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REVIEW ZERO EMISSION VEHICLE (ZEV) AND HYDROGEN FUEL CELL VEHICLE (HFCV)

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Abstract

A zero-emission vehicle (ZEV) refers to a vehicle that produces no tailpipe pollutants or greenhouse gas emissions during operation. These vehicles use alternative energy sources instead of traditional fossil fuels to power their engines. Hydrogen Fuel Cell Vehicles use hydrogen gas to generate electricity, powering an electric motor. Proton exchange membrane fuel cell (PEMFC) is an energy conversion device, especially in future use in vehicular and stationary applications. Global warming and air pollution in our world are a series of issues. As well known human activities are the main cause of air pollution and global warming due to waste from industry, and transportation that uses conventional engines. PEM of hydrogen fuel cell vehicles provide zero-emission with high efficiency and power density, low operating temperature, quick start, silent during operation, quick refueling, require less space, avoiding the dependence on crude oil and long life automotive. The only byproduct of their operation is water vapor, making them emit zero greenhouse gases. However, the availability of hydrogen refueling infrastructure is limited in many regions. The number of operating parameters is determined, including the operating pressure, temperature, Hydrogen and Oxygen mass fractions distributions with different shapes, assembly, and flow directions, and current density for the PEMFC with different flow channels can be also captured by the model.

Keywords: *Hydrogen fuel cell vehicle (HFCV); Gas flow channel (GFC); Green Vehicles (GV); Proton Exchange Membrane fuel cell (PEMFC); Zero emission vehicle (ZEV).*

Introduction

Our planet, mostly from the sun, is constantly blasted with massive amounts of radiation. Solar radiation reaches the Earth's atmosphere in the form of visible light, ultraviolet (UV), infrared (IR), and other forms of radiation that are not visible to the human eye. According to NASA, about 30% of radiation striking Earth's atmosphere is immediately reflected out to space by clouds, ice, snow, sand, and other reflecting surfaces. The remaining 70% of incoming solar radiation is absorbed by the atmosphere, the ocean, and the land. To make the earth habitable the incoming and outgoing radiation must be balanced. The exchange of incoming and outgoing radiation that warms the earth is known as the greenhouse effect. Gas molecules that absorb thermal infrared radiation, and are insignificant enough quantity, can force the climate system. Global warming and air pollution in our world are a series of issues. As well known Human activities are the main cause of air pollution and global warming due to waste from industry, and transportation that uses a conventional engine that is gasoline and petrol engine. According to NASA, the average temperature of the planet Earth is continuously increasing, which causes many problems besides global warming and air pollution including the melting of the arctic ice, which together with heating of the water makes the ocean levels rise, flooding, etc. This increase in temperature together with a rise in the sea level will in the future make several places on the Earth uninhabitable [1]. As we see in Fig 1. Sunlight passes through the atmosphere and warms the earth's surface. Most of the outgoing heat is absorbed by greenhouse gas molecules and re-emitted in the direction, of warming the surface of the earth. As a result, the global population will rise from 6 billion in 2000 to 10 billion in 2050, and the number of automobiles on the road will rise from 700 million to 2.5 billion [1].

There are recent forecasts by the year 2020 about 1.5 billion vehicles will be on the roads. It will increase by half a million from today's existing vehicles on the road [2]. Human society is one of the major causes of carbon dioxide emissions when using the burning of oil, natural gas, and coal from transport cars and powerhouses. Carbon dioxide is the most frequent greenhouse gas emitted by different human activities. Today, there are approximately 900 million vehicles on the road in the world. Around 96 percent of these vehicles' propulsion fuel is derived from fossil fuels.

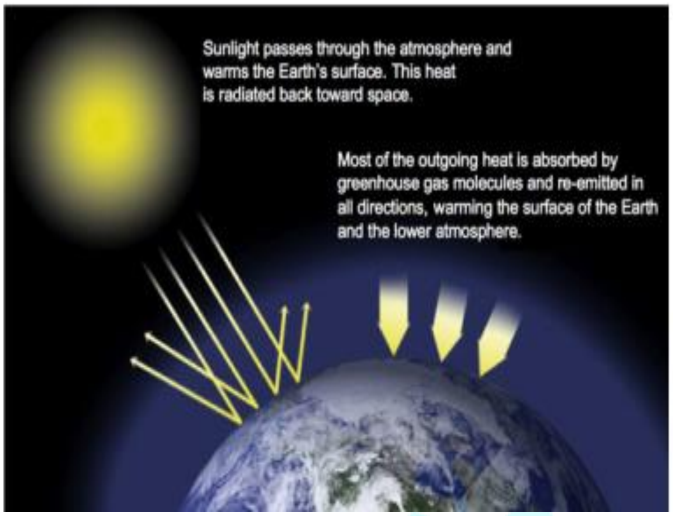

Figure 1. The greenhouse effect [3]

The world's total energy consumption is highly dominated by the transport industry which accounts for nearly 55% of the world's energy consumption and 30.9% of carbon dioxide gas emissions according to recent research studies [3]. According to recent research studies, nearly 55% of the world's energy consumption and 30.9% of carbon dioxide gas emissions are highly dominated by the transport industry [4]. Conventional vehicles are a major source of pollution emitting toxic gases like nitrogen oxides which contribute to the production of ground-level ozone (smog), acid rains, hydrocarbons, and other toxic air, Particulate matter (soot), etc. [5].

