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# The perspectives of “mild hybrid” technology for creation of vehicle hybridization system

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***Abstract. Problem.*** *At the present stage of science and technology development the problem of creating energy efficient vehicles is solved by electric vehicle designing: electromobiles and hybrid vehicles. Despite perspectives of a battery electric vehicles, it could be complied with a “Zero Emissions” criterions only in case if the electricity is generated from renewable sources. In addition, electric vehicle may not always provide the desired range on charge. Lithium-ion batteries are now used to power the electric drive, and an important problem of that is a significant weight which vehicle have to carry, it is also necessary to balance their elements, which significantly increases the charging time from the external mains.* ***Goal.*** *The goal of the work is to develop the theoretical basis for the creation of a system for the conversion of the "mild hybrid" vehicles in operation.* ***Methodology.*** *Many countries cannot afford to make the rapid transition to renewable electricity and replace the fleet with electric vehicles. Instead, a faster effect can be obtained if you re-equip vehicles that are already in use to hybrids. To successfully fulfill this goal, it is necessary to justify the parameters of the hybridization system of vehicles in order to obtain significant energy efficiency with a favorable payback period.* ***Results.*** *The analysis of hybrid classification and drive architecture allowed to offer new functions for "micro hybrid" and "mild hybrid" technologies. Analysis of power losses during the movement of the vehicle allowed to predict the number and power of electric motors sufficient to perform new functions.* ***Originality.*** *The structural scheme of the hybridization system of the motor vehicle which provides its conversion into a hybrid is developed. The study is aimed primarily at improving the "mild hybrid" technology in which electric motors of relatively low power, which are not inherent in this technology, are proposed to partially implement the functions inherent in the technology of "full hybrid".* ***Practical value.*** *The combination of the features of "micro hybrid" and "full hybrid" technologies in "mild hybrid" technology should provide sufficient energy efficiency, ease of installation of the system equipment and low costs.*

***Key words:*** *vehicle, “mild hybrid”, maintenance of constant movement, rational modes of movement, electric drive with frequency control, energy efficiency.*

## Introduction

At the present stage of science and technique development the problem of creation energy efficient vehicles is solving by electric vehicle creation: electromobiles and hybrid vehicles [1]. Despite perspectives of a batteries electric vehicles it could be complied with a “Zero Emissions” criterions only in case if the electricity is generated from renewable sources.

In terms of obtaining electricity from fossil fuels at CHP, hybrid vehicles, which are built as a serial hybrid, has the same level of pollution as battery electric vehicles [2], [3]. Lithium-ion batteries are now used to power the electric drive, and important problem of that is a significant weight which vehicle have to carry, it is also necessary to balance their elements, which significantly increases the charging time from the external mains [4]. Developers of hybrid vehicles don’t have a single approach to create a scheme and structure of hybrid power units [5]. An important problem is the comparison of energy efficiency of hybrid, electric and conventional vehicles, as well as the development of methods for determining the energy costs of electric and hybrid vehicles [6], [7], [8]. In recent years, a new class of hybrid cars has appeared and is developing - "mild hybrid" [3]. Such “mild hybrid” vehicles are quite promising and economically attractive development of road transport for the period of transition from internal combustion engines to mass electric drive. Well-known car manufacturers are now following this path [9], offering, together with battery electric cars, hybrids that built on various technologies. It should be noted the possibility of expanding the functionality of such systems as "Start-Stop". For instance, the German manufacturer of automotive components is considering the wider use of rolling mode and recuperation due to the use of automatically controlled clutch [10].

## Analysis of publications

The classification of hybrid vehicles is considered in scientific articles [11] and improved by scientists who offer new approaches to their creation [12].

According to the location of the electric motor in the internal combustion engine (ICE) and vehicle's transmission, built on the technology of "mild hybrid" have the greatest variety (see Fig. 1) [11] and are divided into:

– architecture P0 (Electric machine is located on the front of the engine and has a belt drive. For efficiency and durability requires a special tensioning mechanism);

– architecture P1 (Electric machine integrated in the moving parts of the crank mechanism of the ICE, usually in the place of the flywheel. Performs the function of starter and generator);

– architecture P2 (The electric machine is connected to the primary shaft of the gearbox. It can have any drive.);

– P3 architecture (The electric machine is connected to the secondary shaft of the gearbox. It can have any drive.);

– P4 architecture (The electric machine is connected to the drive of the wheels. It can have any drive. It can be in the form of a motor wheel).

