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EVALUATION OF THE USE OF HYBRID ELECTRIC POWERTRAIN SYSTEM IN URBAN TRAFFIC CONDITIONS

OCENA ZASTOSOWANIA NAPĘDÓW HYBRYDOWYCH W WARUNKACH RUCHU MIEJSKIEGO

The conditions of use of the vehicle significantly affect the performance results. Traffic conditions in a specific city directly affect the consumption of energy, fuel and emissions of harmful compounds in exhaust fumes. Conduction of the measurements of a vehicle's performance parameters in operating conditions is very troublesome and is often not possible to realize. An alternative is to use the simulation programs. Vehicle simulation programs offer options related to vehicle models or drive unit components and allow development of new models. Based on the results of simulation testing, it is possible to analyse the level of fuel and energy consumption as well as emissions of harmful compounds in exhaust gases and the operating effectiveness of the drive system in the speed profile. The paper presents the evaluation of the effectiveness of using hybrid electric drive system in passenger cars in medium-sized city traffic conditions using the Kielce example. The simulation tests were based on the speed profiles recorded during real-world test drives in various times of the day. The simulation results were used to conduct an analysis of fuel consumption and pollutant emissions recorded by conventional and hybrid vehicles.

Keywords: *hybrid electric vehicles, real-world conditions, fuel economy, air pollutants.*

Warunki użytkowania pojazdu mają znaczący wpływ na parametry eksploatacyjne pojazdu. Warunki ruchu w określonym mieście bezpośrednio wpływają na zużycie energii, paliwa i poziom emisji szkodliwych związków zawartych w spalinach. Przeprowadzenie pomiarów parametrów eksploatacyjnych pojazdu w warunkach rzeczywistych jest kłopotliwe i często niemożliwe do zrealizowania. Alternatywą jest wykorzystanie symulacji komputerowych. Programy do symulacji pojazdów oferują, między innymi, modele pojazdów lub komponentów układu napędowego oraz pozwalają na opracowanie nowych modeli. Na podstawie wyników badań symulacyjnych możliwa jest analiza poziomu zużycia paliwa, energii, emisji szkodliwych związków zawartych w spalinach oraz efektywności pracy układu napędowego w profilu prędkości. W niniejszej pracy przedstawiono ocenę efektywności zastosowania napędów hybrydowych w samochodach osobowych w warunkach ruchu miasta średniej wielkości na przykładzie Kielc. Do badań symulacyjnych wykorzystano profile prędkości, zarejestrowane podczas rzeczywistych przejazdów w różnych porach dnia. Na podstawie wyników symulacji przeprowadzono analizę zużycia paliwa oraz emisji zanieczyszczeń, zarejestrowanych dla pojazd z napędem konwencjonalnym oraz pojazdów z napędem hybrydowym.

Słowa kluczowe: *hybrydowe układy napędowe, rzeczywiste warunki jazdy, zużycie paliwa, emisja.*

1. Introduction

Vehicles equipped with hybrid drive system are becoming more and more popular. The technological solutions used in them are subject to continuous development. Both individuals and companies are increasingly willing to purchase this type of vehicles. One of the advantages of purchasing a hybrid is mainly the lower fuel consumption in comparison to conventional vehicles, which translates into lower maintenance costs [5, 15, 21].

Recognition and specification of the operating conditions of a hybrid vehicle allows for more precise estimation of fuel and energy consumption as well as emissions of harmful compounds in exhaust fumes. This is important, because the traffic intensity and type of road (city centre streets, suburban streets, highways), topography or ambient temperature affect the values of the aforementioned performance parameters. Research paper [23] features a study of the impact of the aforementioned factors on the effectiveness of using hybrid vehicles in the traffic conditions of the Quebec province (Canada). The authors collaborated with 95 vehicle owners: 74 – with conventional drive units equipped with gasoline engines and 24 – with hybrid drive units. The vehicles were fitted with instrumentation (data loggers) that recorded the instant speed, fuel consumption and idle downtimes. The data was collected for a year. The presented results demonstrated that the fuel consumption in operating conditions recorded by the hybrids were 28% lower on average than in the case of conventional vehicles. Works [2, 22] present the methodology of selection of the optimal vehicle hybrid system by studying the mobility and travel tendencies of the analysed city's residents. The data was collected by mounting GPS recorders in private vehicles for 1-18 months. The conducted studies and the analysis of the data collected allowed for estimating the average energy used per test drive. The calculations were used to determine the energy capacity of the hybrid vehicle's energy storage and distribution of the charging stations.

