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Hydrogen-Fuelled Car : A Need for Today's Era

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Abstract: *By introducing its newest hydrogen-fuelled vehicle named mirai- the zero emission vehicle, Toyota has proven that this energy carrier is in principle conceivable alternative to fossil fuels in terms of vehicle technology. Companies will continue the development of this drive system technology in collaboration with expert partners, with particular emphasis on crucial factors such as safety and user acceptance. Using this could offer the advantage of minimal pollutant emissions in conurbations, for instance, where the need to avoid pollution is particularly pressing. The cost and effort of creating the required energy supply infrastructure in such areas would moreover be rendered transparent.*

Keywords-*Stoichiometric, Combustion ,Conurbation, Tribological, Propulsion, Mirai*

I. INTRODUCTION

Today, we can look back on over 100 years of automobile history. Throughout this period developments evolved according to user requirements, with the general good as an added consideration in recent years, in part steered by legal specification.

The passenger car represents the ultimate consumer article in industrialized nations. Individual mobility is on the one hand an agreeable accomplishment of our affluent society, and on the other one of the fundamental conditions of an efficient and competitive economy. This explains why, for instance, passenger cars currently account for over 80% of passenger transport in Germany. On the strength of the passenger car's almost unbeatable qualities, this statistic is unlikely to change much in the foreseeable future.

The future focus of automotive development will be on further improving traffic safety, the efficiency of road traffic and its environmental compatibility. The challenging aims of avoiding emissions and preserving natural resources will continue to exert a considerable influence on the development and production processes, the way in which a vehicle is used and the disposal of scrap vehicles in the future.

The amount of pollution generated when energy is converted by a vehicle and during the preceding stages of energy recovery and distribution is to be kept to the necessary minimum. It will probably become necessary to cut emissions of carbon dioxide, the main product of the combustion of fossil energy carriers, by a drastic degree in the medium term. These two requirements cannot be met simply by the increasingly cost-intensive measures of weight-saving vehicle design and efficient energy conversion. This is why scientists and the industry worldwide are seeking new, cleaner energy paths involving new forms of energy storage and energy conversion for propelling passenger cars.

II. ALTERNATIVE ENERGIES FOR THE AUTOMOBILE

Almost exclusively the mineral oil products gasoline and diesel oil are used as fuel for road-going vehicles, as they are easy to handle and exhibit a high energy density.

As a result of regionally varying supply, certain other fuels produced from fossil energy sources have been and are used: if methanol, liquid gas (LPG) or methane (CNG) are used, the levels of certain emission components are cut. Isolated market niches can therefore be exploited in order to alleviate certain regional problems caused by pollutant emissions. However, the above hydrocarbons are scarcely likely to gain global significance as vehicle fuels because natural resources are limited. In addition, when the energy conversion chain and cumulative emissions are considered as a whole, especially those emissions which are not yet governed by legal limits, no particular advantages over conventional fuels are to be expected.

The situation is the same for the production of fuels from biomass. These energy carriers on the one hand are hardly likely to achieve a very low level of pollutants and odoriferous components, and on the other total carbon dioxide emissions are not as favorable as is often assumed when the overall process is taken into account.

