HYBRID VEHICLES

G. St. Cholakov
University of Chemical Technology and Metallurgy, Sofia, Bulgaria

Keywords: Alternative energy, Electric Batteries, Electric vehicles, Environmental Pollution, Flywheels, Fuel cell electric vehicles, Fuel Cells, Gasoline, Hybrid Electric Vehicles, Hydrogen Fuels, Methanol, Natural gas, Ultra capacitors, Zero emission vehicles.

Contents

Summary

The previous chapters have outlined the present status and the future developments in internal engine vehicle technology, the concept for zero emission vehicles and the prospects of electric vehicles to become a zero emission alternative to heat engines. They lead to the conclusion that hybrid electric vehicles are the more likely and practical solution to present environmental problems, at least for the foreseeable future. That is why this chapter is devoted to hybrid electric vehicles.

Hybrid electric vehicles (HEV) emerge from a concept, which is aimed at capturing the advantages of the presently available vehicle technologies, while trying to avoid disadvantages. Furthermore, these are designed to bridge the gap in time between the first encouraging results of electric vehicle technology, and its future mature status and significant contribution to the overall reduction of transportation emissions.

A hybrid electric vehicle is a vehicle that has two sources of motive energy – an internal combustion engine and an electric engine. There are different concepts for the development of hybrid systems. These include the employment of fuel cell and conventional electric engines, gas turbines, diesel engines, and lean burn gasoline engines in combination with flywheels, batteries, and ultra capacitors. However, the electric and fuel system of a hybrid vehicle can have either a parallel configuration or a series configuration. Both configurations have their advantages and disadvantages.

Modern hybridization concepts are looking for the right proportion of the participation of the two power sources.

The present chapter describes the major technical concepts employed in the development of hybrid vehicles, their advantages and disadvantages, and the impact they are going to have on the future of transportation and related industries. Special attention is given to the technologies for the development of fuel cell hybrid electric vehicles, since they are considered a strategic automotive alternative for the future.

1. Introduction

Hybrid electric vehicles (HEV) aim at capturing the advantages of the present vehicle technologies, while trying to avoid disadvantages. Furthermore, these are designed also to bridge the gap in time between the first encouraging but not yet competitive results of electric vehicle technology and its projected future significant role in the overall reduction of transportation emissions.

A hybrid electric vehicle is one that has two sources of motive energy – an internal combustion engine and an electric engine. There are different concepts for the development of hybrid systems. These include the employment of fuel cell and conventional electric engines, gas turbines, diesel engines, and lean burn gasoline engines in combination with flywheels, batteries, and ultra capacitors. However, the electric and fuel system of a hybrid vehicle can have either a parallel configuration or a series configuration.

A series hybrid vehicle typically uses a hybrid power unit - an internal combustion engine with a generator or a fuel cell system to supply electricity for the battery pack and electric motor. It does not have a mechanical connection between the hybrid power unit and the wheels. All motive power is transferred electrically to an electric motor that drives the wheels.

The typical parallel configuration of a hybrid vehicle includes a direct mechanical connection between the heat power unit and the wheels as in a conventional vehicle, but has an electric motor driving the wheels as well. A parallel vehicle could use the power created from an internal combustion engine for highway driving and the power from the electric motor for accelerating.

The chapter on *Zero Emission Vehicles* outlined the potential of hybrid vehicles and fuel cells and the significant impact their future implementation would have on transportation emissions. The present chapter will concentrate on the major technical concepts employed in the development of hybrid vehicles, their advantages and disadvantages, and the impact they are going to have on future transportation. Fuel cell electric vehicles will be also described in some detail.

2. The Hybrid Electric Vehicle Concept

A hybrid electric vehicle combines electric propulsion with an on-board energy storage system and an on-board energy conversion system. The series and parallel configurations described above mark the extremes in the role of the two power sources. In the series system, the wheels are driven entirely by electric propulsion. In the parallel system, the wheels can be driven either by electric propulsion or by the heat engine. The fuel cell hybrid electric vehicles employ entirely electric power but can use either the energy provided by the fuel cell power plant or the energy stored on-board. The main advantages of the series over the parallel hybrid configuration are presented below.

- The engine never idles, which reduces vehicle emissions.
- The engine drives a generator to run at optimum performance.
- Allows a variety of options when mounting the engine and vehicle components.
- Some series hybrids do not need a transmission.

