

Wacław BANAŚ<sup>1</sup>  
Gabriel KOST<sup>2</sup>  
Andrzej NIERYCHLOK<sup>3</sup>

## **MODELLING AND SELECTION OF THE WORK OF A POWERTRAIN HYBRID WHEELED VEHICLE**

The paper presents the main issues of control the combustion engine by stabilizing power. Algorithms work, certain flue units for which the work of the internal combustion engine is most effective. A method of modeling the flow of energy between an engine and an electric generator as a function of engine speed and load of the specific fuel consumption - the greatest efficiency. Presented a stabilization system diagram under the internal combustion engine and generator for hybrid vehicle. Described to adopted algorithm the stabilization of power for the engine and generator exhaust in the rotational speed to stabilize at a point and stability in the area.

### **1. INTRODUCTION**

Environmental considerations and the fuel crisis of 1973, contributed to the search for new solutions for the wheeled vehicle engines. Diesel-type combustion engine with direct fuel injection with turbocharger features within  $0.40 \div 0.45$  efficiency (petrol engine does not exceed 0.40), with the highest efficiency has a very narrow rpm range, while the electric motor-driven vehicles have a zero emissions of toxic substances (Zero-Emissions Vehicle, ZEV) and the greater efficiency of the propulsion system, since the efficiency of power units in the best structures is 0.95 [5].

Vehicles powered by electric powertrain are classified as ecologic. However, such a propulsion system is cumbersome in operation due to the small range of the vehicle and the problems associated with the source of electricity. The way to eliminate these defects can be a hybrid vehicle with ICE-electric powertrain. Conducted in many centers of research and development works, focused on ensuring the development of these drives. In particular, they are directed to [1],[4]:

- ICE drive improvement through the elimination of reduction noise and fuel efficiency, as well as the use of alternative fuels,

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<sup>1</sup> Institute of Engineering Processes Automation and Integrated Manufacturing Systems, Silesian University of Technology, Poland

- replacing the internal combustion engine by electric motor, and developing efficient electric batteries, by technology acquisition and storage of electricity in a wheeled vehicle.

## 2. COMBUSTION ENGINE POWERED VEHICLE

Internal combustion engines used in cars are a source of power with relatively low efficiency. In addition, a side effect of them occurring in the combustion process, gaseous pollutants are emitted into the atmosphere. The internal combustion engine works most efficiently in a narrow range of speed for which the best is to use energy of the fuel. Increase the effective range of the engine (an increase in effective range of RPM) is carried out by using a charger for the units and enlargement of the scope of the so-called "eye" of maximum efficiency (BSFC – Brake Specific Fuel Consumption), as shown in Fig. 1.

