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ДОСЛІДЖЕННЯ ВИКОРИСТАННЯ ТЕПЛОВОГО АКУМУЛЯТОРА ДЛЯ ЗНИЖЕННЯ ШКІДЛИВИХ ВИКИДІВ АВТОМОБІЛЬНОГО ДВИГУНА ШЛЯХОМ ПРИСКОРЕНОГО ПІСЛЯПУСКОВОГО ПРОГРІВУ КАТАЛІТИЧНОГО НЕЙТРАЛІЗАТОРА

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RESEARCH OF USE THE THERMAL ACCUMULATOR FOR REDUCING HARMFUL EMISSIONS OF THE VEHICULAR ENGINE BY RAPID AFTER-START HEATING OF THE CATALYTIC CONVERTER

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ИССЛЕДОВАНИЕ ИСПОЛЬЗОВАНИЯ ТЕПЛОВОГО АККУМУЛЯТОРА ДЛЯ СНИЖЕНИЯ ВРЕДНЫХ ВЫБРОСОВ АВТОМОБИЛЬНОГО ДВИГАТЕЛЯ ПУТЕМ УСКОРЕННОГО ПОСЛЕПУСКОВОГО ПРОГРЕВА КАТАЛИТИЧЕСКОГО НЕЙТРАЛИЗАТОРА

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Introduction. The problem of reducing vehicular engine harmful emissions under operating conditions can be solved when using the combined heating system (CHS) of the vehicle described in [1] and systems approach. Depending on operating conditions it provides for the combined thermal development of vehicle components. They are: a coolant, motor oil, the catalytic converter (CC) of the exhaust gases cleaning system of the vehicular engine and the vehicle interior.

To solve this problem, the research was conducted at the departments of Kharkiv National Automobile and Highway University (KhNAHU), National Transport University (NTU) and Rzeszow University of Technology (RUT). The researchers developed and investigated thermal development system components of the vehicular engine with phase-transitional thermal accumulators (TA) [2]. The scientists also improved basic elements of mathematical models to evaluate fuel economy and environmental performance of engines and vehicles under operating conditions [3]. Computer integrated technology and remote monitoring systems of vehicle technical condition parameters [4] during operation in terms of ITS (Intelligent transport system) capabilities [5] were developed and adapted for use.

The results of experimental studies [6, 7] show that using the heating system can reduce the total engine heating period by 17.8% - 68.4%. Fuel consumption for heating is also reduced by 19.5% - 56.25%. It depends on the ambient temperature and heating mode of the engine (idling, heating in motion, etc.). The investigation of the vehicular engine heating system when the vehicle is in motion in the driving cycle [1] has shown that using the heating system enables to reduce total fuel consumption by 2.1% - 7.1%. Emissions of separate harmful substances are also reduced by 5.6% - 45.5% with a slight increase of nitrogen oxide emissions. However, to investigate its efficiency, it is necessary to use the combined heating system of the vehicle with phase-transitional thermal accumulator integrated with the CC of the exhaust gases cleaning system.

Determining of the article task. The target of the article is research of use the thermal accumulator for reducing harmful emissions of the vehicular engine by rapid after-start heating of the catalytic converter.

The simulation of thermal development processes for the “vehicular engine-thermal accumulator-catalytic converter” system. A systems approach has been applied to simulate fuel consumption and harmful emission performance of the vehicular engine using the vehicle thermal development system under certain operating conditions. It allowed the researchers to present the operating processes of the vehicular engine, the catalytic converter and their thermal development system as a functional structure of the “vehicular engine-thermal accumulator-catalytic converter” system. It is shown in Fig. 1.

