Ways to increase the energy efficiency of locomotives

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Summary. This article gives an analysis of the energy reserves of the locomotive, consider using them. The results of theoretical studies on the effect of ozone and hydrogen as a fuel additive on the fuel consumption and toxicity exhaust. The possibility of the use of these additives in the locomotives with regard to their use in the process of obtaining energy electrodynamic braking.
Key words. A locomotive, energy reserves, the efficiency, the electrodynamic braking, compressed air energy, the energy of exhaust.

INTRODUCTION

Rate of growth of greenhouse gas emissions over the last twenty years continue to grow. The report of the International Energy Agency (IEA) states that energy-related emissions of carbon dioxide equivalent last year exceeded 30 Gt, which is 5% more than in a record year 2008, (fig 1) [Kick the Habit: A UN Guide to Carbon Neutrality, 2008].

In this case, existing alternative technologies for production and use of energy rather expensive. Analysis of the role of existing technologies to reduce CO_2 emissions has shown that the main effect at this stage of energy is achieved by the introduction of energy saving technologies (fig. 2) [IEA, 2006].

However, despite the huge amount of research work towards the improvement of existing technologies of burning fuels, including in locomotive[Romanov K., 2007], in the last decade there was no breakthrough technology that would fundamentally solve the problem of fuel efficiency and thus reduce the environmental load of emissions. Growth efficiency in the conversion of the chemical energy of fuel into mechanical work for the last 10 years has not changed and remains at the level of 40-50% [Viarshyna H., Volochko A., Pilatau A., Nozhenko E., Izabela A., 2010].

Economic efficiency any kind of transport is determined by the completeness of its technical capabilities, management and economical use of energy resources [Mogila V., Nozhenko Y., Ignatev O., Nozhenko V., 2011].

ANALISIS OF LAST REASEACHES AND PUBLICATIONS

Functioning of the internal combustion engine, locomotive auxiliary systems, a energy wheels in contact with the rail are the main sources of possible energy reserves of the locomotive.

The trend of improving workflow ICE now bears optimization nature, according to the survey presented in [Marchenko A. ets, 2004], and the energy of combustion is only 25% is used for useful (fig. 3) [GREEN CAR CONGRESS, 2005].

Huge spread in recent years for the idea of the use of alternative fuels [Werner K., 1995., Vasilev I.P., 2009, Semenov V.G., 2002, Mysłowski J., Wołoszyn R., 2007], replacing some or all hydrocarbons. However, in most cases, for the successful use of such fuels requires a constructive re-engine or the technology is not enough to get a rational and economically justified. Therefore, in the current realities of the transition to renewable energy sources, relevant research aimed at improving the working process is:

