A Comprehensive Review of Hydrogen Automobiles Future Prospects

Om borawake[1] , Yash khandarkar[1] , Tariq alam[1] , Dr.sandeep kore[2]

[1]*Department Of Mechanical Engineering Vishwakarma Institute of Information Technology, Pune 411048, India*

[2]*Professor Of Department of Mechanical Engineering Vishwakarma Institute of Information Technology, Pune 411048, India*

Abstract - *In recognition of the harmful effects of typical gasoline automobile emissions, the scientific community is turning to environmentally benign energy sources. Despite the abundance of renewable energy sources, hydrogen is the most effective one for use as automobile fuel. Like electricity, hydrogen is a powerful energy carrier capable of carrying large quantities of energy. The capacity of the vehicle's onboard hydrogen storage must be taken into account while developing fuel cell cars. This research looks at a recent advancement in hydrogen fuel cell engines to investigate the practicality of utilising hydrogen as a primary fuel in transportation systems, A fuel cell is an electrochemical device that produces energy by reacting chemical gases and oxidants. The fuel cell separates the cation and anion in the reactant in addition to using anodes to produce power. Reactants are compounds employed in fuel cells that cause a chemical reaction that results in the production of water as a byproduct. Hydrogen is one of the most efficient energy carriers, therefore the fuel cell can provide direct current (DC) electricity to run the electric car. A hydrogen fuel cell, batteries, and a control system along with methods can be used to make a responsible hybrid vehicle.*

***Key Words*:** hydrogen; fuel cell, battery, clean transportation, electric vehicle.

1. INTRODUCTION

A country's economy, infrastructure, transportation, and way of living are all influenced by this energy. The discrepancy between global energy availability and use is an issue. All countries now rely on non-sustainable sources of energy, namely fossil fuels, to provide their energy. In order to meet the energy needs of the world's population, which is growing more quickly, it is crucial to switch to an alternative, sustainable energy source that has no detrimental environmental effects [1,2]. The United States has prioritised lowering petroleum reliance and the environmental effect of the transportation industry in recent decades. One of the primary concerns with the current energy situation is the depletion of non-renewable conventional fuels, which leads to environmental challenges like the greenhouse effect and renders the energy sector unsustainable [3,4]. The percentage of fossil fuels used today is still significant, and it is predicted that by 2050, they will produce around 75% of all energy [5]. In general, the present The energy scenario has several drawbacks. Future generations will have far more hope if they employ more of the several renewable energy sources that now exist. Environmentalists believe that various actions will prevent the worst-case scenario of global warming and its effects from occurring.

cars have improved in fuel efficiency over the past 20 years, and hybrid electric cars are becoming increasingly prevalent. Electricity is one of the alternative fuels in automobiles that is expanding the quickest. Electricity is not a main energy source, like traditional energy sources like coal and oil. An energy carrier is a battery that is completely charged. Battery electric vehicles (BEVs) are very effective at turning grid energy into tractive force. They also have the ability to recover energy while driving by using regenerative braking. Due to the size and expense of the batteries required for the power and energy requirements of the vehicle, BEVs often have a restricted range. When compared to a conventional vehicle (CV), the "refuelling" of battery systems might take many hours rather than only a few minutes. An alternative is taken into consideration in order to utilise the benefits of both conventional and electric cars and to close the gap between CVs and BEVs. With an energy density greater than most batteries—39.39 kWh/kg—hydrogen is a chemical energy carrier that can generate electricity. There is a clear parallel between an internal combustion engine (ICE) and a fuel cell (FC). Chemical energy is changed by an ICE. to create rotating mechanical energy, stored in the gasoline fed to the engine [6]. The generated rotational energy is then concentrated through a generator to create electrical energy, which may be utilised to power a vehicle. In that chemical energy is immediately turned into electrical energy in an FC through an ecologically benign method, an FC functions similarly to an ICE [7–12]. As long as fuel is being supplied to them, internal combustion engines and fuel cells operate as continuously operating power sources, unlike batteries that deplete while being utilised to power electrical components [13]. As a result, it is anticipated that the hydrogen fuel cell will be able to overcome the drawbacks of BEVs, making hydrogen the preferred fuel for transportation in the future.