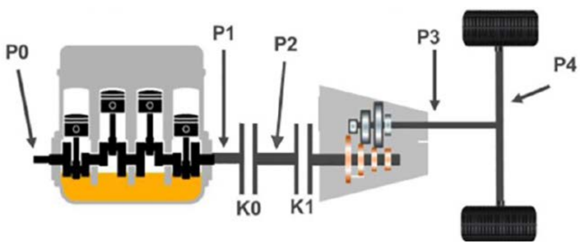


Fig. 1. Hybrid vehicle transmission architecture based on electric machine location [11]

Another classification measurement is based on the power of the electric machine installed in the vehicle. According to the power of the electric machine, the corresponding functions can be implemented. Technologies for hybrid cars make it possible to use new functions in the operation of vehicle by adding one or more electric motors, for example:

– Start - Stop function;

– braking energy recuperation;

– ICE assistance (change of ICE operating point and acceleration);

– electric traction movement;

As shown in Figure 2 [13], the set of functions aimed at helping the internal combustion engine form:

– micro hybrid;

– mild hybrid.

The set of functions aimed at fully ensuring the movement of the vehicle by means of an electric motor or the movement is limited by certain conditions form:

- full hybrid;
- plug in-hybrid;
- hybrids with extended range.

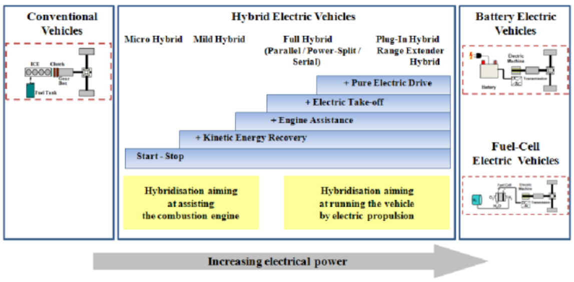


Fig. 2. Classification of hybrids according to the European road map [13]

The Start-Stop function allows you to stop the ICE during short-term stops in the city at traffic lights or traffic jams. The engine is started and stopped automatically without the driver's participation. Thereby, the ICE does not work in modes when there is no need for mechanical energy to move the car. The use of this function is limited by the conditions of providing rational modes of units and components of the car and the ICE itself. In addition, the efficiency of the Start-Stop function increases with increasing number of stops along the route, which indirectly encourages the driver to accelerate more intensively and move at the maximum allowed speed to reduce the time on the route.

The braking energy recuperation function provides charging of the battery with electric power while driving in the run-in mode or braking before stopping or when reducing the speed due to the use of kinetic energy of the vehicle, as well as potential energy when driving downhill. The possibilities of energy recovery are limited by the characteristics of the electric machine operating in the generator mode, the capabilities of electronic converters operating in the recovery process and the ability of the battery to charge quickly.

The function of changing the operating point helps the ICE in transient modes when gaining speed or when increasing the load. In addition, the motor has less delay in response to changes in the position of the accelerator, which increases the comfort of movement.

The vehicle acceleration function promotes a more intensive set of speeds by adding torques of the ICE and the electric motor or provides unloading of the ICE during acceleration. Due to both results, emissions of harmful substances and fuel consumption are reduced. The action of the function is limited by the acceleration time during which an additional electric motor is used [14].

Accordingly, for the implementation of these functions at the level of technology "mild hybrid" there are two configurations - "mild hybrid" and "mild hybrid plus" [13], which are equipped with appropriate equipment to provide the necessary functions. For vehicle category M1, the corresponding values of the characteristics of hybrids are given below.

The "mild hybrid" configuration provides for the use of a rechargeable battery in the range of 60 - 120 V and a starter-generator with a power in the range of 8 - 14 kW. This gives the potential to reduce $CO_2$ emissions by 4% - 9% [13].

The "mild hybrid plus" configuration provides for the use of a rechargeable battery in the range of 60 - 280 V and a starter generator with a power in the range of 8 - 30 kW. This gives the potential to reduce CO2 emissions by 7% - 14% [13].

## Purpose and Tasks

The goal of the work is to develop the theoretical basis for the creation of a system for the conversion a vehicles in operation to a "mild hybrid".

To solve this goal it is necessary, to propose a block diagram of the system for converting vehicles into "mild hybrid" based on the analysis of the existing classification of hybrids and functions of vehicles built on "mild hybrid" technology and to justify the power electric motor and architecture of a hybrid vehicle based on the analysis of power losses on vehicle resistance.

## Calculation of power expended on drag for vehicles of different categories

In accordance with the classical traction calculation [18], we determine the power expended on the resistance to the movement of different vehicles categories. The total power of the resistance to motion is defined as the sum $N_\psi$ and $N_w$ (see. Fig. 3).

The analysis of literature sources [19], [20] makes it possible to estimate the statistical limit of accelerations at different gears and speeds for vehicles of the respective categories.