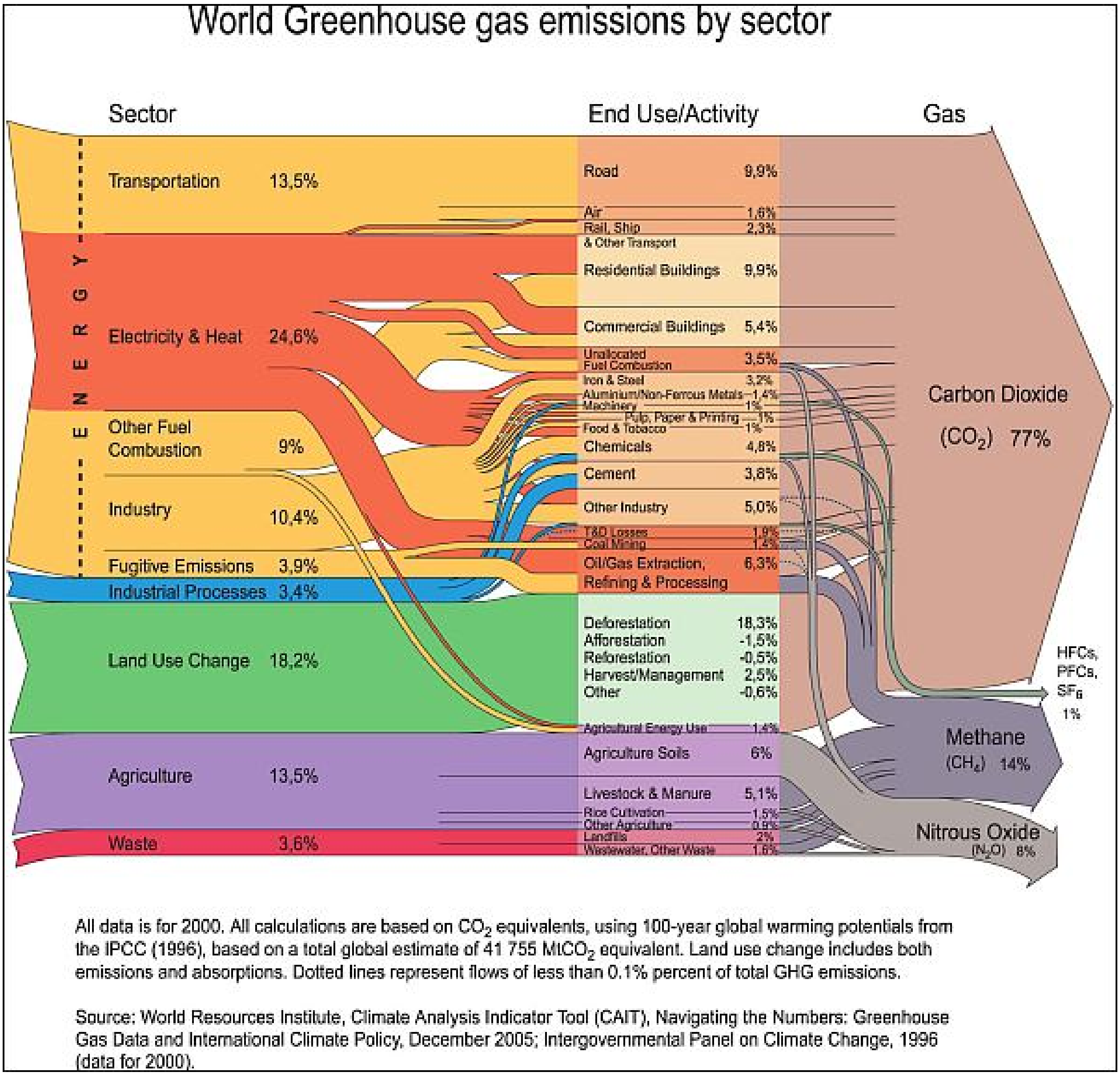

Fig. 1. The structure of the greenhouse gas emissions according to [Kick the Habit: A UN Guide to Carbon Neutrality, 2008].

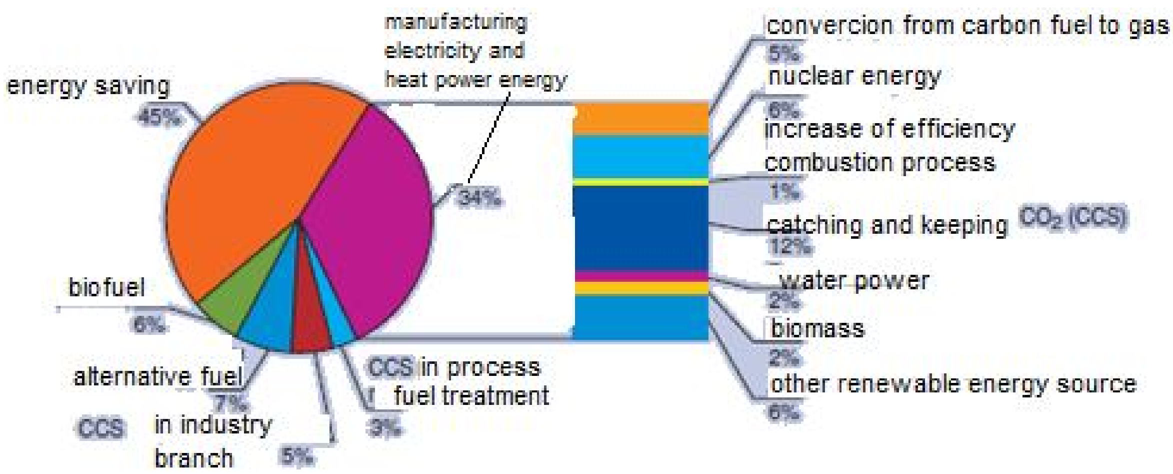

Fig. 2. Measures to reduce greenhouse gas emissions [IEA, 2006.]

