid and storage-battery locomotives is brought.

Practice proves that middle power of diesel-locomotive switcher's diesels folds 10-15% from nominal power of diesel. Therefore the use of energy store exactly for diesel-locomotive switcher is most appropriate. For realization of this project it is necessary to decide next questions:

- ground of modernisation method is by transfer it in the system of hybrid diesel locomotive;
- ground of necessary power of the diesel-generator setting;
- development of the diesel-generator setting of small capacity direct current;

Table 1. Comparative description of hybrid and storage-battery locomotives

Parameter	Series of locomotive					
	CKD (Prague) TA436.05 (718)	Railpower GG20B GreenGoat	Railpower GG10K GreenKid	GE Evolution Hybrid locomotive	LAM-01	CHME3
Type of energy store (ES)	storage battery of NiCd NKS300	lead-acid storage battery		storage battery of NaNiCL2	storage battery of NiCd	-
Power of ES max., kW	400			1300 (1460)		
Economy, %	to 24	20-70	to 55	15		-
Energy, kW·h	172,8	720	360	1000		
Energy, mega Joile	622	2592	1296	3600		
Tension, V	576	600	300			
Capacity, A·h	300	1200	1200			
Mass of ES, t	11,5					-
Year of making	1986	2002	2004	2007	2003	1960
Axial formula	Bo' - Bo'	Bo - Bo	Bo - Bo	Co - Co	1o-1-1o+ 1o-1-1o	3_O-3_O
Operating mass, t	64	127	112,5	207	96±3%	123
Content of fuel, l	1280			9000	-	6000
Type of electricity transmission	alternating- direct current			alternating - alternating current	direct current	
N_{max} of disel+ storage batteries, kW	600	1400	700		-	-
Ne, kW	189	200	90	3280	129	993
F_{max}, kN	161			534	160	362
F_{∞}, kN	104			427	30	225
v_{max}, kilometre/h	65	96,5	48,3	120	80	95

- ground of necessary capacity of energy store;
- ground of type energy stores;
- development of electric charts of power transmission from the energy store to the railway motor.

It is foreseen that after modernization of switcher and conversion of it in the hybrid diesel locomotive, expense of diesel fuel can diminish to 50% and emission in the atmosphere of harmful substances will go down on 80 - 90%.

Quantitative description of object technical perfection degree is determined of it technical level and presents a component of technical estimation at the general estimation of transport vehicles quality.

Expecting the coefficients of K technical level for the considered switchers in relation to the diesel locomotive CHME 3, will get their next values:

$$K_{(TA\ 436.05\ (718))}=0{,}68,\ K_{(LAMAS\text{-}01)}=0{,}52,\ K_{(GG10K\ GreenKid)}=1{,}02,\ K_{(GG20B\ GreenGoat)}=1{,}32.$$

Coming from aforesaid, it is possible to draw conclusion that creation of hybrid locomotive on the base of switcher CHME 3 is an expedient decision.

For planning of hybrid diesel locomotive it is necessary to be determined with the parameters of the diesel-generator setting and energy stores. A locomotive will work on a next chart: work on the middle loading will be provided by the engine of low power, during work on idling and subzero loading the engine of will fill up the supply of energy in a store and carry out work of diesel engine, and on the high loading of diesel engine will come true due to energy of store and due to the engine of low power.

Existent models of calculation of locomotive parameters of [Kamaev 1981, Ivanov 1974, Birukov, Savoskin, Burchak 1992] does not foresee hybrid traction, that is why in this kind used can not be and require their revision. The model of determination of technical and economic indices was worked out to the diesel engine with a hybrid transmission [Falendish, Volodarets 2010], but there is a necessity for determination of it optimal parameters.

For the decision of this question the programming algorithm of power intensity calculation of energy store and switcher's power with a hybrid transmission was made, which is represented on fig. 1.

For the analysis of BISP input data are: power-plant power of Nf, which was determined during a journey each 2 minutes Δτ. As a result get: value of the fixed data amount n, duration of work to the diesel engine τcm, and also dependence of Nf(τ).

