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The Honda FCX Clarity – A viable Fuel Cell Electric Vehicle for today and beyond 2015?

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1 Introduction

Honda has developed a new fuel cell electric vehicle (FCEV) in order to respond to global warming and energy issues. The new vehicle, the FCX Clarity, incorporates enhancement in driving performance and fuel efficiency against previous Honda Fuel Cell Electric Vehicles (Honda FCX) and embodies a new appeal not available in the reciprocating engine powered vehicle.



Figure 1: Honda FCX Clarity.

The key to the FCX Clarity's development was the achievement of size and weight reductions and increased efficiency in the fuel cell power train.

In 2002, Honda introduced the 2003 model year FCX, the first fuel cell electric vehicle certified by the US Environmental Protection Agency (EPA), and thereby demonstrated the strong basic performance of the vehicle. Since then, research and development was conducted targeting for enhancing the performance of this new technology and thus promoting it.

Without the necessity to arrange the fuel cell stack close to the electric motor and its transmission powering the fuel cell car, components can be distributed within the vehicle allowing for a radically changed package layout and design. However, the Honda FCX introduced 2005 had a number of limitations that were due to a larger powerplant (fuel cell and related system components) as well as the chassis borrowed from Honda's first electric vehicle brought to the market in California beginning of 1998. Because of these chassis limitations, nothing about the exterior identified the FCX as an automobile created with leading edge technology.

For Honda's new fuel cell electric vehicle (FCEV), the FCX Clarity, a new powerplant that includes a new, smaller and higher output fuel cell stack and most importantly a new vehicle

platform specifically for a fuel cell car with a new package layout and design taking full advantage of the freedom related to innovative packaging was developed. The target is conveying the message of the potential of the new technology to a much broader audience, immediately recognizing the vehicle as Honda's advanced fuel cell car.

2 Style and Design of the FCX Clarity

The design concept was to create a futuristic automobile easy to be recognized as being something new thus meaning an eye-catching design and providing a glimpse into the future when opening the door and inspire a new generation of drivers having visions about the automobile society and the global environment.

Additionally the designers felt that the uniqueness of the technology and available features, namely strong environmental performance, interior spaciousness enabled by the new package, and the high torque yet quiet ride due to electric propulsion were appropriate for a premium car of the future. Design features are the exterior design with its new proportions, a short nose and long cabin emphasized through its dynamic surface design. The new form is completely unlike that of any conventional sedan.

Up to now, large fuel cell stacks have been located under floor of a relatively high standing vehicle such as MPVs or SUVs. The new Honda FC Stack was given an innovative new structure that made it efficient and compact enough to be placed in the centre tunnel. As a result, the sedan package has the required low floor, low centre of gravity and the low overall height having been impossible in a conventional FCEV. Additionally the more compact front-wheel drive motor made the short nose design possible with achieving at the same time a long cabin that increases interior space for all occupants without making the vehicle any longer.

The result is generous cabin space of a large-class body in a medium-class body.

Furthermore by reducing the hydrogen tank system size and the auxiliary power source and adding a high-deck trunk, sufficient trunk space has been made available.

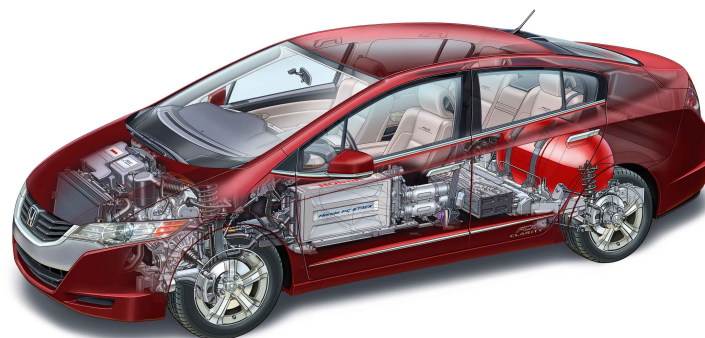


Figure 2: Honda FCX Clarity ghost drawing.

The interior was explicitly designed ahead of time, optimizing its wide open cabin space to create spacious and comfortable occupant space and a cockpit which gives a new sense of fun with futuristic features.

3 FCX Clarity Power Train

The FCX Clarity's fuel cell power train system has Honda's proprietary V Flow FC Stack at its core with a weight power density 2 times higher and a volume power density 2.2 times higher than the fuel cell power train of the previous Honda FCX. In addition to increasing the maximum power to 100kW, the V Flow stack achieves a 50% increase in volume power density and 67% increase in weight power density compared to the previous Honda FC Stack.

