HYDROGEN ELECTRIC BIKE

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Summary: The study is based on the use of hydrogen and how it can power an electric motor, with a focus on the components that are taking part in the process. The method of converting hydrogen into a voltage source for the electric motor is presented, as well as the transmission of the generated power to the wheel of a bicycle in order to achieve the motion of the vehicle.

Key Words: Hydrogen, Bike, Fuel Cell.

1. Introduction

In hydrogen-powered vehicles, power is generated by converting hydrogen's chemical energy into mechanical energy by reacting hydrogen with oxygen in a fuel cell to power the electric motor. Hydrogen is stored in high pressure tanks.

2. Current status

In the automotive field, the development of hydrogen vehicles is in a relatively early stage. In the United Kingdom some manufacturers have already taken the step and developed models based on hydrogen fueling technology. Meanwhile, 23 hydrogen stations for cars have already been built in Germany.

Starting from 2021, there are two publicly available hydrogen car models on the market: the Toyota Mirai, which is the world's first series-produced dedicated fuel cell electric vehicle, and the Hyundai Nexo.

As for hydrogen bikes, they are still in their early stage of development. At the moment, no manufacturer has made a mass market launch, only prototypes or concepts. Among the previously named manufacturers we can mention: Studio MOM – LAVO bike, The Linde Group – Linde H2 bike and Pragma Industries – Alpha Hydrogen Bicycle

3. Design and Product

3.1 Power system

3.1.1. The hydrogen tank

Hydrogen presents itself as a particularly attractive alternative to liquid fuel in the context of increasingly scarce and less reliable supplies of liquid hydrocarbons, due to a set of distinctive characteristics. At the same time, alternatives to this ever-dwindling supply are being persistently sought.

The oxygen is a chemical element with symbol O and atomic number 8, belonging to the chalcogen group. Being a highly reactive non-metallic element and a strong oxidizing agent, oxygen easily binds with most elements, forming compounds, especially oxides. In the universe, oxygen is the third most abundant element after hydrogen and helium.

There are two physical forms in which hydrogen can be stored: compressed gas or cryogenic liquid. It is also possible to store it by binding it with other substances through a reversible chemical reaction.

Currently, hydrogen tanks are made of carbon fiber reinforced plastic to reduce weight, and metal or polymer gaskets are used to ensure gas tightness. The outer laminated layer of the tank provides the necessary structural integrity.

Table 1 shows a range of materials from which hydrogen tanks can be made, along with brief comments on each.

Table 1. Materials

Type	Material	Characteristics
Type 1	Full metal tanks (steel)	Heavy, unsuitable for vehicles
Type 2	Metal tanks wrapped with windings like filament (fiberglass)	Heavy, not reliable due to internal corrosion
Type 3	Composite materials (carbon fiber) with inner metal linings (Al or steel)	Suitable for vehicles: lightweight , 25% - 75% increase in mass compared to I and II. High burst pressure, no permeability
Type 4	Composite materials (carbon fiber) with polymer linings (thermoplastics, polyethylene or polyamide)	Lighter (4% mass increase over III), cheaper, longer life (no creep fatigue) than type III. Lower burst pressure.

The hydrogen tank is characterized by an increase in the amount of gas for two distinct reasons. First, at the filling pressure and temperature, hydrogen exhibits a negative Joule-Thomson coefficient, meaning that a flow of gas from the high-pressure feed banks through the narrow manifold to the lower-pressure reservoir can cause an increase in the temperature. Second, the compression of the gas inside the tank by the incoming high-pressure gas can cause a rise in temperature, due to the heat of compression. If the filling process is done slowly, there is enough time to remove the heat generated through the walls of the tank [4].

Hydrogen refueling stations must adapt to the increase in the number of hydrogen fueled vehicles by developing a standardized and uniform refueling infrastructure.