The ability to study the operating parameters of a vehicle in specific conditions is very troublesome. Due to the above, there is a need to use other methods of conducting the measurements. The estimation of energy consumption, emissions of harmful substances in exhaust gases or fuel consumption of the selected vehicle in specific driving conditions can be conducted during stationary tests on a chassis dynamometer or obtained as result of simulation conducted using vehicle simulation computer programs. Firstly, it is necessary to determine the vehicle's operation conditions. One of the methods of reflecting vehicle performance is the speed profile recording during the real-world test drive. The recording is usually conducted using the GPS satellite navigation system receivers mounted in the vehicle. The obtained speed profile reflects the dynamic properties of the selected vehicle in specific conditions. The examples and methodology of conducting measurements in real-world conditions can be found in the following works [6, 12, 16].

Another method of representing the real-world traffic conditions of a specific city or region is to develop a driving cycle. It is the speed profile consisting of the sequences of acceleration, constant speed driving, braking and idling time. The cycle is substantially affected by: infrastructure, e.g. distribution and set-up of traffic lighting, type of intersections, distribution of bus stops, type of road (urban, suburban, highway), the route's vertical profile as well as the traffic intensity. The methodology of the drive cycle structures based on the speed profiles of real-world test drives is specified in a broader manner in the following works [4, 10, 11, 25]. Recorded speed profiles or developed drive cycles can be used for testing vehicles on a chassis dynamometer or in simulation testing.

The aim of this paper was to evaluate the effectiveness of hybrid passenger cars equipped with batteries of different capacities. The analysis was based on the simulation carried out using the speed profiles collected in real-world condition in various times of the day.

2. Vehicle test methods

Chassis dynamometers allow for simulating the vehicle's drive unit operating conditions in stationary conditions. The essence of the dynamometer's operation is the replacement of a static road pavement by a movable track. Smooth speed adjustment and motion resistance allows for conducting tests in steady and transient states. As result of the tests conducted with the use of the chassis dynamometer, it is possible to obtain an evaluation of the drive unit's technical condition, fuel consumption and emission of toxic compounds included in exhaust gases using additional instrumentation (e.g. the AFR – Air to Fuel Ratio sensor). The measurement can also utilize the On-Board Diagnostics. The advantage of conducting tests on a chassis dynamometer is ensuring the repeatability of measurements and the ability to check the vehicle in the conditions of particular load which is difficult to obtain during normal operation.

When conducting tests on a chassis dynamometer, it is possible to realize any selected speed profile. It allows for testing the fuel consumption and emission of harmful compounds included in exhaust gases in specific drive conditions. Using the results of tests conducted on a chassis dynamometer, the authors of papers [3,18] have compared the fuel consumption and emissions in speed profiles reflecting urban, suburban and highway driving. Research paper [9] presents fuel consumption and CO emission values recorded by a hybrid vehicle during chassis dynamometer tests. The testing was conducted based on the standard ECE-15 cycle and the Loughborough University Urban Drive Cycle (LUUDC) developed on the basis of real-world test drives. The measurement results demonstrated fuel consumption higher by 12% in the LUUDC cycle than in the ECE-15 cycle.

Vehicle testing on a chassis dynamometer allows comparison of the fuel consumption and emission of harmful substances included in exhaust gases for vehicles with various types of drive systems. For example, paper [17] presents the analysis of fuel consumption as well as CO and NO_x emissions of hybrid and conventional delivery trucks. The testing was conducted on a chassis dynamometer. The studies were carried out using the drive cycle developed on the basis of real-world operating routes of vehicles from one of the companies dealing in package deliveries in Los Angeles (USA). The presented analyses show that in the set speed profiles, hybrid vehicles demonstrate lower CO and NO_x emissions by as much as 43.9% when compared to conventional vehicles. Hybrids also demonstrate lower fuel consumption by as much as 59.8%.