The benefits of a parallel configuration as compared to the series configuration are:

- The vehicle has more power because both the engine and the motor supply power simultaneously.
- Most parallel vehicles do not need a generator.
- The power obtained from the vehicle is directly coupled to the road and driving requirements, so it can be used more efficiently.

The role of the batteries can be also twofold. The California Air Resources Board (CARB) defines two types of hybrid vehicles – type A and type C. Type A hybrids are essentially battery driven vehicles. The on-board power source is used as a battery charger and/or to drive the vehicle when the batteries are near exhaustion. Batteries can be also recharged from the electric utility grid.

The type C hybrid would not rely heavily on batteries for primary energy. The fuel cell or heat engine will drive the vehicle at more or less constant load. Batteries, flywheel systems, ultra capacitors or other storage media will accumulate energy, which will be used for smoothing the load of the prime mover and accepting the energy recovered in regenerative breaking. In a type C hybrid, the prime mover will be sized for the average power demand of the driving cycle in contrast to mechanically driven systems without energy storage, which must be designed for the peak power demand. The prime mover will operate at 50 to 100 per cent of its designed power input most of the time. This will allow its average efficiency to be much greater than that of present internal combustion engines. The latter operate at less than ten per cent of their maximum power rating on average.

The separation of the engine from the wheels, and the avoiding of the need for response to rapid changes in speed and power output, provides for the eventual use of the most environmentally advanced internal combustion prime movers in hybrid electric vehicles. These include Stirling engines, ultra lean burn internal combustion engines, gas turbines, etc. (see *Control of Exhaust Emissions from Internal Combustion Engined Vehicles* and *Catalytic Converters and Other Emission Control Devices*). These engines have low emissions. For reasons described in *Control of Exhaust Emissions from Internal Combustion Engined Vehicles*, they have not found wide application in the traditional ICE vehicles. An additional advantage of HEVs is that natural gas or neat methanol may also be used as fuels in the heat engines, in order to limit fossil fuel dependence and reduce emissions of carbon dioxide.

The battery technologies can be adapted beneficially for use in a hybrid vehicle or another more efficient storage media may be used. The result of all this eventually will be high efficiency and low emissions. Fuel cell technologies can further contribute to an overall more efficient and less polluting vehicle.

Figure 1 presents the main challenges facing the hybrid electric vehicles technology.