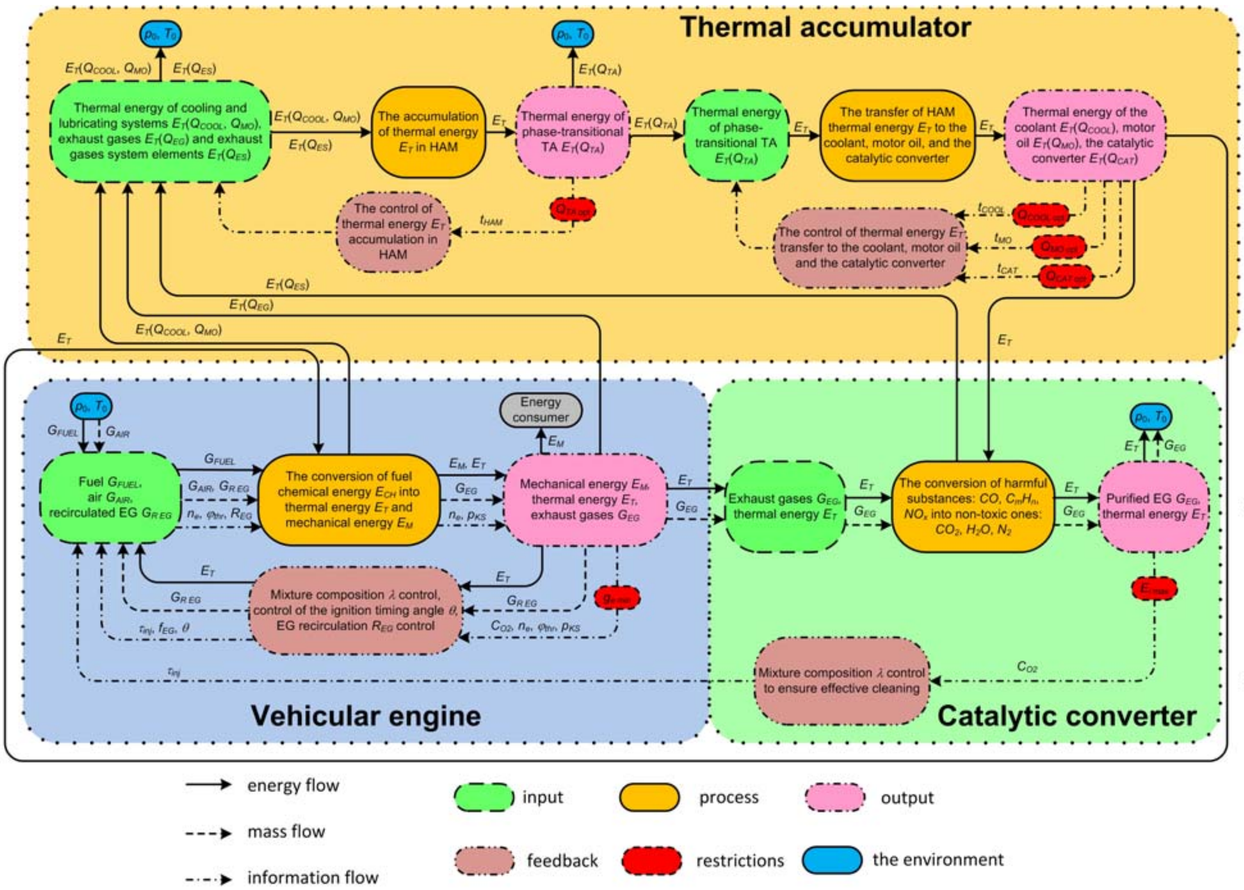

Figure. 1 – Functional structure of the “vehicular engine-thermal accumulator-catalytic converter” system

The introduced functional structure is based on the “engine-catalytic converter” system [1, 3] which integrates the processes of accumulating thermal energy E_T by heat accumulating material (HAM) and transferring thermal energy E_T to the coolant, motor oil and the catalytic converter (levels E and G).

The operation of the system is as follows. During the operating processes of the engine (level A) and CC in the exhaust gases system (level C) the unused thermal energy of cooling $E_T(Q_{COOL})$ and lubricating $E_T(Q_{MO})$ systems, exhaust gases $E_T(Q_{EG})$ and exhaust gases system elements $E_T(Q_{ES})$ is accumulated in HAM as a thermal energy of phase-transitional thermal accumulator $E_T(Q_{TA})$.

The process of accumulating thermal energy in TA is controlled by feedback (level F) to provide the optimal charge of TA $Q_{TA\,opt}$ based on HAM temperature parameter t_{HAM}.

During the process of the level G the accumulated thermal energy of TA is transferred to the coolant $E_T(Q_{COOL})$, motor oil $E_T(Q_{MO})$ and the catalytic converter $E_T(Q_{CAT})$ to provide their optimal thermal condition ($Q_{COOL\,opt}, Q_{MO\,opt}, Q_{CAT\,opt}$) due to controlling temperature parameters of the coolant t_{COOL}, motor oil t_{MO} and the catalytic converter t_{CAT} (level H).

After reaching the optimal charge level of TA and the optimal thermal condition of cooling, lubricating and EG cleaning systems, the excess thermal energy $E_T(Q_{COOL})$, $E_T(Q_{MO})$, $E_T(Q_{ES})$, $E_T(Q_{EG})$ and $E_T(Q_{TA})$ is released into the environment characterized by pressure p_0 and temperature T_0.

The simulation of main operating processes of the engine and the CC is performed using the methodology and algorithms detailed in [1, 3]. Fig. 2 shows the algorithm to study vehicle fuel economy and environmental performance using thermal accumulator for rapid after-start heating of the coolant and the catalytic converter.

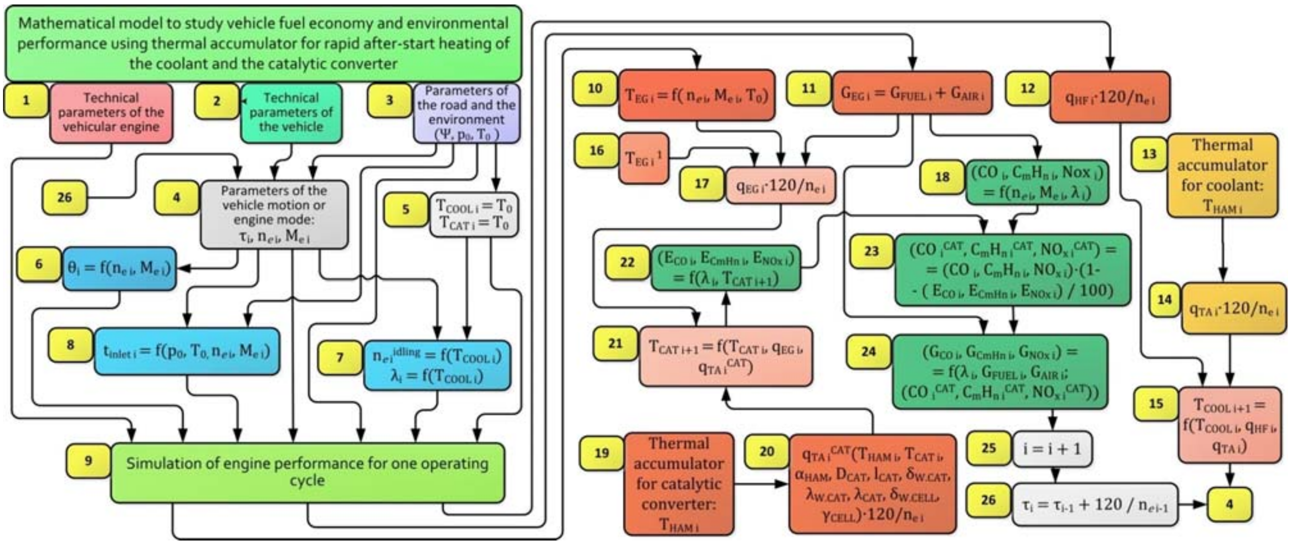

Figure. 2 – The algorithm to study vehicle fuel economy and environmental performance using thermal accumulator for rapid after-start heating of the coolant and the catalytic converter

Blocks 1 and 2 determine vehicle parameters. The parameters include: vehicle weight, fuel type, number, bore size and capacity of engine cylinders, engine compression ratio, gearbox ratios, final drive ratio, wheel tyre rolling radius and other parameters of KIA CEE"D 2.0 5MT2 with the G4GC engine.

Block 3 determines the parameters of the road and the environment: rolling resistance coefficient ψ, atmospheric pressure p_0, Pa, the ambient temperature T_0, K.

