

Report 1: An Assessment of the use of Hydrogen Within a Touring Car Internal Combustion Engine

Introduction

To fully assess the feasibility of using hydrogen within a motorsport application, there are a number of distinct areas that need to be examined:

- Engine performance evaluation
- Fuel storage and fuel system safety
- Overall vehicle new performance analysis
- Resultant fuel consumption
- Vehicle emissions

Hydrogen as a Fuel: Summary of Existing Automotive Hydrogen Technology

BMW has been carrying out research into the use of hydrogen in automotive applications for over 30 years. Considerable research work has been carried out using the 7 Series platform with a 5.4 litre V12, engine capable of running on either hydrogen or gasoline supplied by two independently controlled fuel induction systems. The 140-litre Cryo fuel tank gives the vehicle a range of 350 km, and 140,000km have been completed in hydrogen powered 7 series without problems. The vehicle accelerates to 100km/h in 9.6 seconds running on hydrogen with a top speed of 226km/h. BMW believes, with the right infrastructure in place, thousands of such hydrogen powered cars could be produced by 2010. Refuelling the vehicle only took three minutes, at the first public robot fuel station for liquid hydrogen at Munich Airport. BMW has also recently launched a Mini concept car, with an engine that runs purely on hydrogen.

Mazda has been carrying out hydrogen research, based on a rotary Wankel engine approach for over 10 years now, storing the hydrogen in metal hydride tanks. Research has concentrated on a prototype model called the HR-X, and using the MX-5.

Ford have converted a 2.0 litre Zetec engined Focus to run on hydrogen, stored in very high pressure tanks, and believe the hydrogen fuelled engine could be in cars by 2006. Ford have found that power torque and resultant acceleration is down by about 30-35% in comparison with the gasoline equivalent. This is similar to BMW's findings with the 7 Series. Ford envisages using hydrogen, within internal combustion engines, as the bridge between gasoline engines of today and the hydrogen technology of tomorrow.

Fuel System Options

A) Cryogenic Liquid Hydrogen Storage

- Employed by BMW and other motor manufacturers.
- Hydrogen stored at pressures up to 250 bar, and cooled to temperatures of -253°C, or 20K to ensure it remains in liquid form during storage.
- Two safety valves ensure controlled ventilation in the case of excess pressure. The tanks proved reliable in numerous crash tests, even in the case of massive rear end collisions
- Typical mass for a 140-litre tank is around 60kg.

B) Metal Hydride Tanks

- The metal hydride absorbs hydrogen into metal lattice, stored in the form of a metallic compound. When heated the metal hydride releases the hydrogen.

- Hydrogen is stored as a metallic compound rather than a gas, and at lower pressures reducing safety issues.
- Tanks can be any shape, benefiting their packaging within a vehicle.
- Weight penalty draw back at moment, equivalent hydride tank around 280kg.

Leak Safety and Impact Resistance

Work carried out at the University of Miami, comparing an ignited hydrogen fuel leak with an ignited gasoline leak, demonstrated the hydrogen venting in a single flame plume, and then extinguishing. The ignited gasoline leak resulted in an explosion that eventually engulfed the car. Leaks within enclosed spaces, like garages, pose the greatest hazard. This would need to be considered for any fuel handling guidelines that would be issued to race teams using the fuel. A great deal of literature indicates that hydrogen as a fuel is considerably safer than commonly perceived. Opinion is often influenced by the Hindenburg Zeppelin disaster in 1937, or the Challenger space shuttle disaster in 1986, and not balanced by any other widely known positive hydrogen experience since.

Conclusions

Based on the performance of present road going hydrogen engines, and the performance analysis carried out, it is suggested that the following hydrogen vehicle specification could be acceptable for use within a Touring Car Championship, in the medium term. Note that as hydrogen engine technology develops these engines may not require forced induction.

Table 1: Hydrogen Touring Car Engine and Vehicle Specification

Vehicle Specification	
Configuration	4 cylinder in line
Capacity	2000cc
Fuel	Liquid Hydrogen
Fuel Storage Required	200 litres
Induction	Turbocharged* with 1.0bar boost
Compression Ratio	17:1
AFR	50:1
Peak Volumetric Efficiency	1.16
Max Power	291bhp or 217kW@8,500rpm
Max Torque	272Nm@7,000rpm
Vehicle Mass	1253kg
0-60mph	3.5 sec.
Top speed	145mph

*Based on the assumption that volumetric efficiency is a combustion-limiting factor presently.

A 10% increase in power will deliver equivalent performance to the gasoline vehicle. It appears that the fuel tank could be accommodated within the roll cage of a hatchback based Touring Car.

Extensive testing of fuel tanks and fuel delivery systems in accident situations will need to be fully evaluated. Although BMW have tested their tanks in extreme road accident situations, with impressive results, it is clear that special motorsport hydrogen fuel tanks would need to be developed.

Once safe hydrogen fuel storage in accident situations, and safe hydrogen fuel handling at race weekends, is accomplished in the same way that gasoline fuel safety within motorsport has improved since the 1970s, then a hydrogen fuelled Touring Car will become a feasible concept.

This could be developed, and become reality in 5 -10 years. This is dependent on the level of research and investment into hydrogen storage and fuel tank safety in the interim.

The use of metal hydrides and other storage systems, where the hydrogen is not stored in a pure form, offer enormous potential from a safety perspective.

In terms of performance, a hydrogen-fuelled Touring Car could be marketed to the public. However, it is the technical quality of the fuel system's safety, and how the public perceives this safety, that will determine the long-term success and viability of hydrogen in a motorsport application. The bigger issue associated with the use of hydrogen, within everyday cars on a large scale, remains the production of the hydrogen in the first place - and reducing emissions associated its production.

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