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A Review on Hydrogen Fuel Cells for Electric Vehicles

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ABSTRACT: The hazardous effects of pollutants from conventional fuel vehicles affects the scientific world and to move towards environmental friendly energy sources. Though we have so many types of renewable energy sources, the perfect one is to use, as an energy source for vehicles is hydrogen. Same as electricity, hydrogen is an energy carrier and is capable to deliver huge amount of energy. Onboard hydrogen storage is an important factor that has to be considered while designing fuel cell vehicles. In this study, a recent feat in hydrogen fuel cell engines is reviewed to study the dependency of using hydrogen as a major fuel in transportation systems. A fuel cell is an electrochemical hardware that can produce electricity by using gases and oxidants as reactants. With anodes and an electrolyte, the fuel cell splits the reactants into cations and anions and produces electricity. Fuel cells use reactants, which do not affect the environment and releases water as a by-product. Hydrogen is the best energy carrier, the fuel cell generates direct current (DC) power to power an Electric Vehicle (EV). By combining a hydrogen fuel cell with batteries and the control system with strategies, one can produce a sustainable hybrid car.

KEYWORDS: fuel cell; battery; hydrogen; electric vehicle; electricity

I. INTRODUCTION

In previous years, due to the rapid improvement in the world economy, people's living standard is being increased, that is why people's purchasing power is also greatly increased, so people are capable of purchasing car. So the question is raised. First: internal combustion engines drive the majority of the world's cars; fuel used is petrol, diesel, or gasoline and the world's oil resources are decreasing everyday and is becoming expensive, hence the EVs are expensive. Second, the internal combustion engine causes environmental pollution problems, since the fuel used is petrol, gasoline or diesel, so the emission of exhaust gases includes many harmful molecules, the environment we live is on a great amount of pollution, and there is great threat to our health. By considering these two points, it is important that new energy vehicle research has been widely attention. Now how one can find alternatives to internal combustion engine, there are two things to consider 1: Efficient energy consumption. 2: less emission and low pollution. Electric cars should meet these two requirements, and the advantage of electric cars is less noise and low pollution, vibration and high-energy efficiency. Fuel cell technology leads the electric vehicle market, fuel cell can be used for electrochemical power generation, in accordance with the chemical way, in this case electricity is directly converted from the chemical energy with the help of carnot cycle limit so the energy utility rate is very high and pollution is very less, which converts it as an ideal energy, and will be accepted by people, and the fuel cell technology is more and more mature, fuel cell vehicles will certainly be a great idea, fuel cell vehicles will hold for more market share. Now, the trend of new energy vehicles with zero emissions of electric vehicles and low emissions of electric vehicles.

II. PRINCIPLE OF FUEL CELL

For a fuel cell system, three components are required: anode, cathode, and an electrolyte. The type of electrolytic material used categorizes FCs. FC can be composed of hundreds of individual cells, but each has three fundamental components. An electrolyte located between the two electrodes. Fig. (1) Shows a schematic of a polymer electrolyte FC (PEMFC) operation diagram. This FC type is also called as a proton exchange membrane FC. The function of FC is as follows—fuel (pure hydrogen) is sent to the anode of the fuel cell and oxygen or air is fed to the cathode. On the anode side, electrons are separated and the gas tries to make its way through the electrolytic membrane. The electrolytic membrane acts as a filter to separate the electrons and the hydrogen ions, which only allow the hydrogen ions to pass through. In the cathode compartment, the hydrogen ions are passed through the membrane combine with the oxygen atoms from the air supply to produce H₂O as a by-product; heat is also a by-product.