The necessary initial data are prepared for the mathematical model in blocks 4 - 8 of the algorithm. Thus, block 4 determines operating mode parameters of the vehicular engine at the current time: τ_i is the current value of time since starting the engine, s, $n_{e\,i}$ is the current value of crankshaft rotation speed, min^{-1}, $M_{e\,i}$ is the current value of the effective engine torque, N·m.

Block 5 determines the initial values of the coolant temperature $T_{COOL\,i} = T_0$, K and the catalytic converter temperature $T_{CAT\,i} = T_0$, K.

Block 6 determines the ignition timing angle θ_i, degrees of crankshaft rotation, as a function $\theta_i = f(n_{e\,i}, M_{e\,i})$. Block 7 determines the current values of crankshaft rotation speed $n_{e\,i}^{idling}$ in an idling mode and excess air coefficient λ_i as a function of $T_{COOL\,i}$: $n_{e\,i}^{idling} = f(T_{COOL\,i})$, $\lambda_i = f(T_{COOL\,i})$. Block 8 determines the temperature in the inlet manifold of the engine $t_{inlet\,i} = f(p_0, T_0, n_{e\,i}, M_{e\,i})$, °C.

All prepared initial data enter block 9 where the engine performance is simulated for one operating cycle.

Block 10 determines EG temperature in the exhaust manifold before the CC $T_{EG\,i} = f(n_{e\,i}, M_{e\,i}, T_0)$, K. Block 11 determines exhaust gas flow per hour, $G_{EG\,i}$, kg/h, according to fuel consumption per hour $G_{FUEL\,i}$, kg/h, and air consumption per hour $G_{AIR\,i}$, kg/h, of the vehicular engine.

Block 12 determines the thermal energy lost because of the heat flowing through the walls of the cylinder and the combustion chamber to the coolant $q_{HF\,i}$, W, during the time of an operating cycle $120/n_{e\,i}$, s.

Block 13 determines the HAM temperature $T_{HAM\,i}$, K, of the thermal accumulator for the coolant. Block 14 determines the additional thermal energy according to the heat flow through TA heat exchange part to the coolant $q_{TA\,i}$, W, during the time of an operating cycle. Block 15 determines the coolant temperature $T_{COOL\,i+1} = f(T_{COOL\,i}, q_{HF\,i}, q_{TA\,i})$, K.

Block 16 determines the temperature of exhaust gas leaving the CC $T_{EG\,i}^{1}$, K. Block 17 determines the EG thermal energy, that is transferred to the CC during the time of an operating cycle.

Block 18 determines the concentration of CO (%), C_mH_n (ppm), NO_x (ppm) before the catalytic converter: $(CO_i, C_mH_{n\,i}, NO_{x\,i}) = f(n_{e\,i}, M_{e\,i}, \lambda_i)$.

Block 19 determines the HAM temperature $T_{HAM\,i}$, K, of the thermal accumulator for the catalytic converter. Block 20 determines the additional thermal energy according to the heat flow through TA heat exchange part to the CC $q_{TA\,i}^{CAT}(T_{HAM\,i}, T_{CAT\,i}, \alpha_{HAM}, D_{CAT}, l_{CAT}, \delta_{W.CAT}, \lambda_{W.CAT}, \lambda_{CAT}, \delta_{W.CELL}, \gamma_{CELL})$, W, during the time of an operating cycle. Block 21 determines the temperature of the catalytic converter unit $T_{CAT\,i+1} = f(T_{CAT\,i}, q_{EG\,i}, q_{TA\,i}^{CAT})$, K.

Block 22 determines the efficiency of cleaning CO, C_mH_n, NO_x, %, namely: $(E_{CO\,i}, E_{CH\,i}, E_{NOx\,i}) = f(\lambda_i, T_{CAT\,i+1})$. Block 23 determines the concentration of CO (%), C_mH_n (ppm), NO_x

(ppm) after the catalytic converter, namely: $(CO_i^{CAT}, C_mH_{n_i}^{CAT}, NO_{x_i}^{CAT}) = (CO_i, C_mH_{n\,i}, NO_{x\,i}) \cdot (1 - (E_{CO\,i}, E_{CH\,i}, E_{NOx\,i}) / 100)$. In addition, block 24 determines the mass emission of CO, C_mH_n, NO_x, (kg/h), namely: $(G_{CO\,i}, G_{C_mH_n\,i}, G_{NO_x\,i}) = f(\lambda_i, G_{FUEL\,i}, G_{AIR\,i}, (CO_i^{CAT}, C_mH_{n_i}^{CAT}, NO_{x_i}^{CAT}))$.

Block 25 changes the serial number of the calculation cycle to the next one, $i = i + 1$. Block 26 changes the current time since starting the vehicular engine: $\tau_i = \tau_{i-1} + 120/n_{e\,i-1}$, s.

Simuation is continued in block 4 after determining the new current parameters of the engine operating mode.

During the process of accumulating thermal energy from the cooling, lubricating, EG cleaning systems and exhaust gases system elements, total HAM thermal energy of phase-transitional thermal accumulator (Q_{TA}, J) is described by equation:

$$Q_{TA} = Q_{COOL} + Q_{MO} + Q_{EG} + Q_{ES} = - m_{HAM} \cdot \int_{T_1}^{T_{PH}} C_{SOL}(T)dT + m_{HAM} \times r_{THAM} + m_{HAM} \cdot \int_{T_{PH}}^{T_2} C_{LIQ}(T)dT, \quad (1)$$

where m_{HAM} is the weight of HAM that undergoes a phase transition of melting-solidification, kg; $C_{SOL}(T)$, $C_{LIQ}(T)$ is specific mass heat capacity of HAM depending on its temperature, in solid and liquid phases respectively, J/(kg·K); r_{THAM} is specific thermal energy of melting-solidification phase transition, J/kg; T_1, T_2, T_{PH} are HAM temperatures: initial, final and phase transition respectively, K.

The current value of the coolant temperature is determined depending on the ambient temperature. It is based on the values of the heat flow from the walls of the cylinder, the combustion chamber and TA heat exchange part, K:

$$T_{COOL}(\tau) = T_0 + \int_0^{\tau_{HP}} \frac{(q_{HF}(\tau) + q_{TA}(\tau))}{m_{COOL} \cdot C_{COOL}} d\tau, \quad (2)$$

where τ is the current value of simulation time, s; τ_{HP} is total heating period of the engine, s; $q_{HF}(\tau)$ is the heat flow through the walls of the cylinder and the combustion chamber to the coolant, W; $q_{TA}(\tau)$ is the heat flow through TA heat exchange part to the coolant, W; m_{COOL} is the coolant weight in the system, kg; C_{COOL} is coolant heat capacity, J/(kg·K).