During the choice of engine power by a input data are: vector i from BISP data, steps amount Nsteep of engine power change which settles accounts, and on the basis of it vector j. Thus we calculated: coefficient of power change bj, middle power from BISP data Ncp, power Npr, which is accepted at quality base for calculations, engine power which settles accounts, Nustj.

For the calculation of energy store power intensity use next data: initial power of calculation E_o [Gorbunov, Kostyukevich, Kravchenko, Kovtanets 2010]. Thus the necessary power intensity of energy store E_{nej} settles accounts minimum depending on select engine power, and also the power intensity of energy store E_i is determined, j on every stage of treason of necessary power to the diesel engine, and dependence of objective power *E(τ)* from time of work τ.

For determination of dependence *Ene(Neng)* of necessary power intensity of energy store and power of diesel locomotive engine by a input data is a vector of $Neng_j$ of values of power installation and vector Ene_j of values of store minimum power intensity, necessary for providing initial work of locomotive.

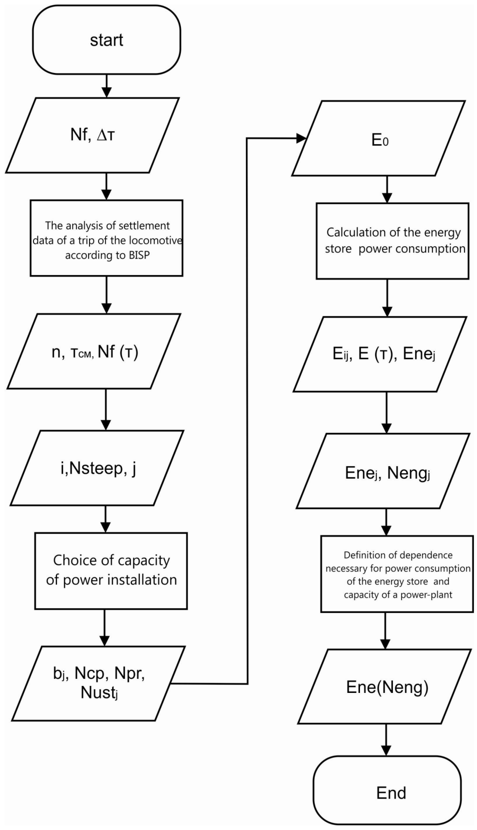

Fig. 1. Programming algorithm of power intensity calculation of energy store and switcher's with a hybrid transmission

On the basis of the offered algorithm the program of necessary power intensity calculation of energy store and power installation was worked out to the diesel locomotive with a hybrid transmission by means of program package MATHCAD [Mogila, Nozhenko 2007].

Using this program for design switcher with a hybrid transmission, it is possible to choose rational correlations it power installation and energy store [Gatchenko 2011, Gorbunov, Kostyukevich, Kravchenko 2010.].

We consider it application on an example to the diesel locomotive CHME 3.

From data of BISP for the diesel locomotive CHME 3 №2191 dependence of locomotive operating power Nf_i is built on time of it work τ_{and}. This dependence is represented on fig. 2.

It is farther necessary to choose power of locomotive power installation and depending on it expect power intensity of energy store for every *i* step of change of locomotive operating power. Graphicly it is represented as dependence of power intensity E_i of energy store on time of locomotive work τ_{and}.