Due to conventional automobile exhaust that causes air pollution and global warming, electric vehicle (EVs) that are zero/ ultra-less emission vehicles continues to evolve in a more passionate way to meet the demand for a world more habitable. Electrical energy, often known as a zero-emission source of energy, has been considered an alternative energy source for many years. Virtually most car manufacturers intended to reduce the usage of fossil fuels like gasoline and diesel as an energy source for automotive applications, they studied to develop a lower emission power train system known as Electrical power train vehicles.

Historical background

Hydrogen Fuel Cell Vehicles: These vehicles use hydrogen gas to generate electricity, powering an electric motor. The only byproduct of their operation is water vapor, making them emit zero greenhouse gases. However, the availability of hydrogen refueling infrastructure is limited in many regions.

Sir William Grove, a British amateur scientist, and lawyer invented the first fuel cell in 1839. During an electrolysis experiment, Sir William accidentally unplugged the battery from the electrolyze and linked the two electrodes together, observing a current flowing in the opposite direction, consuming hydrogen and oxygen gases. The invention was dubbed a 'gas battery' by him. It consisted of an electrode immersed in a bath of dilute sulphuric acid known as platinum, which was placed in test tubes containing hydrogen and oxygen. It produced voltages of around 1 volt. Grove connected many gas batteries in sequence to construct a "gas chain" in 1842.

Grove's fuel cell gas battery was not practical, due to problems of instability of the materials and corrosion of the electrodes. As a result, there were different researchers further developed fuel cells for many years to follow. Like Bacon fuel cells, Alkaline fuel cells, and PEM fuel cells.
In the 1950s, English engineer Francis Thomas Bacon successfully created the first practical fuel cell, which was an alkaline type that utilized an alkaline electrolyte (molten KOH) instead of the dilute form of sulphuric acid. When compared to other types of fuel cells, it had the advantage of a high power-to-weight ratio. For space uses, alkaline fuel cells were suitable.

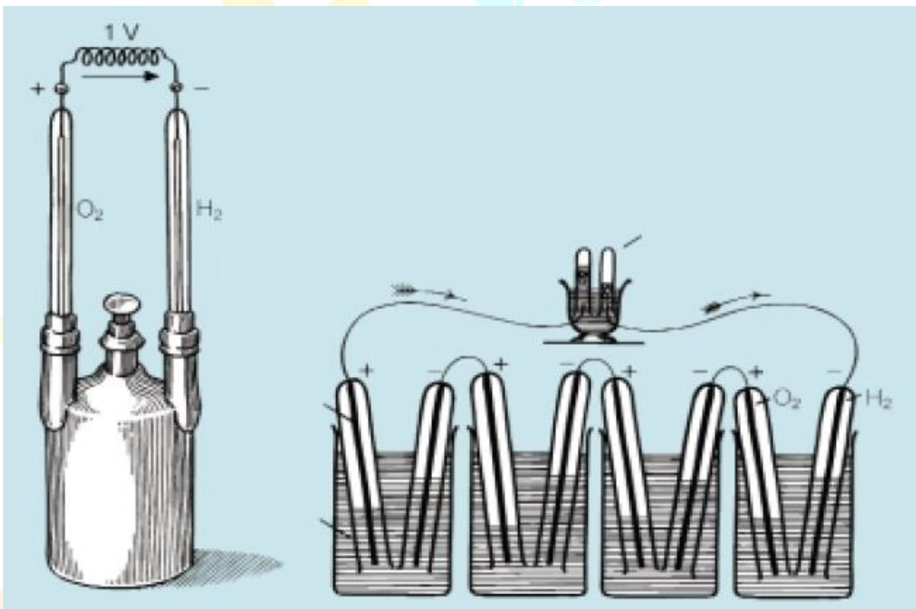

Figure 2. Grove's 'gas battery' (1839) produced a voltage of about 1V (left); Grove's 'gas chain' powering an electrolyzer (1842) [17]

These fuel cells include solid oxide fuel cells (SOFC), phosphoric acid fuel cells (PAFC), molten carbonate fuel cells (MCFC), and polymer electrolyte membrane or proton exchange membrane (PEM) fuel cells.
Honda, GM, Toyota, Mercedes-Benz, Honda, General Motors, Hyundai, and Nissan Automobile companies are working to expand and commercialize FCEV to the public market [6].
Green vehicles, also known as environmentally friendly vehicles or eco-friendly vehicles are automobiles that have a reduced or minimal impact on the environment compared to conventional vehicles powered by internal combustion engines. These vehicles are designed to emit lower levels of greenhouse gases and pollutants while maximizing fuel efficiency. Green vehicles can take several forms, such as:

