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With a Fuel Cell Motorcycle around the world

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Abstract

The prototype of a hydrogen fuel cell powered Motorcycle that was developed at the Universiti Teknologi Malaysia is on an endurance journey to be driven in all continents around the world. Aiming to be an ambassador for silent and locally emission free transport.

The development is driven by the facts that in Asia millions of motorcycles are the most popular vehicles for individual transport and cause the majority of traffic-based air pollution.

This hydrogen fuel cell driven motorbike shows an alternative in Malaysia and South East Asia there it was developed and tested also in Africa.

Interesting data about real world efficiency and endurance are won by the test drive under very different environments. Reliability of fuel cell systems and system integration are gained and shared.

Keywords: demonstration, fuel cell, hydrogen, motorcycle, scooter

1 Introduction

Pios fuel cell motorcycle is a hydrogen polymer electrolyte fuel cell powered motorbike [1] developed at the Technology University of Malaysia. It was completed in ‘September 2008. The development was driven by the fact that in Asia, motorcycles are the most popular vehicles for individual transport and they cause the majority of traffic-based air pollution.

This hydrogen fuel cell driven motorbike shows that there is an alternative to the pollution problem in Malaysia as well as South East Asia, where it was developed and tested. Further extensive road test was done as a participant (and winner) in the technology class of the South African Solar Challenge October 2008, Picture 1.

Picture 1. Pios fuel cell motorcycle during South African Solar Challenge 2008 technology Class

Aiming to be an ambassador for hydrogen powered silent and locally emission free transport.

The result of the real world tests shows so far that a fuel cell motorbike has 52% lower energy consumption than an equivalent 125cc petrol driven motorbike with the same autonomy of 300km.

Based on the technical test results in a further step a commercial fuel cell motorbike could be developed.
For demonstrations and endurance tests a portable filling station was developed and successfully tested. The portable filling station enables us to make demonstrations and test before a hydrogen infrastructure is in place. It gives positive influence to decision makers like Malaysian prime minister and Minister of Science and Technology.

2 The Concept, Technology and Design

The concept is based on a roofed scooter,(figure 2) for at least two passengers, as the average number of passengers on motorbikes for daily transport in South East Asia is 1.8 people [2]. The roof caters for some rain and sun protection as the weather in the region of Malaysia and South East Asia with hot sun and heavy rain requires.

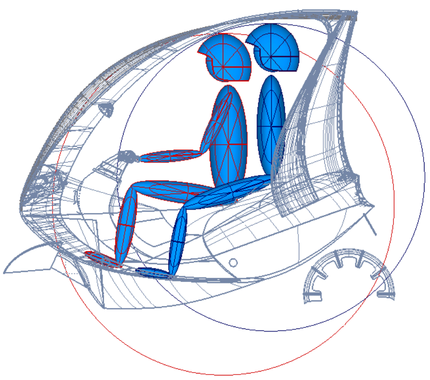

Figure 2. The Industrial Design and the Ergonomic study Concept of the Motorbike

Several technical [3;4,5] components are required for the fuel cell motorbike drive train.(Figure 3) The adequate pacing of this components in terms of weight, size and the balance of the Motorbike is important to get a vehicle with an stable driving behaviour and easy handling. So was the Fuel Cell system as heaviest parts placed in the lower centre of the vehicle; for a low centre of gravity. Lighter parts like cooling Radiator where placed in the upper part of the motorbike. At first a radiator position behind the pillow rider was favoured because of space reasons. Like shown in Figure 3. A custom made design of the radiator and the usage of the casing as cooling body gave the possibility to move the radiator to the front; as an area with higher cooling air flow.

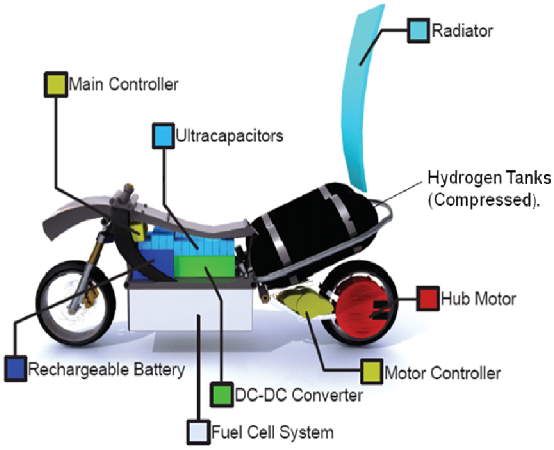

Figure 3: Schema of Fuel Cell Motorbike

Curb mass	290kg
Aerodynamic drag	0.5
Rolling Resistance	0.014
Frontal area	0.8m²
Max. Speed	84 Km/h
Range	300km
FC-system Power	7kW
Motor Peak Power (two motor)	10kW
Buffer Battery(LiPo)	1.780kW/h

Figure 4: Technical specs of fuel cell motorbike

The heart of the motorcycle power train is a 7 kilowatt fuel cell system. It produces electricity for the electric motor which drives the back wheel. (Figure 4 shows technical specs, Figure 5 gives the schematic overview.)
A fuel cell makes electricity from Hydrogen gas (H2) and Oxygen (O2) from the air. The only by product is very pure water (H2O) and heat.

