Electric automobile VS hybrid

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Abstract. This article considers advantages and disadvantages of hybrid and electric automobiles. A possibility of using a hybrid drive in automobile combining with energy recovery is discussed.

Introduction

Any automobile may be considered as autonomous vehicle, that is, it must have: an energy supply; a motor (a device for converting one type of energy into another); transmission (a device for transferring energy from engine to wheels); control systems (steering, braking, driving, etc.); wheels.

There are not so many really used energy sources for vehicle engine, so Figure 1 shows their main types. Exotic types of energy, for example: solar, nuclear, etc. are not considered as they are either less effective or of little promise especially for vehicles.

Improvement of modern automobiles is developing in scope of fuel consumption reducing and environmental friendliness increasing (the quality of something depicting its ability not to harm an environment).

There are a large number of ways to reduce fuel consumption. Let us consider the most promising in our opinion: electric vehicles and the use of a hybrid drive.

1. Electric vehicles.

On the one hand, the electric automobile seems to be the most economical and environmentally friendly transport vehicle to solve the problem, but this is not so!
First of all, electrical energy obtaining is a complicated process and if it occurs not in the vehicle itself, this does not mean that it does not cause environmental pollution. It doesn't just relate directly to the automobile. At the same time nuclear power plants (NPP) are potentially dangerous and harmful, but they generate up to 80% of all electricity on the planet, and TPP (Thermal Power Plant) is the same heat engine, only large and permanent-set. It distributes received electric energy to consumers. In this case, an electric automobile is the same energy consumer as a light bulb or an iron. As it is known from physics course, any process of energy conversion does not proceed without energy losses!

What about an electric automobile? Initially, electricity is generated at power plant - there are first losses: the efficiency of hydroelectric power plant (hydro power plant) reaches up to 90-92%; efficiency of TPP does not exceed 34-40%; NPP efficiency is no more than 30-35%. According to official data, in 2016 the structure of electric power generation in Russia in percentage concerning power plants is as follows: TPP - 65.7%; HPP - 15.9%; NPP - 18.3%; non-traditional - 0.1%. That means that the biggest part of all electricity in our country is produced by thermal power plants that are large internal combustion engines (ICE), working on liquid or gas fuel in combination with generators!

After that, electricity from power plants is transmitted via high-voltage transmission line wires (TLW) to distribution substations and then to consumers. The efficiency of transmission lines and distributors is 60-80%. Then electricity accumulates in automobiles batteries that also have their own efficiency up to 80-90%. And finally, electricity is converted into mechanical energy in electric motor. The efficiency of electric motor is about 75-95%. If we summarize the efficiency range of electric vehicle from the beginning of generation of electricity at power plant to its driving wheels, the result will be approximately 10% in the winter and 18% in summer. In winter, the efficiency is much less as the capacity of batteries falls when it is cold and part of energy (up to 80%) is spent on heating the cabin! An ordinary automobile with internal combustion engine has an overall efficiency consisting of the following parts: oil production (about 70% efficiency), transportation through the oil pipeline to refinery facility (98% efficiency); conversion of oil into fuel (efficiency 90%); delivery of fuel to gas stations (efficiency 98%); filling an automobile tank (efficiency 98%). As a result, the conversion and transmission of energy to the driving wheels of the vehicle remains (efficiency of gasoline engines of modern automobiles is about 32-35%. diesel engines - 42-45%, transmission efficiency is 95%). Eventually the overall efficiency of an ordinary automobile with internal combustion engine is as follows: with gasoline - 21%; with diesel - 27%. Unlike the electric automobile, the efficiency of a vehicle with an internal combustion engine falls in the summer because of the use of air conditioner, and in the winter it grows, as some part of heat produced by engine is spent on heating of passenger compartment!

As a result an overall efficiency of electric vehicle is lower than efficiency of conventional automobiles with internal combustion engine!!! It should also be noted that theoretically achievable efficiency of internal combustion engine is more than 60%, thus, there is an opportunity to increase the efficiency at least up to 15-20% of present value!

Second, after a certain number of charging/discharging cycles electric batteries lose: efficiency, capacity, productivity and need to be replaced! Regarding electric vehicles the cost of electric batteries reaches a half of automobile cost itself!

Third, the disposal of batteries in mass production and operation, as well as the need to change them every 5-7 years can be a real problem, especially in environmental terms.

And the last: binding to the socket, low mileage, poor infrastructure, etc. reduce the concept of an electric vehicle as an autonomous vehicle.

2. Hybrid automobiles.
Hybrid (from Latin “hibrida”, “hybrida” means “mixing”). A hybrid automobile is a vehicle that uses a heterogeneous energy for driving wheels. Typical schemes:
1. By connection of motor and storage device to the drive unit:
• Parallel. Engine and storage device are joined to differential, which is connected to wheels drive. This scheme is used in automobiles with “Integrated Motor Assist (Honda)”. It is characterized by simplicity (it is possible to be used together with mechanical transmission) and low cost.