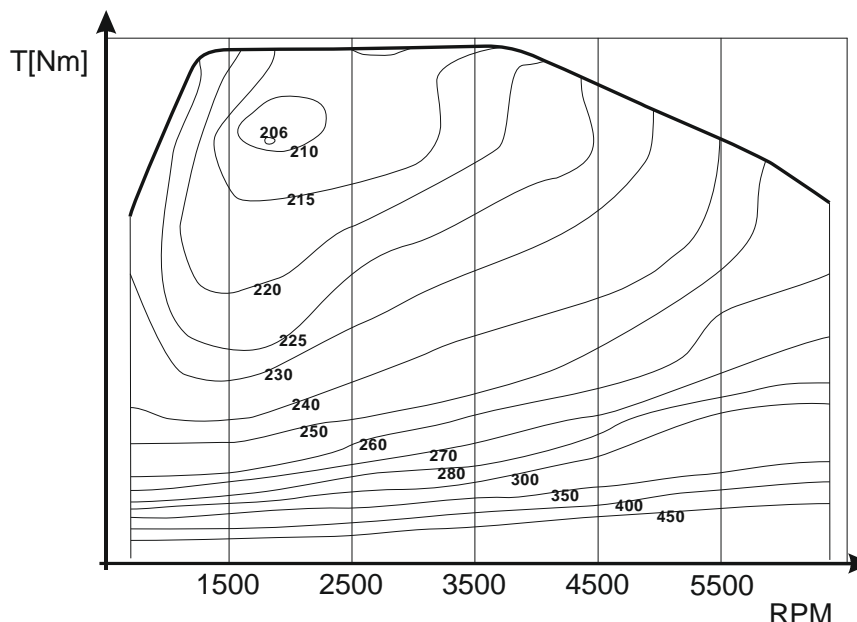


Fig. 1. Sample characteristics of the universal unit of petrol-type engine [5]

In addition, a very inefficient operation of the engine is at idle work (at a standstill and in a traffic jam), as produced power by the engine is not used. To improve the level of efficiency of internal combustion engine, especially at idle, the car companies introduce high-performance integrated starter-alternator type, so that working the petrol engine at a standstill can be turned off. At the time of stopping a wheeled vehicle, internal combustion engine is turned off, and including the movement (moving from the place), simply press the acceleration pedal. This raises in a very short time (about 0.4 sec.) automatic start of ICE units and movement of the vehicle. A large part of energy is wasted at the time of starting the vehicle from the stop-place, it has an impact on the low efficiency of the transmission to first gear and riding on the so-called half-pressured clutch.

Modern combustion units equipped with electronic engine control, systems regulate dosage of fuel injection according to the measurement of oxygen in the exhaust. For the amount measuring of oxygen in the exhaust gas corresponds to the lambda sensor, which is associated with the volume control of the air-fuel mixture in engines with indirect injection. Directly from this measurement is determined rate of oxygen  $\lambda$ . The introduction of direct injection (ICE units), enabled quality control of dose the fuel (used for a long time in diesel engines, such as TDI) by [2],[3]:

- quantitative control - used in spark ignition engines with indirect injection, which occurs under the influence of current load, adjusting the amount of fuel to the amount of air (air mass and the mass of fuel must be equal participation of stoichiometric),

- quality control - used in diesel engines and gasoline engines with direct fuel injection, which is characterized by the variability of excess air ratio, i.e. the composition of the stoichiometric air-fuel mixture, taking part in the combustion process and arbitrarily can vary according to the given load.

### 3. ELECTRIC VEHICLE

It is expected that in the future, cars will be powered by individual electric motor. On the diffusion of electric drives have an impact such inventions as the electric Voltaic cell, battery acid, a fuel cell. The basic advantages of electric propulsion is [6]:

- low noise,
- easy installation in the vehicle (electric motor requires no transmission or clutch, it can even be incorporated directly into the drive wheel),
- simplicity of control maintenance,
- no exhaust.

The main disadvantage of this type of propulsion used in road vehicles is a large mass and low capacity of battery, or consequently a worse ratio of their vehicle payload, and a very limited range of the vehicle.

In order to eliminate the drawbacks of the above engines is created a hybrid wheeled vehicles, i.e. a vehicle with more than one power unit. In most common hybrid vehicles equipped with an internal combustion engine and electric motor. In such a system the primary energy source is the internal combustion engine, electric motor helps the petrol engine with an increased load (increased demand for power and torque).

Power unit diesel electric motor is connected with overcoming hills and acceleration of a wheeled vehicle. More and more common design solutions in which the electric motor is a machine used to starting the vehicle.

The use of electrical units which drive the main influence on increasing the efficiency of the drive-train, this is particularly evident in urban areas, and to reduce the amounts of toxic substances excreted into the atmosphere as combustion products. The concept of a solution of a wheeled vehicle with hybrid drive shown in Fig. 2.