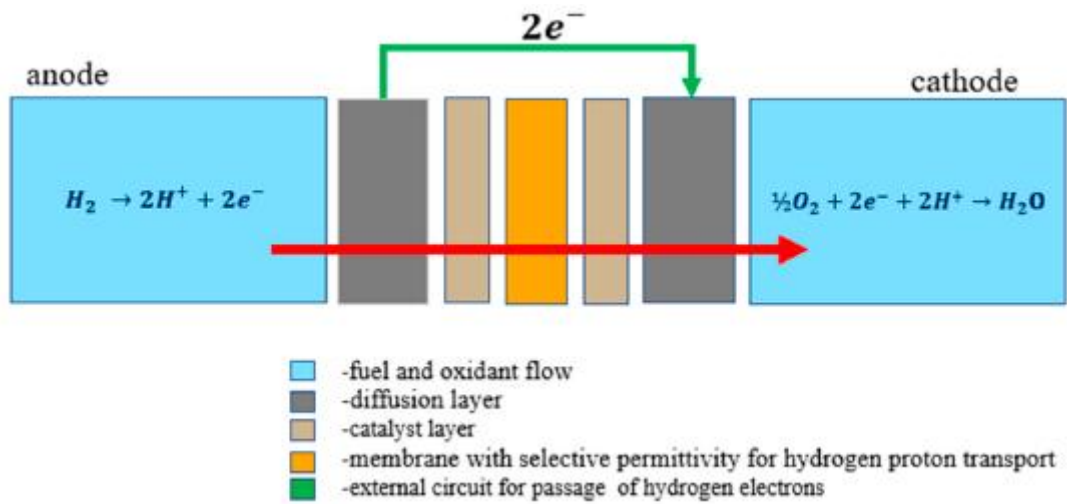


Figure 1. Reactions in a Fuel Cell

Table 1. Comparison of Different Fuel Cell

	PEFC	AFC	PAFC	MCFC	SOFC
Electrolyte	Hydrated Polymeric Ion Exchange Membrane	Mobilized or immobilized Potassium Hydroxide in asbestos matrix	Immobilized Liquid Phosphoric Acid in SiC	Immobilized Liquid Molten Carbonate in $LiAlO_2$	Perovkites (Ceramics)
Electrodes	Carbon	Transition metals Carbon	Carbon	Nickel and Nickel Oxide	Pervoskite and pervoskite/metal cement
Catalyst	Platinum	Platinum	Platinum	Electrode material	Electrode material
Interconnect	Carbon or metal	Metal	Graphite	Stainless steel or Nickel	Nickel, Ceramic, or steel
Operating Temperatures	40 – 80°C	650 - 220°C	205°C	650°C	600 – 1000°C
Charge Carrier	H^+	OH^-	H^+	CO_3^-	O^-
External Reformer for hydrocarbon fuels	Yes	Yes	Yes	No, for some fuels	No, for some fuels and design
Prime cell components	Carbon- based	Carbon- based	Graphite- based	Stainless- based	Ceramic
Product heat management	Process Gas + Liquid Cooling Medium	Process Gas + Electrolyte Circulation	Process Gas + Liquid cooling medium or steam generation	Internal reforming Process Gas	Internal Reforming + Process Gas

III. COMPONENTS OF A FUEL CELL

3.1 CATALYST

Platinum and its alloys like platinum-ruthenium alloy, palladium and other catalytic materials are some of the most commonly used materials for fuel cell applications. Carbon is best suited for this application because of its electrical conductivity, inert nature and its large surface area.

3.2 ELECTRODES

Fuel cells have always been dependent on platinum and its alloys for the electrodes but that is changing. We can make use of various electrodes like alkaline, carbon-do-oxide and clearance electrode depending upon the application.

3.3 MEAs & GDL

In a 5 layer MEA the GDL acts as a bridge between the MEA and graphite plate. The GDL needs to undergo hydrophobic treatment (wet proofing) as it enables water transport. If the PEM retains water it can result in lower efficiency hence they are tested with Teflon to make them hydrophobic. The GDL is a carbon cloth with a MPL (microporous layer) applied to one side. The cloth is treated with Teflon so that it does not retain water.