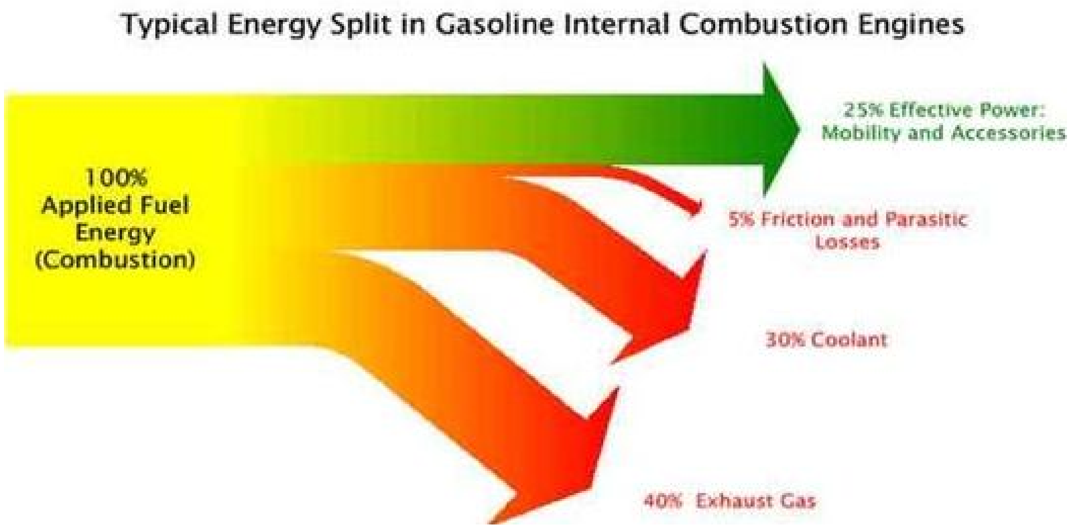

Fig. 3. Diagram of the heat balance of modern internal combustion engines [GREEN CAR CONGRESS, 2005]

- improving the uneven distribution of fuel-air mixture in the cylinders, reducing mechanical losses, improved carburetion fuel mixture by treatment with a variety of ways (handling electric field plasmatron magnetic field, ionization, ultrasound), the use of multi-stage fuel injection, changing the shape of the combustion chamber, a special place of which is the use of additives or change the properties of fuels [Nozhenko E.S., 2010]. Good results in improving the quality of combustion achieved using additives, which increase the cetane number [Danilov A.M., 2004], interesting work aimed at changing the physical and chemical properties of the fuel during engine operation, the so-called physical and chemical regulation [Kaznacheevsky V.L., 2006]. Main problem with such a regulation is to find an activator (catalyst) burning or additives, which to respond to changing conditions of the diesel engine. As this additives can be used ozone and hydrogen for subsequent saturation of fuel. Significant energy reserve lies in the use of energy electrodynamic braking, the maximum value of which is 1 - 1,2 Ne locomotive. [Mogila V., Nozhenko Y., Ignatev O., Nozhenko V., 2011].

The energy of the compressed air in brake system of the locomotive is a energy source on the lokomotives. The preliminary calculations showed that for the train on the basis of the composition of the locomotive 2TE116 60 and freight cars hourly consumption of compressed air braking is 60,000 liters, which are produced in the atmosphere after braking. At the same time, taking into account the power consumption of locomotive compressors on their work for the restoration of the brake system for the issued volume of air required from 540 to 600 kW (depending on the model of the compressor).