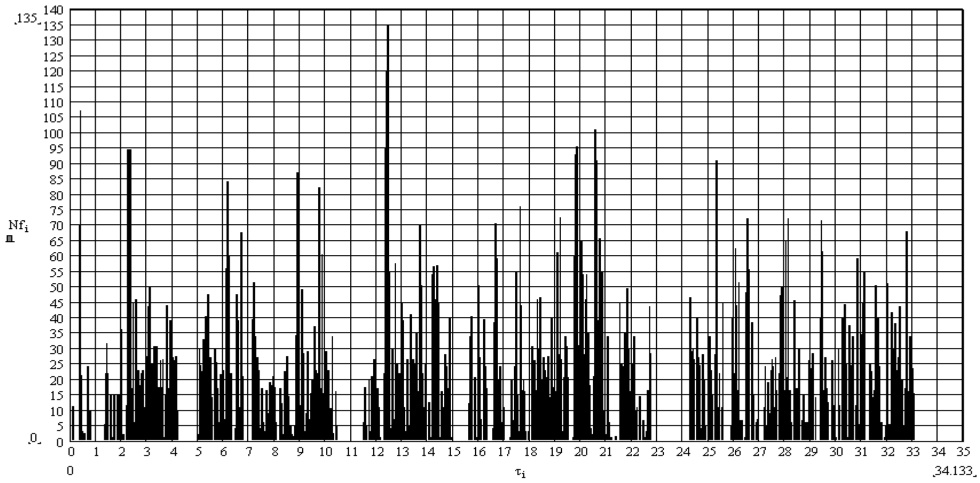

Fig. 2. Dependence of operating power to the diesel locomotive CHME 3 from time of it work from BISP data

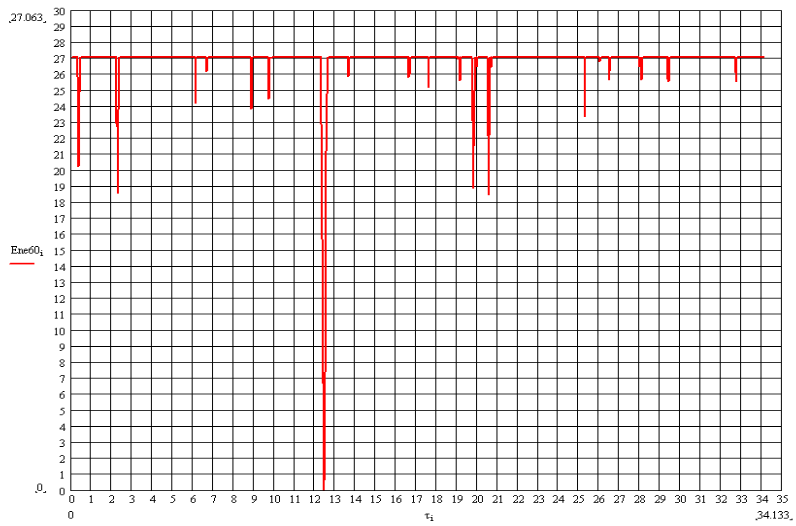

Fig. 3. is Dependence of power intensity of energy store on time of locomotive work τ_{and}. for power installation power 60 kW

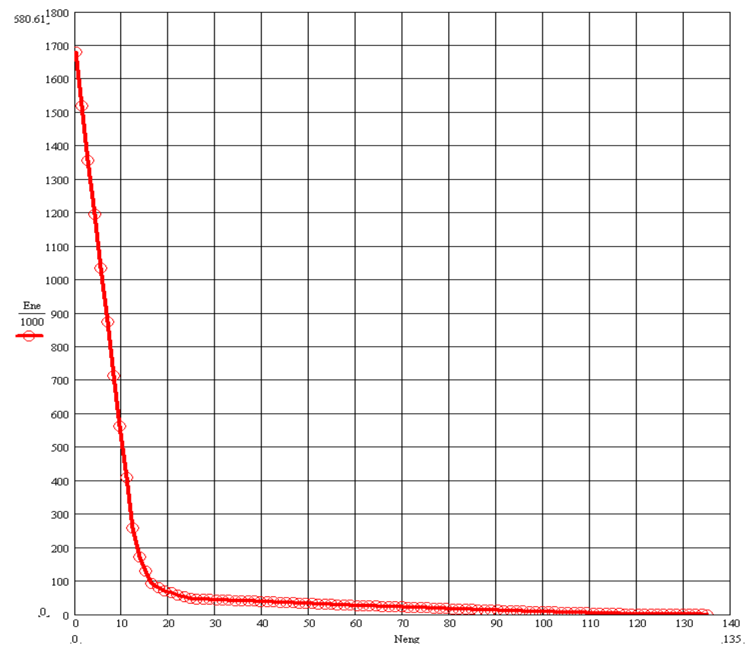

Fig 4. Dependence of power intensity of energy store *Ene* on power of select power-plant *Neng* for basic work reference

On fig. 3 for the examined operating mode of diesel locomotive CHME 3 considered dependence E_i (τ_i) is brought at select power *Neng* of power installation 60 kW [Falendish, Volodarets, Bragin, Zaytsev 2010].