1.1 Hydrogen as a Transportation Fuel

The simplest form of a molecule is hydrogen, which has the highest energy content of any fuel by weight but the lowest energy content by volume. Both as a gas and a liquid, it may be found in the atmosphere and in water. Hydrogen is used as a fuel in devices like FCs and rockets due to its high energy content. One of the biggest disadvantages of fossil fuels is their production of toxic pollutants, which hydrogen eliminates, and it has a heating value that is three times more than that of petroleum. Hydrogen generation entails significant costs, given that it is a synthetic fuel and that refining petroleum costs nearly three times as much, [14]. The development of an effective and sustainable method for producing hydrogen and the use of hydrogen in engines for transportation are the subject of extensive study. Fuel cell vehicles (FCVs) using hydrogen as the fuel are now being produced by automakers including Honda, Toyota, and Hyundai. These FCVs are now on the market in North America, Asia, and Europe, and early adopters have mostly purchased them. The present consumers, or early adopters, are mostly highly educated individuals, wealthy families, and those with greater family units, people who are open to changing their way of life, and those with additional traits comparable to these [15]. More than 6500 FCVs have been sold to customers as of June 2018. Due to the fact that California has the greatest network of hydrogen refuelling stations in the world and that manufacturers sell the cars there, the state is the main market for FCVs, receiving over 3000 of the 5233 vehicles sold globally. Several automakers are currently encouraging consumers to purchase FCVs, which are likened frequently to BEVs. BEVs and FCVs both have electric motors, zero tailpipe emissions, and the capacity to be powered by renewable and sustainable energy sources. The driving range and refuelling method are the two main distinctions between FCVs and BEVs. With a driving range of more than 300 miles and a hydrogen refuelling time of under 10 minutes, FCVs are more like conventional ICE fossil fuel powered cars. Future fuel utilisation of hydrogen has a bigger potential. According to estimates, by the year 2030, Based on the technological advancements being made and the growing availability, fuel cells will be priced similarly to ICEs [14]. More effective storage is one of the biggest obstacles to broad hydrogen utilisation. Hydrogen cannot be stored as easily as conventional fossil fuels due to its low density. Compression, cooling, or a combination of the two are necessary for hydrogen. Physical confinement, notably in pressurised tanks, is the most advantageous technique of hydrogen storage since it is practical and accessible. Metal lined composites (Type III) are occasionally utilised, although all composites (Type IV) are typically employed. When the hydrogen is pre-cooled, the filling time for these tanks is competitive with that of fossil fuels. The biggest obstacle to the widespread usage of compressed hydrogen (CH2) tanks is the high cost of the material and the assembly. The public's worry over deploying such high pressure (70 MPa) storage tanks in cars is another possible drawback [16]. A tank with an internal skeleton, which is a complicated design of struts under tension within the tank to resist the stresses of the compressed gas, is an alternative to conventional CH2 tanks that is currently being investigated. Storage for liquid hydrogen (LH2) the best specific mass (15%) of any other car hydrogen storage device, and was greatly enhanced [17]. The usage of liquid hydrogen results in a reduction in energy efficiency. Before LH2 systems are extensively adopted, boil off needs to be improved. A cryo-compressed tank, where hydrogen is strongly compressed at cryogenic temperatures, is a possible alternative design. To ascertain the method's long-term viability and widespread adoption, more research must be conducted. Systems for storing hydrides demand There has been a lot of research and development to satisfy the needs of widespread use. NaAlH4 has received the greatest attention, however it lacks the capacity required for practical use. Based on the findings of the limited research that are now available, it is suggested that tanks without internal heat transmission devices might be built using the mild heat of hydrogen absorption on surfaces [18]. Despite being present in large amounts in the atmosphere, hydrogen is not in its purest form. From water, hydrocarbon fuel, hydrogen sulphide, and other chemical components, hydrogen may be extracted [19]. Hydrogen is created from its constituent components using external energy, including thermal, electrical, photonic, and biological energy. Ammonia, a chemical element with a high concentration of hydrogen, was suggested as a fuel for internal combustion engines since it may decompose on board into hydrogen and nitrogen. Both non-renewable and renewable energy sources can be used to extract hydrogen.