Types of Green Vehicles (GV)

These are just a few examples of green vehicles. The automotive industry is continually evolving, and new technologies and concepts are being developed to promote sustainability. There are several benefits of green vehicles, also known as eco-friendly or electric vehicles (EVs):

- Hybrid electrical vehicle (HEV),
- Plug-in hybrid electric vehicles (PHEV),
- Pure battery electrical vehicle (BEV),
- Hydrogen Fuel cell vehicle (HFCV) [7].
- Biofuel Vehicles
- Natural Gas Vehicles (NGVs)

Among them, pure Battery electric vehicles (BEV) and Hydrogen Fuel cell vehicles (HFCV) are zero-emission electrical vehicles. Electric cars have their disadvantages some of these are a shorter range than gas-powered cars, Recharging the battery takes time, it can sometimes be difficult to find a charging station (for BEVs), they are usually costlier when compared with gas-powered cars, there aren't as many model options like conventional vehicles they are still in development.

1. Hybrid Electric Vehicles (HEVs): HEVs combine an internal combustion engine (typically gasoline) with an electric motor and a battery. HEVs can switch between the electric motor and the combustion engine, resulting in improved fuel efficiency and reduced emissions.

2. Plug-in Hybrid Electric Vehicles (PHEVs): PHEVs also have both an electric motor and an internal combustion engine. However, PHEVs have larger batteries that can be recharged by plugging into an electrical outlet. They offer extended electric driving range before switching to the combustion engine.

3. Electric Vehicles (EVs): These vehicles run on electricity stored in rechargeable batteries. They produce zero tailpipe emissions and are considered one of the most environmentally friendly modes of transportation.

4. Hydrogen Fuel Cell Vehicles (FCVs): FCVs use fuel cell technology to convert hydrogen gas into electricity, powering an electric motor. The only byproduct is water vapor, making FCVs emit zero greenhouse gases. However, infrastructure for hydrogen refueling is limited.

5. Biofuel Vehicles: These vehicles use renewable fuels made from organic matter, such as ethanol or biodiesel. Biofuels are derived from crops, waste materials, or even algae. They can be used to power conventional internal combustion engines with fewer emissions.

6. Natural Gas Vehicles (NGVs): NGVs use compressed or liquefied natural gas (CNG/LNG) as fuel. Natural gas is considered a cleaner alternative to gasoline or diesel, as it produces fewer emissions and pollutants.

Green vehicles play a crucial role in reducing air pollution, dependence on fossil fuels, and mitigating climate change. They contribute to a cleaner and more sustainable transportation system, promoting a greener future.

Hydrogen Fuel cell vehicles

As we see in the introduction part, the world continues to strive for clean and pure power sources to power various automobiles on the road, which are the primary contributors to hazardous pollutants released into the atmosphere from internal combustion engines. These toxic emissions contribute to climate change and air pollution and impact negatively people's health. To solve those problems automakers studied to develop zero-emission power train systems. Among those technologies fuel cell is one of the most popular types an alternative source of energy. It consumes hydrogen and oxygen as fuels and produces water vapor and heat as the only exhaust products. Hydrogen fuel cell vehicle produces zero tailpipe greenhouse gas (GHG) emissions with its high range and efficiency in a short refueling time. Hydrogen is one of the most abundant elements that exist in our universe. It is an excellent energy carrier, it can be produced in several ways through many sources (natural gases, methanol, ethanol, etc.), it is very clean to use, it provides energy security so any country can produce it by its own, and the world wants environmentally friendly fuel hydrogen has that potential.

The fuel cell is an electromechanical device. Fuel cell vehicles are not only pollution-free, but they can also have higher efficiency making them an excellent choice for power generation. When comparing vehicles with hydrogen fuel cells with conventional engine vehicles it has better performance. On the other hand, conventional engines are limited to efficiencies of up to 40 % for diesel engines, and about 30 % for gasoline on the other side FC exhibits tank-to-wheel electric efficiencies of up to 60 % [7-8].