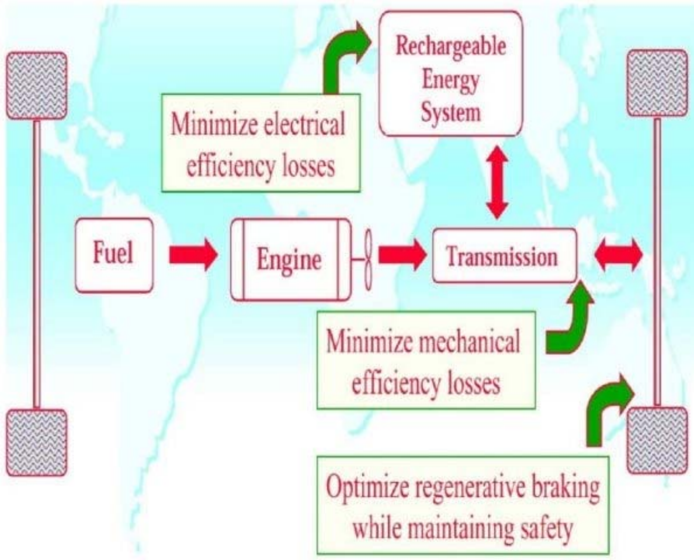


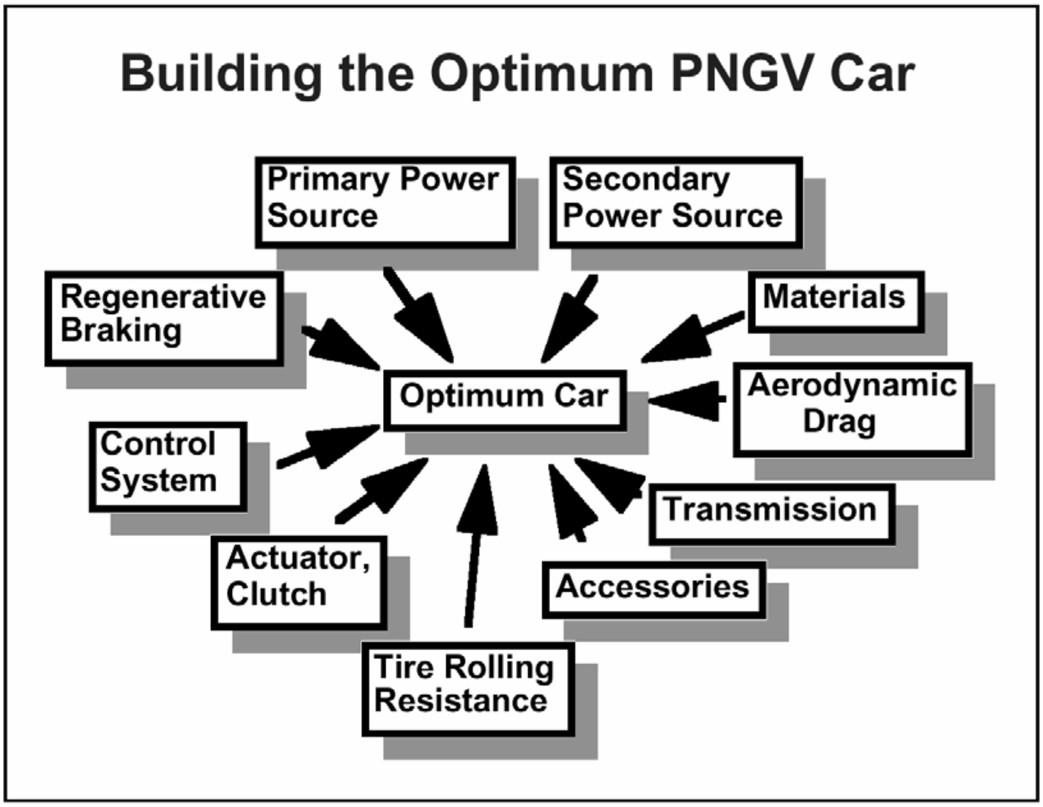
Figure 1: The Main Challenges Facing the Hybrid Electric Vehicle Technology.

In 1993, an alliance was formed in the USA with the common goal of creating a most fuel-efficient generation of vehicles at the level of performance, utility and cost the consumer can afford. This partnership now known as the "Partnership for a New Generation of Vehicles" (PNGV) includes US federal agencies, national laboratories, universities, and others with three of the major US automotive corporations. It has chosen to concentrate on the hybrid vehicle technologies and is now one of the major developers of such technologies. The goals of the PNGV have been so formulated as to build a vehicle with the following parameters:

- Fuel efficiency of up to 80 mpg (34 km per liter, around three liters per 100 km).
- Confirming to the US Tier 2 emission standards.
- Meeting all US federal safety standards.
- Having size, performance, and cost of ownership comparable to today's midsize family sedans.
- Employing "leapfrog" (most advanced) technology for engine, drive train and vehicle.

Figure 2 presents the strategic approaches studied by the PNGV for their new car commitment.

The PNGV is not the only alliance to pursue the development of the new hybrids. All major companies, environmental institutions, universities, etc., involved with the automotive business are participating in the drive towards the creation of a new generation of vehicles. Among the countries leading in these efforts are not only the US, but also Japan, Germany, France, U.K. and others.



Source: Environmental Fact Sheet: Partnership for a New Generation of Vehicles and the Environment Environmental Protection (1997), US EPA Document EPA420-F-97-019.

Figure 2. Approaches Studied by the Partnership for a New Generation of Vehicles (PNGV) for building their conceptual car.

The major present achievements in the reduction of emissions through the hybrid vehicle technology have been summarized in *Zero Emission Vehicles*. One of the impressive results, reported for a year 2000 prototype hybrid vehicle is the achievement of the lowest yet drag coefficient of 0.163. The importance of the drag coefficient for the fuel economy has been explained in *Electric Vehicles*.

The brief review of the main parameters of the hybrid vehicle technology, presented above, implies that the right solutions can be reached through optimization. The latter includes mainly the balance between the two main sources of power in the hybrid vehicle – the electric and that of the internal combustion engine.

Other trade-off decisions include the most suitable battery thermal management approach, the rational use of energy for climate control and other auxiliary functions, the choice of fuel and engines, etc.