During chassis dynamometer tests, it is also possible to evaluate the impact of ambient temperature of the drive system's operating parameters. Paper [8] features the estimation of the impact of temperature on energy consumption and range of an electric vehicle. The testing featured three electric passenger cars. Tests conducted on a chassis dynamometer in the temperature of -20°C demonstrated increased energy consumption of up to 9% when compared to energy consumption during testing in the temperature of +23°C. It was estimated that in the Finnish Road Cycle carried out in the temperature of -20°C, the range of an electric vehicle decreased by 51% in comparison to the range specified by the manufacturer.

Another method that allows estimating the vehicle's operating parameters in specific driving conditions is simulation testing. Computer programs and software provide the ability of modeling and simulating new solutions in vehicles drivetrain without the need to construct prototypes. A hybrid drive is a complex system that combines electrical, mechanical, electrochemical and electronic components. The tools intended for modeling and simulation of hybrid drive support complex interactions between the drive unit's mechanical and electrical elements. The functionalities of vehicle modeling and simulation programs allow for using existing solutions and available vehicle models, drive units and their elements or developing new concepts and models. The most popular programs intended for simulating hybrid vehicles are: AVL Cruise, Autonomie/PSAT, GT-SUITE, LMS AMESim, ADVISOR, DYNA4 Advanced Powertrain.

Computer simulation programs allow for analyzing the operation of particular drive unit components in the set drive profile. They allow conducting simulation testing in terms of analyzing the dynamics (e.g. ability to accelerate, overcome elevations, reach maximum speed); forecasting, evaluation and optimization of fuel consumption; analyzing the control system and diagnostics; analyzing the structure's cohesion to facilitate the testing and validation of components; preliminary evaluation and analysis of a new concept or solution; estimation of predicted emission.

The vast majority of simulation programs allows for implementing customized drive cycles. This allows analyzing the level of fuel and energy consumption as well as emissions of harmful compounds in exhaust gases and the operating effectiveness of the drive system in real-world traffic conditions. Research papers [14,19] present the comparison of fuel consumption and emission of harmful compounds included in exhaust gases. The simulation testing of vehicles with various type of drivetrain was conducted in drive cycles based on real-world test drives. Paper [7] presents the model of a hybrid commercial vehicle developed in the Autonomie program. The simulation was carried out using the speed profiles recorded during real-world operating routes. The author demonstrated the impact of the vehicle's load on the fuel consumption in the analyzed operating cycles.

Vehicle simulation tests allow for analyzing the operating effectiveness of particular drive elements. By using the vehicle simulation programs, it is possible to conduct an evaluation and determine the operating characteristics of the following:

- combustion engine,
- exhaust gases treatment system,
- cooling system,
- temperature distribution among the drive system's components,
- lubrication system,
- fuel injection system,
- hydraulic and pneumatic systems,
- analysis of the energy storage performance,
- electric engine,
- energy management system.

The paper [1] presents an analysis of the performance parameters of a combustion engine as well as the fuel consumption and CO_2 emissions of vehicles with conventional and parallel hybrid drive. The simulation was conducted for three standard cycles: UDDS, FTP and US06HWY, as well as for the drive cycle developed for the city of Baqubah (Iraq). The presented results demonstrate that the use of a hybrid drive in the driving conditions of the analyzed city can reduce fuel consumption by up to 68%. Paper [13] presents the simulation results of conventional, series hybrid and plug-in hybrid vehicle in the drive cycle developed for Kansas (USA). The authors conducted a comparative analysis of fuel consumption and the performance of the energy storage in the analyzed driving conditions. Work [24] presents an analysis of the effectiveness and the operating parameters of selected elements of a city bus' hybrid drive. The simulation testing was conducted in the AVL Cruise program by using the speed profile recorded during an real-world test drive of a city bus in Madrid (Spain). Paper [20] presents an analysis of operation of a plug-in hybrid vehicle's energy storage. The purpose of the simulation was to investigate various methods of battery charging and configuration of the energy management system.