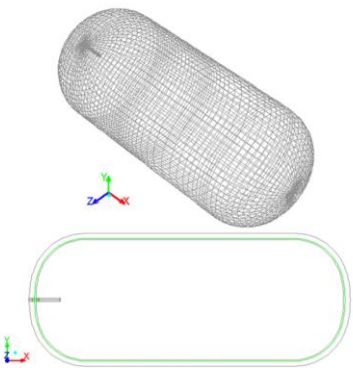

Fig.1. Geometry of the hydrogen tank

This must ensure reliable operation in all environmental conditions and take into account the various tank designs. In addition, charging stations should be able to fill tanks to full capacity in a time similar to that of refueling vehicles with gasoline, without exceeding safety limits.

In the adjacent figure is a model of a hydrogen tank. The model geometry is divided into two domains: the fluid domain filled with hydrogen gas and the solid domain involving the liner and laminate regions on the tank wall and inlet tube. The liner is made of aluminum alloy and the laminate is constructed of carbon fiber reinforced plastic. High pressure tanks are made with a thicker dome region. The exact dimensions of the inner surface of the tank were not available. Therefore, the walls were made of uniform thickness [5].

3.1.2 Compressor

Conventional mechanical (MC) compressors are adequate up to a certain limit. of hydrogen, but these present problems such as: the use of moving parts subject to frictional wear, the embrittlement of the hydrogen, noise and vibration, and contamination due to lubricants used to reduce friction between moving parts.

There are mechanical compressors that use liquids instead of pistons to compress the hydrogen, they are more efficient and cleaner in their operation, but they are also prone to corrosion problems.

Fig.2. Compressor

The electrochemical hydrogen compressor (ECH) is an interesting alternative because it has no moving parts; it increases the volumetric energy density and has the advantage of ensuring the high purity of hydrogen gas due to the nature of the compression system, which is based on a specific electrochemical reaction. In addition, EHC is a more efficient way to store hydrogen at high pressures and with low energy consumption.

3.2 Fuel Cell

A fuel cell is an electrochemical cell that converts the chemical energy of a fuel (often hydrogen) and an oxidizing agent (often oxygen) into electricity through a pair of redox reactions [8].

Fuel cells differ from batteries because they require a continuous source of fuel and oxygen (usually taken from the air) to sustain the chemical reaction, whereas in a battery the chemical energy usually comes from metals and their ions or oxides which, they are usually already present in the battery. Fuel cells can produce electricity continuously as long as they are fed with fuel and oxygen.

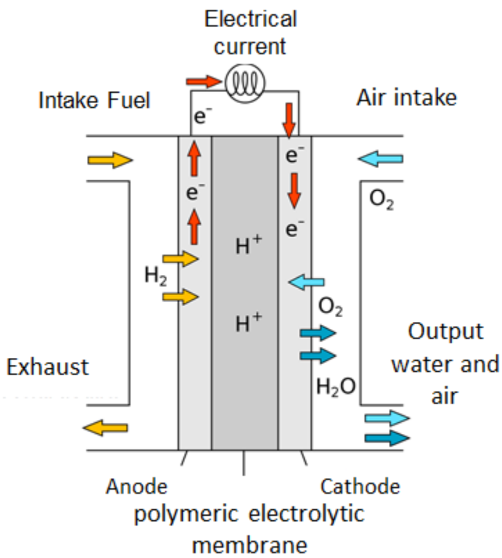

Fig.3 Fuel Cell – Principle of functionality

The generation of electric current in a fuel cell is driven by two primary chemical reactions, as illustrated in (Figure 3).

For fuel cells that run on pure H2, the gaseous hydrogen is split into protons and electrons at the anode.

Protons are conducted through the electrolytic membrane, and electrons circulate around the membrane, generating an electric current.

The charged ions (H+ and e-) combine with oxygen at the cathode, producing water and heat.