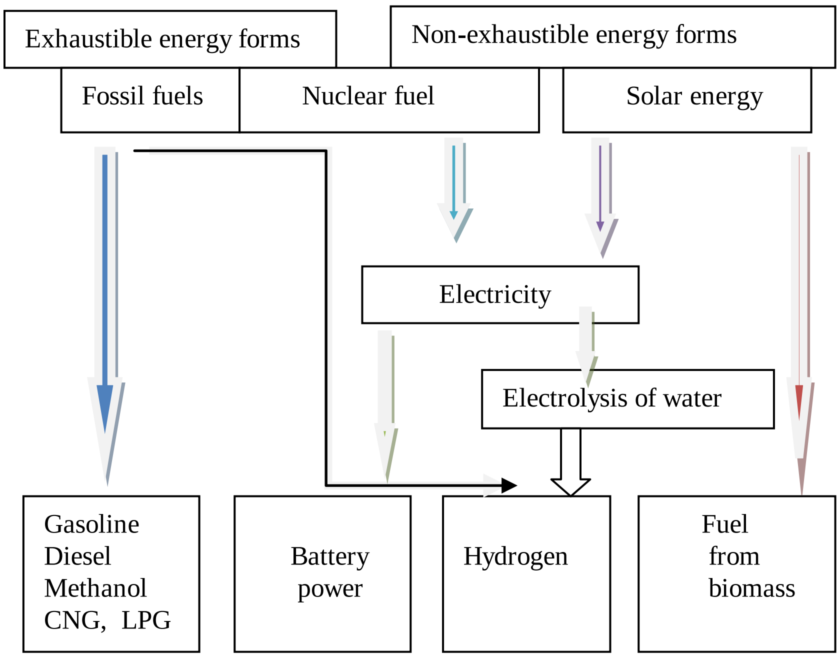

Fig. 1 : Potential energy forms for automotive propulsion

There are numerous ways in which solar energy can be technically exploited (hydro power, wind energy, thermal collectors etc.), many of which still offer ample scope for development. However, these energy paths too involve intervening in nature, with industrial-scale plants in particular imposing major burdens. Although it provisionally appears to be much more environmentally compatible to utilize regenerative energy forms than to burn fossil energy resources, it is not yet possible to draw up a substantiated assessment of all the undesirable effects of the various techniques.

Furthermore, it is not possible to produce easy-to-handle energy carriers for solar energy which are anything as convenient as hydrocarbons, which are available in liquid form at ambient temperatures. Electricity can be generated from solar energy. Batteries are required to store this solar energy; alternatively the secondary energy carrier hydrogen, which is easier to store and transport, can be produced by the electrolysis of water.
The water required in the electrolysis process is returned to the natural cycle when the hydrogen fuel oxidizes with oxygen. The hydrogen is itself, a gas which is approx, 15 times lighter than air in ambient conditions, is colorless, odorless and non-toxic. In suitable combustion conditions with air, the only product of the combustion process is water. Water can safely be termed the cleanest fuel for internal-combustion engines if the problem of how to produce and distribute this energy carrier is solved in a satisfactory manner.

III. CURRENT STATE OF DEVELOPMENT OF HYDROGEN STORAGE SYSTEMS FOR PASSENGER CARS

Compared to the conventional fuels gasoline or diesel oil, storing hydrogen as the fuel for a passenger car is a very complicated matter. Following testing in research vehicles, metal hydride tanks and liquid tanks have proven fundamentally suitable. High-pressure tanks cannot be considered as an option for passenger cars in view of their unacceptably high hazard potential, weight and volume.

Metal hydride storage is based on the property of certain high-grade metal alloys of binding or releasing hydrogen at certain temperatures and pressures. Metal hydride storage, which has already reached a relatively advanced state of development, can be used for special applications where tank weight, vehicle range and cost are of only secondary importance.

Hydrogen stored in liquid form offers the highest energy density of all hydrogen storage system in terms of mass and volume, and is therefore the only form of storage with scope for eventual universal use. Vehicles with a low range of up to 200 km are likely to have electric drive. With the exception of liquid hydrogen technology, all other types of hydrogen storage for an operating range of more than 200 km would increase the vehicle's overall weight by more than 400 kg. Such an increase in passenger-car weights is untenable because of the adverse effects on road behavior and safety levels in a collision. The resulting drastic increase in fuel consumption would be far higher than the energy input for liquefying the hydrogen, which is slightly in excess of the energy input for other storage forms.

Ultra-efficient insulating technology is required for the tanks and lines in order to prevent evaporation losses as far as possible when liquid hydrogen is handled at (-253˚C). In commencing its activities with liquid hydrogen, companies like BMW was able to build on the invaluable groundwork performed by DLR and profit from DLR'S experience in the field of aerospace. Now, several development phases later, tank systems representing a relatively high standard of technical maturity have been designed as a result of this collaboration between expert development partners:

The current cylindrical tanks have a capacity of 120 liquid hydrogen and area of a double-wall design, with an evacuated insulating jacket approx. 3 cm thick, containing up to 70 layers of aluminium foil and inter layered fiberglass matting. The weight of the tanks when full is about 60 kg, and the maximum operating overpressure 5 bar. Such tank systems permit operating ranges of up to approx. 400 km for average universal vehicles. As a result of the cylindrical shape and the required volume, which exceeds that of a conventional fuel tank by almost a factor of four, the area above the rear wheels is effectively the only possible location on a passenger car. For test purposes, it can just about be accommodated by a modern large-size saloon without drastic modifications to the vehicle package.

