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Technical Evaluation of Current Hydrogen Storage Technologies for Vehicles

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Abstract: With the decline of global fossil fuel reserve and the increasing demand for energy, there is a sincere need to develop alternative fuels for automobiles. Hydrogen is an environmentally friendly and renewable energy source. It has been considered an ideal fuel for replacing fossil fuels. Currently, Liquid Hydrogen (LH2) system (with a density of 51 kg m^{-3} and 14 wt.%) is close to practical use. However, the cost of using LH2 as a transportation fuel is nearly twice that of Gaseous Hydrogen (GH2), due to the liquefaction process, increased fuel transportation costs and more complex manipulation of the fuel. If the intention is to use hydrogen on a large scale, storage is a key problem. Researchers have shown that hydrogen could be stored as: compressed gas, cryogenic hydrogen and metal hydrides. However, the number of alternative methods is growing, including the use of carbon novel materials, chemical hydrides and glass microspheres. This are also being considered. The present is study reviews the different solutions for hydrogen storage and highlights the promising technology for vehicle use.

Key words: Hydrogen storage, cryogenic, hydrides, compressed gas

INTRODUCTION

Currently fossil fuels on which most automobiles run are declining, which puts a tremendous pressure on the automotive industry to develop alternative fuels which can meet the demands of the industry. Some of the alternative fuels which are being considered include LPG, LNG, bio-diesel, methanol, ethanol and hydrogen. Table 1, compares the energy contents of various fuels. Of these hydrogen offers the highest energy per unit mass (141.9 MJ kg^{-1}) making it most suitable for automotive applications as discussed by Robert and Setlock. (2004), Banyay (2006), Gopalan (2006) and Ryu (2006). It can thus be seen that hydrogen contains about 2.75 times more energy per unit mass than gasoline. Many properties of hydrogen make it a unique and very promising fuel suited for automotive use. Of these properties: a very high flame speed and a wide range of flammability limit as mentioned by MatWeb (2006), DIAB (2006) and Das (1996). Many problems are associated with the use of hydrogen as an automotive fuel. These problems are associated with its production, distribution and storage. Out of these, storage is the key problem since hydrogen has a very low density (0.0899 kg m^{-3} at STP) and also a low volumetric energy density (0.013 GJ m^{-3}) as discussed by Tiwari *et al.* (2005). Due to this low volumetric energy density, hydrogen has to be stored at a higher pressure in the range 20-80 Mpa in regular sized tanks as mentioned by Zuttel (2006). Hydrogen-powered vehicles are required to provide the same driving distance as today's gasoline-powered vehicles. As per the targets set by the US Department of Energy, storage system for onboard vehicular application must ideally provide a mass efficiency of 6.5 weight percentage of hydrogen for weight and size appropriateness and to facilitate a fuel cell car to drive a distance of 560 km (350 miles).

Table 1: Energy content for various fuels

Fuel	Chemical formula	State	Energy $unit^{-1}$ mass (MJ kg^{-1})	Energy $unit^{-1}$ volume (MJ m^{-3})
Gasoline	$C_{5-10}H_{12-22}$	liquid	47.4	34.900
LPG	$C_{3-4}H_{8-10}$	liquid	48.8	24.400
LNG	~CH_4	liquid	50.0	~230.000
Methanol	CH_3OH	liquid	22.3	18.100
Ethanol	C_2H_5OH	liquid	29.9	23.600
Liquid hydrogen	H_2	liquid	141.9	10.100
Hydrogen	H_2	Gaseous	141.9	0.013
Natural gas	~CH_4	Gaseous	50.0	0.040

HYDROGEN STORAGE TECHNOLOGIES

Storage is the key drawback in utilizing hydrogen-powered vehicle technologies, since hydrogen has a low density (0.0899 kg m^{-3} at STP) and a low volumetric energy density (0.013 GJ m^{-3}) as discussed by Tiwari *et al.* (2005). Due to this, 1 kg of hydrogen at ambient temperature and atmospheric pressure occupies a volume of 11 m^3 as mentioned by Zuttel (2006). Thus hydrogen has to be stored at high pressure limit of 69 to 103 Mpa (10000-15000 psi) in regular sized tanks as mentioned by Zuttel (2006).

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