3.4 GASKETS

Gasket should be an elastomeric material and can be made up of materials like Silicon, Teflon, and EPDM Rubber. The thickness of the gasket is given by (each electrode thickness) – (pinch).

3.5 PLATES

Each individual MEA can only produce up to 1V but most applications need more voltage. This can be done by stacking the individual plates. The plates contain flow field on them, which are machined or stamped through which the flow of fluid like air or hydrogen takes place.

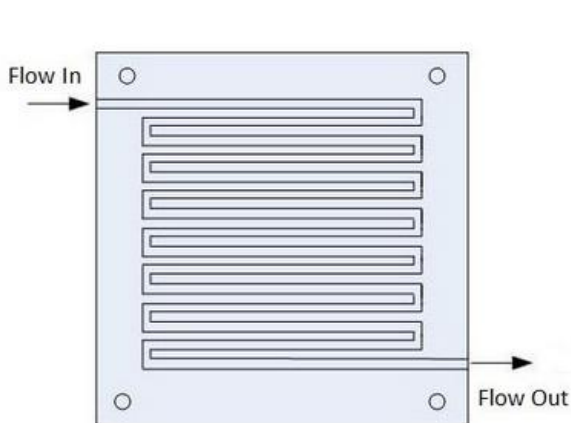


Fig 3.1: Serpentine flow field

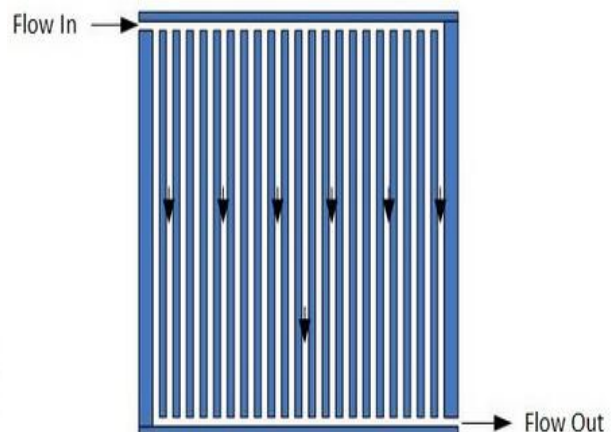


Fig. 3.2 Parallel flow field

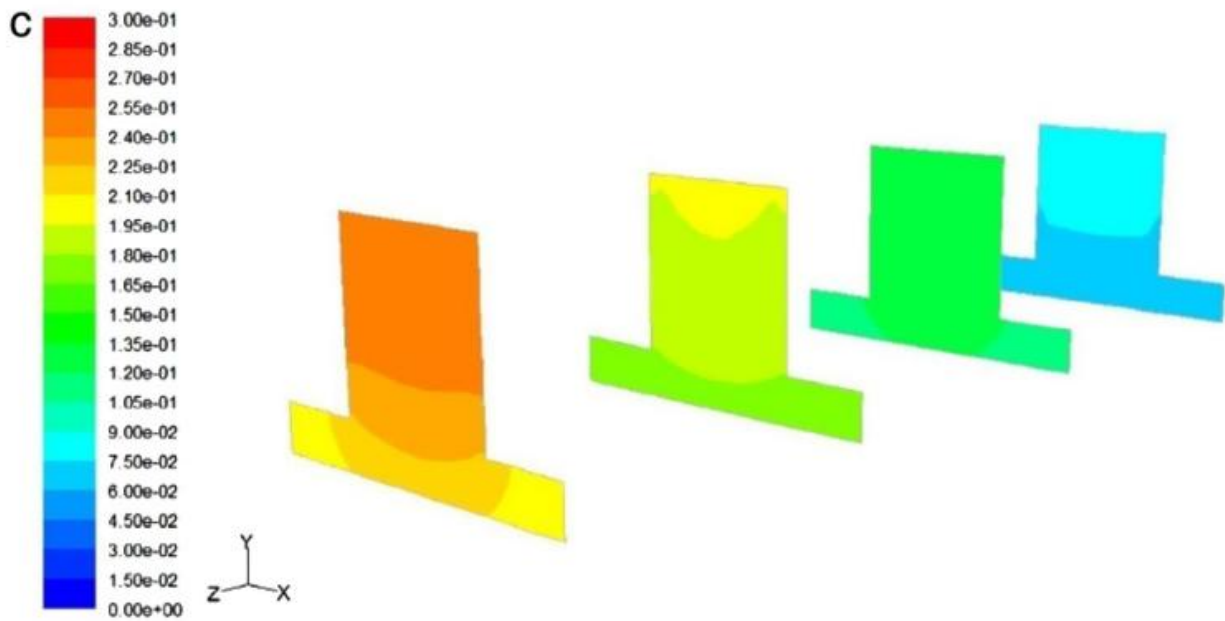


Fig. 3.3 Concentration of hydrogen in the PEMFC with straight channel V= (a) 0.6V

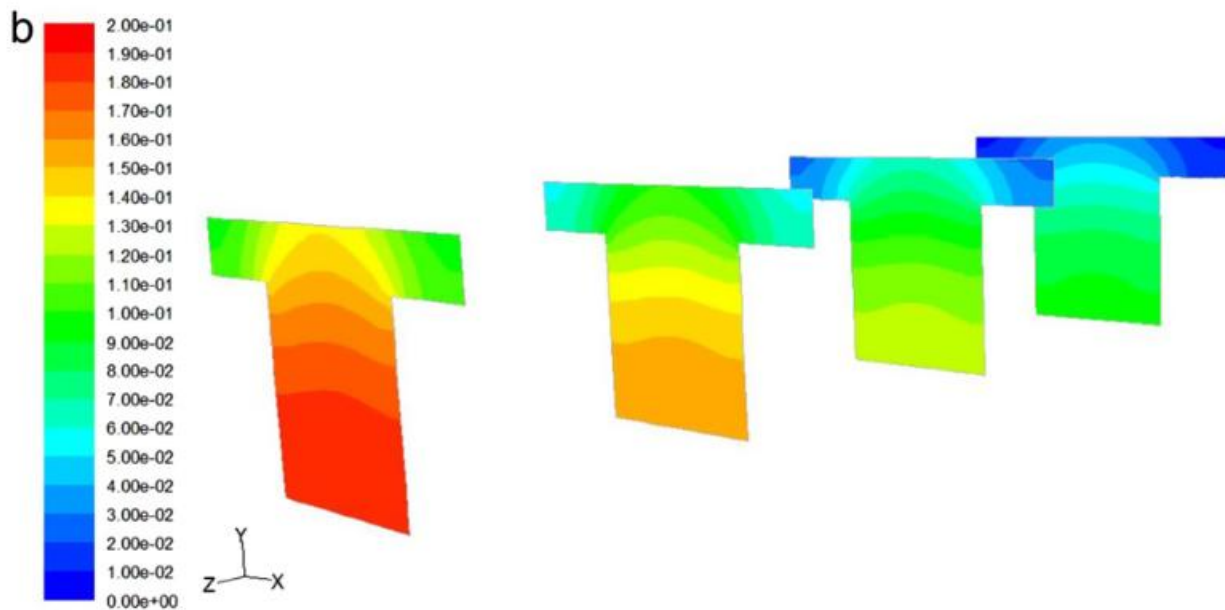


Fig. 3.4 Concentration distribution of oxygen in the PEMFC with straight channel V= (b) 0.6V