The current value of the catalytic converter temperature is determined depending on the ambient temperature. It is based on the values of temperature, mass flow of EG and the heat flow from TA heat exchange part, K:

$$T_{CAT}(\tau) = T_0 + \int_0^{\tau} \frac{G_{EG}(\tau) \cdot C_{EG}(T_{EG}) \cdot \left(T_{EG}(\tau) - T_{EG}^{1}(\tau)\right) + q_{TA}^{CAT}(\tau)}{m_{CAT} \cdot C_{CAT}(T_{CAT})} d\tau, \quad (3)$$

where $G_{EG}(\tau)$ is mass flow of exhaust gas, kg/s; $C_{EG}(T_{EG})$ is exhaust gas heat capacity, J/(kg·K); $T_{EG}(\tau)$ is the temperature of exhaust gas leaving the engine, K; $T_{EG}^{1}(\tau)$ is the temperature of exhaust gas leaving the CC, K; $q_{TA}^{CAT}(\tau)$ is heat flow through TA heat exchange part to the catalytic converter, W; m_{CAT} is the weight of the catalytic converter active unit, kg; $C_{CAT}(T_{CAT})$ is heat capacity of the catalytic converter material, J/(kg·K).

The heat flow through the walls of the cylinder and the combustion chamber to the coolant $q_{HF}(\tau)$, EG mass flow and temperature are determined during the simulation of engine operating process. The mathematical model of the “engine-catalytic converter” system described in [1] is used for this. The heat flow through TA heat exchange part to the coolant $q_{TA}(\tau)$ and the catalytic converter $q_{TA}^{CAT}(\tau)$ is determined by the dependency (1). It is also determined by the structural parameters of the cooling system and the catalytic converter. For example, the heat flow through TA heat exchange part to the catalytic converter ($q_{TA}^{CAT}(\tau)$, W) is described by the equation:

$$q_{TA}^{CAT}(\tau) = \frac{\left(T_{HAM}(\tau) - T_{CAT}(\tau)\right) \cdot \pi \cdot D_{CAT} \cdot l_{CAT}}{\frac{1}{\alpha_{HAM}} + \frac{\delta_{W.CAT}}{\lambda_{W.CAT}} + \frac{D_{CAT}}{0.04 \cdot \lambda_{CAT} \cdot \delta_{W.CELL} \cdot \gamma_{CELL}}}, \quad (4)$$

where $T_{HAM}(\tau)$ is the current value of HAM temperature, K; π is a number approximately equal to 3.141; D_{CAT} is the diameter of the catalytic converter unit, m; l_{CAT} is the length of the catalytic converter unit, m; α_{HAM} is heat output coefficient of HAM, W/(m^2·K); $\delta_{W.CAT}$ is the wall thickness of the CC shell, m; $\lambda_{W.CAT}$ is thermal conductivity coefficient of the wall of the CC shell, W/(m·K); λ_{CAT} is thermal conductivity coefficient of the catalytic converter material, W/(m·K); $\delta_{W.CELL}$ is the wall thickness of the CC separate cell, mm; γ_{CELL} is the density of the CC cell arrangement, 1/cm^2.

The temperature of exhaust gas leaving the CC and the current value of HAM temperature are determined by the experimental data.

The mathematical dependencies describing the temperature condition of the engine and the catalytic converter are used to determine the efficiency of cleaning the harmful substances in CC [1]. It is the basis to study the efficiency of using the combined thermal development system of the vehicle with phase-transitional thermal accumulator integrated with the CC of the exhaust gases cleaning system.

The research results. The experimental research was carried out to study the efficiency of using the engine and the CC heating system in different heating modes of KIA CEE’D 2.0 5MT2 under operating conditions. These research results are presented in [1, 7].

Table 1 contains the technical parameters of the catalytic converter installed in KIA CEE’D 2.0 5MT2.

When choosing HAM for exhaust gases cleaning system 2 materials were chosen, investigated and used. They had the parameters for petrol and diesel engines. In three-component catalytic converter Light-off point is at 250 °C. Meanwhile, in oxidation catalytic converters for diesel engines it is achieved at 160 °C because of high concentration of oxygen in exhaust gases [8]. These heat accumulating materials (Table 2) are hydroquinone and caustic soda [8 – 10].

Table 1 – Technical parameters of the catalytic converter in KIA CEE’D 2.0 5MT2

Title	Specification
Exhaust gases cleaning system	three-component catalytic converter
The diameter of the catalytic converter unit, m	0.180
The length of the catalytic converter unit, m	0.2
The wall thickness of the CC shell, m	0.002
The material of the CC shell	stainless steel
Catalytic converter material	stainless steel foil
The wall thickness of the CC separate cell, mm	0.1
The density of the CC cell arrangement , 1/cm^2	60

Table 2 – The main properties of heat accumulating materials for exhaust gases cleaning system of the vehicular engine

Parameters	Heat accumulating materials	
	Hydroquinone	Caustic soda
A range of operating temperatures, °C	to + 230	to + 530
Chemical formula	$C_6H_4(OH)_2$	NaOH
Molar mass, g/mole	110	39.997
Density, g/m^3	1.3	1.59
Melting temperature, °C	172	323
Boiling temperature, °C	287	1403

The research methodology involves evaluating fuel economy and environmental performance in typical operating modes of the vehicle. They are: an idling mode and when the vehicle is in motion. For further research, therefore, the driving cycle according to the UNECE Regulation № 83-05 [11] was chosen as a set of typical modes of the vehicle motion. The adequacy assessment of modeling temperature condition of the “vehicular engine-thermal accumulator-catalytic converter” system elements is confirmed by the experimental research [12].