While the production of hydrogen from non-renewable sources releases greenhouse gases (GHG), the generation of hydrogen from renewable sources is always ecologically favourable [22,23]. Electrochemical reactions are used to produce hydrogen from waste biomass without emitting greenhouse gases and with low energy and manufacturing cost requirements.

Bread scraps, cypress sawdust, and rice chaff are examples of potential biomass feedstocks [24,25]. Similar to this, newspaper might be directly electrolyzed to make hydrogen. Newspaper, which contains 69.2% cellulose and 11.8% lignin, breaks down into aliphatic keto acid, monosaccharides, and disaccharides in the solvent H3PO4 under electrolysis-like conditions [26,27]. Methane that has been humidified can also be electrolyzed to produce hydrogen [28].

2. Hydrogen Storage in FCVs

One of the most crucial scientific questions in the creation of FCVs is hydrogen storage.Systems for storing hydrogen are being developed in order to use novel techniques to satisfy consumer demands. It is challenging to store enough hydrogen on board a vehicle to have a sufficient driving range without the storage container being too big or too heavy due to hydrogen's poor energy density. A hydrogen FCV with on-board compressed gas storage is depicted in Figure 1 [29]. The following bullet points provide an overview of hydrogen storage methods and the necessary research in this area.

2.1 Pressurized Tank Storage

Cylinders covered in carbon fibre are used to create pressurised tanks strong enough to withstand collisions while also providing impact protection. A 500-km range for compressed hydrogen in such tanks has been demonstrated at a pressure of 34 MPa with a mass of 32.5 kg and a capacity of 186 L. The tank volume is huge for individual automobiles—about 90% of a 55-gallon barrel. Although the 6 wt% objective can be reached, the tank volume is an issue. It has been possible to reach pressures of 70 MPa, and in 2002, Quantum Technology's 10,000 psi (68 MPa) Certification for on-board tanks was attained [30]. According to the office of technology policy report [31] [32], Toyota and Honda vehicles utilised hydrogen that was stored under high pressure and were available for lease in the latter part of 2002. However, hydrogen cannot be retained in the tank in large enough amounts due to its low density when compared to other gases. Liquid hydrogen storage at low temperatures is not practical for use in normal cars, but several manufacturers still conducting low-level research on this capacity. Moreover, a liquid hydrogen.

Boiling can cause storage systems to lose up to 1% of their storage volume per day, and considerable refrigeration is needed to preserve liquid hydrogen at 20 K [31].

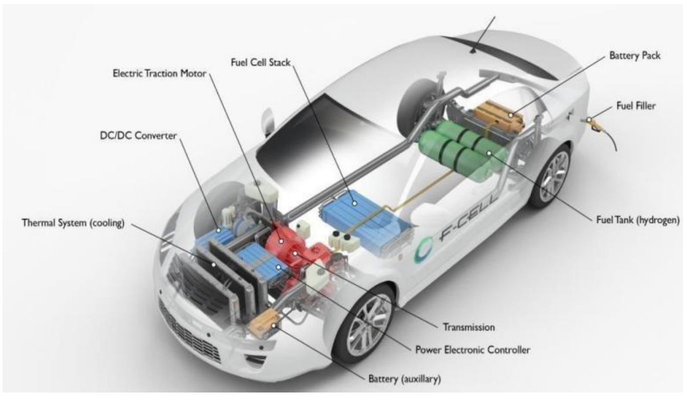

Fig -1: Fuel cell vehicle with on-board storage [29].