Applying electric motors in vehicle can [2],[6]:

- start the engine under load external forces,

- to achieve much greater flexibility in power factor values than internal combustion engine,
- temporarily overload the unit (depending on the type of engine design and up to five times),

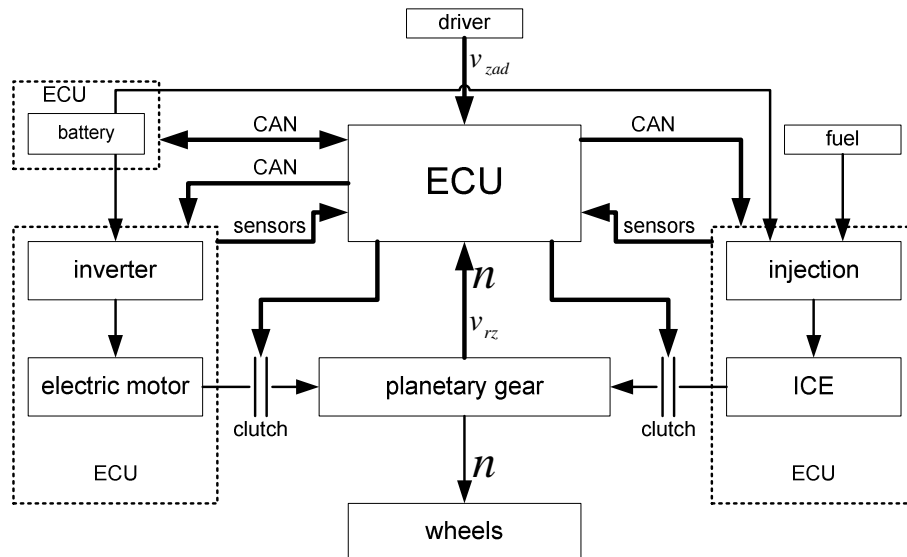


Fig. 2. The concept of hybrid vehicle solution [3]

- used to simplify the transmission system (for example, by placing the engine in the wheels of the vehicle),
- and using the electric motor to brake the vehicle and energy the recovery.

#### 4. THE BASIC TASKS OF THE CONTROL SYSTEM IN A HYBRID VEHICLE

The use of internal combustion engine and electric motor in hybrid vehicle reduces the size of batteries and super-capacitors, which results in increasing the range of the vehicle and engine work on the optimal speed for which the value of specific fuel consumption is minimal, which is directly associated with reducing air pollution. You could say that the degree of expansion the range of the vehicle depends on the ratio of energy drawn from the battery and super-capacitor to the energy supplied at a specific time driving. The energy collected is used to power electrical devices associated with:

- control and regulation of powertrain (traction motors, controllers, converters, fuel system),
- assistive transmission devices, (power steering, ABS, ESP),
- and lighting vehicle devices, and driving comfort (external and internal lighting of the vehicle, active suspension, air conditioning).

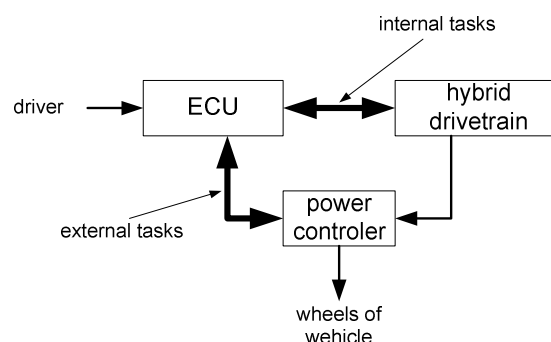
The energy supplied to the batteries and super-capacitors comes from the internal combustion engine and by recuperation kinetic energy when vehicle braking. Please note that the energy supplied to the battery primarily comes from the engine that drives the electric generator. The energy supplied by recuperation kinetic energy does not exceed 10% to 20% of the total energy supplied to the batteries and super-capacitors. The fact is that the value of the recuperation of energy from kinetic energy (in particular the current value) is too large for today's electrochemical batteries, making the adoption of such currents is to risk by damaging the battery. Therefore, energy from the recuperation of the kinetic energy of the vehicle shall be stored in super-capacitors, which can take much larger currents than electrochemical batteries.

