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Methodology to Evaluate the Impact of Hybrid Cars Engine Type on their Economic Efficiency and Environmental Safety

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Abstract

The article presents a comparative evaluation of the environmental and economic efficiency of vehicles with several types of engines. It includes the results of calculation of the size of emissions at production and operation stages, a generalized assessment of the environmental impact on the environment at all stages of the life cycle, the results of the calculation of the cost of the transport operation of the compared vehicles with regard to their cost and fuel consumption.

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Keywords: hybrid car; pollutant emissions; environmental friendliness; efficiency; fuel consumption; environmental safety

Main text

Automobile and machine-building branches perform a task of meeting the needs for automobile transportation of freights and passengers which are necessary for functioning of economy. One of the tasks of sustainable development of these branches is satisfying requirements for sustainable development of cars design, namely economic efficiency. About 17% of all consumed hydrocarbon fuel and 23% of all CO_2 emissions into atmosphere is accounted for motor transport [Gusarov (2009)]. The tendencies of improving modern vehicles design are mostly dictated by accepted environmental standards and safety requirements at their operation [Government of the Russian Federation (2006)].

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So, improvement of environmental characteristics of cars as the main sources of greenhouse gas emissions is one of the topical tasks in many countries of the world today. The results of the 21st World Climate Summit (COP 21) in Paris testify to it where a wish to solve the air pollution problem in big cities and to slow the process of climate change on the planet was strongly emphasized. It is inherently connected with the necessity reducing hydrocarbon fuel consumption by cars. It's no coincidence that the main direction of development of their environmental safety is improving the design of internal combustion engines, expanding production of hybrid cars and electric cars. At the same time the main focus is on reducing pollutant emissions in exhaust gases. Ecological impacts related to increased price of “cleaner” power plants for production of hybrid cars aren’t examined.

The authors made a comparison of economic efficiency and ecological environmental impact of cars with different energetic power plants.

The following vehicle types participated in the comparison: motor cars with traditional petrol ICE, cars with diesel ICE, cars with gas ICE and cars with hybrid power plants. The emissions of carbon oxides (CO), nitrogen oxides (NO_X) and carbon dioxide (CO_2) are chosen as the main indicators of negative impact of cars on the environment. The thermal impact and the impact of exhaust operating fluids weren’t evaluated. The mass of vehicles and their components was accepted as basic data to evaluate the impact at the production stage while the fuel consumption and regulatory values of quantities of hazardous substances in exhaust gases were accepted at the operation stage.

The production stage of cars contributes to environment pollution related to extraction and processing of material resources and production. The authors assume that the bigger the mass of the raw and other materials is used for production of cars, the bigger pollutant emissions are at this stage. The values of the mass of cars are presented in Table 1. Raw materials such as metal, plastic, glass, rubber and other materials are used for production of accessories. The only exception are components of hybrid power plant, electric motors and electric energy store and main leads.

According to Kotikov (2006), energy consumption for assembly of one car with an internal combustion engine amounts to 8.06 GJ of energy, and pollutant emissions in terms of 1 kg of its mass amount to [Government of the Russian Federation (2006)]:

- carbon oxides (CO) – 0.0122 kg/kg;
- nitrogen oxides (NO_X) – 0.00750 kg/kg;
- greenhouse gas (CO_2) – 3.172 kg/kg.

The mass of pollutants is calculated according to the formula

$$M_{PM} = m_C \times m_{SE}$$

where M_{PM} — pollutant mass, m_C – mass of the car, m_{SE} – specific pollutant emissions.

The results of assessment of the environmental impact at the stage of production for each car are presented in Table 1.

The emissions in the process of production of batteries of hybrid cars are considered separately. The mass of Ni-MH batteries is taken to be equal to 53 kg. According to Pistoia (2010), in the process of production of 1 kg of Ni-MH batteries 1.69 kg of greenhouse gases is discharged. The total emissions in the process of their production are also presented in Table 1.

Table 1. Pollutant emissions at the stage of production of a car

Type of engine, car model	Mass of a car, tons	Mass of pollutant emissions, tons		
		CO	NO_X	CO_2
Petrol ICE, Hyundai Solaris 1.6	1.13	0.014	0.0085	3.584
Diesel ICE, Peugeot 408	1.4	0.017	0.01	4.441
Gas ICE Lada Largus 1.6 • car • gas equipment	1.33 0.05	0.017	0.01	4.377