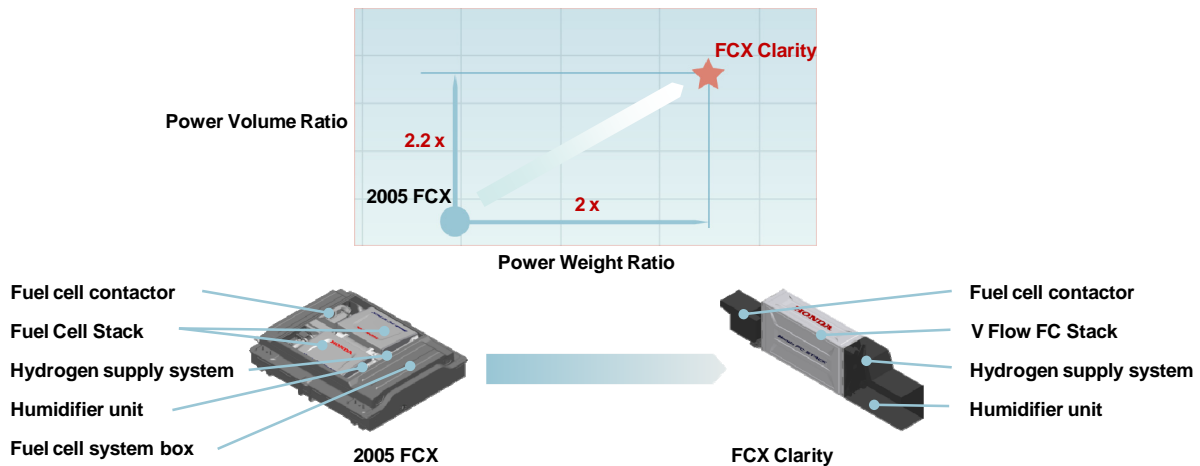


Figure 3: Honda fuel cell stack and system comparison.

4 V Flow FC Stack

In order to generate electricity by the fuel cells it is commonly known that hydrogen and air need to be continuously provided over the electricity generating surfaces of the membrane electrode assembly (MEA). However, if the water produced when hydrogen and oxygen react accumulates in the gas channels, it can impede the gas flow, preventing hydrogen and air from being supplied uniformly to the generating surfaces and making generation unstable. But in order to make a fuel cell stack more compact, it is necessary to reduce the thickness of the cells by reducing the depth of the gas flow channels hydrogen and air. However, reducing the depth of the channels would increase the adhesion force, thereby even promoting water accumulation.

In order to reconcile a stable generation performance with reduced depth of the gas channels, it is necessary to increase the water drainage capacity to the same degree that the water adhesion forces increase. This led to the development of a V Flow cell structure, in which hydrogen and air flow vertically, rather than horizontally, as in the previous Honda FC Stack and conventional fuel cell stacks.

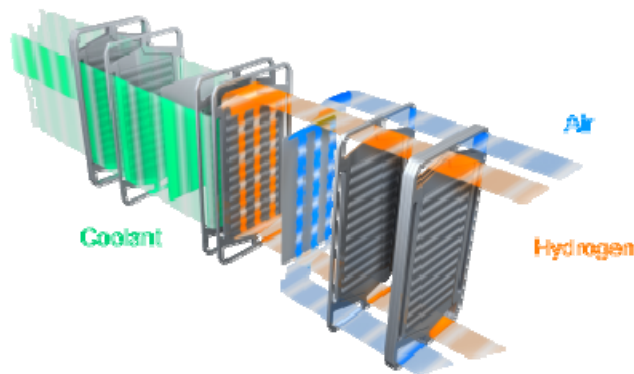


Figure 4: Honda V Flow FC Stack.

In the horizontal-flow cell structure, the pressure difference between inlet and outlet functioned as the only force promoting drainage of the process water in the flow channels. The new vertical-flow cell structure adds gravity to this pressure difference, thus increasing the drainage capacity. This made a much more stable electricity generation possible despite the reduction in depth of the flow channels. As a result, the flow channels depth was reduced by 17% over the previous generation fuel cell stack.

5 Aromatic Polymer Electrolyte Membrane

The Honda V Flow fuel cell stack is based on an aromatic polymer electrolyte membrane with high conductivity and durability.

The membrane material is prepared from the aromatic block copolymer, consisting of alternating stiff sulfonic acid-bearing segments and hydrophobic flexible polymeric sub-units. A bi-continuous microphase-separated morphology of the membrane has been attested, contributing to its excellent water resistance while keeping high proton conductivity. The membrane delivers the same chemical stability as a conventional poly(perfluorosulfonic acid) one, while outperforming the latter in power output of the fuel cell, life time and temperature range. In particular the cold start capability of the V Flow fuel cell stack of the FCX Clarity had been improved from initially -20°C to now -30°C .

6 Wave Flow Channel Separators

Generation performance can be maximized by a high uniform flow of hydrogen and air over the reaction surface as described above but also when allowing for a uniform coolant flow through the cells as well.

If particularly the coolant does not flow uniformly, localized areas of higher temperature (hot spots) will occur in the membrane electrode assembly.

The use of stamped metal separators and straight flow channels creates a configuration in which hydrogen, air and coolant, all flow in the same direction. This required three manifolds positioned in a row in each cell introducing all three media, reducing the width of their supply path to the generating surfaces and limiting supply.