3. Research methodology

3.1. Tests in real-world conditions

Kielce is a medium sized city located in south-central part of Poland. The measurement route went along centre streets in the city of Kielce. The length of the test route was 5.4 km. The route and its vertical profile was presented on Fig. 1. The route started in the point marked as A, went through dual carriageway streets and ended in point B. Due to the city's location in upland areas, the route was characterized by a rather substantial disparity in elevation that amounted to approx. 35 m. The route's maximum gradient of the road amounted to 6%.

The test vehicle was Ford Transit. The recording of the movement parameters was done by using measurement equipment mounted in the vehicle, consisting of:

– the S-350 Aqua Datron® optoelectronic sensor for measuring longitudinal speeds (Fig. 2a),
– the uEEP-12 Datron® data acquisition station (Fig. 2b), with the ARMS® data analysis software.
– GPS DATA LOGGER KISTLER® (Fig. 2c),
– the TAA Datron® three-directional linear acceleration sensor.

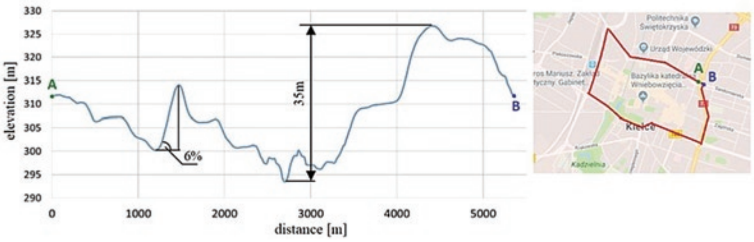

Fig. 1. Location and elevation profile of the test route

Fig. 2. Measurement equipment used to conduct the tests in real-world conditions

The test vehicle was equipped with vehicle tracking system using global positioning system (GPS) and the system for mobile communication (GSM) produced by Globtrak company. System provided detailed information of location, speed, and fuel consumption of the vehicle. Its functionalities allow management of the vehicle fleet and monitoring of the drivers.

The recording of the real-world vehicle movement parameters was conducted during test drives on a working day in four selected times of day: morning, noon, afternoon and evening. During the tests the following parameters were recorded: instantaneous speed, instantaneous acceleration and deceleration, drive time, distance travelled, instantaneous vehicle location. An exemplary speed profile, recorded during a test drive in the morning, between 7:00 - 8:00 A.M., is presented in Fig 3.

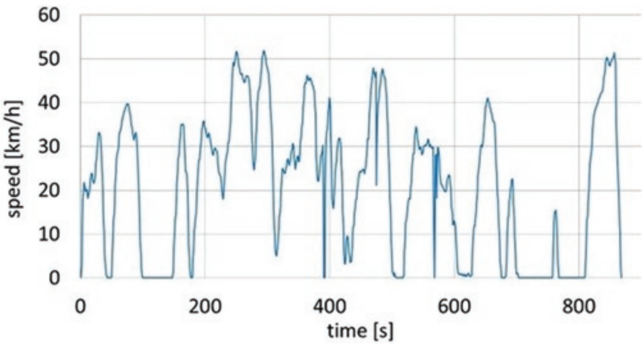

Fig. 3. Exemplary speed profile recorded during a test drive between 7:00 and 8:00 A.M.

As demonstrated on the chart in Fig. 3, in urban traffic conditions, the movement parameters (e.g. instantaneous speed) change quite substantially. The recorded speed profiles change depending on the time of day. Large traffic intensity during the morning (9:00-10:00 A.M.) and afternoon (3:00-4:00 P.M.) rush hours elongates the travelled time. Driving is more smooth during other times of day and is characterized by higher average speed. The selected parameters of the recorded test drives are presented in Tab. 1.

Based on the conducted measurement studies, it is possible to state that test drives during morning and noon hours are characterized by similar average speed and similar travelled time. During the afternoon rush hours (3:00-4:00 P.M.), the average speed is clearly lower and the share of stop phase amounts to 40% of the total time of test drive. In late afternoon (6:00-7:00 P.M.) or evening (8:00-9:00 P.M.), after the rush hours, the time of test drive is substantially shorter, which results in an increase in the average speed. The test drives are characterized by high smoothness, which is caused by lower traffic intensity. They feature an increase in average speed and the share of stop phase can constitute little more than 9% of the total time of test drive.