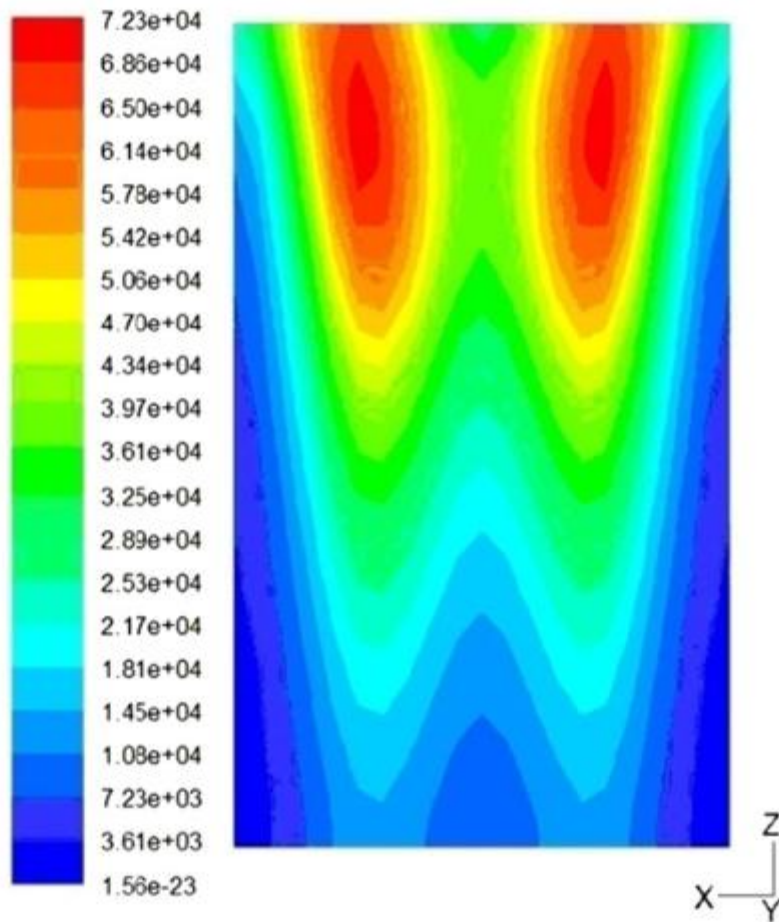


Fig. 3.5 Cross sectional view of current density distribution in the PEMFC with a straight channel in the x - z plane.

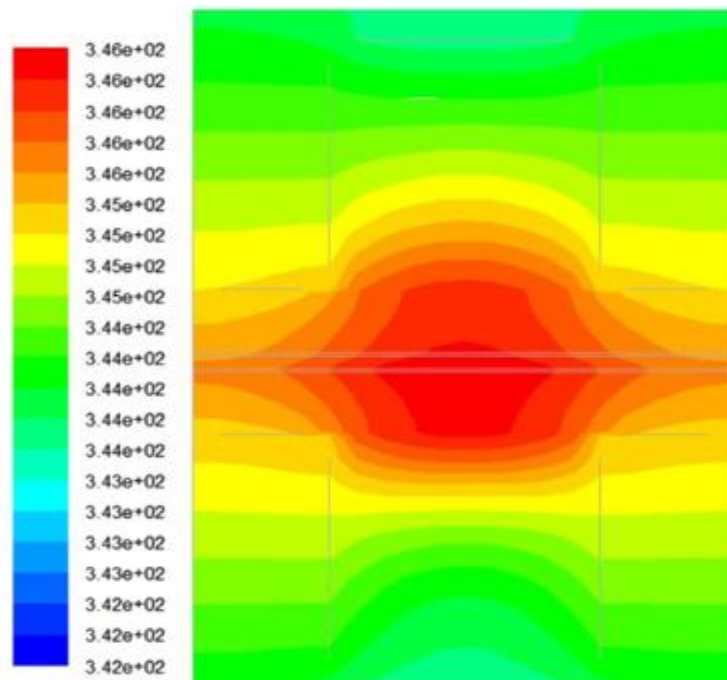


Fig. 3.6 Temperature distribution in the PEMFC with a straight channel in the x - y plane