In addition, up to 6% of the consumed diesel fuel to drive the cooling fan traction electric motors, which operate in a stationary mode, regardless the position of controller driver and operation of traction electric motors. 4 - 5% of the effective power is spent on fan drive cooling system of the locomotive.

MATERIALS AND RESULTS OF RESEARCHES

- Where is the energy reserves of the locomotive, the above-summarized in the diagram shown in fig. 4. As can be seen from fig. 4, the greatest untapped energy potential is a system of electrodynamic braking of the locomotive.

Analysis of the use of braking energy on the locomotive showed [Nozhenko E.S., 2010], what the efficiency of the electrodynamic brakes do not meet modern requirements for economic criteria:

- 84 - 90% of the energy is absorbed by the braking resistors, which transforms it into heat and dissipate it into the environment;
- other ways to use this energy in the locomotive (the creation of a compression point in a diesel engine, the use of energy storage devices, etc.) proved to be ineffective and therefore do not currently apply.

One of the most effective and promising, in our opinion, the use of braking energy for to accumulate in the energy storage device. This circuit braking energy recovery has the best prospects, after accumulating a huge amount of

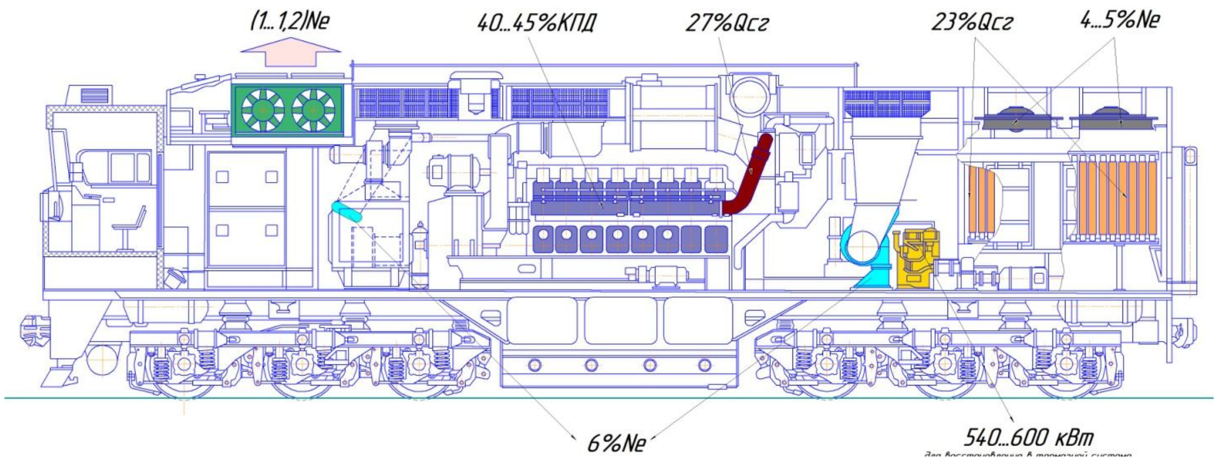

Fig. 4. Analysis of the energy reserves of the locomotive

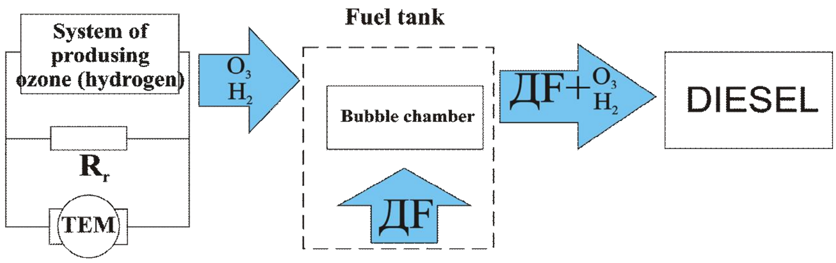

Fig. 5. Energy diagram of of electrodynamic braking for improved fuel economy of diesel locomotive