3. Principles of Fuel Cell

Different FC system types exist. However, the fundamentals of how they work are similar. An anode, a cathode, and an electrolyte are the three fundamental components of a fuel cell system. The type of electrolyte material utilised is used to classify FCs. A FC may consist of hundreds of different cells, yet they all share the same three essential elements. Between the cathode and the anode is where the electrolyte is placed. A schematic of a polymer electrolyte FC (PEMFC) operating diagram is shown in Figure 2 [38]. The proton exchange membrane FC is another name for this type of FC. What exists is the PEMFC utilised most frequently in mobile power applications, such cars. Fuel (pure hydrogen) is supplied into the anode compartment of the fuel cell while air or pure oxygen is injected into the cathode side of the FC. The type of electrolyte material utilised varies depending on the type of FC. Electrons are separated on the anode side of the cell as the gas.

The electrolyte membrane is attempted to be penetrated. Only the hydrogen ions may travel through the membrane, which serves as a filter to separate the electrons from the hydrogen ions. The hydrogen ions that crossed the membrane in the cathode compartment interact with the oxygen atoms from the air supply to create H2O as a byproduct, along with heat [39]. In contrast to internal combustion engines, which combine fuel with air, an FC separates the fuel from the oxidant without burning it. Consequently, FCs don't emit the dangerous pollutants that IC engines generate.

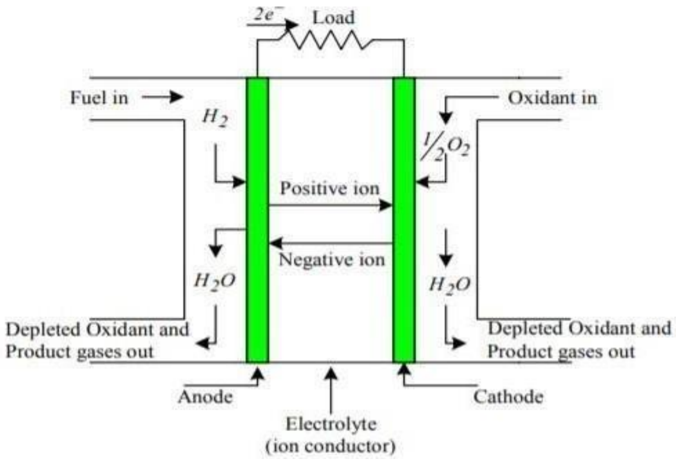

Fig -2:Fuel cell operation diagram [38]

4. Types Of Fuel Cell

POLYMER ELECTROLYTE MEMBRANE FUEL CELLS

1. DIRECT METHANOL FUEL CELLS
2. ALKALINE FUEL CELLS
3. PHOSPHORIC ACID FUEL CELLS
4. MOLTEN CARBONATE FUEL CELLS
5. SOLID OXIDE FUEL CELLS
6. REVERSIBLE FUEL CELLS

5. Working Of Fuel Cell?

Through the usage of a fuel cell, the reaction between hydrogen and oxygen may produce energy. This type of cell was employed during the Apollo space project and performed two functions: it provided fuel and functioned as a source of drinking water (the water vapour it generated, when condensed, was suitable for human consumption)..

This fuel cell functioned by transferring hydrogen and oxygen through carbon electrodes into a concentrated solution of sodium hydroxide. The cell response is expressed as follows:

Cathode Reaction: $O2 + 2H2O + 4e^- \rightarrow 4OH^-$

Anode Reaction: $2H2 + 4OH^- \rightarrow 4H2O + 4e^-$

Net Cell Reaction: $2H2 + O2 \rightarrow 2H2$

However, this electrochemical process has a very slow rate of reaction. With the aid of a catalyst like platinum or palladium, this problem is solved. The catalyst is coarsely split prior to being introduced into the electrodes to maximise the effective surface area. Below is a block schematic of this fuel cell.