IV. CONSIDERATIONS IN FUEL CELL DESIGN

To design a fuel cell you need to consider the following:

- The size of the assembly called stack size
- The Number of cells (Membrane Exchange Electrodes)
- Stack configuration (GDL, flow-field plate)

4.1 Fuel Cell Stack Size

The first step in designing the fuel cell is to calculate the power requirements. The stack is to be designed to meet requirements. Maximum power, voltage, and current are often known. The output power is a product of stack voltage and current.

$$W_{FC} = V_{st} * I$$

It is important to know the current along with power density while designing a fuel cell stack. They may not be available initially and can be determined from the (i) stack voltage (ii) desired power output (iii) efficiency (iv) volume and weight limitations. Current is the product of current density and effective area of the cell.

$$I = i * A_{cell}$$

The cell potential and the current density are related by:

$$V_{cell} = f(i)$$

Most fuel cell manufacturers use a nominal voltage of 0.6 - 0.7 V. The actual fuel cell performance depends upon factors such as pressure, temperature, and humidity. They can be improved by increasing those factors, and optimizing various fuel cell variables.

4.2 Number of Cells

The stack potential is the summation of the stack voltages or the product of the cell average potential and number of cells in the assembly:

$$V_{st} = \sum_{i=1}^{N_{cell}} V_i = \bar{V} * N_{cell}$$

4.3 Efficiencies

The stack efficiency is given by:

$$\eta_{stack} = \frac{V_{cell}}{1.482}$$

The thermal efficiency of a fuel cell is defined as amount of useable energy produced to the enthalpy change, ΔH .

$$\eta = \frac{H}{Useful\ Energy}$$

V. CFD TECHNOLOGY IN DEVELOPING FUEL CELL

A three-dimensional, multi-phase, non-isothermal unit of a PEM fuel cell that includes in it the significant physical processes and some key parameters that affect fuel cell performance has been developed using CFD technology. The model had been developed to enhance fundamental perception of transport phenomena in PEM fuel cells and to deduce the impact of various operation parameters on performance. The model takes into account both gas and liquid in the same computational domain, and thus allows for the application of phase change in the gas diffusion layers. The model includes the transport of gaseous, liquid, protons, water, energy, and water dissolved in the ion-conducting polymer. Water is assumed to be transported between three phases; vapor, liquid, and dissolved, and equilibrium state among these phases is assumed. Water transport in the porous gas diffusion layer and catalyst layer is explained using two physical mechanisms: viscous drag and capillary pressure forces, and is explained by advection within the gas channels. Water movement through a membrane is either because of electro-osmotic drag or diffusion.