energy, to use it as needed and eliminates the need for additional storage devices, such as an activated mixture, eliminates the problem of instability of the received energy. However, the use of such devices on a given level of technology is not acceptable, in connection with such a lack of "supercapacitor", its much weight and high cost, which probably does not pay off entirely from regenerative braking. As noted above, one of the most promising ways to improve the locomotive is the improvement of its ICE. The author conducted research on the use of ozone and hydrogen as a fuel additive to reduce its consumption and emissions. One of the obstacles to wide use of these methods in transportation are significant energy cost on production of ozone and hydrogen. This disadvantage can be overcome in a normal operation of the locomotive using electrodynamic braking energy (fig. 5).The authors conducted research on the use of ozone and hydrogen as a additive fuel to reduce its consumption and emissions by the example of diesel generator 18-9DG locomotive 2TE116 . In the calculations the tabulated data rheostat test diesel [Bulygin Y.I., 2006] and the results of experimental and theoretical studies of the effect of ozone on the efficiency of diesel, described in [Nozhenko E.S., 2010., Pilatau A.Y., 2011] and hydrogen - [Vagner V.A., 1984].

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%. By the method of A.E. Khomich was determined fuel consumption per unit of work done to drive the main generator for the entire time of operation $g_{сэ}$, which for diesel generator 18-9DG at work on ozonized fuel is $g_{сэ} = 0{,}233847\ {kg}/{kW \cdot h}$, and when working on a standard diesel fuel - $g_{сэ} = 0{,}23769\ {kg}/{kW \cdot h}$, from which it follows that the use of ozone in the locomotive diesel average operational fuel consumption is 1.6% (fig. 6).

Specific fuel consumption when operating on fuel saturated with hydrogen, is also reduced by after modeling conducted by the authors. On different modes of decline of 2 - 9 g / (kW · h) (fig. 6). Power on different modes increased by 15 - 25 kW. Significantly reduce emissions of oxides of nitrogen, and the reduction of smoke and soot formation has not happened.

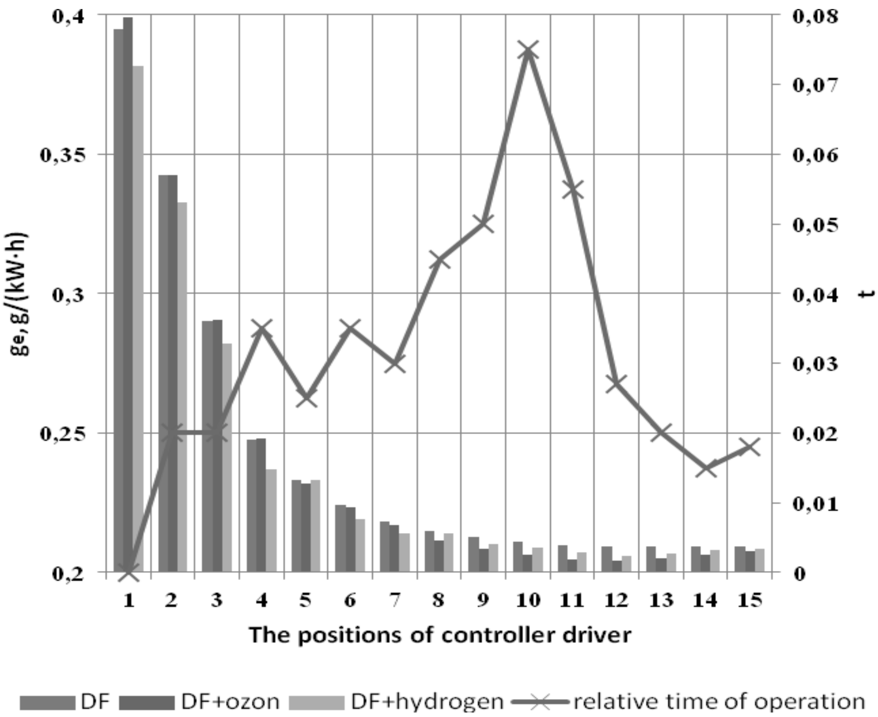

Fig. 6. Changes in specific fuel efficiency for diesel 16GHN 26/26 of locomotive 2TE116U in operation according to the diesel characteristic