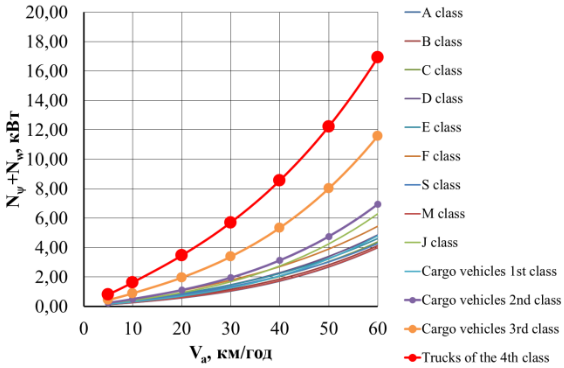


Fig. 3. Comparison of power of resistance of movement of the motor vehicle of various classes

The average level of acceleration for trucks and cars is proposed to be reproduced using exponential dependence (1) [19]:

$$j = k_1 \cdot e^{k_2 \cdot V_a} \qquad (1)$$

where $k_1$ – coefficient (for trucks - 0.667, for passenger cars with diesel ICE - 2.38, for passenger motor vehicles with petrol ICE - 2.5); $k_2$ – coefficient (for trucks – -0.13, for passenger cars with diesel ICE– -0.1, for passenger motor vehicles with petrol ICE – -0.09).

Figures 4, 5 and 6 [19] show experimentally determined values of accelerations of the different vehicles categories and their average values.

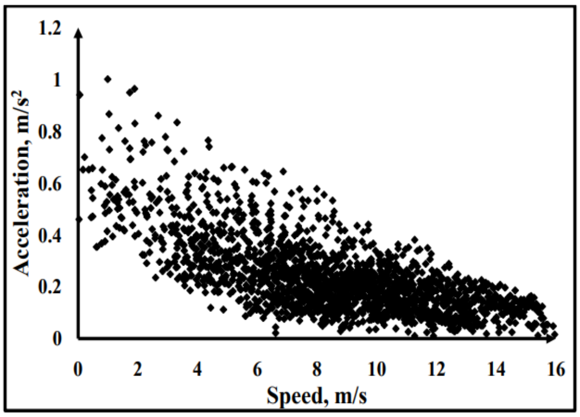


Fig. 4. Distribution of accelerations by velocities for trucks [19]

So, using the average acceleration levels calculated by formula (1), it is possible to determine the required power to ensure the acceleration of the vehicle at a certain speed during acceleration (see Fig. 7).

If you analyze not only the acceleration, but also the entire movement route, the picture of the accelerations distribution will be completely different. Thus, in a study [21] it was claimed that the behavior of transverse acceleration, deceleration behavior during braking and acceleration behavior during acceleration always follow the Pareto distribution in each velocity range.

Similar data were obtained by the authors as a result of experimental rides in the city mode. One of these modes is shown in Figure 8. The $M_1$ vehicle has been driving for almost 20 minutes and covered a distance of 4.43 km. Differentiation of a number of data allowed to determine the accelerations that occurred during the movement of the vehicle (see Fig. 9). As it can be seen from the graph of accelerations, the largest peaks fall on the acceleration modes, and most of the values of accelerations do not exceed 1 m/s$^2$. Particularly small levels of acceleration are observed during motion with a relatively constant velocity.

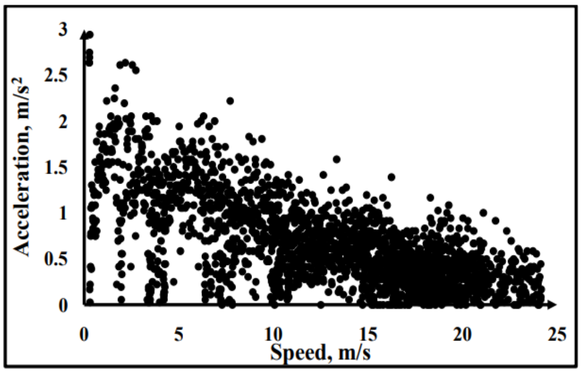


Fig. 5. Acceleration distribution by speed for passenger cars with diesel ICE [19]

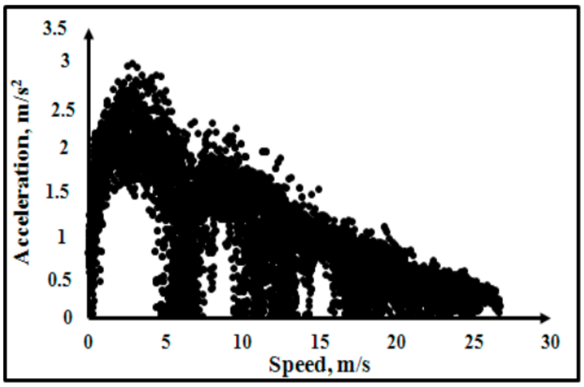


Fig. 6. Acceleration distribution by speed for passenger cars with petrol ICE [19]

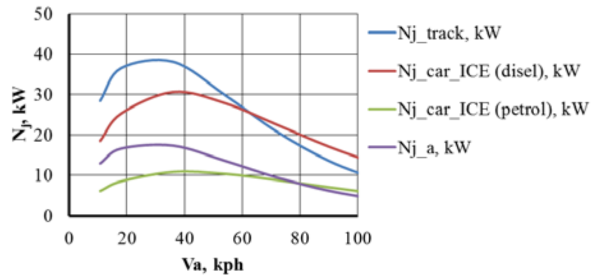


Fig. 7. Power required for acceleration with an average level of acceleration depending on the speed of different vehicles categories

As a result of sorting the data on acceleration in the order of increasing speed, three groups of data were obtained (see Fig. 10). The first group determines the number of fixed acceleration points within the 75% percentile, the second group is the difference between the 95% percentile and the 75% percentile, and the third group is the difference between the 100% percentile and the 95% percentile of the sample. As it can be seen from the figure, 75% of the accelerations do not exceed the limit of 0.5 m/s$^2$, and 95% of the accelerations does not exceed the limit 1.1 m/s$^2$.