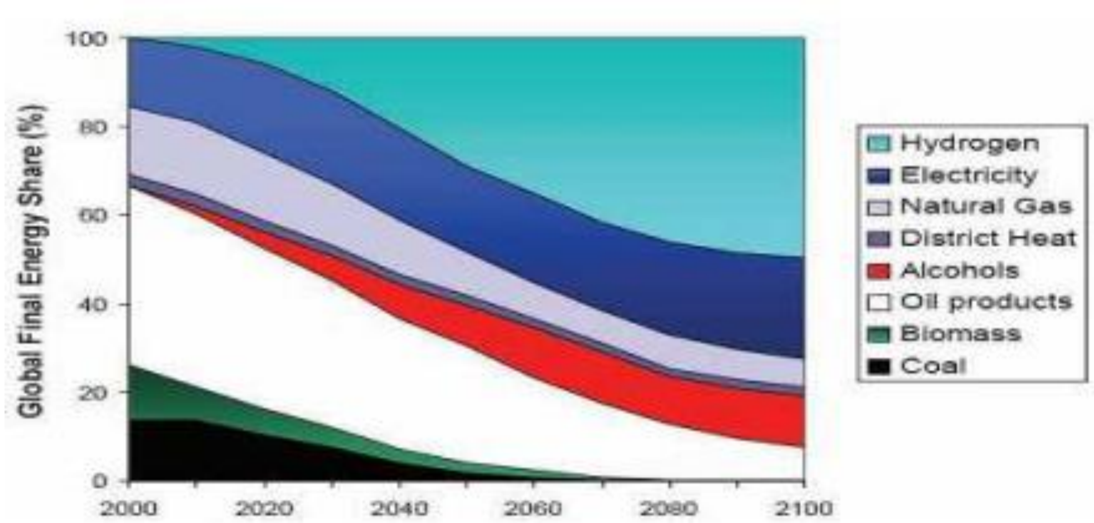

Figure 3 Evolution of global market shares of different final energy carriers for the period 1990-2100 [10]

Hydrogen Fuel cell vehicle has been identified as a viable alternative for power generation purposes due to its efficiency and cleanliness. That alternative power source besides the benefit it has facing different challenges. Cost, durability, and performance are the major challenges delaying PEMFC commercialization. Proton exchange membrane is a key part of the fuel cell as the engine in a conventional vehicle. The performance of a proton exchange membrane fuel cell (PEMEC) is determined by the flow field channel's design; high performance requires the best design.

Hydrogen

Hydrogen is a chemical element in the periodic table with the symbol H and atomic number 1. With an atomic weight of 1.008, hydrogen is the lightest element in the periodic table. Hydrogen is the most abundant chemical element in the universe, representing approximately about 75% of all baryonic mass. As an energy carrier, hydrogen has several enticing characteristics, including a high energy density (140 MJ/kg), which is more than twice that of conventional solid fuels (50 MJ/kg) [11]. Hydrogen by itself is not an energy source; it is an energy carrier and consequently has to be produced through other energy sources.

The name hydrogen is derived from Greek words meaning "maker of water."

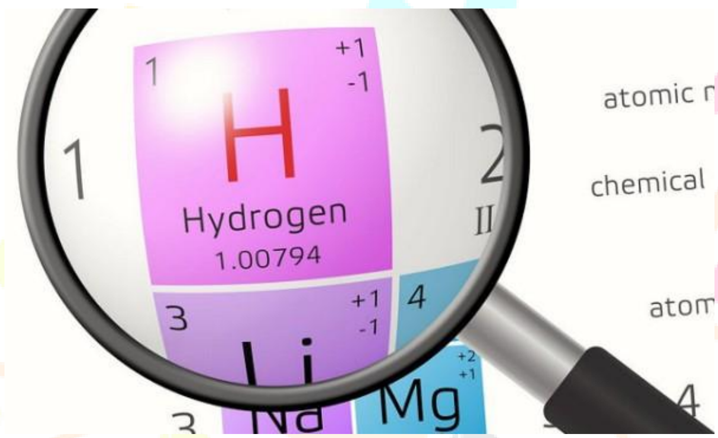

Figure 4. Hydrogen elements [11]

Symbol- H
Atomic mass- 1.00784 u
Atomic number- 1
Electron configuration- $1s^1$
Electro negativity- 2.2

Density (at STP)- 0.08988 g/L
Molar Mass- 2.016g/mol
Melting point- (-259.2^0c)
Boiling point- (-252.9^0c)

Hydrogen is the future fuel. It is a carrier of energy that can transform a fossil fuel-dependent economy into a hydrogen economy, which can provide an emissions-free transportation fuel.

Pure hydrogen is the fuel of the PEMFC, it is the charge carrier. There are major reasons for using hydrogen.

- ✓ Its energy density, the energy density of hydrogen is the largest at 33.3 Wh/g, compared to all the fuels.
- ✓ Hydrogen is the easiest fuel to oxidize under near-ambient conditions in comparison with other fuels is hydrogen.

- ✓ The last reason, the process in the fuel cell can be zero emission (greenhouse gas and pollution-free) if the cathode is fed with the oxygen of the air. Because the only products are electricity, heat, and water.

Generally, Hydrogen may well be the energy carrier of the future.

Hydrogen Production

Hydrogen is always found as a component of another substance, such as water (H_2O) or methane (CH_4), and must be purified into pure hydrogen (H_2) before it can be used in a fuel cell electric vehicle. Providing an abundant, clean, and secure renewable energy source is one of the key technological challenges facing mankind.

There are different ways of hydrogen production; it can be extracted from fossil fuels, oil, biomass, coal, Steam reformation of methane, and water electrolysis with electrical energy. The environmental impact and energy efficiency of hydrogen depend on how it is formed.