3.2. Simulation tests

The speed profiles recorded during real-world measurements tests were implemented into the vehicle simulation program – ADVISOR (ADvanced Vehicle SImulatOR). The program operates in the Matlab/Simulink. ADVISOR is a popular tool for simulating vehicles with various drive configurations. It was developed by the scientists from the American National Renewable Energy Laboratory (NREL). The program features built-in models of vehicles with conventional, series and parallel hybrid, electric and hydrogen cell drive.

With the use of complex database, the user develops vehicle model with the help of drop-down menus in the dialogue box. Firstly, the user selects the vehicle type, drive system and particular elements of the drive by specifying their capacity, efficiency and weight. Then, the

Table 1. Selected parameters of the recorded test drives

	7:00-8:00 A.M.	9:00-10:00 A.M.	11:00-12:00 A.M.	3:00-4:00 P.M.	6:00-7:00 P.M.	8:00-9:00 P.M.
time [s]	868	942	921	1073	773	593
average speed [km/h]	22.06	21.83	22.40	18.05	24.75	33.08
stop phase duration [s]	212	264	282	424	152	56
percentage time of stop phase in total travelled time [%]	24.40	28.00	30.60	39.50	19.70	9.40

user selects the drive cycle. With the assumed drive unit configuration and specified drive cycle, the program estimates the energy consumption and the performance of analysed type of drive train. Fig. 4 presents a parallel hybrid vehicle model developed in the ADVISOR.

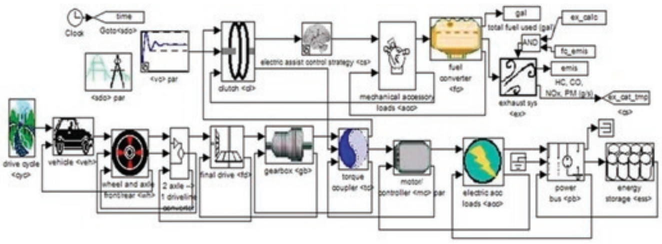

Fig. 4. Model of parallel hybrid vehicle in ADVISOR

ADVISOR allows to modify the models by importing files with the vehicle's data, characteristics and parameters of the drive components and energy storage or developing and implementing new models. It is also possible to add new drive cycle by importing files with such parameters as speed determined as a function of time or road elevation profile determined as a function of road distance.

The vehicle models available in the ADVISOR program were modified and passenger car models with conventional and parallel hybrid (HEV) drive were developed. The front area of the analysed vehicles amounts to 2.66 m^2, rolling resistance coefficient amounts to 0.009 and the aerodynamic resistance coefficient amounts to 0.44. For all simulation cases, the curb weight was 1,200 kg increased by a load of 150 kg was used. In the case of a hybrid vehicle, the weight was additionally increased by the battery weight. The selected parameters of the vehicles used in the simulation are presented in Tab. 2.

Table 2. Parameters of vehicles used in simulation tests

	Conventional	HEV			
engine power [kW]	96	74			
electric machine power [kW]	-	62			
battery capacity [kWh]	-	8,8	6,5	4,6	2,2
weigh [kg]	-	127	95	64	32

In the case of the hybrid vehicle (HEV), simulation was conducted for various capacities of energy storages. The initial battery state of charge prior to any trip amounted to 70%.

The fuel consumption results obtained from simulation of conventional vehicle were compared with data derived from vehicle monitoring system based on GPRS and GPS technology – Globtrak. The fuel consumption values acquired from ADVISOR indicated values nearly 10% higher than those given by Globtrak system.

4. Results

Based on the results of simulation of selected vehicles, the following parameters were used for further analysis: average fuel consumption and emission: PM_x, CO and NO_x. Exemplary simulation results are presented in Fig. 5 and Fig. 6. They include the instantaneous emission of PM_x, CO and NO_x as well as fuel consumption during a test drive at 3:00-4:00 P.M.