Positioning the gas manifolds vertically and widening the gas supply paths in addition to bifurcating the short sides of the generating surfaces, would be an effective means for a more uniform supply.

Wave flow channel separators were therefore used for a horizontal flow of the coolant. The wave flow channel separators that turn the flow into the horizontal direction, across the flow of hydrogen and air, enabled the width of the supply paths for both gases and the coolant to be increased.

In addition, because each wave flow channel is longer than a corresponding linear flow channel, and varies the flow, the dispersion of hydrogen and air increased.

As a result, hydrogen and air pass over the entire surface of the electrode layer.

More effective use is made of the generating surfaces, resulting in a 10% increase in generating performance compared to the linear flow channels.

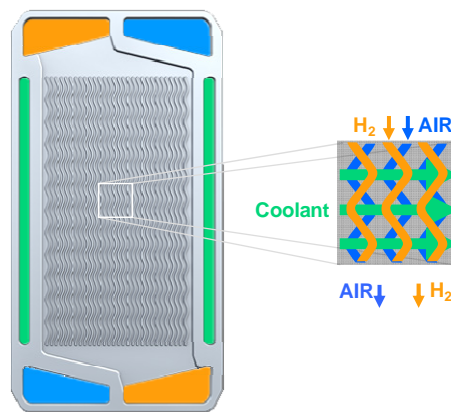


Figure 5: Wave flow channel separator.

In addition, the horizontal coolant flow helps to achieve a better cooling of these generation surfaces allowing coolant layers that were previously needed for each cell to be halved in number, and the number of separators required for every two membrane electrode assemblies to be reduced from four to three.

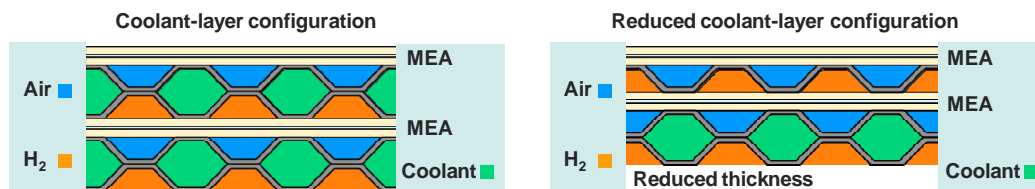


Figure 6: Honda V Flow FC Stack coolant-layer configuration.

Therefore the stack thickness has been reduced by in length by 20% and its related mass by 30%.

7 Increased Productivity

Since fuel cell stacks are made up of hundreds of layered cells, achieving an increased productivity for the cell components is a major issue and subject to optimization. Production technologies that increase productivity including specifications appropriate for these production technologies needed therefore to be developed.

In case of the previous MEA, in order to produce a Catalyst Coated Membrane (CCM) prior to sandwiching between the diffusion layers, the electrode was hot-pressed onto the membrane after the electrode had been coated on a support film. For the new cells, a technique of shape-controlled electrode coating on the membrane has been invented to enable direct formation of the electrodes in a predetermined shape onto the roll-shaped electrolytic membrane. Additionally, progressive stamping using metal coils has been employed to produce the stamped metal separators, in place of the previous method of stamping individual plates in successive batches for continuous production.

Previously MEA easily broke, making their handling during layering a considerable challenge. In the new configuration, two cells formed from two MEA and three separators are treated as one unit, enabling automatic layering by robots.

8 Conclusion

Major achievements have been made in developing the advanced Fuel Cell Electric Vehicle FCX Clarity.

Considering when the actual development of fuel cell related technology has started at Honda and looking to the challenges ahead for its application in transportation, productivity in all areas has to be further improved and made explicitly faster for a typical mass production of such vehicle. Limiting factor is not the body in white and its production but all new fuel cell related components that need to be manufactured at a very high quality level to ensure the required lifetime. Measures have been introduced but need to be further explored and new specifications need to be defined.

In order to tackle all relevant issues after production such as servicing and maintenance, Honda developed already for the FCX Clarity the entirely necessary logistic chain from development to sales and service. All information, such as workshop manuals, spare parts lists and its related ordering system and so on are in place.

Ramping up production to the widely discussed necessary levels, component costs have to be reduced further and this not only based on higher volume but also initial material cost, especially for the fuel cell stack. Defined cost targets are very well established and might possibly be reached. The timing though remains a challenge.

The FCX Clarity as such is showcasing the ultimate solution in clean transport for Honda and therefore remains very high on our agenda.

Comparing the achievements made in the fuel cell power train development with conventional technology, the future is already here today. Looking at the currently discussed alternatives it is very obvious that the fuel cell car has a while ago leap frogged the battery electric vehicle and this for good reasons. The FCX Clarity is a viable solution for today and the near term future while the fuel cell electric power train installed will be the viable and ultimate solution for vehicle propulsion for today and beyond 2015.