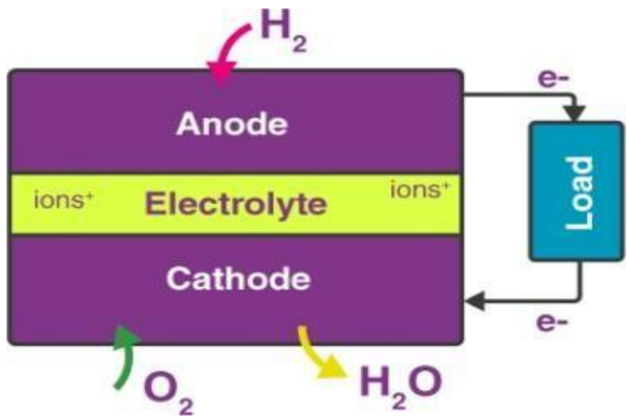

Fig -3: Name of the figure

In comparison to thermal power plants, which have an efficiency of 40%, the fuel cell described above generates energy with a general efficiency of about 70%. This significant efficiency disparity results from the fact that the production of electric current in a thermal power plant requires the transformation of water into steam and the use of this steam to turn a turbine. However, fuel cells provide a means of directly converting chemical energy into electrical energy.

6. Fuel Cell Hybrid Vehicles

An essential component of fuel cell vehicles, the electric motor, was developed as early as the early 19th century. Despite being a strong competitor to replace ICE cars as the primary mode of transportation in the early 20th century, electric vehicles ultimately lost out because of their limited range and high cost. Additionally, the price of petrol dropped because to the discovery of Texan oil, making it more cheap for the ordinary consumer. As a result, ICE vehicles overtook fuel cell and electric vehicles throughout the most of the previous century. the fuel An embargo in 1973 sparked a resurgence of interest in FC power for applications involving personal mobility as countries sought to lessen their reliance on petroleum imports. K. Kordesch converted a car in the early 1970s so that it could run on a 6-kW FC and a lead acid battery pack. For almost three years, the car was driven on public roads. Ballard introduced a fuel cell- powered light-duty transit bus employing a 120 kW FC system in 1993, and a 200 kW FC system-powered heavy-duty transit bus in 1995. Three fuel cell-battery hybrid buses were created by H-Power in 1994 and 1995, each having a 50 kW FC and a 100 kW nickel- cadmium battery.

These publications were crucial because they clarified FC technology for influential government and business decision-makers. These buses contributed to the demonstration of the practical viability of fuel cells.

Due to the simplicity of centralised refuelling and the decreased need for a large range capacity between fill-ups, fleet-vehicle operations like buses and delivery services were early adopters of fuel cell technology. In addition to other cities in Europe and North America, trials of FC-powered buses have taken place in Vancouver and Chicago. The first fuel cell car was leasedto a family in California in July 2005, which was a significant step towards increasing the number of fuel cell automobiles on the road. However, there are still a lot of challenges to be solved before the FC vehicle can become a widely used mode of transportation. The requirement for a hydrogen infrastructure to allow refuelling of the cars is an evident problem. There are presently hydrogen refuelling stations in various nations throughout the world, including Canada, the USA, Germany, Singapore, Japan, Iceland, etc.Although there are presently not enough of these stations for many people to start driving FCVs, it is anticipated that when more FCVs become commercially accessible, additional hydrogen infrastructure will be created. As a result of tremendous development, hydrogen FCVs can now travel between 311 and 597 miles on a single tank. These vehicles are being developed more and more, although they still need a lot of work [14].