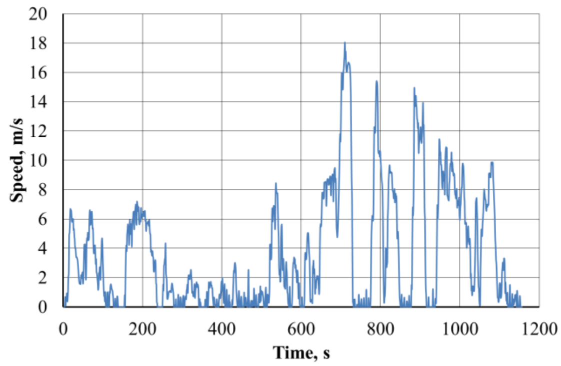


Fig. 8. The oscillogram of the vehicle movement of the $M_1$ category

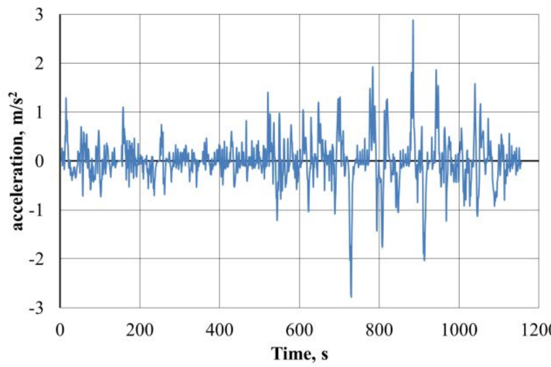


Fig. 9. Acceleration during the movement of the $M_1$ category vehicle

In the context of optimizing the size and cost of the motor and traction rechargeable battery (TRB) for the hybridization system of the vehicle is not rational to use these components with technical characteristics that can cover the entire range of accelerations of the vehicle while driving. Judging by the distribution of accelerations, noticeable effects can be achieved with significantly less motor power and TRB capacity. In addition to reducing the cost of the system, the focus on less power will lead to a moderate increase in the weight of the vehicle, which is converted into a hybrid, primarily due to the small TRB. This will have a positive effect on the dynamic properties without overloading the ICE either or the electric machine.

So, it is possible to compare the powers required to create the corresponding acceleration by pre-determining the analytical dependences of the cloud envelope of the corresponding percentile. Therefore, the cloud envelope of 75% of the percentile is determined by formula (2), and the cloud envelope of 95% of the percentile by formula (3).

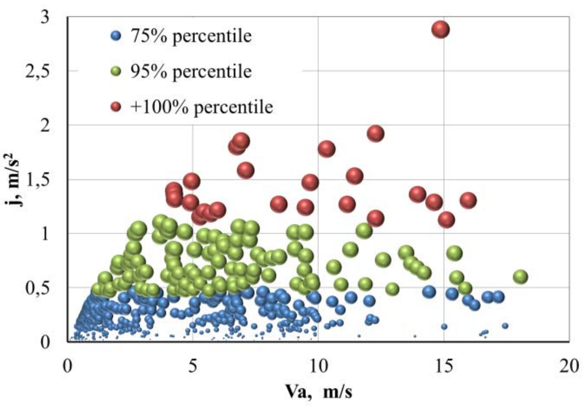


Fig. 10. Distribution of accelerations of a motor vehicle on speeds of its movement

$$j_{75\%} = 0{,}0513 \cdot \ln(V_a) + 0{,}3345 \qquad (2)$$

$$j_{95\%} == -0{,}003 \cdot V_a^2 + 0{,}0312 \cdot V_a + 0{,}9694 \qquad (3)$$

The correlation between the accelerations determined by the dependences (1), (2) and (3) is shown in Figure 11.

We observe a clear dominance of high dynamics at low speeds for dependence, which describes the acceleration exclusively when accelerating a vehicle. The power levels required to implement such acceleration are shown in Figure 7 for the different vehicle categories.

