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Fuel cells for vehicle applications in cars - bringing the future closer

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Abstract

Among all alternative drive systems, the fuel cell electric propulsion system has the highest potential to compete with the internal combustion engine. For this reason, Daimler-Benz AG has entered into a co-operative alliance with Ballard Power Systems, with the objectives of bringing fuel cell vehicles to the market. Apart from the fuel cell itself, fuel cell vehicles require comprehensive system technology to provide fuel and air supply, cooling, energy management, electric and electronic functions. The system technology determines to a large extent the cost, weight, efficiency, performance and overall customer benefit of fuel cell vehicles. Hence, Daimler-Benz and Ballard are pooling their expertise in fuel cell system technology in a joint company, with the aim of bringing their fuel cell vehicular systems to the stage of maturity required for market entry as early as possible. Hydrogen-fuelled zero-emission fuel cell transit 'buses' will be the first market segment addressed, with an emphasis on the North American and European markets. The first buses are already scheduled for delivery to customers in late 1997. Since a liquid fuel like methanol is easier to handle in passenger cars, fuel reforming technologies are developed and will shortly be demonstrated in a prototype, as well. The presentation will cover concepts of fuel cell vehicles with an emphasis on system technology, the related testing procedures and results as well as an outline of market entry strategies.

Keywords: Fuel cells; Electric propulsion; System technology; Fuel cell electric vehicles

1. Introduction

Daimler-Benz demonstrated the feasibility of applying fuel cells for vehicle propulsion with the first fuel cell vehicle in the world, NeCar I, introduced in 1994. Since then, the power density and functionality have been continuously improved and the enhanced prototypes, NeCar II and NeCar III, have been presented in 1996 and 1997, respectively. NeCar II is an hydrogen-fuelled mini-van with six seats and almost fully usable storage capacity. With its 50-kW fuel cell system and two compressed hydrogen tanks on the roof, NeCar II reaches 110 km/h and has a range of more than 250 km. NeCar III, first presented at the International Auto Show in Frankfurt, August 1997, is the first fuel cell vehicle that runs on liquid fuel, allowing convenient refuelling and long range up to 400 km. NeCar III can also be seen at the Tokyo Motor Show in 1997. The NeBus, a fully functioning city transit bus with a 250-kW fuel cell system has also commenced operation during 1997.

This rapid and successful development has encouraged many major car manufacturers and suppliers to consider fuel cell propulsion system development as a viable future prospect. Daimler-Benz is already aiming at large-scale commercial production of fuel cell vehicles.

2. Choice of fuel cell

For vehicle applications, the polymer electrolyte membrane (PEM) fuel cell, which operates at 80°C, has proved the most attractive option. In this system, the membrane functions both as a gas separator and electrolyte, permitting the hydrogen fuel side to react with the oxidiser (oxygen-air) in a controlled manner to produce power at the electrodes, through the mediation of immobilised electrocatalysts bonded to the membrane. This membrane-electrode assembly is referred to by the acronym MEA. Each MEA is interconnected via bipolar plates which perform several functions including gas distribution, heat dissipation and electrode current collection. In this way, stack assemblies are fabricated with higher voltage outputs, being multiples of single cells in series, capable of driving the vehicle motor through its controller. The detailed manner in which these

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various functions of fabrication, assembly and functioning are described in individual papers in this and other journals.

3. Energy efficiency and emissions of fuel cell vehicles

The efficiency of any work-producing engine is limited by the Second Law of Thermodynamics as exemplified by the Carnot cycle. For heat engines, in which the flame temperature is rather high, the maximum efficiency is rather low for operation around ambient temperatures. For fuel cells, the temperature at which work is developed through direct chemical combination on a catalyst surface, is much lower. Thus, in the fuel cell, the thermodynamic efficiency attainable, defined by the critical temperature difference between that at which work is developed and that at which heat is rejected, is much higher. Typically, the PEM fuel cell in a vehicle can operate at 50–80% efficiency, with the higher value pertaining to partial load, e.g. as in stationary traffic. Notwithstanding, the citation of such efficiency values demands considerable qualification. In NeCar II, an overall efficiency of 28.8% was recorded in the European driving cycle. These values were measured on a non-optimised proof-of-concept prototype vehicle, with a projected potential to achieve 40–45% by the year 2003. By comparison, the best diesel car engines are expected to achieve no greater efficiency than 26% by that time.