Fuel cells are an alternative energy technology that generates electricity through the reaction between hydrogen (or a hydrogen-rich fuel source) and oxygen. These devices are particularly interesting due to their high efficiencies compared to traditional combustion engines and low emissions, producing only heat and water as waste products. The development of new component materials with increased performance and cost efficiency is a critical part of emerging fuel cell research.

For automotive industry as well as stationary applications, separate fuel cells are packed together in series, called a stack, to form an integrated three-dimensional structure that includes connections and manifolds to distribute reactants and coolant [1].

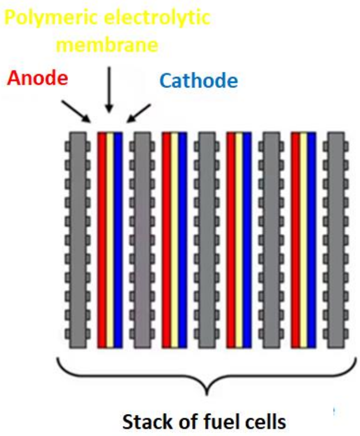

Fig.4. The conceptual diagram of a fuel cells stack

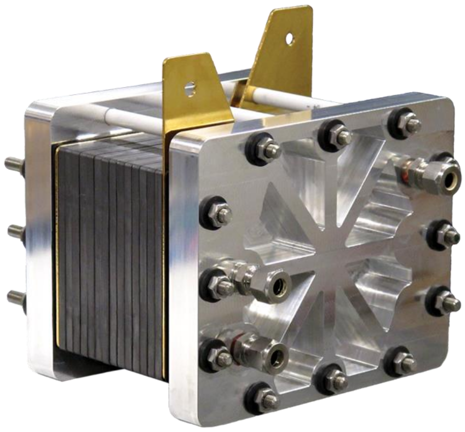
Fig. 5. Stack of fuel cells

The polymer electrolyte membrane is the central component of a fuel cell that helps produce the electrochemical reaction needed to separate electrons. On the anode side of the membrane, the fuel (hydrogen) diffuses through the membrane and is met at the cathode end by an oxidizer (oxygen or air) that binds to the fuel and receives the electrons that have been stripped from the fuel. An essential part of the fuel cell is the catalyst, which facilitates the oxidation reaction at the anode. Catalysts increase the rate of chemical reactions [12].

Air humidity plays a vital role in the well-being and performance of the fuel cell, especially the membrane. The air used in the fuel cell cathode must have a relative humidity above 70%. In operation, the water produced by the fuel cell can be used to humidify the ambient air [12].

Fuel cell stacks with an average power of 100 W can be cooled with ambient air by a simple cell-mounted fan, while 200–2000 W stacks require cooling through separate air channels along with the reactant flows [13].

A "rough" approximation is that the efficiency of a cell is equal to the cell voltage expressed as a percentage - that is, a cell voltage of 0.7 V represents a cell operating at approximately 70% efficiency.

3.3 Electric Motor

Electric motors work on a very simple principle. When an electric current is introduced into a magnetic field, a force is generated. An electric motor uses looped wires (the same wires that carry the current) that are positioned at right angles to the magnetic field in the electric motor. Because the magnetic field has dual polarities, each end of the wires is moved in a different direction. This creates a rotational motion. The torque is controlled by adding more loops to the armatures and the magnetic field is produced by an electromagnet.

The principle of operation of an electric motor consists in the passage of current through a magnetic field that acts a force on a coil, thus realizing the rotational movement.