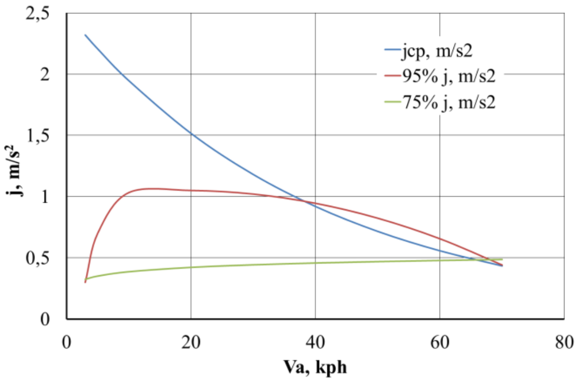


Fig. 11. The correlation between accelerations

Similarly, the dependences of the power for the realization of accelerations at the level of 75% percentile and 95% percentile in comparison with the power for steady movement of the vehicle of category $M_1$ "A class" are shown in Figure 12. These dependences for the curb condition and gross weight of the vehicle demonstrate the difference in power required to maintain steady traffic and a certain acceleration. When choosing the power of the electric motor to rationally focus on the curb weight for passenger cars, because most of the time they drive unloaded, and for trucks and buses to focus on the gross weight of the vehicle.

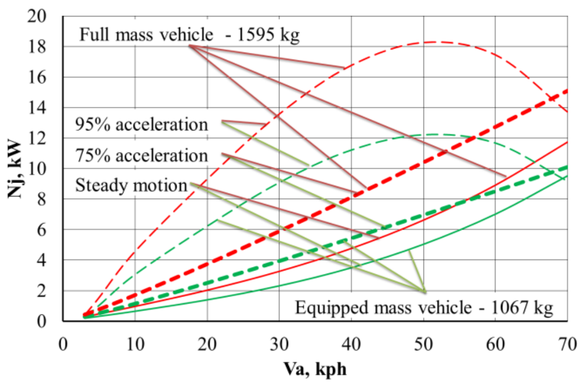


Fig. 12. Power ratio for A-class vehicles

Analyzing the nature of the curves of the required power to implement the corresponding acceleration percentage, it should be noted that the forms of curves depending on the driving style.

## Hypothesis when creating a system for converting vehicles into "mild hybrid" and system parameters

It is proposed to create a system for converting a vehicle into a hybrid from the components shown in Figure 13.

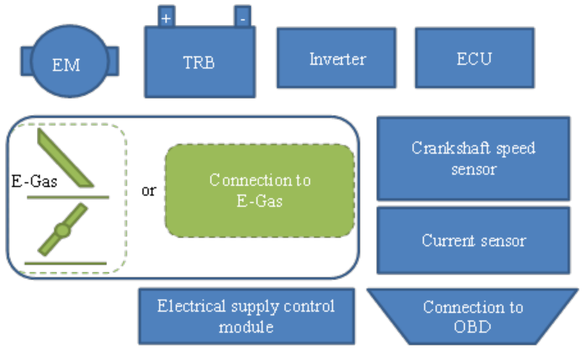


Fig. 13. Scheme of the system for converting a vehicle into a hybrid

The electric machine (EM) provides operation in traction mode and in generator mode. Traction rechargeable battery (TRB) accumulates electrical energy to power the EM. The inverter provides conversion in the electrical circuits of the EM power system and charges the TRB. The electronic control unit (ECU) controls the system, EM and TRB. The engine crankshaft speed sensor provides the ECU with relevant information for timely response to changes in the engine speed. The current sensor provides the ECU with relevant information to control the EM. The connection to the OBD provides the ECU with additional information, the receipt of which does not require a high speed of information retrieval. The connection to the E-Gas provides information from the electronic pedal to form the required power distribution between the ICE and the EM. In the absence of an electronic pedal, its additional installation is required. If there is no connection to the E-Gas, you can use the signal from the choke position sensor. In this case, it is impossible to implement the mode of movement on electric traction. However, efficiency and cost of the system is expected to be lower. The power supply control module provides control of the voltage regulator for the possibility of switching off the generator in certain modes of movement.

Effective use of a hybrid vehicle of the "mild hybrid" level is possible at short distances of daily run with frequent braking for realization increased energy recovery efficiency. [12] As shown by the calculations of traction properties of vehicles of different categories (see Fig. 3) for driving at speeds within the urban cycle is enough from 5 kW to 45 kW of ICE power. Accordingly, the minimum power values for the movement of the vehicle correspond to cars with a mass of about one ton, small frontal area and air resistance. The maximum values correspond to city buses weighing about ten tons.

The hypothesis of the work is to create a system for converting any vehicle into a hybrid with a set of functions close to the technology "mild hybrid". A feature of the new system is the acquisition by vehicles of special functions that are not inherent in the classic hybrid built on the technology of "mild hybrid", through the use of low-power electric drive and traction rechargeable battery (TRB) of small capacity. The new system provides the following functions for vehicles:

– braking energy recuperation;
– ICE assistance (change of ICE operating point and acceleration);
– electric start (when high dynamics is not required, for example when driving in traffic jams) (extension of this function to the technology of "mild hybrid" see Fig. 14);
– support for constant movement (new function, see Fig. 14).