The tasks of the control system in a hybrid wheeled vehicle include external and internal tasks (Fig. 3). External tasks (mostly traction) depend on a driver, which can be mentioned:

- control of the drive motor during acceleration, braking and ride by constant speed,
- control of energy recuperation,
- control of drivetrain devices,
- informing the driver of a voltage-current conditions.

The internal tasks relate to the work area inside the drive units, which is the source of the hybrid powertrain, which slightly depends on the driver's commands, and they include:

- maintenance of the internal combustion engine in the programmed state of the work during all states of load,
- maintaining a proper state of the electrochemical batteries and super-capacitors,
- control the hybrid inside source power, depending on the demand for power transmission equipment,
- information about operation status of source devices.



Rys. 3. External and internal tasks of control system

The main task of the control system, which provides for the basic requirements is to maintain the best possible state of internal combustion engine (under optimal load and speed) and charge electrochemical battery and super-capacitors. This is done by energy dispersed from ICE, which serves as:

- electricity to power an electric motor and to recharge batteries and super-capacitors,
- mechanical energy to driver a vehicle.

Energy dispersed can be done in a way that ignition, if we are dealing with a vehicle of a serial hybrid drive. In this case, the way the integration of engines and power generator is dependent on road conditions, vehicle speed and the condition of the electrochemical battery.

Assuming the above assumptions, it is necessary to provide a combustion engine, working with the generator, the most advantageous load. This task is implemented by the control system by stabilizing its work. The stabilization process usually involves a certain area of points and is called the operational area (the stabilization of the area), or adopt an operating point (in the stabilization point) (fig. 5).

Control algorithm should take into operation the working conditions of electrochemical batteries and super-capacitors, which in any case the ride (acceleration, braking) must have the ability to meet the energy needs to accelerate the vehicle and energy storage capacity for recuperation at the time of braking of the vehicle traffic. Currently, it is assumed that the degree of electrochemical battery discharge should not exceed (SoC - State of Charge) 40%, and the control strategy should take into the critical value such as an electrochemical battery. With such an approach to the problem of controlling the effect that:

- electrochemical battery charge should be more intense, by the discharge rate is higher,
- participation in the energy passing through the battery to the load should be the smaller, by the smaller is the degree of the charge (of course it depends on the electrochemical batteries and other sources of energy storage, such as super-capacitors),
- level of charge should take into the repeatability of the driving cycle, which may result or consequence of the braking load (of course this is dependent on the assumed algorithm and the method of recording information to take account of the burden of individual power units - including daily, near-wheel drive vehicle).

The concept of "stabilization force" is related to the regulatory stabilizing combustion engine. Therefore the "stabilization force" to effect a stabilization and both control system operational area and operating point ICE units.

Fig. 4 shows a conceptual block diagram of control system stability under the primary energy source (ICE) in hybrid vehicle. The object of regulating an internal combustion engine coupled a generator via a planetary gear. Input power to the control system is the amount supplied by combustion engine fuel, expressed in  $\text{kJ}$  (Joule) and a control signal coming from the throttle controller. The output is the RPM of the internal combustion engine and electric power value measured at the terminals of an electric generator.

The control system is to ensure established level of power flowing through the controlled system, corresponding to a fixed internal combustion engine working conditions by control algorithm.

The basic values that describe the choice of method of stabilization, forming a basic principle of operation of the controller are:

- a set of measured values in a block of processed measurement and control of feedback signal,
- set the size of governing, which form the basis of the output signals of the regulator,

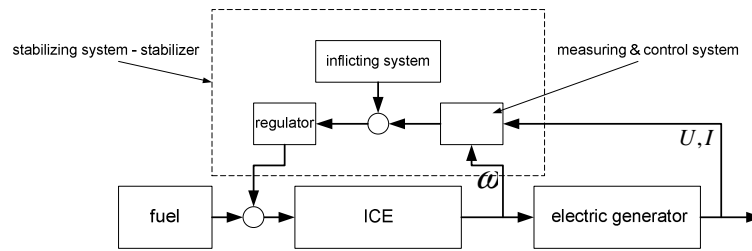


Fig. 4. Block layout of stability power control

Executive element may be adjustable servo fuel pump in diesel engine, electronically controlled throttle, or solenoid valves in the petrol engine.