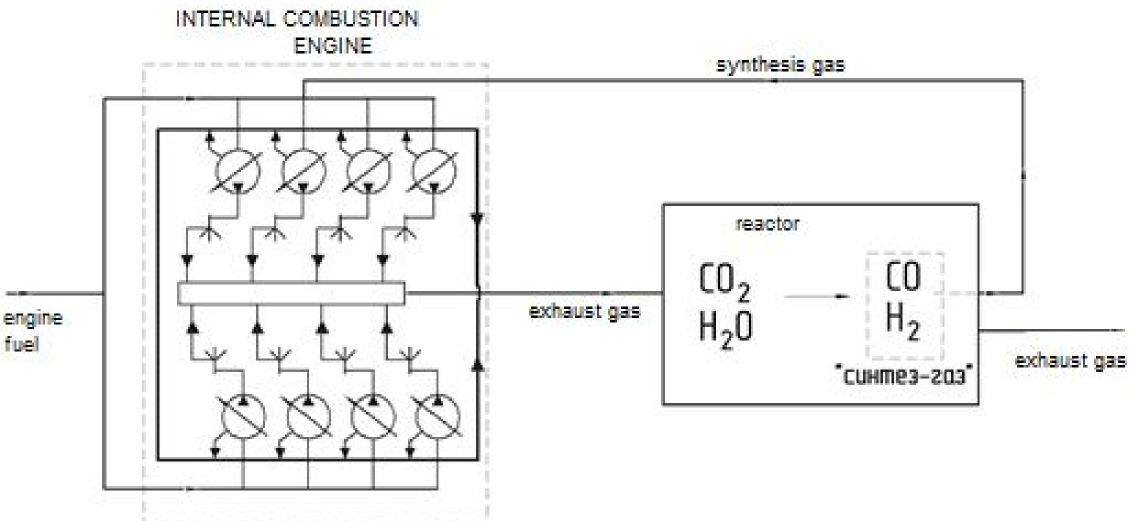

Fig. 7. The diagram of thermochemical reforming during gasification process

One way to improve the energy efficiency of the locomotive can also serve the energy of compressed air brake system of the locomotive. The authors conducted research to develop ways to use the energy of compressed air for:

- cooling the brake discs of the locomotive, in order to reduce energy for a motor-fan cooling them;

- accumulation of air in the pneumatic accumulator and then use on support needs of the locomotive;

- conversion compressed air energy into electricity with subsequent accumulation in the battery;

- the compressed and purified and dried air from the brake system sent in the air supply system of diesel, in order to reduce the cost of cleaning and drying of the air;

- compressed air to cool the braking resistors to reduce the cost of power for a cooling motor-fan;

- the compressed air in the tank to prevent caking, sandbox sand, which will increase the efficiency of the sand system.

Greater energy potential has heat from exhaust gases. The principal schematic of the process for use of diesel exhaust as gasifying agent for the engine based recycling fuel system is presented at fig.7. Burnt gases from an internal combustion engine enter in the carbonic reactor. Process of a chemical reduction of carbon dioxide and water proceed in reaction zone of carbon surface turning to combustible ingredients of syngas (CO and H_2).

For carrying out of researches as prototype the engine of family D245 which is manufactured of Minsk Motor Plant (Belarus) with exhaust gases recirculation is chosen.

On the basis of physical and chemical analysis of the process recuperation it is found [Kravchenko O.P., Lepeshko I.I., Pilatau A.Y., Nozhenko O.S., 2011] that the physical-chemical process is possible in the exhaust manifold engine exhaust gas temperature of about 1400K with exergy efficiency 22-28%. On the basis carried out experimental researches [Sklyarenko E.V., 1988] on a partial mode was found that the total and specific fuel consumption by the same power down to 12%, with the use of conversed fuel to 6%. To determine the performance of the engine for different modes of operation of the engine type, which can work on the synthesis gas is recovered, and to predict efficiency reducing the consumption of diesel fuel it was simulated engine (table 1) in different modes.