It goes out from resulted to figure, that for an engine with power 60 kW it is necessary to choose the energy store with minimum power intensity 27 M Joil.

And on the last stage for to the projected diesel locomotive taking into account the change of it operating power dependence of power intensity of energy store *Ene* is built on power of select power-plant *Neng* [Falendish, Bragin 2011]. Dependence *Ene (Neng)* for the considered regime of work of diesel locomotive CHME 3 is represented on fig. 4.

Electing the type of store, it is needed also to take into account it mass-size indexes [Sumtsov, Bragin, Klimenko 2012]. Therefore there is a necessity for the calculation of maximum power intensity of energy store which is limited to free space of diesel locomotive. For this purpose it is necessary to know it specific weight and capacity [Chernjak, Sazonov, Guschin, Doroshenko, Gatchenko 2006].

In a table 2 specific indexes over of various energy stores are brought.

Table 2. Specific indexes of energy stores

Type of store	Specific mass, kg/kJoil	Specific volume, l/kJoil
Condenser of public corporation «Ekond»	0,37	0,19
Electrochemical condenser of «Esma»	0,068	0,0465
Flywheel	0,0042	0,0009
Nickel-cadmium battery	0,021	0,012
lithium-ion battery	0,0003	0,001

On the basis of these indexes, and also on condition of limitation of free space to the diesel engine of CHME 3, the maximum power-intensity of various stores of energy was expected. Results over of calculation are brought in a table 3.

Table 3. Results of calculation of maximum power intensity of various energy stores for diesel locomotive CHME3

Type of store	Power intensity on the type of limitation, MJoil	
	On mass	On volume
Type of store	54	211
Condenser of public corporation «Ekond»	294	860
Electrochemical condenser of «Esma»	4761	44444
Flywheel	952	3333
Nickel-cadmium battery	66667	40000

From comparison of calculations which over are brought in a table 3 and on fig. 4, it goes out that for the locomotive CHME 3 it is possible to choose any of the cited above stores on condition of their mass-size parameters.

CONCLUSIONS

1. The analysis of existent locomotives which have hybrid traction is conducted, and calculated its expected technical level were fulfilled.
2. Analyses of existent diesel-locomotive switcher's work were conducted.
3. Some of technical decisions is offered in relation to modernization of diesel-locomotive switcher by the hybrid transmission of power.
4. Calculation model of necessary power intensity of energy store and power installation power of switcher with a hybrid transmission procedured, algorithm and program of calculation were developed
5. The uses of various energy stores are reasonable on condition of their mass-size parameters was ground.

REFERENCES

1. **Birukov I.V., Savoskin A.N., Burchak G.P., 1992.:** Mechanical part of a traction rolling stock. Textbook for students, Moscow, Transport, 440 p.
2. **Chernjak U.V., Sazonov V.O., Guschin A.M., Doroshenko V.I., Gatchenko V.O., 2006.:** Reserves of diesel fuel economy by shunting diesel locomotives are not settled. Coll. scient. proceedings, Kharkov, UkrDAZT, Vol. 72, pp. 17-21.
3. **Falendish A.P., Bragin N.I., 2011.:** Information settlement system of an estimation of a technological level of diesel trains. Lugansk, East-Ukrainian National University named after V. Dahl, No. № 3 (147), pp. 185-188.
4. **Falendish A.P., Volodarets N.V., 2010.:** Technological level estimation switcher locomotives with hybrid transfer. Lugansk, East-Ukrainian National University named after V.Dahl, No. №5(147), pp. 134-141.
5. **Falendish A.P., Volodarets N.V., 2010.:** Working out of calculation model of performance characteristics of a shunting diesel locomotive with use of hybrid draught. Coll. of proceedings, DIRT, Dnetsk, No. 23, pp. 156-162.
6. **Falendish A.P., Volodarets N.V., Bragin N.I., Zaytsev A.V., 2010.:** International scientific and practical conference of young scientists and students «Innovation technologies on a railway transport», 23-25 September. Krasny Liman, pp. 108-109.
7. **Gatchenko V.O., 2011.:** Estimation of influence of