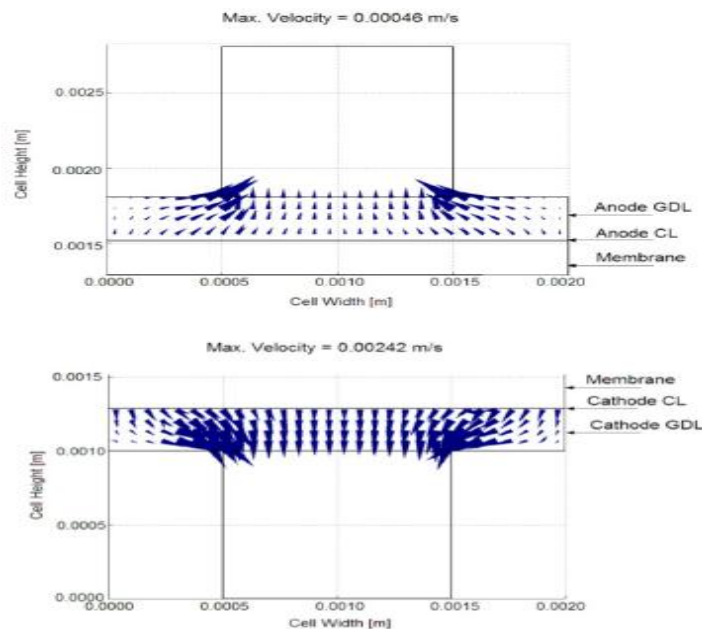


Fig. 5.1 Liquid Water Velocity inside GDLs

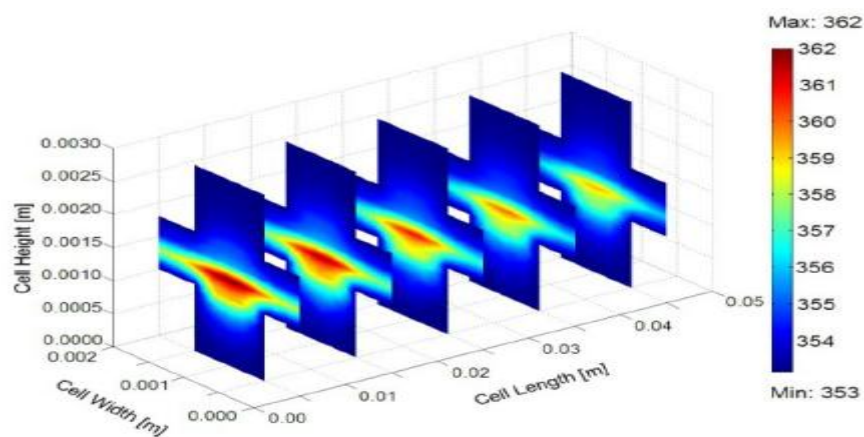


Fig. 5.2 Temperature Distribution in the Cell

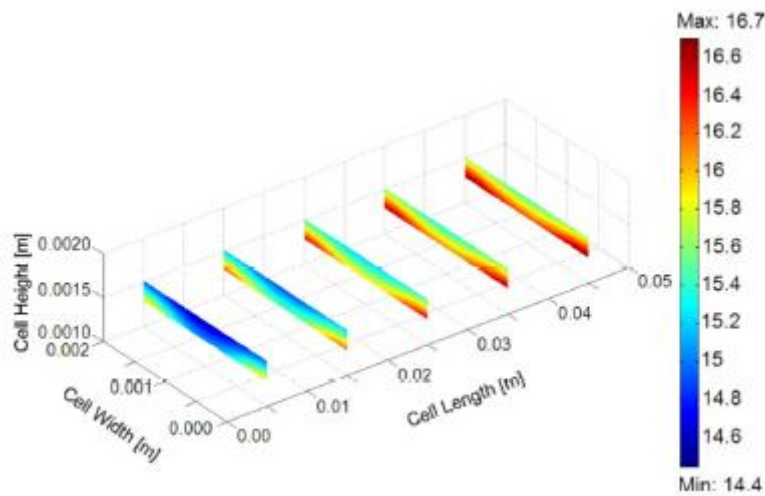


Fig. 5.3 Water Content Profile through the Membrane

VI. CONCLUSION

Hydrogen storage is a major research problem. While progress has been made, existing systems are inadequate or insufficient. On-board storage of H₂ most likely will be as compressed gas. Liquid hydrogen as well as cryo adsorption storage are almost certainly not practical for vehicle use. Metal hydration and metal-N-H systems give good result, but much research is still required for these systems. Advanced carbon materials are interesting, but contradictory research results, with low reproducible storage capacities, have been discouraging and much remains to be done. Unresolved research questions, like hydrogen storage, make the fuel cell vehicle understanding a long-term issue. It is not a quick solution to energy or emissions problems. For the next twenty years, vehicles running on hybrid-electric internal combustion engine can well prove to be just as beneficial, from a perspective of life-cycle, as fuel cell vehicles. A MIT study finds that fuel cell vehicles do not have consequential advantages (in terms of energy consumption or CO₂ emissions) over vehicles powered by hybrid-electric, internal combustion engines.

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