Among different hydrogen production methods, hydrogen production via electrolysis can result in zero greenhouse gas emissions. This paper focused on environmentally friendly technology; therefore among those I prefer water electrolysis for pure Hydrogen production. It helps to get zero greenhouse gas emissions from production up to the final use.

Electrolysis is the process of splitting water into hydrogen and oxygen using an electric current. If the electricity is generated from renewable sources like solar or wind, the hydrogen created is also renewable and has several environmental benefits. A solar hydrogen system can provide a completely emission-free way of hydrogen production. There are different electrolyzers and their function in slightly different ways for example Polymer electrolyte membrane (PEM) electrolyze, Alkaline electrolyzers, Solid oxide electrolyzers, etc. It is expected that hydrogen fuel and its demand will rise rapidly over the next few decades [9].

Table 1. Energy contents of different fuels [13]

Fuel	Energy content (MJ/kg)
Hydrogen	120
Liquefied natural gas	54.4
Propane	49.6
Aviation gasoline	46.8
Automotive gasoline	46.4
Automotive diesel	45.6
Ethanol	29.6
Methanol	19.7
Coke	27
Wood(dry)	16.2

There are several types of fuel cells currently under development, each with its advantages, limitations, and potential applications

Types of fuel cells [12-14]

1. PEMFC or PEFC – Proton Exchange (Membrane) Fuel Cells (also referred to in the literature as Polymer Electrolyte Membrane Fuel Cells).
2. DMFC – Direct Methanol Fuel Cell.
3. PAFC – Phosphoric Acid Fuel Cell.
4. AFC – Alkaline Fuel Cell.
5. SOFC – Solid Oxide Fuel Cell.
6. MCFC – Molten Carbonate Fuel Cell

Among them PEFC is referred to as an effective source of power Chief advantages of PEMs are that they react quickly to changes in electrical demand, will not leak or corrode, and use inexpensive manufacturing materials (plastic membrane) [11].

Proton exchange membrane fuel cells (PEMFC)

Proton exchange membrane (PEM) fuel cells also known as with another name Polymer Electrolyte Membrane (PEM) with hydrogen as the fuel are generation environmentally friendly energy alternatives [12].

PEMFC – Proton Exchange Membrane Fuel Cells

- ✓ Also called polymer electrolyte membrane fuel cells
- ✓ Use a platinum-based catalyst on both electrodes
- ✓ Generally, hydrogen-fueled
- ✓ Operate at relatively low temperatures (below 100°C)
- ✓ High-temperature variants use a mineral acid-base electrolyte and can operate up to 200°C.
- ✓ Electrical output can be varied, ideal for vehicles

PEMFC consists electrolyte that is sandwiched between anode and cathode electrodes. The hydrogen fuel feeds to the anode and oxygen is an oxidant to the cathode to generate electricity. Heat and water are the major by-products of electrochemical reactions within a fuel cell [13].

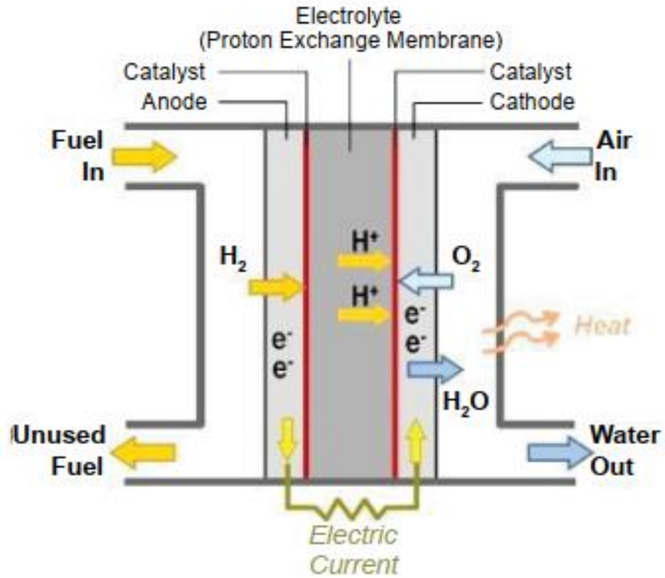

Figure 5. Schematic illustration of a proton exchange membrane fuel cell [14]

The reason that we chose proton exchange membrane hydrogen fuel cell types of the vehicle over other types of vehicles

- Zero tailpipe emission
- Silent during operation
- Refuel quickly
- Quick start-up
- High efficiency
- Avoiding the dependence on crude oil
- Required less space
- Low operational temperature

Those advantages make PEM fuel cells a promising candidate as the next-generation power source for transportation, stationary, and portable applications. Cost, Durability, and performance are the major challenges delaying PEMFC commercialization.

Main Components of PEMFC

As we know Engine is known as the heart of conventional vehicles, in PEMFC vehicles the fuel cell stack is the crucial part.