-
-
-

Bibliography

1. Burch, S. D. (1999) *Trading off HEV Fuel Economy and Emissions through Optimization*, Hybrid Electric Vehicles Here and Now, TOPTEC Conference, May 26, 1999, London U. K. [An example of the systems approach towards optimization of the most important outputs of hybrid electric vehicles. Slides from the presentation can be obtained through the Internet from http//www.nrel.gov].

2. *California Air Resource Board Staff Report (1998): 1998 Zero-Emission Vehicles Biennial Program Review*, 46 pp., California Air Resources Board, USA.[Report on the status of zero emission vehicle technology. This report as well as an executive summary of the year 2000 biennial report can be obtained from the web site of the Agency – http//www.arb.ca.gov].

3. *California Exhaust Emission Standards and Test Procedures for 2003 and Subsequent Model Zero-Emission Vehicles, and 2001 and Subsequent Model Hybrid Electric Vehicles, in the Passenger Car, Light-duty Truck and Medium-duty Vehicle Classes* (1999), 19 pp., California Environmental Protection Agency, Air Resources Board, USA. [The official test procedures for testing hybrid vehicles in the USA. Can be obtained from the web site of the Agency].

4. Faiz A., Weaver, C. S., Walsh, M. P. (1996), *Air Pollution from Motor Vehicles: Standards and technologies for controlling emission*, 250 pp., World Bank, Washington, USA. [Highly informative and comprehensive review on engines, fuels, illustrated with numerous case studies].

5. Kalhammer, F. R., Prokopius, P. R., Roan, V. P.. and Voecks, G. E. (1998). *Status and Prospects of Fuel Cells as Automobile Engines. A Report of the Fuel Cell Technical Advisory Panel*, Section II, 25 pp., Prepared For State of California Air Resources Board, Sacramento, California, USA. [One of the best choices for professional information and analysis of the fuel cell automotive technology. Widely used in the present chapter. Can be obtained from the web site of the California Air Resources Board].

6. McCargar, J. A. (1999), *Paving the Way for EHVs (Environmental Hybrid Vehicles)*, Hybrid Electric Vehicles: Here and Now, TOPTEC Conference, May 26, 1999, London U. K. [Slides from the presentation, available through the Internet, web site http//www.nrel.gov).

7. Nowell, G P. (1999), *Looking Beyond The Internal Combustion Engine: The Promise of Methanol Fuel Cell Vehicles*, 38 pp., Review Prepared for The American Methanol Institute. [A detailed and optimistic review of the prospects for using methanol in fuel cell vehicles (obtained from http//www.methanol.org].

8. Rand, D. A. J., Woods, R. and Dell, R. M. (1998), *Batteries for Electric Vehicles*, 577 pp., Research Studies Press, Taunton, UK. [A latest book on batteries and electric vehicles].

9. Singh, R. (1999), *Will Developing Countries Spur Fuel Cell Surge*, Chemical Engineering Progress, March 1999. 59 – 66. [A general article on fuel cell technology describing their use for power generation in stationary and automotive applications].

10. Wakefield, E.H.(1998) *History of the Electric Automobile: Hybrid Electric Vehicles*. 332 pp, Society of Automotive Engineers (SAE), Warrendale, Pa. USA. [A very well documented and illustrated history of the development of the HEV concept].

Biographical Sketch

Georgi St. Cholakov is Associate Professor at the University of Chemical Technology and Metallurgy in Sofia. He received his first hands-on experience of ecological problems during compulsory his military service as the Head of the Fuels and Lubricants Unit of an airbase. His PhD dissertation was on development of replacements for lubricant additives synthesized from the sperm oil, obtained from blue whales. He did a post doctoral specialization in tribology at the University of Birmingham, U.K. Later he specialized in effective and ecological processing and use of petroleum derivatives at Imperial College, London, the French Institute of Petroleum, and other leading universities. The scientific and research interests of G. St. Cholakov are centered around petroleum processing and petroleum derivatives – environmentally compatible processes and products, process and product design for the petroleum industry, chemistry of combustion and ecology, etc. He is teaching advanced courses in related academic disciplines – alternative fuels and lubricants, air pollution management, chemistry of combustion and ecology, additives for fuels and lubricants, technological computation in petroleum processing, etc. He has contributed more than 50 papers in refereed international journals and co-edited the Bulgarian edition of Miall's Dictionary of Chemistry. He is member and has served in elective positions in different Bulgarian and Balkan professional organizations. He has been member of the editorial boards of two journals, published in Bulgaria in the English language.