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IMPROVING THE ENERGY EFFICIENCY OF DIESEL LOCOMOTIVES BY RATIONAL USING THE ENEGRY OF ELECTRODYMANIC BRAKING

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Summary. The results of the studies of rational using the energy of electrodynamic braking of the locomotive have been presented. A locomotive scheme where some amount of the braking energy is taken away to fuel zonation, the efficiency of which is confirmed by the results of theoretical and experimental research, as well as the scheme of the locomotive where some amount of the braking energy is taken away to produce hydrogen have been developed.

Key words. A locomotive, a diesel, an electrodynamic braking, a fuel.

INTRODUCTION

The railway transport holds one of the leading positions in Ukraine's economy. The traffic volume of the Ukrainian railways takes the 4th place on the Eurasian continent, and the traffic density exceeds the leading European states' indicators in 3-5 times [Sergienko 2010]. However, the moral and physical wear of the rolling stock of Ukrzaliznytsya (UZ) (99% diesel locomotives and 83% of electric locomotives [Sergienko 2010]) and accordingly, the increased cost of rail transport reduce its competitiveness, which is especially important for Ukraine to get out of economic crisis and for the Final of European Football Championship in 2012.

One of the major priorities of restructuring UZ is to take measures to reduce the energy consumption.

OBJECTS AND PROBLEMS

The main factor determining the cost effectiveness of any means of transport is the complete use of its technical facilities [Kuznecov 2004], the rational use and economic consumption of energy resources. According to [Osipov, Mironov, Revich, 1979], the efficiency ratio (ER) of the locomotive depends on the technical perfection of all the systems of the locomotive on the whole:

$$\eta_{lok} = \eta_{diesel} \cdot \eta_{p.t.} \cdot \beta, \quad (1)$$

where: η_{diesel} - ER of the diesel; $\eta_{p.t.}$ - ER of the power transmission; β - the coefficient taking into account the amount of power taken away for the additional needs.

Thus, the issues of increasing the energy efficiency of the locomotive cover the operation of the vehicle as a complex multifunctional system, both at the design stage, operation, the solution of the above mentioned problem requiring a complex system approach.

When the energy efficiency of the locomotive in operation is increased, the greatest effect can be achieved from the use of the energy of electrodynamic braking of the locomotive, the maximum value of which is 1 - 1,2 N_e of the diesel locomotive [Basov, Bykadorov, Mishchenko, Naysh, 2006]. To identify the ways of rational use of the energy of electrodynamic braking for the needs of the locomotive, including the increase in its fuel efficiency, more research and evaluation of the expediency and its possible use are needed.

The experiments on the locomotives in the mode of electrodynamic braking showed that the power developed by the traction motors is 1300 - 4000 kW, and diesel locomotive power in a brake mode is superior in traction in the 1,2 - 1,3 times (table. 1) [Krasnyanskaya 1979].

Table 1. **Diesel locomotive power in traction and brake mode**

The series of the diesel locomotive	Power, кW	
	in traction mode	in brake mode
130	2206	1300
140	2941	1800
TE114	1912	1300
2TE116	2206	2700
TEP 70	2941	3600
TEP 75	4411	3600
2TE121	2941	4000

The analysis of existing designs of electrodynamic brakes showed that according to the method of accumulation and use of obtained braking energy, all the known technical solutions can be divided into [Golubenko, Mogila, Nozhenko 2007]:

- an energy storage device with a mechanical energy accumulator in which the energy is used for acceleration (the flywheel [Nikishin 2005], the pneumatic accumulator [Miagkov 2002], the springs [Vahrushev 1999]);
- an energy storage device with the heat energy accumulator in which the energy is used for additional needs of vehicle [Lakhno 2003];
- an energy storage device with electrical and chemical energy accumulator in which the energy is used for additional needs of vehicle [Kossov, Azarenko, Komarnitsky, 2007].

The analysis of the use of braking energy on the locomotive showed [Mogila, Nozhenko 2007] that the efficiency of electrodynamic brake does not meet the modern requirements as for the economic criteria:

- 84 - 90% of the energy is absorbed by the electrodynamic braking resistors that are through transforming it into heat, dissipate it into the environment;

- other ways to use this energy in the locomotive (the creation of the compression moment in diesel, the drive of auxiliary machines, the use of energy storage, the use of energy storage devices etc.) proved to be ineffective and therefore are not currently used.