The efficiency of using the heating system in different heating modes of the vehicular engine and the catalytic converter was investigated at the ambient temperatures (-20 °C, 0 °C and 20 °C). It was done with the use of the developed simulation methodology. Fig. 3, 4 and 5 show the results of investigation the efficiency of using the heating system at the ambient temperature 0 °C. Fig. 3 shows the obtained dependencies of the coolant and the CC temperatures.

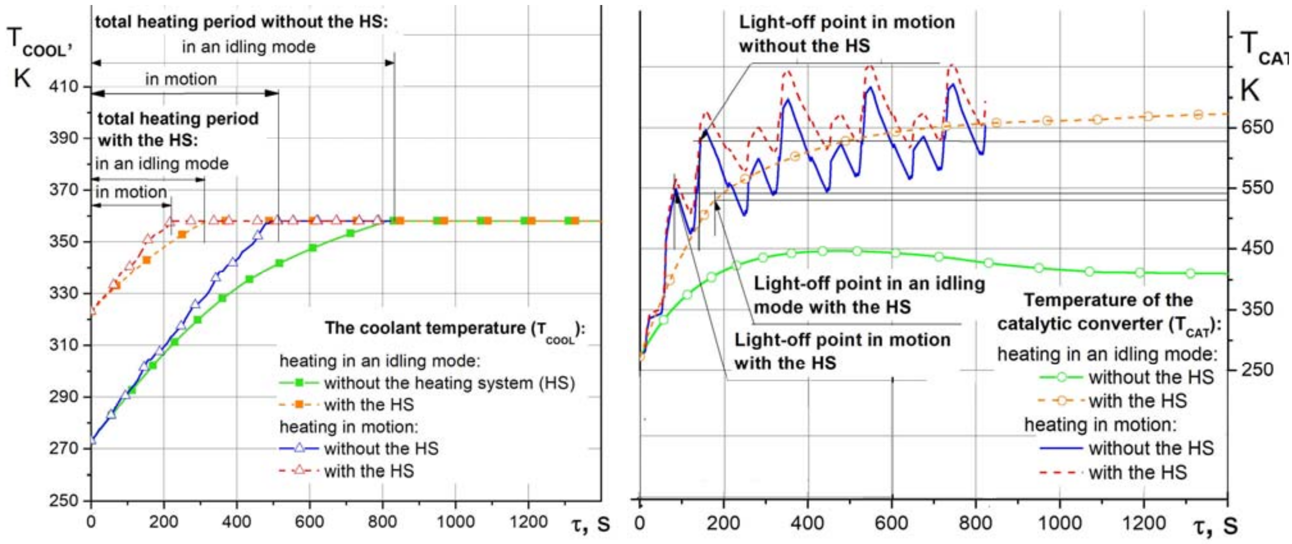

Figure 3 – The dependencies of the coolant and the CC temperatures for different heating modes of the vehicular engine and the catalytic converter (for the ambient temperature 0 °C)

The presented dependencies show that heating mode has a substantial influence on the time of achieving the coolant complete heating, the temperature and the time of achieving the catalytic converter Light-off point at which the efficiency of cleaning harmful substances is more than 50%. Using the vehicular engine heating system enables to decrease the time of complete heating in an idling mode for the ambient temperature 0 °C by 61.1 %. In the mode of heating in motion it is decreased by 54.5 % (Fig. 6). Using the obtained dependencies of the CC temperature in different heating modes the efficiency of cleaning harmful substances is determined (Fig. 4, 5).

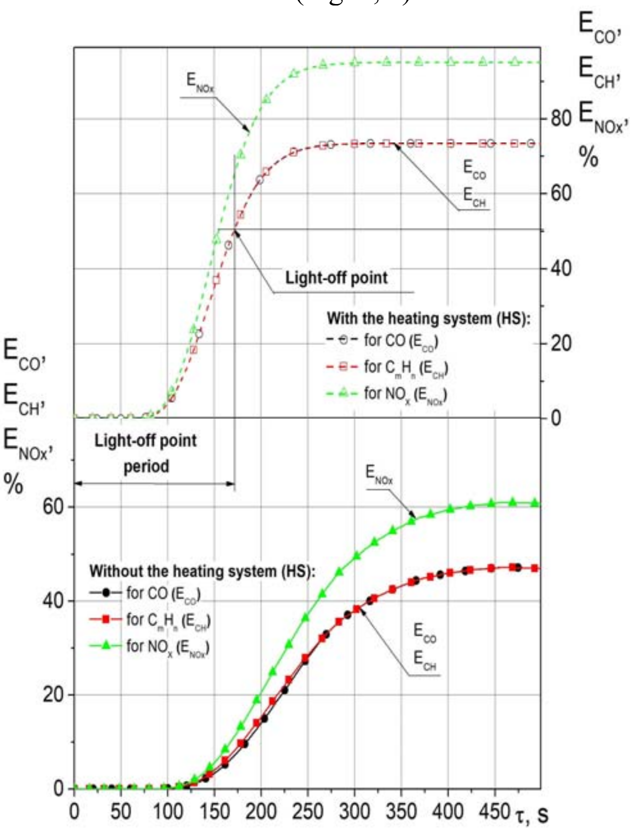

Figure 4 – The dependencies of the CC efficiency during heating of the vehicular engine and the catalytic converter in an idling mode (for the ambient temperature 0 °C)

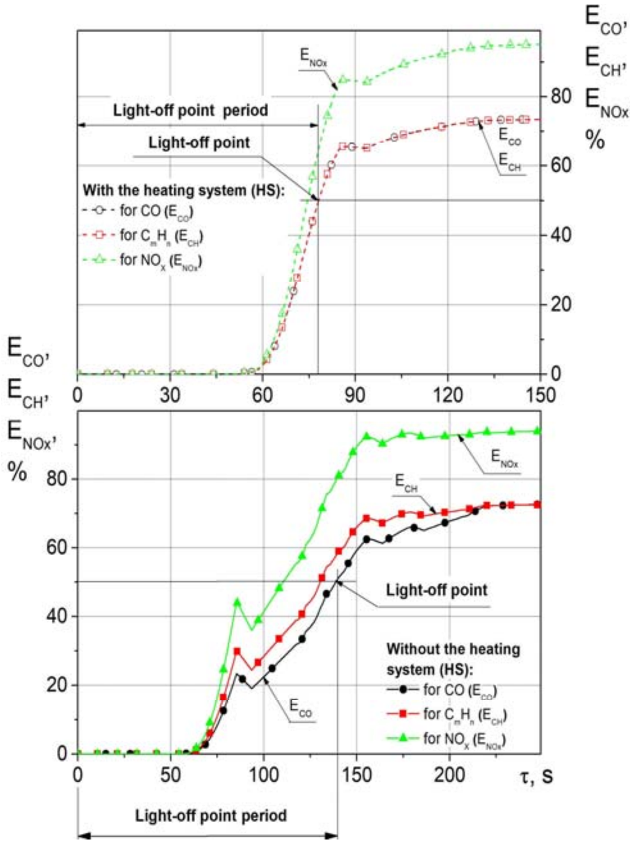

Figure 5 – The dependencies of the CC efficiency during heating of the vehicular engine and the catalytic converter in motion (for the ambient temperature 0 °C)