To a large extent on the choice of stabilization of the internal combustion engine depends on the proper selection of electric generator and its characteristic velocity. The basis of the correct stability criterion is the efficiency of internal combustion engine, for which the most important criterion is the least polluting.

Fig. 5 presents a method of working ICE with marked points of the optimal criterion for the job. Point **P1** is responsible for the optimal control the operation of the internal combustion engine for propulsion and only the electric generator. The control system maintains speed and engine load at the point for which the efficiency (specific fuel consumption) is the largest. Point of this is shown in fig. 1, which can be seen that the lowest fuel consumption is in an area of approximately 1700 RPM at  $\frac{3}{4}$  load ICE unit. The working area between points **A1** and **A2** correspond to the work unit as a ICE to assist electric motor when vehicle need greater driveline torque. Speed in this case was limited to 3000 RPM and assist the electric drive, in this case is only possible in urban areas for which the linear velocity of the vehicle does not exceed 60 km/h. In turn, work area contained between the points **S1** and **S2** represents the theoretical work of individual ICE driving vehicle by outside built-up areas, when driving a wheeled vehicle only on ICE unit, which works most efficiently under such conditions.

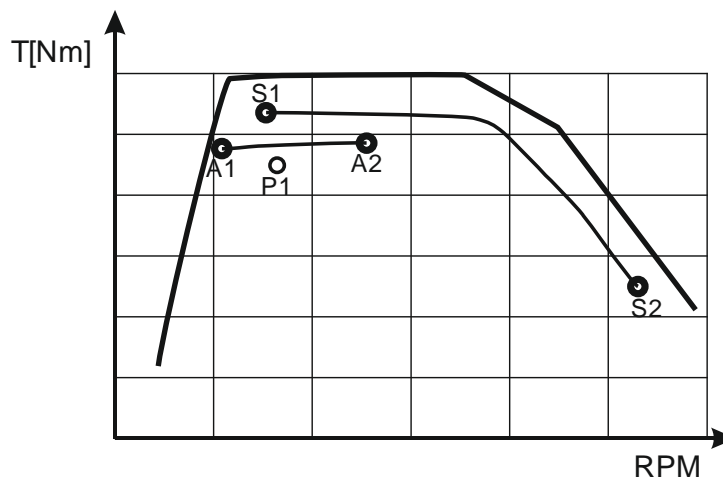


Fig. 5. Stabilization process in the area and point of the adopted control algorithm

For such adopted conditions developed in the Matlab / Simulink system model of a wheeled vehicle with hybrid drive. Fig. 6 shows the simulation results, which can be seen that for a clear work area starting an internal combustion engine, which does not reflect the torque used to drive a vehicle or generator. Work area 2 shows to include an electric generator and thereby achieving stabilization of the engine power to the lowest specific fuel consumption. The work area 3 can be read to support an electric motor engine.