Fuel is supplied to the fuel cell from two 25liter 350bar hydrogen pressure vessels, mounted under the rider and pillion rider seat. The range with a full hydrogen tank is 300kilomeeter, at the speed of 80 kilometer per hour. The transmission on the back wheel is done with two parallel motors.

The second motor can be added on as "booster motor" for climbing hills easily. This design give the advantage of climbing hill slops up to 30 per cent step. During the endurance test at the Sout African solar challenge 2008 this design gave the advantage of climbing all hills and the special award "Leopard Award - King of the Mountains!"

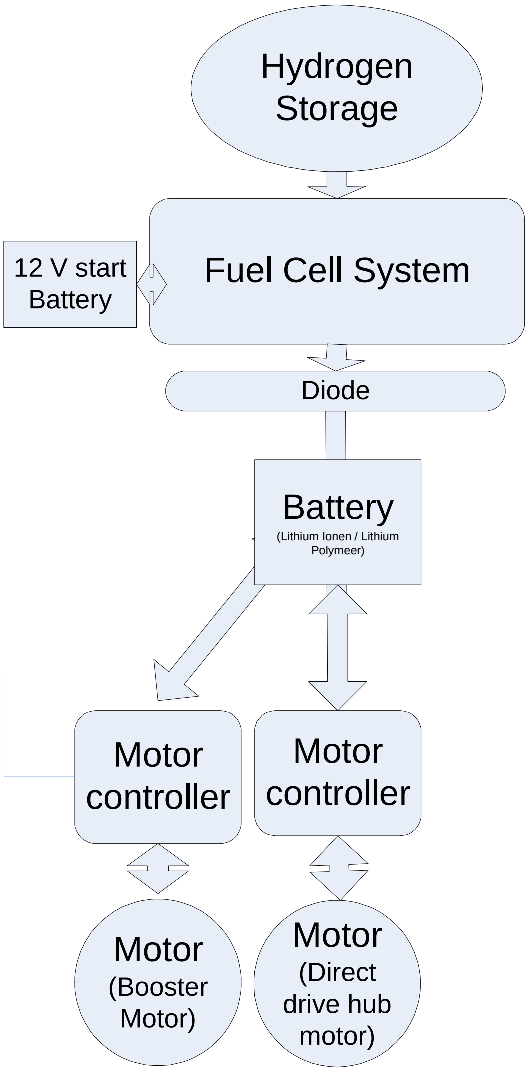

Figure 5. First implemented Drive train schema of motorbike [6]

In an ongoing research project different fuel cell and fuel cell hybrid drive trains will be tested and quantified.

3 The Manufacturing of the Motorbike

The manufacturing of the motorbike take place in several steps . One of the early steps after concept and the delivery of the components was the final design and manufacturing of the custom made frame with gives place for the fuel cell system and hydrogen tanks (Figure 6). Reliability and safety was the key design criteria for the prototype

Figure 6. Custom made fuel cell motorbike frame with fuel cell system and hydrogen cylinders installed.

The bodyworks for the motorbike there performed in carbon fiber and fiber glass (figure 7). The main design criteria were the protection of the components and the rider from weather/water and the environment [7].

Figure 7. Bodyworks of motorbike with negative casting of Fibre glass and carbon fibber fairing parts

3.1 The launching of the fuel cell motorbike

Shortly after completing of Bodyworks the final motorbike was launched to the public by the Malaysia Prime Minister (figure8).

Figure 8. 17th September 2008 was the launching of the fuel cell motorbike "H2 Motive" with the Malaysian flag by Prime Minister Adullah Badawy.

4 The endurance Testing of the Motorbike

4.1 Testing at the South African Solar Challenge 2008; and the winning of the Technology Class Award.

Competing with the Hydrogen Fuel Cell Powered Motorbike, the team of university Teknologi Malaysia reach first in there category the finish in line in Pretoria, the capital of South Africa, on 8th of October 2008. It was a silent and environmental friendly finish because the motorbike makes no noise and locally no exhaust fumes.

Figure 8. logo of the South African Solar Challenge 2008

The "South African Solar Challenge 2008"was organized 2008 for the first time (figure 8); it is so far the longest and most difficult solar challenge on the world. With a distance from over 4000km and a mountain profile from sea Level up to 1800 meters. The rally takes place every two years on public roads for 11 days around South Africa. Start and finish is in Pretoria, it passes through Cape Town and Durbain before it returns to Pretoria. (like to see on the map figure 9)