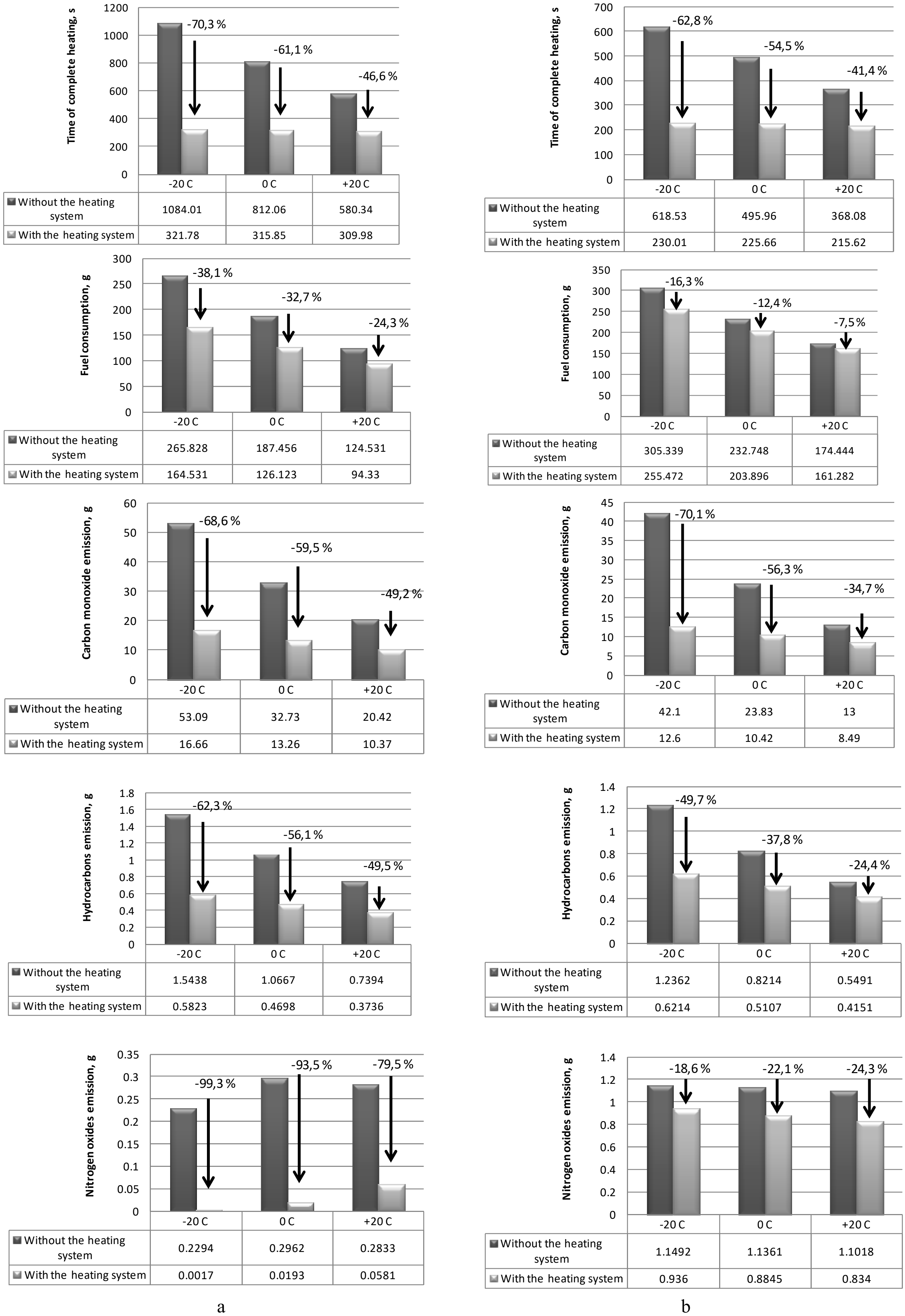

Figure 6 – The results of investigating the efficiency of using the heating system of the vehicular engine and the catalytic converter in different heating modes and at different ambient temperatures (-20 °C, 0 °C and 20 °C): a – heating in an idling mode; b – heating in motion

The obtained dependencies confirm that in an idling mode without the CC heating system the Light-off point is not achieved. Using the heating system in an idling mode the Light-off point is achieved in 171 seconds. For heating mode in motion the use of the heating system decreases the time of achieving the Light-off point from 146.02 to 78.12 seconds or by 46.5 %. Also, when using the heating system for different heating modes, the Light-off point is achieved at different CC temperatures. Without additional heating in motion it is achieved at 638.56 K. With additional heating in an idling mode it is achieved at 526.12 K. When heating in motion it is achieved at 532.55 K. Thus, using the catalytic converter heating system decreases the temperature of achieving the Light-off point by 16.7 %. This effect of changing the temperature of achieving the Light-off point is explained by the fact that the efficiency of cleaning harmful substances depends not only on the CC temperature, but on air-fuel mixture composition. It, in its turn, depends on the coolant temperature. Thus, the coolant temperature for heating mode in motion without using the heating system is less at Light-off point than for heating mode with the heating system (Fig. 3). This is confirmed by the values of the efficiency of nitrogen oxides cleaning at Light-off point in both heating modes. Without the heating system the efficiency of nitrogen oxides cleaning at Light-off point is higher because the air-fuel mixture is richer.