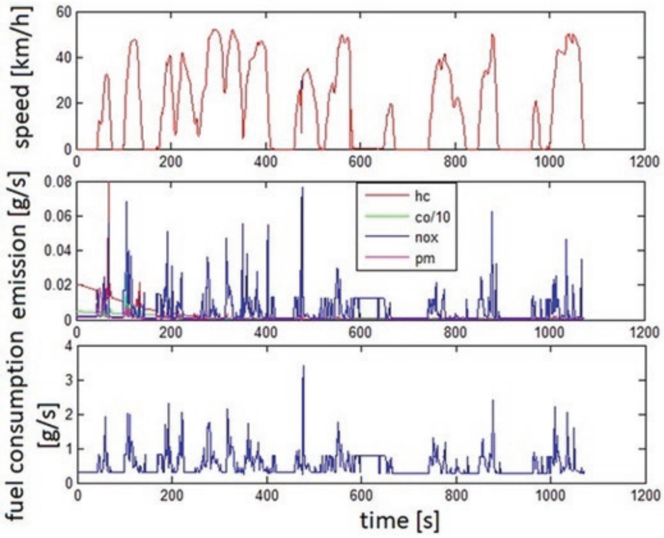

Fig. 5. Results of simulations of a conventional drive unit for the test drive at 3:00-4:00 P.M.

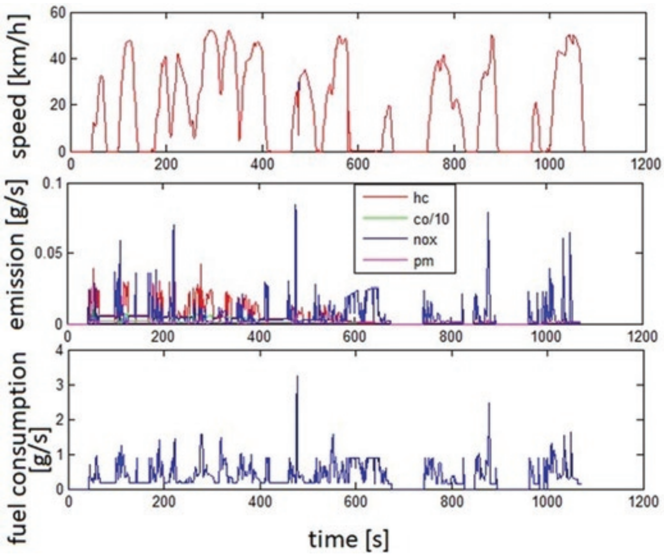

Fig. 6. Results of simulations of a hybrid drive unit with battery capacity of 8.8 kWh for the test drive at 3:00-4:00 P.M.

The average fuel consumption of the analysed vehicles is presented in Fig 7. Regardless of the time of day, the conventional vehicle recorded the highest average fuel consumption.

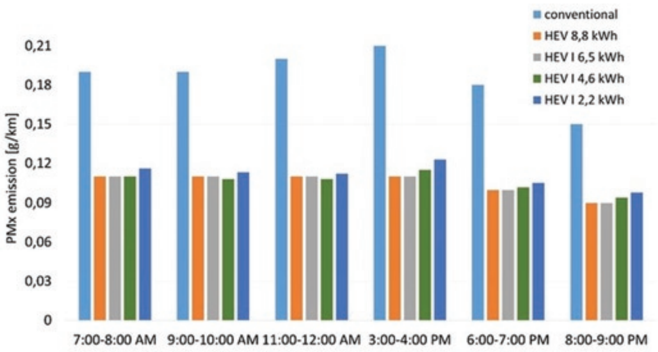

Fig. 7. Average consumption during the analysed test drive

The average fuel consumption obtained by hybrid vehicles clearly demonstrate that the higher the energy storage capacity is, the lower is the fuel consumption. In the analysed cases, the hybrid vehicle, equipped with energy storage system with the capacity of 8.8 kWh, recorded lower fuel consumption by 24% on average in relation to a conventional vehicle. It is worth noting that the differences in average fuel consumption recorded by hybrid and conventional vehicles were the highest during test drives at 3:00-4:00 P.M. It is caused by the road conditions. During the stop time, HEV using the electric engine only, did not used fuel, thereby the idling was eliminated. At that time there was no emission of harmful substances included in exhaust gases. Percentage reduction of the fuel consumption of the hybrid vehicle in comparison to a conventional vehicle in analysed test drives is presented in Tab. 3.