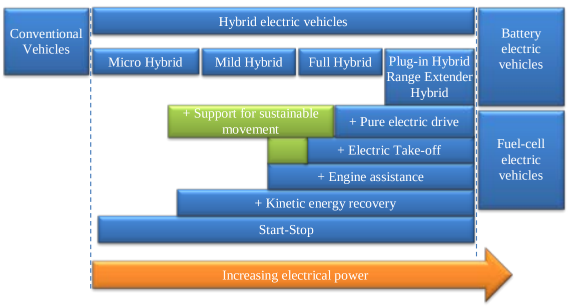


Fig. 14. Extending the functionality of hybrid vehicles in the classification of hybrids according to the European road map [13]

The new function for "mild hybrid" vehicles provides for a partial expansion of such a function as electric propulsion only. The hypothesis of the steady-state support function is illustrated in Figure 15. The speed $V_1$ in Figure 15 indicates the speed limit to which movement is possible when the electric motor is fully covered by the power to move the vehicle. To the right of point $V_1$, in green, are marked options for changing the power of the electric motor to provide different percentages of power compensation of the ICE. After point $V_2$, the movement of the vehicle is fully provided by ICE, and the electric machine can turn off or go into generator mode to charge the TRB. When increasing the speed of the vehicle, the crankshaft speed reaches the zone with sufficient efficiency when increasing the load on the engine [15], [16] for efficient charging of the battery. The formation of the law of power distribution between the ICE and the electric motor shown in Figure 15 is provided by the characteristics of the accelerator pedal (see Fig. 16). In Figure 16, the red dotted line indicates the linear dependence of the position of the ICE choke on the angle of the accelerator pedal.

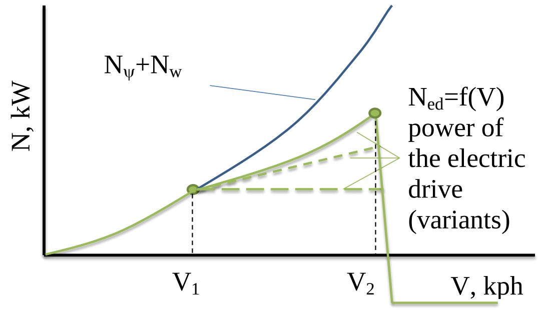


Fig. 15. Formation of electric motor power to maintain constant movement of the vehicle

Point $\alpha_1$ determines the limit to which pushing the accelerator pedal provides movement exclusively on electric traction. This is necessary in the "creeping" mode of movement in traffic jams for a short distance. The point $\alpha_2$ determines the limit at which the EM is transferred from the traction mode to the generator. The point $\alpha 1$ is predetermined and is set parametrically when setting up the system.

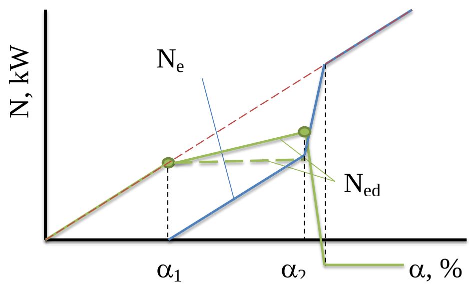


Fig. 16. Power generation for ICE and electric motor

The point $\alpha_2$ is determines during the movement of the vehicle on the basis of speed information and has a variable value when the speed of the vehicle exceeds the limit $V_2$ (see Fig. 15). In this mode, the ICE choke occupies a position that corresponds to its classic workflow.

### Architecture of a hybrid vehicle with an installed system

According to the calculations of the power expended on the movement of the vehicle and the analysis of the accelerations statistics (see Fig. 11), we determine the rational limit of the speeds in the hybrid mode for each category of vehicles. As can be seen from Figure 3 for most cars, the power to support steady traffic does not exceed 6 kW at a speed of 50 km / h. The lowest value at the specified speed is inherent in vehicles with the lowest weight and size (Class A and Class B). For the most popular class C [17], this figure is about 5.2 kW. Thus, for vehicles of category $M_1$ of the most popular classes B and C [17], the red line indicates the total power of the electric motor (see Fig. 17). This power is designed to cover the part of the power needed to maintain steady motion (marked in green) and the power to create acceleration. If we impose on these curves the power characteristic of a real electric motor, it is possible to choose not only the required power, but also the gear ratio from the electric motor to the wheels to match the operating range of the motor and ensure its maximum efficiency. As already mentioned, the idea of improving the technology of "mild hybrid" is to give it the function of supporting the movement of the vehicle without increasing the drive power. Rational minimization of the power of the electric motor and TRB will allow to reduce the cost of the hybridization system of the vehicle and not to overload it. As can be seen from Figure 14, the proposed new feature can be partially extended to "micro hybrid" technology. Due to the partial unloading of the ICE, two results are achieved:

– partial coverage of power by the electric motor to maintenance relatively constant movement allows to reduce fuel consumption;

– the working condition of the ICE ensures its constant readiness to deliver the required power for acceleration.