Using the obtained parameters of the vehicular engine and the catalytic converter in different modes of additional heating the data on fuel consumption and harmful emission were received. The received values of fuel consumption and harmful emission are given for the appropriate time period of complete heating in an idling mode and when the vehicle is in motion, with the heating system being not used. They enable to determine the efficiency of additional heating of the engine and the catalytic converter (Fig. 6). Thus for the ambient temperature 0 °C, using the additional heating in an idling mode reduces fuel consumption by 32.7 %, carbon monoxide emission by 59.6%, hydrocarbons emission by 56.1%, nitrogen oxides emission by 93.5%. In the mode of heating in motion fuel consumption is reduced by 12.4%, carbon monoxide emission by 56.3%, hydrocarbons emission by 37.8% and nitrogen oxides emission by 22.1%. So, using the additional heating of the catalytic converter during heating in motion enables to reduce the total nitrogen oxides emission increasing with the use of additional heating only of the engine [1].

The investigation of the heating modes of the engine and the catalytic converter at different ambient temperatures confirmed the growing efficiency of additional heating at lower temperatures (Fig. 6). Further research will be focused on the dependencies between the vehicle coolant heating from thermal accumulator and the catalytic converter heating when using the combined heating system [7] and thermal accumulator under operating conditions.

Conclusions. The rapid after-start heating of the vehicular engine catalytic converter by reducing the time of achieving Light-off point enables to substantially reduce harmful emissions under operating conditions.

The system to improve the processes of the catalytic converter thermal development using phase-transitional thermal accumulators was suggested. The simulation of thermal development processes was carried out with the use of a mathematical model of "vehicular engine - thermal accumulator - catalytic converter" system. It describes the accumulation processes of thermal energy from different sources in thermal accumulators during the engine operation. Within the system the accumulated energy is transferred to the coolant, motor oil and the catalytic converter to provide their optimal temperature condition. It also enables to determine the efficiency of cleaning harmful substances taking into account the peculiarities of catalytic converter heating processes.

The research results confirmed the substantial influence of heating modes on the time of achieving the coolant complete heating, temperature and the time of achieving catalytic converter Light-off point at which the efficiency of cleaning harmful substances was more than 50%. In particular for the ambient temperature 0 °C, with the additional after-start heating the time of complete heating in an idling mode decreases by 61.1% and in the mode of heating in motion it decreases by 54.5%. It was established that in an idling mode without additional catalytic converter heating the Light-off point was not achieved. In the mode of heating in motion using the heating system reduces the time of achieving the Light-off point by 46.5 %.

With the given parameters of the vehicular engine and the catalytic converter in different modes of the additional heating the data on fuel consumption and harmful emissions were received. They enable to determine the efficiency of additional heating of the engine and the catalytic converter. For the ambient temperature 0 °C using the additional heating in an idling mode reduces fuel consumption by 32.7 %, carbon monoxide emission by 59.6%, hydrocarbons emission by 56.1%, nitrogen oxides emission by 93.5%. In the mode of heating in motion fuel consumption is reduced by 12.4%, carbon monoxide emission by 56.3%, hydrocarbons emission by 37.8% and nitrogen oxides emission by 22.1%.

The investigation of the heating modes of the engine and the catalytic converter at different ambient temperatures confirmed the growing efficiency of the additional heating at lower temperatures.

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РЕФЕРАТ

Цюман М.П. Дослідження використання теплового акумулятора для зниження шкідливих викидів автомобільного двигуна шляхом прискореного післяпускового прогріву каталітичного нейтралізатора. / М.П. Цюман, І.В. Грицук, М. Смешек // Вісник Національного транспортного університету. Серія «Технічні науки». Науково-технічний збірник. – К.: НТУ, 2018. – Вип. 3 (42).

У статті розглянуто особливості оцінювання шкідливих викидів автомобільного двигуна в різних режимах прогріву при використанні системи теплової підготовки каталітичного нейтралізатора з тепловими акумуляторами з фазовим переходом.

Об'єкт дослідження – вплив режиму прогріву та температури навколишнього середовища на паливну економічність та шкідливі викиди транспортного двигуна під час використання теплового акумулятора.

Мета роботи – дослідження використання теплового акумулятора для зниження шкідливих викидів автомобільного двигуна шляхом прискореного післяпускового прогріву каталітичного нейтралізатора.

Метод дослідження – аналіз паливної економічності і шкідливих викидів транспортного двигуна під час використання теплового акумулятора на основі результатів експериментального дослідження і математичного моделювання.

Розглянута система використовує теплову енергію з різних джерел автмобільного двигуна під час його роботи, щоб накопичувати її в теплових акумуляторах. Показана функціональна схема теплової підготовки системи "автомобільний двигун - тепловий акумулятор - каталітичний нейтралізатор". Функціональна схема враховує витрату палива, механічну енергію та шкідливі викиди під час роботи автомобільного двигуна, оснащеного системою нейтралізації відпрацьованих газів і системою теплової підготовки з тепловим акумулятором фазового переходу. У статті наведено основні математичні залежності для опису процесів теплової підготовки автомобільного двигуна та каталітичного нейтралізатора при використанні системи теплової підготовки з тепловим акумулятором фазового переходу.

У статті використано результати експериментальних досліджень температурного стану каталітичного нейтралізатора при використанні системи теплової підготовки автомобільного двигуна в різних режимах прогріву.

Чисельний експеримент показав, що без засобів додаткового прогріву швидка теплова підготовка каталітичного нейтралізатора до точки Light-off можлива лише під час руху транспортного засобу.

Використання системи теплової підготовки каталітичного нейтралізатора автомобільного двигуна може зменшити час досягнення повного прогріву транспортного двигуна та точки Light-off каталітичного нейтралізатора на 54,5% -61,1% у експлуатаційних умовах, що змінюються.

Результати статті можуть бути впроваджені у науково-дослідних установах, організаціях, що займаються поліпшенням ефективності експлуатації транспортних засобів, а також підприємствами автомобільного транспорту при використанні систем теплової підготовки транспортних засобів.

Прогнозні припущення щодо розвитку об'єкта дослідження – пошук способів практичної реалізації елементів системи теплової підготовки транспортного засобу в умовах експлуатації.