Taking into account the above mentioned facts and based on the complex approach to solving the problem of energy efficiency of the locomotive, there was an attempt to construct a locomotive scheme with the 'ideal' use of braking energy (fig. 1) [Mogila, Nozhenko 2010],where it was proposed to use it for various needs of the locomotive, beginning from the use of energy storage devices [Kossov, Azarenko, Kornev, Komarnitskiy, 2008], activation of the working media [Golubenko, Tiupalo, Nozhenko, Mogila, Vasilev, Ignatev, 2009], electrification of sand [Gorbunov, Kravchenko, Popov, Kovtanec, Nozhenko, 2009], obtaining hydrogen [Lakhno 2003] and ending with production of carbon monoxide from the exhaust gases to use it for creating the microclimate and improving the traction characteristics [Gorbunov, Kravchenko, Kovtanets 2009].

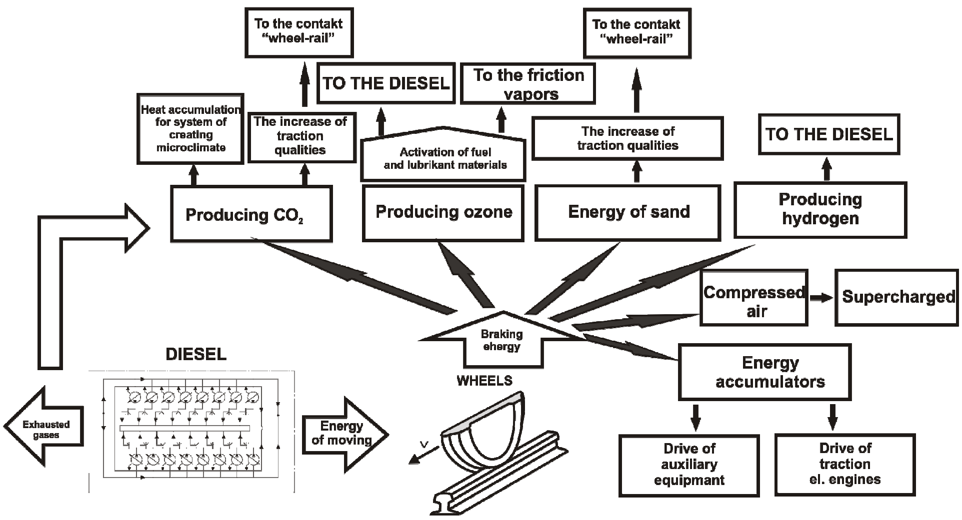

Fig. 1. The locomotive scheme with rational use of the braking energy

All the proposed methods to use the energy of electrodynamic braking, many of which seem to be extravagant, are perspective and require a detailed study.

The scientists from the East-Ukrainian National University named after Volodymyr Dahl worked out two of the proposed methods to use the energy of electrodynamic braking, i.e. the activation of the fuel and lubricants by ozone and obtaining the hydrogen to be added it to the fuel.

The use of ozone as an oxidizing additive to fuel is not new in the scientific world. Even in the 50 years of the twentieth century there were studies on the use of ozone as an oxidizer of rocket fuel [Pappok, Semenido 1962], which afterwards were implemented into life [Doktorov 2000]. For the motor fuel, the ozone was considered as an oxidant instead of the traditional air mixture. The researches in this direction were carried out in the late 80's - early 90's both in our country [Stepanov, Dychkov, 1968; Lewis, Elbe, 1968] and abroad [Lee, Park, Cha, Chung 2005; Stan, Guibert, 2004; Gluckstein, Morrison, Khammash, 1955; Nasser, Morris, James, 1998]. The prerequisites of using ozone instead of oxygen are based on its physical and chemical properties. A detailed study of petrol ozonation with the purpose of reducing fuel consumption and the emissions of exhaust gases [Stoliarenko 2000] has been done and it was proved that the ozone delivery in the fuel is more efficient than the delivery of the ozonized air to the carburetor.