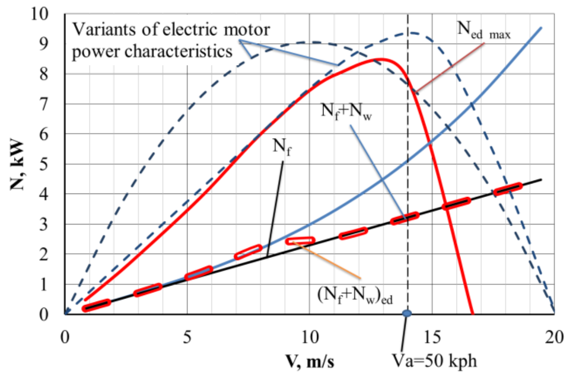


Fig. 17. Variant of the ratio between the power required for movement and the characteristic of the power of the electric motor in the architecture P3

With the architecture P3, for the variant of the characteristic of the electric motor, shown in Figure 17, it is possible to implement the following functions:

– braking energy recuperation;

– ICE assistance (change of ICE operating point and acceleration);

– electric start (when high dynamics is not required, for example when driving in traffic jams);
– maintenance of constant movement (during the movement of the vehicle with conditionally constant speed when accelerations are insignificant).

The disadvantage of this variant of the hybridization system is the relatively high power of the electric motor and the complexity of its placement according to the P3 architecture on small vehicles of category $M_1$. When assembling such a system on vehicles of categories $M_2$ and N, the problem of placing the electric motor of such power does not arise.

As can be seen from Figure 17 to maintain constant motion at speeds up to 50 km / h (up to 14 m / s) enough power of 5 kW. With partial power coverage, 2 kW - 4 kW is required to maintain constant movement, depending on the degree of coverage. To provide traditional "mild hybrid" functions, such as ICE assistance (changing the operating point of the ICE and acceleration), it is necessary to have an electric motor with more power, up to 10 kW. But this power is less than that traditionally used to maintain the movement of the vehicle in technologies such as "full hybrid" and "plug-in hybrid" [13]. The use of the architecture P0 + P3 allows you to combine the use of electric motors. A variant of the relationship between electric motors of the same power with the curves of their total power is presented in Figure 18. As can be seen from the figure, the total power of electric motors may not necessarily cover the needed range of required power. This is due to the number of gear ratios available in vehicles. Since it is possible to install a hybridization system on vehicles that are already in operation, their gear ratios have some influence. In addition, a positive aspect of the P0 + P3 architecture is the possibility of separate use of electric motors to ensure the position of the operating point of the motor in the most energy-efficient zone of speed characteristics.

The hybrid vehicle built on the architecture P0 + P3 will provide the following functions:
– braking energy recuperation;
– ICE assistance (change of ICE operating point and acceleration);
– electric start (when high dynamics is not required, for example when driving in traffic jams);
– maintenance of constant movement (during the movement of the vehicle with conditionally constant speed when accelerations are insignificant);
– Start-Stop function.

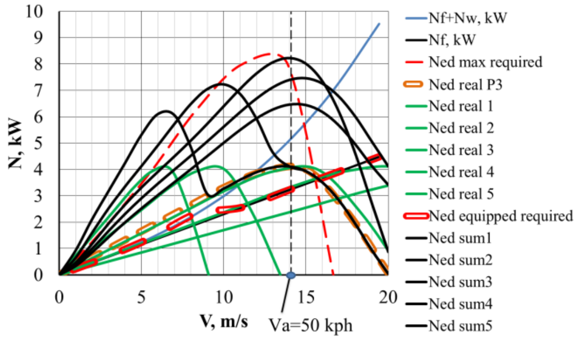


Fig. 18. Variant of the ratio between the power required for movement and the characteristics of the power of electric motors in the architecture P0 + P3

Using only the P0 architecture also has its advantages (see Fig. 19). The electric motor of small power and the sizes has advantages in a layout. It can be placed both instead of the standard generator with the drive through a belt drive and instead of the standard starter with the drive through a gear-belt or gear transfer. Changing gears allows you to make better use of the motor due to the rational location of its operating point. A vehicle built on such an architecture is able to perform the following functions:
– braking energy recuperation;
– maintenance of constant movement (during the movement of the vehicle with conditionally constant speed when accelerations are insignificant);
– Start-Stop function.

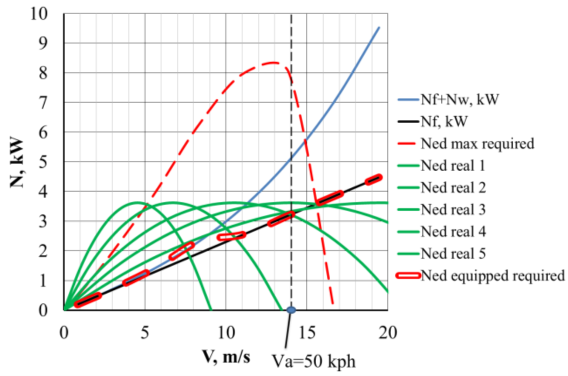


Fig. 19. Variant of the ratio between the power required for movement and the characteristics of the power of electric motors in the architecture P0

When the electric motor is installed instead of the standard generator in the traction mode, it is impossible to generate electricity in the onboard main. To maintain the required voltage of the onboard main and to compensate for the discharge of the standard starter battery, it is necessary to increase the capacity of the TRB by the amount of energy that the generator can hypothetically produce during the function of maintaining the constant movement of the vehicle.