7. Parallel Hybrid

The parallel hybrid architecture was one of the first hybrid drive train designs. In this setup, the internal combustion engine and the electric motor may each be utilised independently to power the vehicle. The ICE is very wasteful in stop-and-go driving cycles because it produces little torque at lowspeeds. Electric motors, on the other hand, offer practically immediate torque, which makes them perfect for stop-and-go driving cycles. When a parallel hybrid system is used, each power source— or both—can function to various degrees depending on when it is most necessary. dependable during the driving cycle. For instance, the electric motor would be used predominantly while the internal combustionengine would be mostly off during low speeds and stop-and-go cycles. On the other hand, under steady- state highway driving circumstances, the ICE would take over, using the high energy density of the gasoline to power the car while the electric motor would be off. When the torque requirement exceeds the torque generated by either the ICE or the electric motor, both can be operated simultaneously in the parallel arrangement. motor on their own. It enables the engine and the motor to be scaled down in size as most of the time the drive cycle will not have a high torque need since both power sources may be run simultaneously when torque demands are high. The total efficiency of the parallel arrangement may be further improved by reducing the size of both motors. Regenerative braking, a feature of the parallel hybrid drive train architecture, allows for the energy to be captured during drive cycle deceleration. Regenerative braking may be used by practically all hybrid vehicles to recover mechanical brake heat energy that would otherwise be lost. It is not just possible with parallel hybrid design. During pauses and decelerations in the drive cycle, regenerative braking transforms the electric motor into a generator; this energy is then stored in the vehicle's batteries for use at a later time in the driving cycle. Figure 4 below shows an illustration of a parallel hybrid drive train.

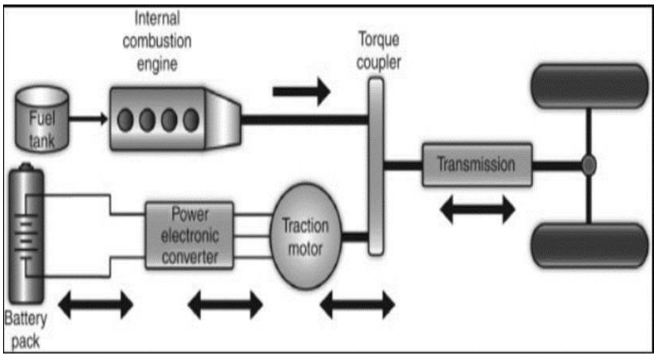

Fig -4: Parallel hybrid configuration

8. Series-Parallel Hybrid

Series and parallel hybrid drive train designs are combined to create the series-parallel hybrid. Both the ICE and the electric motor may operate the car either separately or in tandem in a series-parallel hybrid. The ICE may split its power between powering the vehicle and concurrently recharging the batteries. Since the modes of operation may be optimised to account for the present driving cycle, this system offers the greatest degree of control flexibility. However, this design has certain limitations, including the number of hardware is needed. A gearbox is necessary because the ICE must be able to move the car, and a generator is necessary so that the ICE can charge the batteries. The series-parallel design is more adaptable to various driving cycles since it has all the advantages of both the series design and the parallel design, but it also has all their disadvantages. Figure 5 provides an illustration of a series-parallel hybrid design.

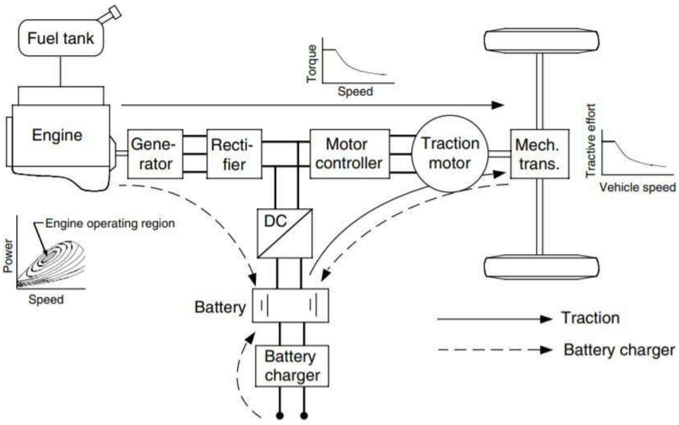

Fig -5: Series hybrid configuration

3. CONCLUSIONS

This study looked examined fuel cells' use in hybrid cars and the production of hydrogen-based electricity utilising them. Applications for different FC types, namely the use of FCs in hybrid cars, were examined. Batteries may not always be the best option for applications in cars, but FCs with effective control systems may.

Hydrogen fuel cells will play a significant role in the transportation industry in the near future. The price of fuel cells will reduce when producing fuel cells in large quantities and commercializing them. We could expect fuel cell-based transportation, power plants, and electricity generators to become prominent in the coming decades.

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