The scheme of implementing the proposed method of increasing the energy efficiency of the locomotive is shown in fig. 2 [Nozhenko, Mogila, Basov ets. 2010]. It includes the following: some energy of electrodynamic braking, which is generated by traction motors TEM, is taken from the braking resistors R_r and is spent for ozone production, which is in the bubble chamber (for example, located in the fuel tank) fills the fuel with ozone ($DF+O_3$), activating it and giving it new properties (because of its high oxidative capacity), and further the power installation of the locomotive works on the ozonized fuel (DIESEL).

Thus, the increase of the fuel efficiency of diesel and the rational use of the energy of electrodynamic braking are achieved, which allows eventually to improve the efficiency of the locomotive as a whole.

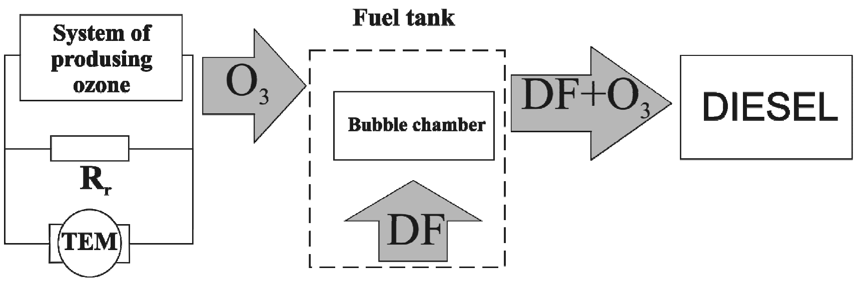

Fig. 2. The scheme of use of the energy of electrodynamic braking for obtaining ozone with further ozonized fuel

Experimental and theoretical studies of the ozone activation of diesel fuel showed that when implementing the proposed system on locomotive 2TE116U, produced by JSC HC “Luganskteplovoz” at a certain rational ozone concentration in the fuel k_{O_3} = 0,125 g/l the decrease in average operational fuel consumption of the effective specific fuel consumption was 1, 6% (the results of the studies on the positions of controller driver are shown in fig. 3).

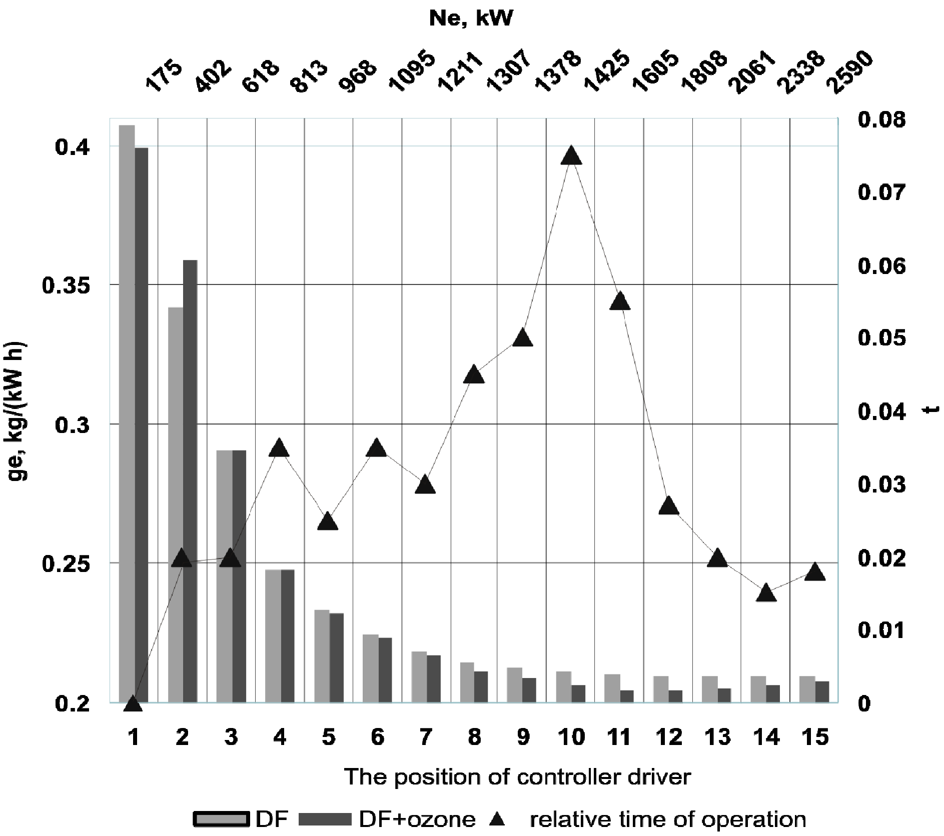

Fig. 3. Changes in specific fuel efficiency for diesel 16GHN 26/26 of locomotive 2TE116U in operation according to the diesel characteristic

Thus, the greatest effect of the fuel ozonation was observed in 11 position of controller driver, where the effective specific fuel consumption decreases by 2,5%. The results of changing the exhaust opacity of the exhaust gases on the positions of the controller driver are shown in fig. 4.