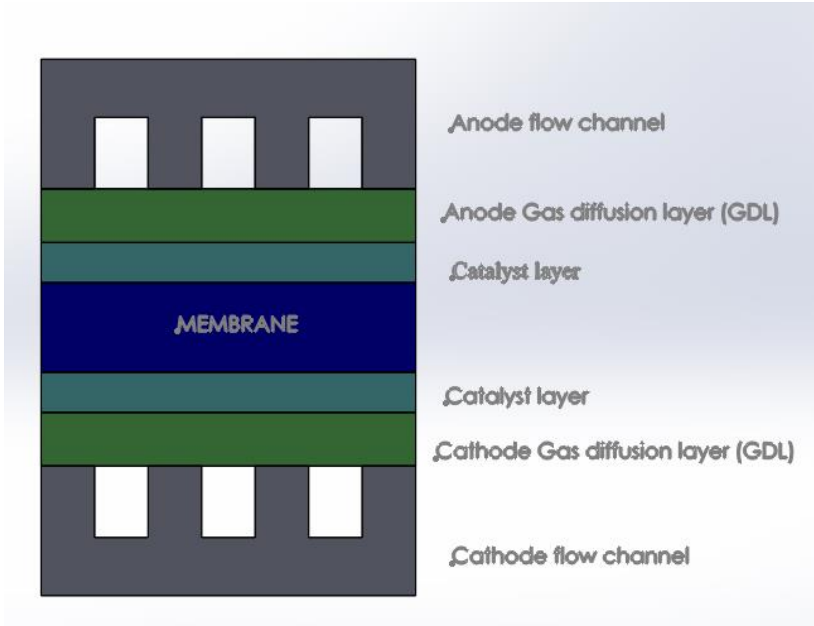

Figure 6. PEMFC components

Generally, in PEMFC the fuel cell stack consists of the following parts

- Gas flow channel (GFC)
- An electro-catalyst
- Proton Exchange membrane
- Gas diffusion layer (GDL)

Basically, PEM fuel can be made of the following components, namely an anode that accommodates the fuel, a cathode that supplies oxidant, and an electrolyte that separates the two electrodes known as the anode and the cathode and provides a passage for the transport of ions.

Both the electrodes those are the anode and the cathode have three distinct components: thus, are the gas diffusion layer (GDL), the gas flow channel, and the catalyst layers.

The fuel and the oxidant are distributed through the gas channel to the diffusion layer across the fuel cell. The gas diffusion layer and the catalyst layer are made of porous materials so that the fuel and the oxidant can be further transported from the diffusion layer to the catalyst layer where electro-chemical reactions take place to generate electricity.

Gas diffusion layer (GDL)

The gas diffusion layer (GDL) is the outer layer of the membrane electrode assembly (MEA) and it is placed between the gas flow channel and catalyst layer. It helps to uniformly distribute the reactants across the surfaces of the catalyst layers. It is made of carbon paper or cloth. In the PEMFC, the GDL, which is thicker than the catalyst layer, performs a variety of critical functions.

- For the catalyst structure and membrane to provide mechanical support,

- Conduct electrons between the bipolar plate and the electrode,
- Contribute to heat and water removal and prevent flooding
- It is a pathway that diffuses gas from the flow channel to the catalyst layer

The GDL should have high electronic and thermal conductivity, have a porous nature, be thicker when compared with the catalyst, and be hydrophilic. It serves as a connection bridge between the membrane electrode assembly (MEA) and graphite plate.

Generally, the Gas diffusion layer (GDL) serves two main purposes.

- ➢ The first is to uniformly distribute reactants across the catalyst layer the surface area while at the same time facilitating the removal of liquid water produced at the cathode.
- ➢ The second is to provide an electrical connection between the collector plate and the catalyst layer.

Where electrochemical reactions take place to generate electricity, Fuel, and oxidant are transported further from the diffusion layer to the catalyst layer

Catalyst

The purpose of the catalyst layer is to initiate hydrogen dissociation on the anode side and to speed up the oxygen reduction reaction on the cathode side. The protons pass through the membrane to the cathode side, where they react with oxygen and electrons from the external circuit to produce water and heat.

Initially, the development of the PEM fuel cells has suffered a lot due to the high costs of the platinum I that is used as a catalyst in the catalyst layer, and many potential users switched to other types of fuel cells due to the cost factor. However, the development over the recent years has helped in increasing the current densities to a higher level, while at the same time reducing the amount of platinum used and nowadays, the Pt loading of the catalyst layer has been reduced. It helps to reduce the price of hydrogen fuel cell vehicles.

Membranes

The polymer electrolyte membrane is sandwiched between two electrodes which are known as an anode and a cathode. The proton exchange membrane conducts protons from the anode through the membrane that is used to complete the electrochemical reaction to the cathode. A polymer membrane is a slim plastic film that is permeable to protons, but it does not conduct electors.

All the electrolyte membranes should essentially have the following properties;

• They should be chemically resistant,

• They should be strong so that they can be cast in very small thicknesses,

• They should absorb large quantities of water and,

• When they are hydrated, hydrogen ions should move freely (higher protonic conductivity).