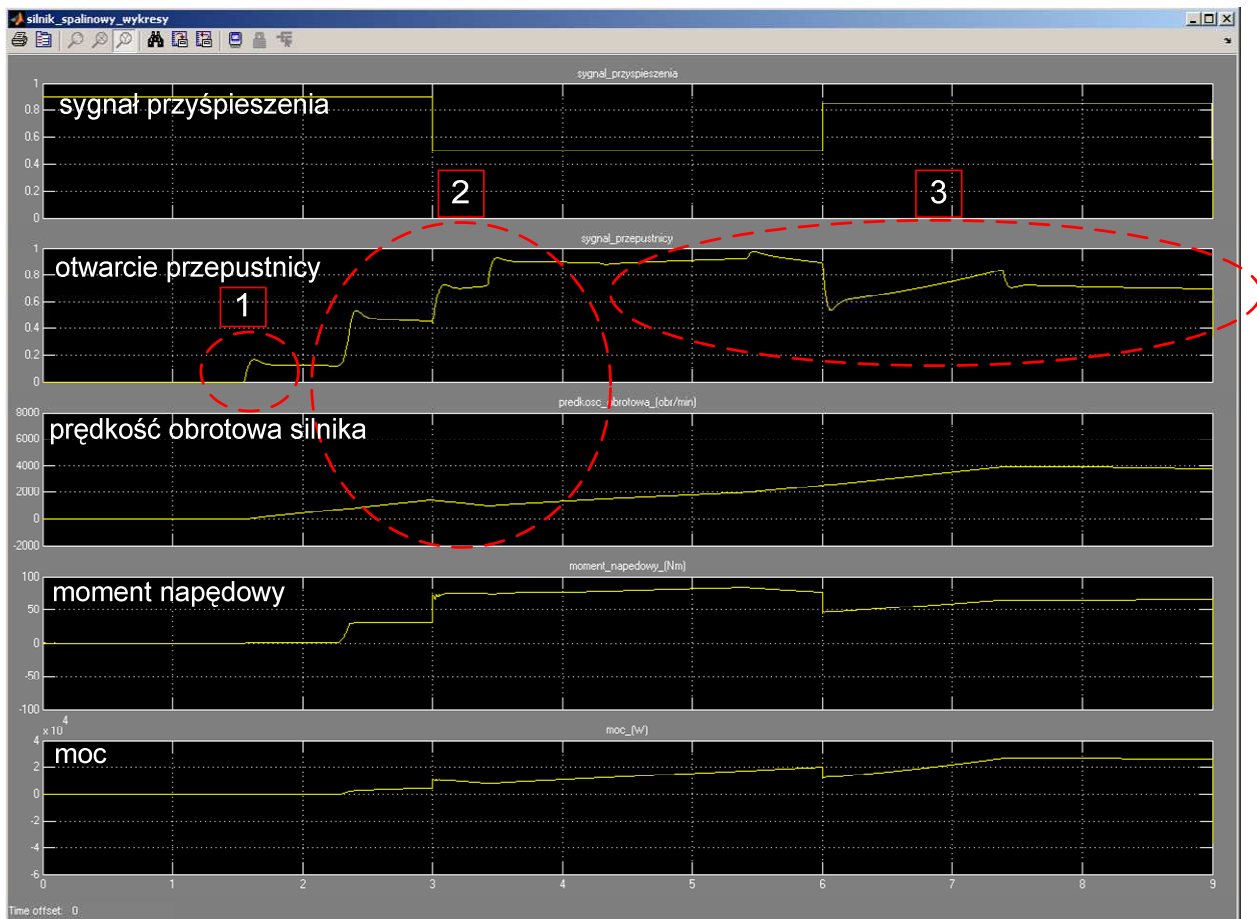


Fig. 6. Results of the simulation in MatLAB/Simulink software

## 5. CONCLUSIONS

The paper presents the problem of controlling the petrol engine in the hybrid wheeled vehicle. An engine's algorithm work by stabilizing the generator power. The solution is based on controlling the selection of optimum operating point of ICE unit driven the generator, and choosing the optimal work area where the internal combustion engine drives a generator and a wheeled vehicle. This enables the most efficient work for internal combustion engine thus reducing the amount of toxic products generated by the combustion engine.



## ACKNOWLEDGEMENT

*The work was co-financed by the European Union under the European Social Fund Project "Activation of the academic community as part of the Regional Innovation Strategy" POKL.08.02.01-24-019/08".*

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