operational factors on operating mode and the expense of fuel of shunting diesel locomotives which work on system of two units. Coll. of proceedings, DIRT, Dnetsk, No. 25, pp. 145-150.

8. **Golubenko A., Mogila V., Nozhenko H., 2007.:** Energy of diesel locomotive's electrodynamic braking for increase of efficiency of diesel locomotive engines, Coll. of scientific labours, Zilina. Issue 69, pp. 163 - 170.
9. **Gorbunov N., Kostyukevich A., Kravchenko K., 2010.:** Efficiency function for evaluation of the locomotive traction and adhesion qualities, TEKA Commission of Motorization and Power Industry in Agriculture V. X, Poland 2010. – pp. 80 - 86.
10. **Gorbunov N., Kostyukevich A., Kravchenko K., Kovtanets M., 2010.:** Influence of operatonal factors on redistribution of wheel pairs vertical loads upon rails, TEKA Commission of Motorization and Power Industry in Agriculture XIA. Poland 2011. – pp. 92-99.
11. **Gulia N.V., 1980.:** Energy stores. Science, Moscow, pp. 137-138.
12. **Ivanov V.N., 1974.:** Design and dynamics of diesel locomotives. Moscow, Transport, 336 p.
13. **Kamaev A.A., 1981.:** Design, calculation and designing of locomotives. Textbook for students, Moscow, Mechanical engineering, 351 p.
14. **Kossov Y.Y., Azarenko V.A., Komaritsky M.M., 2007.:** To a question about choice of power characteristics of a perspective independent traction rolling stock. Transport of the Russian Federation. No. 10, pp. 20-21.
15. Methodical instructions of diesel fuel expenses calculation in locomotives shunting work,: 2000, CT-2421.
16. Methodical recommendations about rationing of specific expenses of fuel and energy,:2001, CT-249.
17. **Mogila V.I., Nozhenko Y.S., 2007.:** Using wasted energy used for braking of the locomotive efficiency diesel engines, Collected scient. proceedings, Kharkov, UkrDAZT, Vol. 82, pp. 153-157.
18. **Sumtsov A.L., Bragin N.I., Klimenko O., 2012.:** The analysis of service systems of the modernised shunting diesel locomotives. Lugansk, East-Ukrainian National University named after V. Dahl, No. № 3 (147), pp. 185-188.
19. The instruction on technical rationing of electric energy expenses and fuel locomotives on draught of trains,: 2003, CT-0059.
20. **Кossov Y.Y., Azarenko V.A., Kornev A.N., Komarnitskiy M.M., 2008.:** Influence the efficiency of energy storage in the fuel efficiency of the locomotive, Locomotivinform, №3, 2008, pp. 44 – 45.

МОДЕРНИЗАЦИЯ МАНЕВРОВОГО ТЕПЛОВОЗА ГИБРИДНОЙ ПЕРЕДАЧЕЙ МОЩНОСТИ

Анатолий Фалендыш, Никита Брагин, Никита Володарец

Аннотация. В статье рассмотрены вопросы модернизации маневрового тепловоза гибридной передачей и разработки модели определения необходимой энергоемкости накопителя энергии и мощности силовой установки, которые установлены на нем.

Ключевые слова: маневровый тепловоз, гибридная передача, модель, энергоемкость, накопитель энергии, силовая установка.