Table 1. Parameters of an Engine Scania

Bore, mm	Stroke, mm	Compression ratio	Mode	Power, kW	Engine speed, rpm	Fuel consumption, kg/h	Pressure aspiration, MPa	Inject duration, CA^0
127	160	13	1	25	1800	73	0.25	15
			2	387	1800	8	0.12	10.8

The composition of the synthesis gas recovered by the method [Kravchenko O.P., Lepeshko I.I., Pilatau A.Y., Nozhenko O.S., 2011] is shown in table 2.

Table 2. Synthesis gas composition (% Volume)

CO carbon monoxide	H_2 hydrogen	N_2 nitrogen
34.1	51.1	14.8

Mathematical description of the workflow engine was carried out at the initial stage to the previously developed method [Kucko DR.A., Pilatau A.Y., Tamkovich E.S., 2009] of calculating the diesel engine. The basis of the physical model of the combustion process that has been determine the fact that the combustion process of a diesel engine with the addition of synthesis gas is homogeneous-diffusion process fuel combustion of diesel, which is dominated by this addition its homogeneous component.

The result of the simulation of main diesel engine performance are presented on the fig. 8. The analyze of the obtained results have established that the synthesis gas addition can be increased the maximal cylinder pressure up to 1 MPa and cylinder temperature up to 200 K for the engine especially for the high-boosted mode which result is drawn on the right.

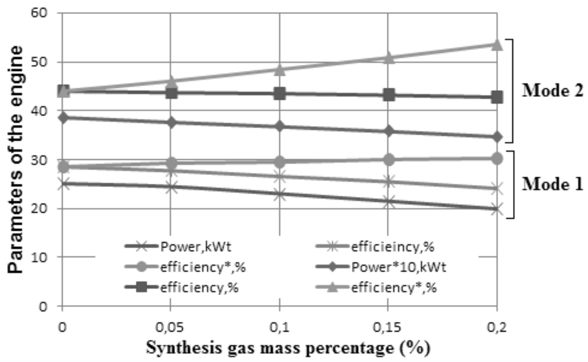

Fig. 8. Simulated diesel engine (table 1) performance. «Efficiency» is an efficiency of the engine with syngas addition through without recuperation. «Efficiency*» is fuel saving as efficiency of the engine with syngas addition through with recuperation.

On the basis of the above, based on an integrated systems approach to solving the problem of energy efficiency of the locomotive, the attempt of construction schemes locomotive with the "ideal" use of its energy resources (fig. 9), which suggested the use of diversified them for the different needs of the locomotive from the use of energy storage, activation work environments, the electrification of sand, hydrogen, ending with production of carbon monoxide from the exhaust gases for use in microclimate and increase towing characteristics, etc.