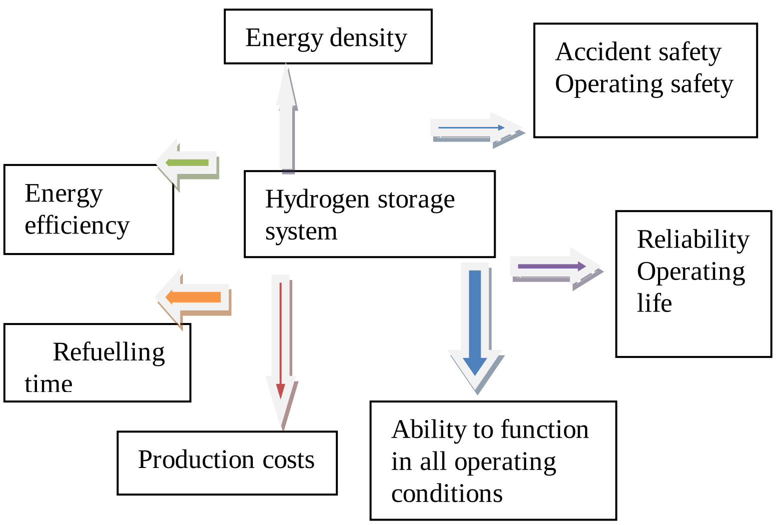

Fig. 2: A selection of important requirements of hydrogen storage systems for passenger cars.

Tanks for conventional fuels satisfy many of the requirements shown in Fig. 2 more effectively than hydrogen storage systems. However, analysis of the current development status leads us to conclude that liquid hydrogen technology in all probability offers the potential for satisfying all requirements at an acceptable cost or with defensible restrictions on use.

A factor of central importance in the design of liquid hydrogen tank systems was and is the need to treat safety aspects as a priority. Valuable indicators of how liquid hydrogen can be handled safely in passenger cars have been available for some time now. In the meantime, further progress has been achieved especially in the field of operating safety. The durability of several system components has been confirmed in simulations of extremely tough operating conditions. In order to protect the tanks against an impermissible buildup of pressure, more efficient and reliable valve combinations have been developed.

IV. ESSENTIAL DEVELOPMENT STEPS FOR LIQUID-HYDROGEN TANK SYSTEMS

The tank of optimizing the function and economy of tank systems is clearly one of the responsibilities of car manufacturers and their component-manufacturer partners. This aspect of development work is progressing fruitfully. Problems have been encountered in the organizational and financial processing of more general task areas. In this field of storage technology, this primarily means preliminary work for filing official approval and overall consideration of methods of transportation and re-tanking, in other words problem areas which extend beyond the tasks of individual vehicle manufacturers.

Company like BMW is actively involved in several projects which aims in improving the method of tanking liquid hydrogen and bringing it to practical maturity. The constellation of energy generating company and supplier, gases producer and distributor and vehicle manufacturer constitutes a highly promising interface between energy supply and energy utilization. Once suitable components and the process technology have been developed, the entire refueling process will probably take less than 10 minutes (compared with the previous 1 hour) with virtually negligible energy losses.

Companies like BMW, Toyota etc, are conducting experimental research into the effect of fire on liquid hydrogen vehicle tanks and into the destruction of tanks by excessive internal pressure or mechanical force. Suitable research departments, industrial companies and the bodies responsible for issuing official approval are involved in this project. The cost and effort of obtaining an initial operating permit for liquid hydrogen tank systems in passenger cars are not yet foreseeable.