Gas flow channel (GFC)

The gas flow channel (GFC) is a critical component that distributes fuel gases on the electrode surface while also removing water as a byproduct. Flow channels are physical flow paths manufactured on the BP surfaces that serve as a guide for gas distribution throughout the BPs.

The major role of flow fields in the membrane electrode assembly is to uniformly distribute the reactants to the following layers, known as the gas diffusion layer (GDL), and the reactants flow through the porous electrode to the active catalyst layer (MEA).

Gas flow channels are curved into bipolar plates to provide pathways for reactant gases and, in practice, straight, serpentine, interdigitated, biometric flow fields are commonly used designs.

Bipolar plates, also known as flow field plates, account for more than 60% of the weight and 30% of the overall cost of a hydrogen fuel cell vehicle's fuel cell stack [17]. It is one of the most essential components for cost reduction and performance improvement in a PEMFC stack is the design of an adequate flow field channels layout. Improvements of up to 50% of the original output power density are possible.

BPP is one of the most significant components in PEMFC stacks since it can execute a variety of functions at the same time, resulting in better stack performance and lifetime. The failure of flow distribution across different unit cells can have a big impact on the fuel cell stack's operation.

The flow plates should be designed in such a way that the hydrogen fuel and oxidant are efficiently distributed to the following layer, the catalyst layer. The flow channels can generate an uneven distribution of electrochemical reactions, resulting in inconsistent catalyst consumption.

Generally, Flow fields' primary function is to evenly distribute reactants to the gas diffusion layer (GDL) and then to the next layer, the active catalyst layer in the membrane assembly (MEA), via the porous electrode. A well-designed bipolar plate flow field is the major player in these processes. Homogeneous current and temperature distribution, as well as effective water removal, are key functions in a PEMFC that need careful flow field design. BPPs are used to electronically connect one cell to the next in an electrochemical cell stack by supplying reactant gases to the electrodes through flow channels. These plates also provide structural support for the MEAs, which are thin and mechanically weak, as well as a way to control water within the cell. The BPPs also help with heat management in the absence of specific cooling plates [14].

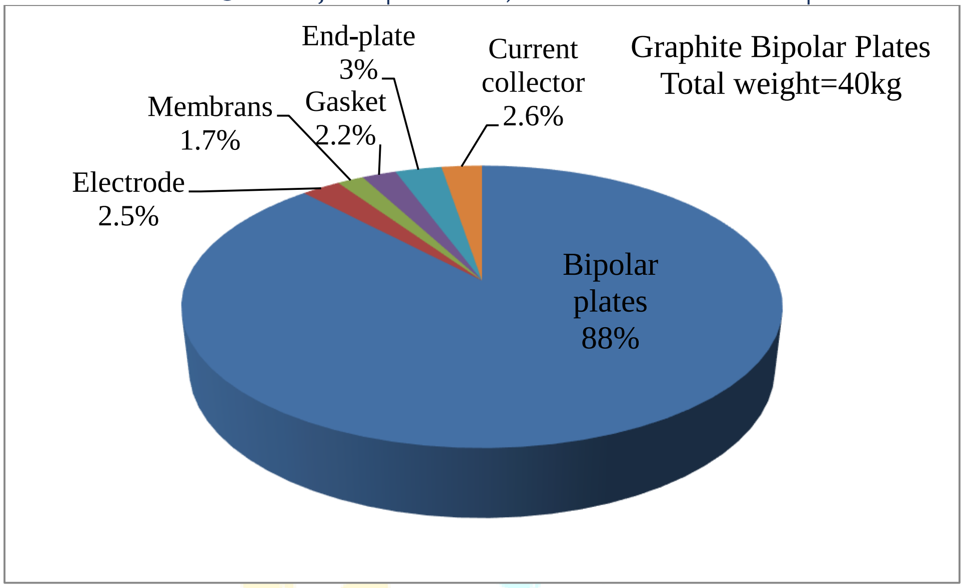

Figure 7. Mass distribution in a 33 kW PEMFC stacks [16]

Good flow field plates give uniform gas distributions, low-pressure drops for transport, and sufficient rib area to provide high electronic conductivity. A better flow field design should also remove water efficiently, prevent water condensation, and provide sufficiently high moisture content in the membrane [15]. The gas diffusion layer comprises > 60% of the weight and 30% of the total cost of the FC stack. A good design of the FFP can thus improve the overall PEMFC stack performance in terms of costs by as much as 50%.

The flow channels in the PEMFC are essentially used to distribute the fuel gases on the electrode surface and remove the by-product water. Therefore, the types and dimensions of flow channels play an essential role in the performance of PEMFC.

Operating Principal of PEM Fuel Cells

FCVs represent a transportation solution that can reduce both oil use and harmful emissions. A single-cell fuel cell consists of an electrolyte proton membrane sandwiched between two electrodes, an anode, and a cathode. A fuel cell is a device that creates electricity by using hydrogen and oxygen in the electrochemical process.