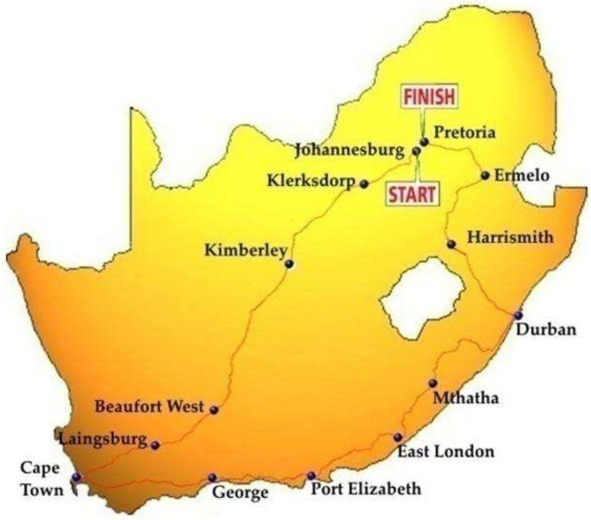

Figure 9. the map of South Africa showing the rout of the 4000km of the South African solar challenge 2008

Vehicles are divided into 2 categories, solar race cars and "Technology Class"; e.g. the hydrogen fuel cell motorcycle named "*H2Motive*". The Technology Class is especially for vehicles with environmental friendly fuel and technology. The fuel cell motorcycle is two times more fuel efficient than conventional motorbike, with no noise and no pollution. Figures 10; 11 and 12 shows Driving conditions and Impressions of the race.

Figure. 10 Fuel Cell Motorcycle during the South African Solar Challenge 2008 - Garden rout, Western Cape District (Photos: K.Arbeus)

Figure 11. Driving conditions there not always perfect they include fog, heavy rain and windy mountain roads.

Figure 12. The winning team (from left) H2Motive motorcycle with Etianne Zind, Hairul Izmail, Prof. Hamdani Saidi, Dr. Kamarul, Kristofer Arbeus, Jörg Weigl

5 The Portable Hydrogen Filling Station

The event of a long distance test rune includes of a mobile hydrogen filling system (figure 13). The fact that the endurance test was performed oversees made a portable hydrogen filling system necessary. It consists of a Main flow with hydrogen filling nozzle which is connected to a locally standard hydrogen cylinder (figure 14).

Special care has to be taken that several different connection treat standards, pressure levels and purity classifications exist for hydrogen gas in different countries.

The Main flow connects to six hydrogen cylinders at the same time. Always 2 cylinders are connected in parallel together on one pressure gauge and one hand valve. The Main flow connects the three individual hand valves together to a main filling valve which is connected to the standardized filling nozzle for the fuel cell motorbike.

For a filling the vehicle filling gets connected first and the cylinders with the lowest pressure level gets opened first till a pressure between the hydrogen cylinders and the hydrogen cylinders in the vehicle are equalized. Than the second highest hand valve for the second highest pressure level gets opened. And so on. Check valves block the back flow of hydrogen to the hydrogen cylinders with lower pressure level.

Figure 13. Mobile hydrogen filling during South African solar challenge 2008

In the currently used design we get three pressure levels. The maximum hydrogen filling pressure with could be achieved is always lower than the maximum pressure of the hydrogen source cylinders. The hydrogen cylinder pressure varies f in different countries from 138bar for example in Australia to 168bar in Malaysia to 200bar in South Africa and Europe to special 300bar standard in Europe. For a complete filling of the hydrogen tank to 438bar at a 350 bar nominal system a hydrogen compressor is required.

Figure 14. Portable Main flow for hydrogen filling; connected to locally standard hydrogen cylinders

6 The Results and Discursion

The Results of the endurance test of the fuel cell Motorbike are

6.1 Efficiency:

Consumption 0.510 kg H2 per 100Km
(0.510kg x 33kW/kg =16,83kwh per 100km
it equals 1.91 l Petrol per 100kmA Comparable Motorbike [5] with 380kg total mass at 75km/h would consume about 4l petrol a100Km that makes ~54% less consumption.

6.2 Motorbike Design

- **Handling:**
  Good for prototype,
  Reverser need to be activated
- **Sitting Position:**
  Relaxed, cushion need to improve in ergonomic for long distance ride.
- **Suspension:**
  front too stiff, back good
- **Reliability:**
  75%fin working,
  (Errors: 15% Software, 9% hardware, 1%human)
- **Maintainability:**
  very good for software, good for hardware,
- **FC-system:**
  diagnostic good repair difficult
- **Availability:**
  ~90% with engineer in team, target 99.9%

Drive train variations:

- Tested was a hybridized drive train with a relatively small *High current Lithium battery (*20Ah = ~10minute operation)

Further test with:

- big* Lithium battery
  (*80Ah= ~40minute operation)
- Hybridized with Ultra capacitor
- Dual hybridized with Capacitor and Battery (new for fuel cell drive train)
- Direct FC-drive with DC-DC converter

Overall conclusions:
A fuel cell Motorbike is makeable and proven reliable, but on the way to a product maintainability has to be improved. Systems have to get compacter and lighter [8;9]. Costs and infrastructure are another issue. This factor can be overcome if there is a strong economic and politic demand to change from the conventional petrol combustion technology.

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Joerg Weigl from Germany(*1977,Ulm), started in his youth with solar vehicles, won in the young research competition.
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