V. STATE OF DEVELOPMENT OF ENERGY CONVERTERS FOR PASSENGER CARS WITH LIQUID HYDROGEN TANK SYSTEMS

At the start of the 20th century, the reciprocating internal-combustion engine supplanted all other versions as a result of the breakneck development of its benefits. Even when run on hydrogen, this energy converter will not see its dominant status dwindle in the foreseeable future. The internal-combustion engine's principle is the one which best satisfies the wide-ranging requirements of an energy converter for the utilization of hydrogen as a vehicle fuel.

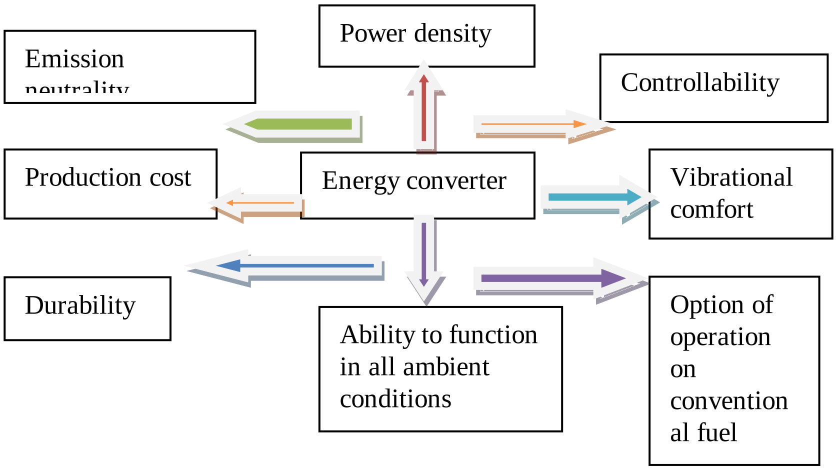

Fig. 3 : Several important requirements for energy converters for hydrogen-powered passenger cars

Modern spark-ignition engines designed to run on unleaded gasoline can also run on hydrogen if a new mixture formation system if fitted and if modifications are made to the ignition system and the gas exchange organs. The operating data of future engines which are fully optimized for operation on hydrogen will, however, differ from current spark-ignition engines. The mixture formation system is nevertheless initially the most important development target. The way the hydrogen is prepared and metered exerts a greater influence on engine functions and system complexity than other assemblies.

High-energy, i.e. stoichiometric hydrogen/air mixtures can at present only be governed by technically very advanced internal mixture formation, or with the aid of additional measures such as water injection in the case of external mixture formation. Such engines can emulate spark-ignition engines in terms of power output. BMW has teamed up with DLR on the development of components for the direct injection of cryogenic hydrogen. The liquid-hydrogen delivery pump and injectors are particularly complex components in view of the low fuel temperature and the fuel's lack of lubricating properties. These components have to be driven hydraulically, for instance, necessitating auxiliary systems on the vehicle.

Development results obtained to date from hydrogen-powered engines reveal that reciprocating gasoline engines which can also run on liquid hydrogen exhibit similar operating characteristics to present-day car engines, and moreover achieve extremely low pollutant emission levels without exhaust-gas treatment. However, these results must not be allowed to obscure the fact that numerous engine details still need to be solved and fundamental matters concerning the approval procedure remain to be clarified before a hydrogen engine which is suitable for everyday use can be developed.

VI. THE NEED FOR FURTHER DEVELOPMENT WORK ON ENERGY CONVERTERS FOR CARS WITH LIQUID HYDROGEN TANK SYSTEMS

Development work on hydrogen-powered spark-ignition engines must be pursued in order to confirm the approach which has been adopted for the engine design concept, with a view to achieving ultimate series maturity and suitability for everyday driving. The main task is to resolve the conflict between high performance density and the need to prevent nitrogen oxide emissions even more effectively. The mixture formation system still offers considerable scope for development in this respect.

Alongside its own development activities company like BMW has teamed up with Robert Bosch GmbH on the development of sequential hydrogen metering into the intake air. Mixture formation using cryogenic hydrogen moreover offers crucial advantages in its scope for boosting efficiency and performance, but also harbors a large number of complications. In addition to the mixture formation system, the gas exchange layout together with a suitable supercharging process, the ignition system and the tribological properties are in need of further development, always bearing in mind that optional gasoline operation should be assured.