It is also developed and tested by us method of using a worthless power of EDB for producing hydrogen from water or steam that is of great interest due to its technical uniqueness. Hydrogen, when combined with an oxidizer, takes the first place in calories per 1 kg of among all the fuels used to generate electricity and heat. An obstacle to the wide use of hydrogen in energy is an expensive way to obtain it, which in certain cases is not economically justified, as the electrolysis or reactor installations applied are inefficient and energy intensive.

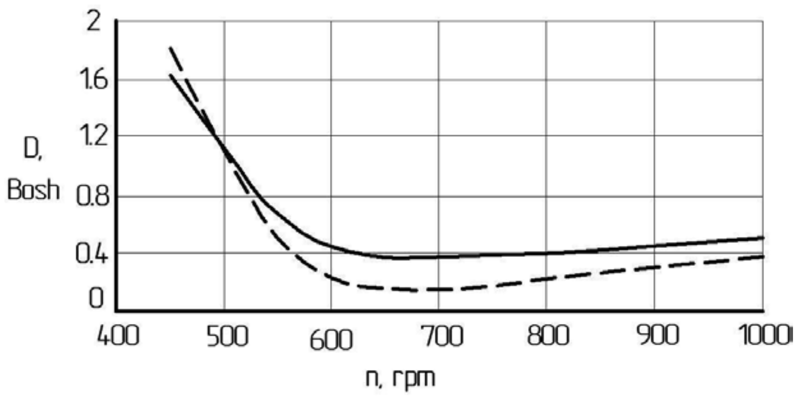

Fig. 4. The change of the exhaust opacity at operation according to the locomotive characteristic of diesel 16GHN 26/26 of locomotive 2TE116U

Therefore, in our opinion, on locomotives with EDB there is a real opportunity periodically to produce hydrogen and then use it as diesel fuel. One of the features of the method and system as a whole is the superheated steam by heating water of the cooling wall of the electrolysis or reactor installations. The investigations showed that the final products of the molecular decomposition of superheated steam may be hydrogen and oxygen in proportion 1:5; hydrogen-oxygen-nitrogen mixture; the hydrogen-nitrogen mixture, and ozone. It depends on the design and technological parameters of the installation associated with the voltage and amperage values applied to the electrodes, the water vapor and temperature consumption, air consumption and many other factors.

CONCLUSION

The analysis of the problem of energy efficiency has shown that it is reasonable to use the energy of electrodynamic braking of the locomotive. It was found out that the percentage of energy when it is returned to the contact network by electrical diesel locomotives is 5 - 8% (Lviv Railway, 2004 - 2008) and is growing every year, and on 01.01.2004 the recuperation of the electrical diesel locomotives' energy was equivalent to 1,7% of total UZ costs. In this regard the proposals for improving the energy efficiency of diesel locomotives by means of using the energy of electrodynamic braking are the promising way of improving the modern rolling stock.

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ПОВЫШЕНИЕ ЭНЕРГЕТИЧЕСКОЙ ЭФФЕКТИВНОСТИ ТЕПЛОВОЗОВ ЗА СЧЕТ РАЦИОНАЛЬНОГО ИСПОЛЬЗОВАНИЯ ЭНЕРГИИ ЭЛЕКТРОДИНАМИЧЕСКОГО ТОРМОЖЕНИЯ

Валентин Могила, Елена Ноженко,
Олег Игнатьев, Владимир Ноженко

Аннотация. Представлены результаты исследований по рациональному использованию энергии электродинамического торможения тепловоза. Разработана схема локомотива с отбором части энергии торможения на озонирование топлива, эффективность которой подтверждена результатами теоретических и экспериментальных исследований, а также схема локомотива с отбором части энергии торможения на получение водорода.

Ключевые слова. Локомотив, дизель, электродинамическое торможение, топливо.