The second major advantage of fuel cell vehicles lies in their capability to deliver substantial reductions in emissions. The tailpipe emissions of hydrogen-fuelled fuel cell vehicles, in terms of the normally monitored pollutants, is zero. The overall emissions from the system are 90% less than from conventional vehicles, taking into account the entire energy conversion chain – onboard and at the remote hydrogen generating plant.

For passenger cars, a liquid fuel like methanol might be preferred as it allows for simplified refuelling; conventional filling stations could be modified to distribute this fuel. In this scenario, methanol would be converted to hydrogen, with by-product carbon dioxide, onboard the car in a reformer. This would lower the overall efficiency slightly compared with the hydrogen-based system. Nevertheless, even this methanol-powered car would consume less energy than a diesel or gasoline engine. Furthermore, the 90% improvement in overall emissions holds true for the methanol-powered vehicle as well.

4. Daimler-Benz strategy toward fuel cell technology

Any producer of premium products such as Daimler-Benz can only distinguish itself from competitors through outstanding technical achievement. From the present viewpoint. The fuel cell offers the alternative drive system with the greatest potential for successful competition with the internal combustion engine. All of the worlds' major motor manufacturers are presently working on fuel cell technology. In the USA, a joint development project between GM, Ford and Chrysler is being sponsored by the departments of Energy and Transport. At the end of 1996, Toyota in Japan unveiled a vehicle which incorporated an hybridised battery and fuel cell drive train system. Whoever becomes the first to cross the finishing line in this particular race, that is to say, whoever produces the first marketable vehicle, will be able to determine the rules of the game. For this reason Daimler-Benz has a strong commitment in this field and is targeting a high volume product rather than small or medium niche applications. Daimler-Benz would like to be the first to offer a fuel cell powered mass-production vehicle in the marketplace.

5. Co-operative venture with Ballard

In a C$450 million venture, Daimler-Benz has agreed to pool its experience in both mass-production process and design of vehicle fuel cell engines with the notable expertise in PEM fuel cell fabrications of Ballard Power Systems of Canada. The objective of this alliance is to commercialise and market fuel cell engines, being the first in the world with volume-production for mobile applications. As part of this agreement, Daimler-Benz has acquired a 25% share in Ballard Power Systems, through a rights issue of new share capital. Furthermore, a joint venture company named dbb Fuel Cell Engines, has been founded; its aim will be to prepare the fuel cell system as a unit for the market. Daimler-Benz holds a two-thirds share and Ballard a one-third share in this new company. Marketing these fuel cells and related engine systems will be the task of another company in which Ballard and the joint venture organisation will have an equal share: this company will commence trading as Ballard Automotive.

6. dbb Fuel Cell Engines – the company

dbb Fuel Cell Engines is a German-registered company having two overseas branches in Vancouver and San Diego. The former employs approximately 35 staff, the latter 25 staff. The company headquarters is located at Nabern near Stuttgart, it employs about 75 staff.

The role of dbb Fuel Cell Engines is to develop and produce all systems technology required for operation of PEM fuel cells, i.e. fuel processing, cooling, water and air management, electric and electronic control and other system components including software, for example. dbb's business approach implies that fuel cell systems including all related customer engineering aspects will be offered in the world market on a non-exclusive basis. The first products of dbb Fuel Cell Engines will be six transit buses equipped with 250-kW hydrogen fuel cell systems presently undergoing delivery to the Chicago and Vancouver transit authorities for customer evaluation.

7. Future challenges

In order to assure customer acceptance, the fuel cell drive system must not compromise performance, space availability, nor overall cost. However, like all new technologies, presently, fuel cells and fuel cell propulsion systems still suffer from initial technical constraints, such as gravimetric, volumetric and cost premiums, compared with established combustion engines. Daimler-Benz, Ballard and their new ventures aim both to improve the power density of their fuel cell systems and to make them affordable. The first objective will be to integrate the system into small cars such as the Mercedes-Benz A-class range, without compromising the available passenger or luggage space. The parallel improvements being introduced in manufacturing will lead to cost-reduction such that high volume production will yield unit costs comparable with the present diesel engine. This programme is expected to reach fruition in about eight years.