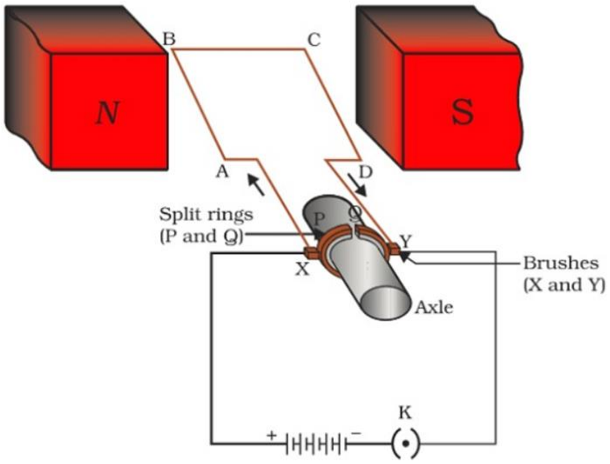

Fig.6 The representation of how the electric motor works

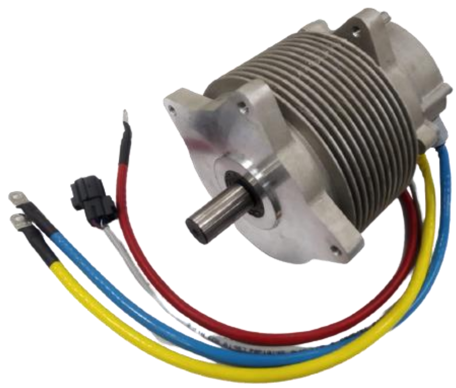

Fig.7. Electric Motor

3.3.1 The components of the electric mtor

- Rectangular coil with wire ABCD
- Two magnets of opposite pole
- he ends of the coil are connected by two split rings (the rings serve as a switch to reverse the direction of the current in the electrical circuit)
- The inner ring is insulated and attached to the rotating shaft
- The outer ring is connected to the tow stationary brushes which connect to the battery to create the electrical circuit

3.3.2 Mode of operation:

When the battery is switched on, the current flows through the coil AB and the magnetic field flows from north to south, the force applied on AB being downward (Figure 6) [2].

The upward force is applied to CD, so rotation is done with AB moving down and CD up. The direction of the current changes after half a turn through the switch.

The coil rotates with the rings, the coil reaches a position parallel to the magnetic field, the stationary brushes X and Y collide with the split ends of the rings and the circuit is interrupted.

Due to inertia the ring maintains its motion and the opposite end of the ring is connected to the positive end of the wire. (P is connected to coil CD and Q to coil AB) – the reverse of the current direction.

Current reversal occurs every half turn and the coil rotates until the battery is turned off. Split rings are used to achieve a single rotation in the same direction, otherwise only half a clockwise rotation and one clockwise rotation is achieved [2].

3.4 Distribution

To understand how an electric bicycle works, we need to know how a classic, fully mechanical construction works. The principle of the two is similar, the difference is made by their evolution through the electrical components.

In a classic bicycle the mechanical energy is realized through the pedals, their actuation transmits the power to the rear wheel through the chain. The hub and pinion assembly receives the power and sets the bike in motion.

Bearings play an important role because they provide an uninterrupted, agile ride. If the bearings are seized then the transmission does not work optimally. Valid for both hub and gear

.In the case of an electric bicycle, the additional component is the electric motor. The motor is the heart of the electric bike and can be positioned on the front wheel (Front Hub Motor), on the rear wheel (Rear Hub Motor) or even in the area of the pedals (Mid-Drive Motor). The most common motors are brushless, but there are cases where the motor used is with brushes [11].

Fig.8. Placement for the engine

For a hydrogen-powered bicycle, the electric motor remains unchanged, the difference is made by replacing the battery pack with a fuel cell stack pack. Another considerable additional component is the hydrogen tank.

3.5 The interconnection principle of the components

Another challenge is the realization of the complete fuel cell supply circuit. Fortunately, in the case of the bike proposed as a theme, the circuit will be of less complexity, compared to that of a car. Therefore, I thought it would be of interest to attach a complete schematic of such a circuit as discussed.