The presence of a more powerful electric motor allows you to expand the functionality of a hybrid vehicle (see Fig. 20). In this embodiment, the hybrid vehicle can perform the following functions:

– braking energy recuperation;
– ICE assistance (change of ICE operating point and acceleration);
– maintenance of constant movement (during the movement of the vehicle with conditionally constant speed when accelerations are insignificant);
– Start-Stop function.

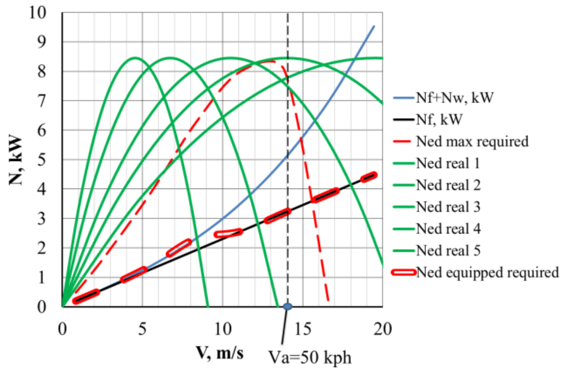


Fig. 20. Variant of the ratio between the power required for movement and the characteristics of the power of electric motors in the architecture P0

The use of the considered architectures of hybrid vehicles will allow to create a wide range of systems for hybridization of vehicles in different price categories and functionality.

## Conclusion

The use of low-power electric motors will simplify their layout on the vehicle, will ensure the use of a small-capacity traction battery, which will avoid overloading the car with excess weight.

The analysis of energy losses for movement allows to state that the electric motor with power up to 3,5 kW will give the chance to realize new function of technology "mild hybrid" - maintenance of constant movement.

Analysis of vehicle accelerations while driving suggests that 75% of the acceleration times do not exceed 0.5 m/s$^2$. Compensation of accelerations for realization of support function of the internal combustion engine can also be realized by the electric motor with power from 5 kW to 6 kW provides coverage of 75% of accelerations.

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## Conflict of interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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**Перспективи технології “mild hybrid” для створення системи гібридизації автотранспортних засобів**

***Анотація. Проблема.*** *На сучасному етапі розвитку науки та техніки проблема створення енергозберігаючих транспортних засобів вирішується за рахунок впровадження електричних транспортних засобів: електромобілів або гібридних транспортних засобів. Попри перспективність батарейних електромобілів їх екологічність може відповідати парадигмі технології “Zero Emission” лише за умови видобутку електричної енергії в мережі з поновлюваних джерел. На додачу електромобілі не завжди можуть забезпечити бажану дальність пробігу на зарядці. Для живлення електроприводу зараз використовуються акумуляторні батареї літій-іонного типу, важливою проблемою яких є велика вага, яку треба постійно возити на автотранспортному засобі, також необхідність балансування їх елементів помітно збільшує час заряду від зовнішньої електричної мережі.* ***Мета.*** *Метою роботи є розробка теоретичних основ для створення системи конвертації автотранспортних засобів, що знаходяться в експлуатації у «mild hybrid».* ***Методологія.*** *Багато держав не можуть собі дозволити організувати швидкий перехід на видобуток електроенергії із відновлюваних джерел та замінити парк автотранспорту на електромобілі. Натомість швидший ефект можна отримати якщо переобладнати автотранспортні засоби, що вже в експлуатації у гібриди. Для успішного виконання такої мети необхідно обґрунтувати параметри системи гібридизації автотранспортних засобів задля отримання помітної енергоефективності при вигідному терміну окупності.* ***Результати.*** *Проведений аналіз класифікації гібридів та архітектури приводів дозволив запропонувати нові функції для технологій «micro hybrid» та «mild hydrid». Аналіз втрат потужності на рух автотранспортного засобу дозволив виконати прогнозування кількості та потужності електродвигунів достатньої для виконання нових функцій.* ***Оригінальність.*** *Розроблено структурну схему системи гібридизації автотранспортного засобу, яка забезпечує його конвертацію у гібрид. Дослідження націлено насамперед на удосконалення технології «mild hydrid» в якій електродвигунами відносно низької потужності, що не притаманні цій технології, запропоновано часткове виконання функцій, що притаманні технології «full hybrid».* ***Практичне значення.*** *Поєднання особливостей технологій «micro hybrid» та «full hybrid» у технології «mild hydrid» повинно забезпечити достатню енергоефективність, легкість установки обладнання системи та невелику її вартість.*

***Ключові слова:*** *автотранспортний засіб, “mild hybrid”, підтримка сталого руху, раціональні режими руху, електропривод з частотним керуванням, енергоефективність.*

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