КЛЮЧОВІ СЛОВА: АВТОМОБІЛЬНИЙ ДВИГУН, ШКІДЛИВІ ВИКИДИ, КАТАЛІТИЧНИЙ НЕЙТРАЛІЗАТОР, ПРИСКОРЕНИЙ ПІСЛЯПУСКОВИЙ ПРОГРІВ, ТЕПЛОВИЙ АКУМУЛЯТОР.

ABSTRACT

Tsiuman M.P., Gritsuk I.V., Smieszek M. Research of use the thermal accumulator for reducing harmful emissions of the vehicular engine by rapid after-start heating of the catalytic converter. Visnyk of National Transport University. Series “Technical sciences”. Scientific and Technical Collection. Kyiv. National Transport University. 2018. Vol. 3(42).

The article examines the peculiarities of evaluating the vehicular engine harmful emissions in different heating modes when using thermal development system of the catalytic converter within phase-transitional thermal accumulators.

Object of the study – the impact of heating mode and ambient temperature on the vehicular engine fuel economy and harmful emissions using the thermal accumulator.

Purpose of the study – research of use the thermal accumulator for reducing harmful emissions of the vehicular engine by rapid after-start heating of the catalytic converter.

Method of the study – analysis of the vehicular engine fuel economy and harmful emissions using the thermal accumulator based on the results of experimental research and mathematical modeling.

The system under review uses thermal energy from different sources of the vehicular engine during its operation to accumulate it in thermal accumulators. The functional scheme of thermal development of the "vehicular engine - thermal accumulator - catalytic converter" system is shown. The functional scheme takes into account fuel consumption, mechanical energy and harmful emissions when operating the vehicular engine equipped with the exhaust gases cleaning system and the thermal development system with phase-transitional thermal accumulator. The article shows main mathematical dependencies to describe the processes of thermal development of the vehicular engine and the catalytic converter when using thermal development system with phase-transitional thermal accumulator.

In the article the experimental research results of the catalytic converter temperature condition when using thermal development system of the vehicular engine in different heating modes are used.

A numerical experiment has shown that without additional heating means rapid thermal development of the catalytic converter to Light-off point is possible only when the vehicle is in motion.

Using thermal development system of the vehicular engine catalytic converter can reduce the time of achieving the vehicular engine complete heating and the catalytic converter Light-off point by 54.5% -61.1% under changing operating conditions.

The results of the article can be incorporated in research institutions and organizations, which improving the efficiency of vehicles operation and road transport enterprises when using thermal development system of the vehicles.

Forecast assumptions about the object of study - searching the ways of practical implementation of the vehicle thermal development system elements under operation conditions.

KEYWORDS: VEHICULAR ENGINE, HARMFUL EMISSIONS, CATALYTIC CONVERTER, RAPID AFTER-START HEATING, THERMAL ACCUMULATOR.

РЕФЕРАТ

Цюман Н.П. Исследование использования теплового аккумулятора для снижения вредных выбросов автомобильного двигателя путем ускоренного послепускового прогрева каталитического нейтрализатора / Н.П. Цюман, І.В. Грицук, М. Смешек // Вестник Национального транспортного университета. Серия "Технические науки". Научно-технический сборник. – К. : НТУ – 2018. – Вып. 3(42).

В статье рассмотрены особенности оценивания вредных выбросов автомобильного двигателя в различных режимах прогрева при использовании системы тепловой подготовки каталитического нейтрализатора с тепловыми аккумуляторами с фазовым переходом.

Объект исследования – влияние режима прогрева и температуры окружающей среды на топливную экономичность и вредные выбросы транспортного двигателя при использовании теплового аккумулятора.

Цель работы – исследование использования теплового аккумулятора для снижения вредных выбросов автомобильного двигателя путем ускоренного послепускового прогрева каталитического нейтрализатора.

Метод исследования – анализ топливной экономичности и вредных выбросов транспортного двигателя при использовании теплового аккумулятора на основе результатов экспериментального исследования и математического моделирования.

Рассмотренная система использует тепловую энергию из различных источников автмобильного двигателя во время его работы, чтобы накапливать ее в тепловых аккумуляторах. Показана функциональная схема тепловой подготовки системы "автомобильный двигатель - тепловой аккумулятор – каталитический нейтрализатор". Функциональная схема учитывает расход топлива, механическую энергию и вредные выбросы при работе автомобильного двигателя, оснащенного системой нейтрализации отработавших газов и системой тепловой подготовки с тепловым аккумулятором фазового перехода. В статье приведены основные математические зависимости для описания процессов тепловой подготовки автомобильного двигателя и каталитического нейтрализатора при использовании системы тепловой подготовки с тепловым аккумулятором фазового перехода.

В статье использованы результаты экспериментальных исследований температурного состояния каталитического нейтрализатора при использовании системы тепловой подготовки автомобильного двигателя в различных режимах прогрева.

Численный эксперимент показал, что без средств дополнительного прогрева быстрая тепловая подготовка каталитического нейтрализатора к точке Light-off возможна только во время движения транспортного средства.

Использование системы тепловой подготовки каталитического нейтрализатора автомобильного двигателя может уменьшить время достижения полного прогрева транспортного двигателя и точки Light-off каталитического нейтрализатора на 54,5%-61,1% в изменяющихся эксплуатационных условиях.

Результаты статьи могут быть внедрены в научно-исследовательских учреждениях, организациях, занимающихся улучшением эффективности эксплуатации транспортных средств, а также предприятиями автомобильного транспорта при использовании систем тепловой подготовки транспортных средств.

Прогнозные предположения о развитии объекта исследования – поиск способов практической реализации элементов системы тепловой подготовки транспортного средства в условиях эксплуатации.

КЛЮЧЕВЫЕ СЛОВА: АВТОМОБИЛЬНЫЙ ДВИГАТЕЛЬ, ВРЕДНЫЕ ВЫБРОСЫ, КАТАЛИТИЧЕСКИЙ НЕЙТРАЛИЗАТОР, УСКОРЕННЫЙ ПОСЛЕПУСКОВОЙ ПРОГРЕВ, ТЕПЛОВОЙ АККУМУЛЯТОР.

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