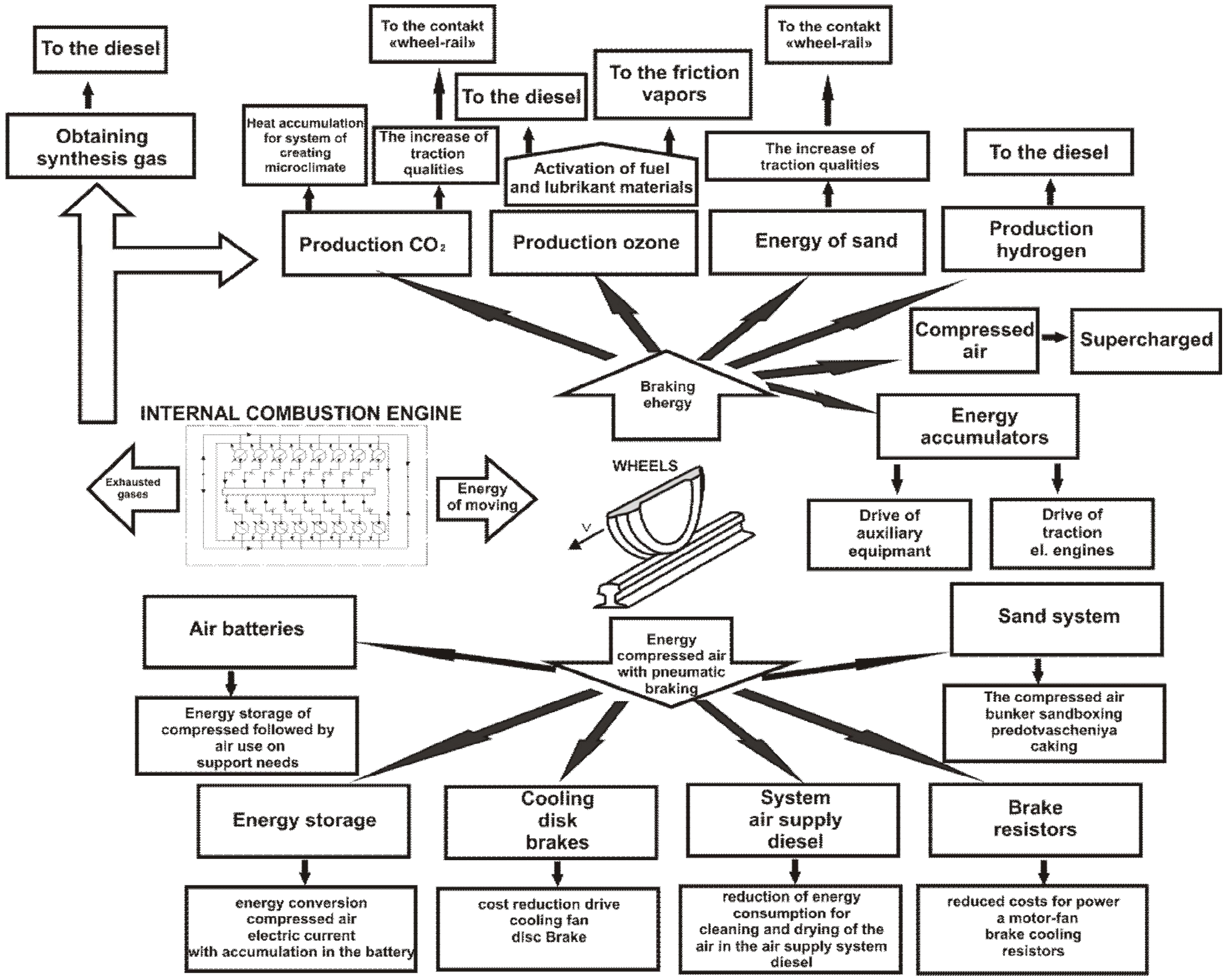

Fig. 9. The scheme of the vehicle with the "ideal" use of energy resources

CONCLUSIONS

The preliminary studies of the energy reserves of the locomotive, allowed to establish possible areas for improvement. In particular, the expediency of using the energy of compressed air exhausted from the brake system, the brake release and directions of use. And also shown that the use of electrodynamic braking energy for improvement engine (production of ozone, hydrogen) and improve contact with the rail wheels (sand electrification, supply of ozonated air).

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ПУТИ ПОВЫШЕНИЯ ЭНЕРГОЭФФЕКТИВНОСТИ ЛОКОМОТИВА

Елена Ноженко, Николай Горбунов, Валентин Могила, Александр Пилатов, Вячеслав Черников, Андрей Анофриев

Аннотация. В статье выполнен анализ энергетических резервов локомотива, рассмотрены возможности их использования. Приведены результаты теоретических исследований по влиянию использования озона и водорода как присадки к топливу на расход топлива тепловозом и токсичности его отработавших газов. Рассмотрена возможность применения этих присадок на тепловозе с учетом их получения в процессе эксплуатации при использовании энергии электродинамического торможения.

Ключевые слова. Локомотив, энергетические резервы, КПД, электродинамическое торможение, энергия сжатого воздуха, энергия отработавших газов.