• Sequential. Engine is connected only to storage device, which in its turn is connected to the wheels drive system. This scheme is not used in passenger vehicles because of low efficiency. A similar principle is used in electric transmission, which is applied in cases where it is necessary to transfer a large torque from internal combustion engine to wheels. For example it is used for railway transport or for dump trucks.

• Sequential-parallel. This system can work either sequential or parallel way, depending on the operation mode. It is implemented for vehicles with Hybrid Synergy Drive (Toyota), for example, Toyota Prius.

2. By the type of storage device:
• Electrical: based on electrochemical batteries; on the basis of inertial storage devices; based on super capacitors (prospects).

• Mechanical: based on pneumatic accumulators, hydro accumulators with pneumatic storage device; on the basis of inertial storage device.

At the moment, there are many design schemes of hybrid cars and control algorithms of their power plant, developed in different organizations and companies. This diversity shows that the most rational schemes have not yet been created and the field of activity is enormous. It can be reasonably assumed that success will be achieved where these things (design and control algorithm) are developed and improved together, because it is well known that a good driver can perfectly drive a bad car, and a mediocre driver will not go far on a good car.

The components of the hybrids efficiency

The efficiency of hybrid vehicles consists of:
• the reduction of the volume and engine power;
• engine operation in optimal and steady mode, much less depending on driving conditions;
• elimination of non-productive operation of internal combustion engines during run-out and stops;
• complete engine stop when it is necessary;
• ability to move using only alternative energy sources;
• regenerative braking with charging from energy storage device.

It is also very important that reduction of fuel consumption leads to a reduction of total amount of exhaust gas emissions (exhaust gases). The reserve of energy storage device allows to manipulate the operation of internal combustion engine, thus in the most environmentally responsible areas it generally dulls or operates in mode of minimum emissions level.

Let us consider two energy balances of an ordinary vehicle (Figure 2) and hybrid vehicle (Figure 3) that were obtained in accordance with the theory of vehicle operational properties [1] at a vehicle speed value of 40 km/h. The data depicted in schemes is averaged, but it allows to visually assess places of energy losses in the vehicle, ways and directions of energy saving and maximum achievable benefit from using the hybrid drive scheme.
From Figures 2 and 3 it is evident that the greatest reserve of efficiency is generated in the possibility of return, reserve for some time and reuse of kinetic driving energy (recovery). To implement this vehicle transmission needs to be supplemented with special units—regenerative energy storage devices (Table 1) and continuously variable energy converters (Table 2). Both can be implemented in different ways by design features and operation principle which can be combined in different ways.

**Table 1. Regenerative energy storage units for automobiles**

| Principle     | Execution                                                   |
|---------------|-------------------------------------------------------------|
| Kinetic       | Flywheel                                                    |
| Potential     | Hydro Accumulator, Spring, Torsion Bar, etc.                |
| Electrochemical| Battery                                                     |
| Electrical    | Condenser                                                   |
| Thermal       | Storage device (400-900 ° C) + Stirling Motor               |

**Figure 2** Energy balance of conventional automobile with an internal combustion engine

**Figure 3** Power balance of automobile with hybrid system and regeneration during braking actions.
Table 2. Stepless power converters (drives) for vehicle

| Principle     | Execution                                      |
|---------------|-----------------------------------------------|
| Hydrostatic   | Pump motor                                    |
| Mechanical    | Transforming transmission (Variomatic)         |
|               | (Transmatic)                                  |
|               | Friction drive                                |
|               | Discrete Variable Speed Gear [2]              |
|               | Differential coupling and elastic link [3]    |
| Electrical    | Motor Generator                               |
| Hydrodynamic  | Turbine Pump, Hydro Torque Converter          |

Each of these options has its own advantages and disadvantages [4, 5]. The most progressive, cheapest and durable is mechanical, but now it has no solutions that may be widely and successfully applied. Implementation of this method - regenerative braking using mechanical structure is an interesting technical task.

3. Summary:
The use of hybrid drive in the vehicle together with energy recovery system is the most promising development of its design. It contains huge potential for fuel economy and emissions reducing, while maintaining and even increasing the autonomy features of the vehicle. Considering the electric vehicle from the moment of energy conversion (power plants), it can be seen that it is also a hybrid; only from the energy source to the wheel of the electric vehicle energy is consumed too intensively. From this it follows that clean electric vehicles are not likely to be widespread, and different types of hybrids will be developed: ICE (or fuel cells) + additional electric drive and electric accumulators together with mechanical drives.

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