Fig. 8 presents the emission of particulate matter (PM_x) obtained as result of the simulations of hybrid and conventional vehicles. The highest PM_x emission during test drives in the analysed times of day were recorded for the conventional vehicle. In the case of hybrids, the values were similar in each of the analysed test drives.

The lowest emission of particulate matter was recorded during test drives in the afternoon and evening (6:00-7:00 P.M. and 8:00-9:00 P.M.). In comparison to conventional vehicles, hybrid vehicles demonstrated even 42% lower PM_x emission on average (Tab. 4). It is worth noting that the biggest differences in particulate matter emission recorded by hybrid and conventional vehicles took place during test drives at 3:00-4:00 P.M. At that time, the hybrids demonstrate lower PM_x emission by up to 48%.

Fig. 9 presents the CO emission, obtained as the simulation result, recorded for the analysed vehicles. The highest CO emission in the analysed road conditions was demonstrated by the conventional vehicle.

Table 3. Percentage reduction in hybrid vehicle fuel consumption in comparison to a conventional vehicle

	HEV 8,8 kWh	HEV 6,5 kWh	HEV 4,6 kWh	HEV 2,2 kWh
7:00-8:00 A.M.	24%	24%	22%	16%
9:00-10:00 A.M.	25%	24%	21%	16%
11:00-12:00 A.M.	24%	23%	22%	17%
3:00-4:00 P.M.	28%	26%	25%	17%
6:00-7:00 P.M.	22%	21%	20%	15%
8:00-9:00 P.M.	21%	20%	19%	15%
average	24%	23%	22%	16%

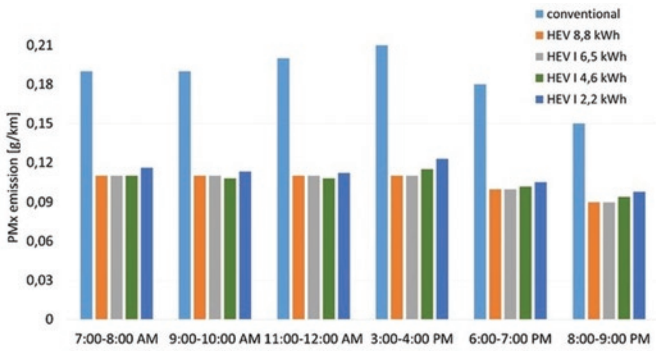

Fig. 8. PMx emission during test drives at specific times of day

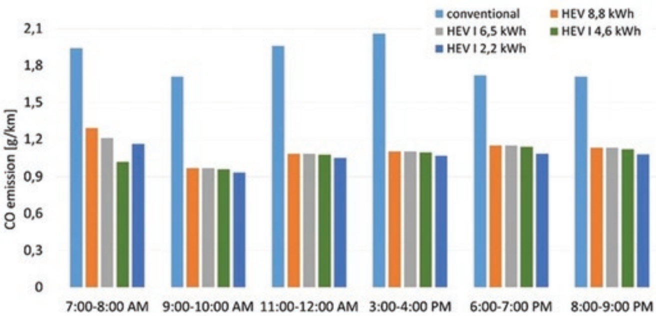

Fig. 9. CO emission during trips at specific times of day

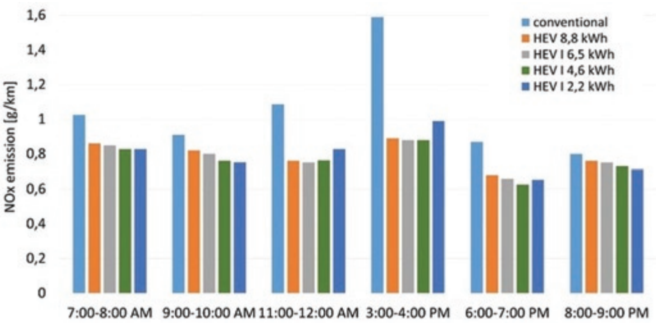

Fig. 10. NO_x emission during trips at specific times of day

In each of the analysed test drives, the hybrid vehicles demonstrated substantially lower CO emissions, regardless of the energy storage capacity. The lowest carbon oxide emissions were recorded during the afternoon test drive (Tab. 5). During the test drive at 3:00-4:00 P.M., the CO emissions recorded by the hybrids were lower by 42% in comparison to the conventional vehicle.