Appropriate tools and methods first had to and have to be devised for development work to proceed efficiently. For example, BMW planned and built the first test rig for hydrogen engines in the world. This complex setup incorporating particularly advanced safety technology was started up in early 1989. A large number of new testing and measuring methods will need to be devised in future as flanking measures to development work proper. Improved exhaust emission measuring techniques capable of recording and assessing emissions by mass, which differ considerably from those on conventional engines, are particularly important.

Steady progress has been made on fuel cell technology in recent years, zero emission vehicle- mirai launched by Toyota shows advancement in fuel cell technology. But the problems like endurance and the number of refueling station are still to be improved in order to attract the trust of people all around the world. Via various fuel cell projects, companies like BMW, Toyota etc. are contributing the expert knowledge of a car manufacturer of this type of technical system with a view to defining the requirements and design criteria for the overall vehicle.

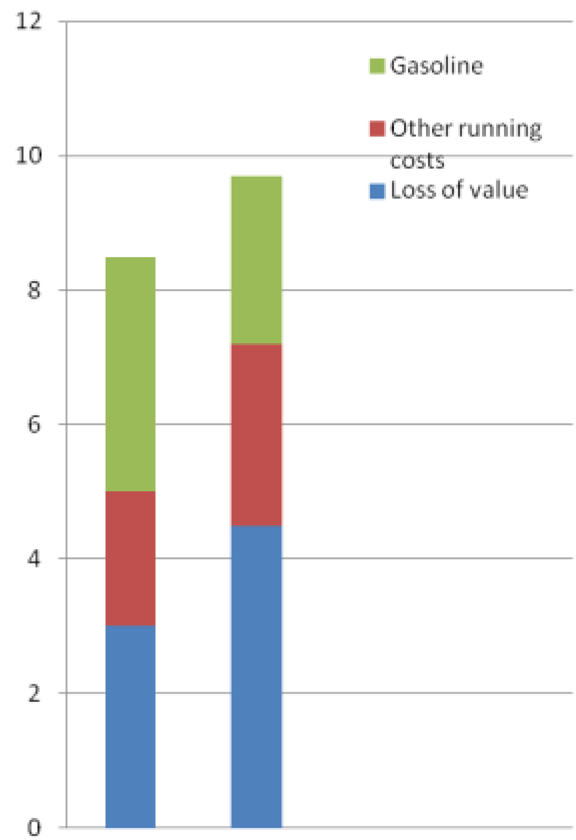

Fig. 4 : Estimate of user-relevant upkeep costs for a two-fuel vehicle(hydrogen/gasoline) compared to the conventional gasoline vehicle.

Chart 1 : Conventional gasoline-engine vehicle
Chart 2 : Vehicle with 2 fuel types (hydrogen/gasoline, run 50:50 on each)

A comparison of user-relevant costs of upkeep for both the aforementioned drive systems reveals that although a hydrogen car is appreciably more costly to run, the added expense is not out of all proportion even though the hydrogen itself is comparatively expensive. The above estimates are conservative. The steady progress being made in technologies for utilizing renewable energy sources and in introducing environmental legislation is likely to reduce the difference in cost between conventional vehicles and hydrogen-powered vehicles.

VII. CONCLUSION

The energy supply has always been one of man's major problems. The Gulf War at the start of 1991 once again drove home the fact that the question of resources holds the power to destabilize society, both now and in the future. The growing global population and the desires of an increasing number of people to share in the prosperity of industrialized nations are causing the world's energy requirements to spiral, with the result that it is becoming an increasingly pressing concern to establish an environmentally compatible energy supply.

The experts agree that new, pro-environmental energy paths which are immune to political crises must be opened up. However, our energy supply structures can only be changed to any significant degree with lengthy preparation and high expenditure. It is therefore essential to push through the development of the necessary new technologies as soon and as concertedly as possible, so that mature systems suitable for everyday use will be available in good time.

Political organs are now called upon to provide assistance in dealing with overriding problems and in establishing the basic conditions for systematically developing these highly promising technologies

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