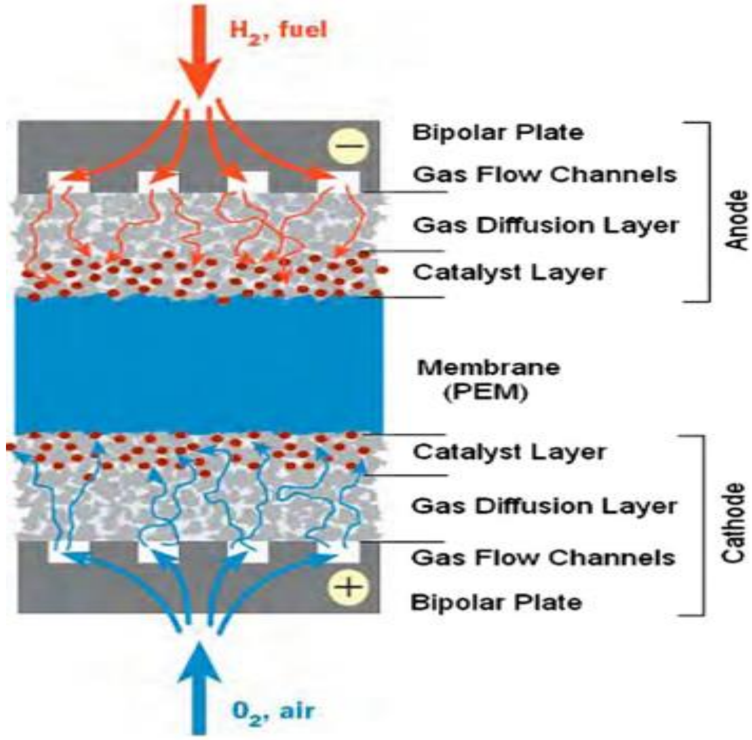

Figure 8. Delivery of reactants from gas flow channels to the catalyst layer [15]

Pure hydrogen gas enters the anode channel and diffuses through the porous anode electrode towards the catalyst layer of the anode, where hydrogen molecules are stripped of their electrons with the help of a platinum catalyst and become positively charged hydrogen protons ions, based on the oxidation reaction of hydrogen (ORH):

$$H_2 \rightarrow 2H^{+} + 2e^{-}$$

Hydrogen oxidation reaction (HOR) is a slightly endothermic reaction.

To generate an electric current, protons pass through the positive ion-permeable membrane, whereas electrons pass through the external circuit. A stream of humidified air enters the cathode channel and diffuses towards the cathode-side catalyst layer on the cathode side. Following the reduction reaction of oxygen (RRO), protons recombine with electrons and oxygen molecules at the platinum catalyst surface to produce water and heat:

The reduction reaction of oxygen (RRO):

$$1/2O2 + 2H^{+} + 2e^{-} \rightarrow H2O$$

Oxygen reduction reaction (ORR) is a strongly exothermic reaction.

The overall reaction in the PEM fuel cell is summarized as

$$H2 + 1/2O2 \rightarrow H2O + heat + electrical\ energy$$

The most general indicator of fuel cell performance is the polarization curve.

Overall, green vehicles play a vital role in reducing environmental impacts, promoting energy sustainability, and improving overall transportation efficiency.

Conclusion

Global warming and air pollution in our world are a series of issues. As well known human activities are the main cause of air pollution and global warming due to waste from industry, and transportation that uses conventional engines.

A zero-emission vehicle (ZEV) refers to a vehicle that produces no tailpipe pollutants or greenhouse gas emissions during operation. These vehicles use alternative energy sources instead of traditional fossil fuels to power their engines. ZEVs typically include electric vehicles (EVs), hydrogen fuel cell vehicles (HFCV), and some hybrid vehicles that can operate solely on electricity for a certain distance. By promoting the use of ZEVs, we can reduce air pollution, mitigate climate change, and move towards a more sustainable transportation system.

Hydrogen fuel vehicles are a promising candidate to lead an eco-friendly source of energy. In hydrogen fuel cells there is a crucial part known as the fuel stack with gas flow channel (GFC), electrocatalyst, proton exchange membrane (PEM), and gas diffusion layer (GDL).

Fuel cell electric vehicles have the potential to be a cleaner and more efficient alternative to traditional combustion engines. As infrastructure improves and technology evolves, FCEVs could play a significant role in reducing greenhouse gas emissions and advancing sustainable transportation.

The gas flow channel (GFC) is the crucial part essentially used to distribute the fuel gases on the electrode surface and to remove water as a byproduct. A PEM fuel is made of an anode that accommodates the fuel, a cathode that supplies oxidant, and an electrolyte that separates the two electrodes (anode and the cathode) and provides a passage for the transport of ions. Both electrodes have three distinct components: thus, are the gas diffusion layer (GDL), the gas flow channel, and the catalyst layers.

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