Fig. 10 presents the nitrogen oxides emission during test drives in the selected times of day. The conducted simulation tests demonstrate that in each of the analysed test drives, the highest NO_x emission was achieved by the conventional vehicle. The traffic conditions substantially affect the nitrogen oxide emission. This is especially clear in the case of the conventional vehicle. The NO_x emission achieved during the test drive at 3:00 – 4:00 P.M. is nearly twice as high as during the evening test drive at 8:00-9:00 P.M.

The hybrids demonstrate a 16-19% lower NO_x emission on average in comparison to the conventional vehicle (Tab. 6). It is worth noting that the nitrogen oxides emissions change depending on the traffic conditions. When comparing the NO_x emission achieved by the hybrid and conventional vehicles, the smallest differences occur during test drives with relatively small traffic intensity. The biggest differences can be observed during test drives in the afternoon rush hours (3:00-4:00 P.M.). The nitrogen

Table 4. Percentage reduction in a hybrid vehicle's PM_x emission in comparison to a conventional vehicle (conventional PMx = 100%)

	HEV 8,8 kWh	HEV 6,5 kWh	HEV 4,6 kWh	HEV 2,2 kWh
7:00-8:00 A.M.	42%	42%	42%	39%
9:00-10:00 A.M.	42%	42%	43%	41%
11:00-12:00 A.M.	45%	45%	46%	44%
3:00-4:00 P.M.	48%	48%	45%	41%
6:00-7:00 P.M.	44%	44%	43%	42%
8:00-9:00 P.M.	40%	40%	37%	35%
average	42%	42%	42%	39%

Table 5. Percentage reduction in a hybrid vehicle's CO emission in comparison to a conventional vehicle (conventional CO = 100%)

	HEV 8,8 kWh	HEV 6,5 kWh	HEV 4,6 kWh	HEV 2,2 kWh
7:00-8:00 A.M.	34%	38%	47%	40%
9:00-10:00 A.M.	43%	43%	44%	45%
11:00-12:00 A.M.	45%	45%	45%	47%
3:00-4:00 P.M.	47%	47%	47%	48%
6:00-7:00 P.M.	33%	33%	34%	37%
8:00-9:00 P.M.	34%	34%	35%	37%
Average	34%	38%	47%	40%

Table 6. Percentage reduction in a hybrid vehicle's NO_x emission in comparison to a conventional vehicle (conventional NO_x = 100%)

	HEV 8,8 kWh	HEV 6,5 kWh	HEV 4,6 kWh	HEV 2,2 kWh
7:00-8:00 A.M.	16%	17%	19%	19%
9:00-10:00 A.M.	10%	12%	16%	17%
11:00-12:00 A.M.	30%	31%	30%	24%
3:00-4:00 P.M.	44%	45%	45%	38%
6:00-7:00 P.M.	22%	24%	28%	25%
8:00-9:00 P.M.	5%	6%	9%	11%
Average	16%	17%	19%	19%

oxide emission recorded by the hybrids at that time is lower by up to 45% in comparison to the conventional vehicle.

5. Conclusion

The presented results demonstrate that the biggest differences in the emission and the average fuel consumption between the conventional and hybrid vehicles occur during the afternoon rush hours (3:00-4:00 P.M.). During that specific test drive, as much as 40% of the total test drive times are stop phases. The use of an electric engine in hybrid vehicles eliminated the idling. Thanks to this solution, hybrids do not emit harmful exhaust gases compounds during a stop phase. The presented results demonstrated that the use of a hybrid drive contributes substantially to the reduction in fuel consumption and emission. This applies especially when driving with low speed in high traffic intensity conditions.

The energy capacity of the battery used in the hybrid drive significantly affects the vehicle's performance parameters. The higher is the capacity of the energy storage devices, the bigger amount of the energy electric drive delivers for traction purposes. This translates into lower fuel consumption and emissions.

The conducted simulations confirm the possibility of verifying the effectiveness of use of a hybrid vehicle with specific parameters in relation to the specificity of a particular city traffic condition. This can facilitate specific configuration of an hybrid drive system to make its use as optimal as possible in terms of emission and fuel consumption in real-world conditions.

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