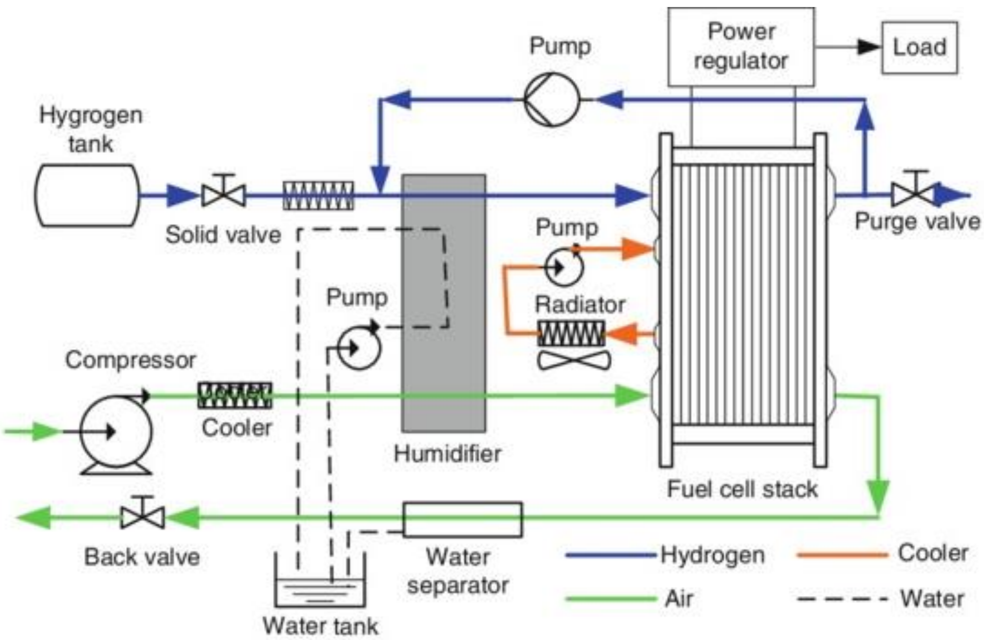

Fig.9. Diagram of operating system

4. Conclusions

Hydrogen-powered electric vehicles are a real contender in the near future. These types of vehicle only produce water and heat while driving, thus making them harmless to the environment. Since hydrogen as a fuel has a very good consumption ratio, the autonomy of these vehicles is comparable to that of combustion cars. The loading time is also short.

5. Future studies

Next, we set out to create the functional links between the components presented in this study in order to establish the final specifications, with the aim of creating a first prototype of this bicycle. We believe that this theme presents a large potential for research.

5.1 Electric motor power supply experiment

For the presentation we wanted to demonstrate the potential of hydrogen as a feasible fuel source. We decided to carry out an experiment, the purpose of which was to supply hydrogen to a small direct current electric motor. The electric motor is connected to a fuel cell (Figure 10). The cell is fueled with both hydrogen and oxygen taken directly from the atmosphere.

In order to ensure the hydrogen that reaches the fuel cell, we improvised the construction of a generation and supply circuit. This is how we achieved a chemical reaction between aluminum (Al) and sodium hydroxide (NaOH), also known as caustic soda. The resulting products are hydrogen (H2) and sodium aluminate ($NaAlO_2$).

Due to the need to purify the hydrogen from the initial reaction, we used a container of water to filter out impurities and acid fumes.

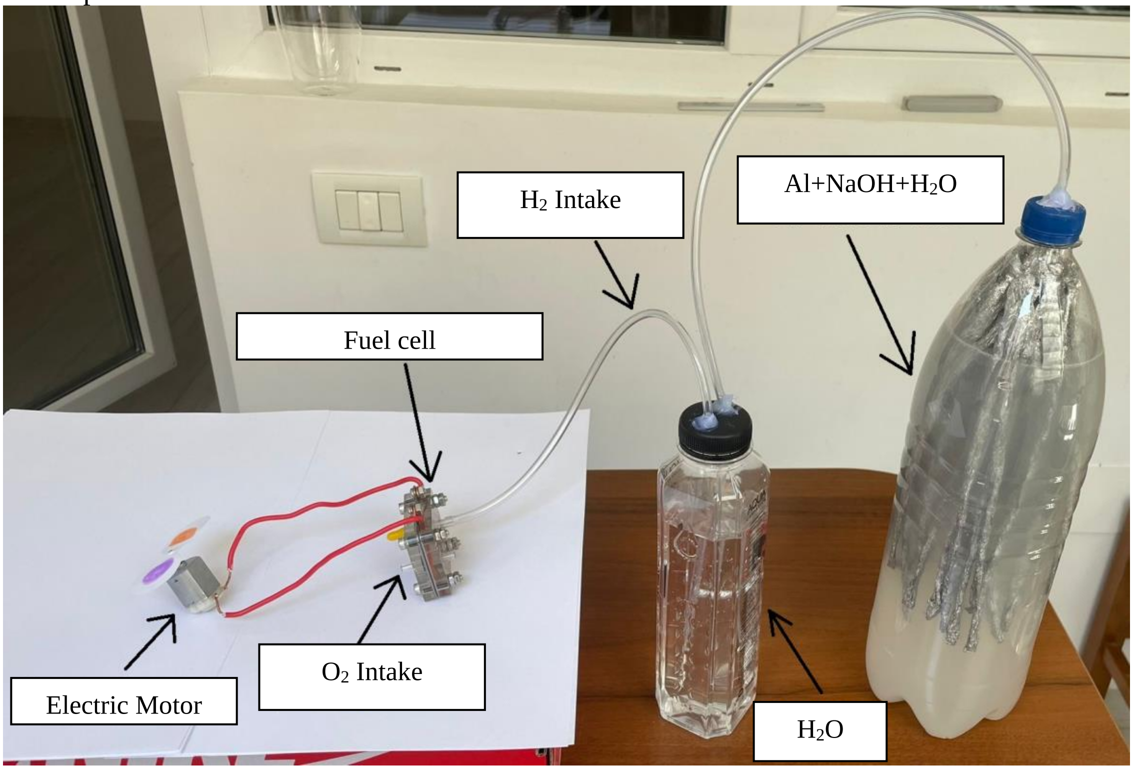

Fig.10. Experiment

Another method of powering the electric motor is the direct connection of the cell to a balloon previously inflated with hydrogen. This way is much closer to the current reality of fueling electric cars with hydrogen.

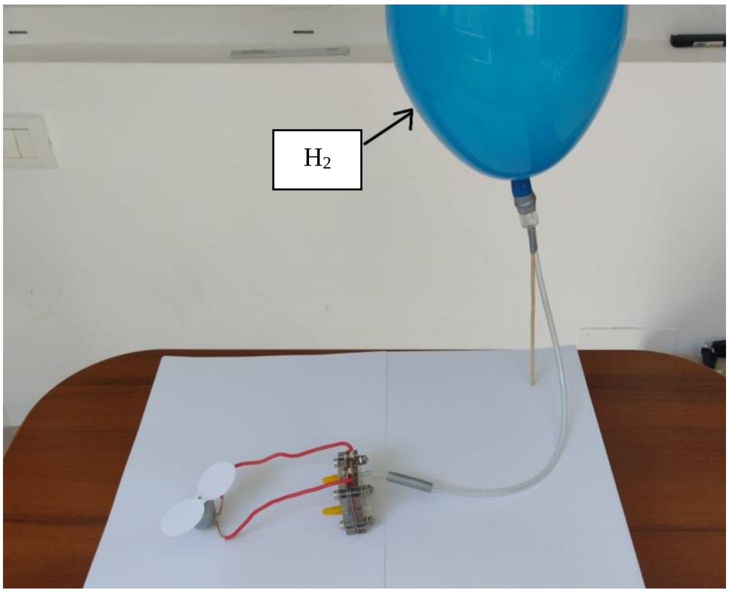

Fig.11. Alternative method

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