DESIGN AND FABRICATION OF A HYDROGEN GENERATOR USING WATER ELECTROLYSIS

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Abstract

This project focuses on the design and fabrication of a hydrogen generator using the water electrolysis process. The main objective is to produce hydrogen–oxygen (HHO) gas as a clean and alternative energy source. In this system, water is mixed with potassium hydroxide (KOH) to improve electrical conductivity and enhance gas production. A 12V DC power supply is used to carry out electrolysis, which splits water into hydrogen and oxygen gases.

The setup consists of an electrolysis chamber with inlet and outlet ports and eight stainless steel plates acting as electrodes. For safety, the generated gas is passed through a bubbler and a flashback arrestor to prevent any backflow of flame. The system performance is observed based on gas generation and stability during operation.

The results indicate that the addition of KOH improves hydrogen production efficiency. This project demonstrates a simple, low-cost, and effective method for hydrogen generation, which can be used for small-scale applications and as a supplementary fuel in internal combustion engines.

Keywords: Hydrogen Generator; Water Electrolysis; HHO Gas; Potassium Hydroxide (KOH); Renewable Energy; Electrolysis Cell; Hydrogen Productio

Introduction

Hydrogen has emerged as one of the most promising alternative energy carriers due to its high energy density and environmentally friendly nature. Unlike conventional fossil fuels, hydrogen combustion produces only water as a by-product, making it a clean and sustainable energy source [12], [18], [53]. With increasing concerns over global warming, climate change, and depletion of fossil fuel reserves, hydrogen is being widely explored as a future energy solution [8], [9], [49]. The concept of a hydrogen economy has gained significant attention in recent years, where hydrogen serves as a primary energy carrier for various applications including transportation, power generation, and industrial processes [52].

Various methods are available for hydrogen production, such as steam methane reforming, coal gasification, biomass conversion, and water electrolysis [13], [31], [55]. Among these methods, water electrolysis is considered one of the most efficient and environmentally friendly techniques, especially when powered by renewable energy sources [1], [2], [6]. Electrolysis involves the decomposition of water into hydrogen and oxygen gases using electrical energy, making it a clean and sustainable method of hydrogen production [15], [19]. The integration of electrolysis systems with renewable energy technologies such as solar and wind power further enhances the sustainability of hydrogen production [24], [27].

Water electrolysis can be broadly classified into alkaline electrolysis, proton exchange membrane (PEM) electrolysis, and solid oxide electrolysis [4], [38], [45]. Among these, alkaline electrolysis is widely used due to its simplicity, cost-effectiveness, and long operational life [4], [15]. In alkaline electrolysis, electrolytes such as potassium hydroxide (KOH) or sodium hydroxide (NaOH) are added to water to improve electrical conductivity and increase hydrogen production efficiency [6], [43]. The presence of these electrolytes reduces the resistance of the solution and enhances the rate of electrochemical reactions occurring at the electrodes [41].

Recent advancements in electrolysis technology have focused on improving efficiency, reducing energy consumption, and lowering the overall cost of hydrogen production [48], [50]. The development of advanced electrode materials, improved membrane technologies, and optimized system designs have significantly contributed to the performance of modern electrolysis systems [25], [39], [46]. In addition, ongoing research aims to enhance durability and scalability to enable large-scale hydrogen production for industrial applications [22], [51].

Hydrogen generated through electrolysis can be utilized in various applications, including fuel cells, internal combustion engines, and energy storage systems [17], [28], [36]. In fuel cells, hydrogen is used to generate electricity with high efficiency and zero emissions, making it suitable for clean energy applications [28], [45]. Hydrogen can also be used as a supplementary fuel in internal combustion engines to improve combustion efficiency and reduce harmful emissions [21], [31]. Furthermore, hydrogen plays a vital role in energy storage by converting excess renewable energy into a storable form, which can be used during periods of high demand [49], [52].

Despite its advantages, hydrogen production and utilization involve several challenges, particularly related to storage, transportation, and safety [20], [52]. Hydrogen is highly flammable and requires careful handling to prevent accidents. Therefore, the design of hydrogen generation systems must include appropriate safety measures to ensure safe operation [23], [41]. Components such as bubblers and flashback arrestors are commonly used in hydrogen generators to prevent backflow of flame and reduce the risk of explosion [6], [23]. Proper material selection and system design also play a crucial role in maintaining safety and reliability [44].

In recent years, small-scale hydrogen generators, commonly known as HHO generators, have gained attention due to their simple construction and low cost [17]. These systems produce a mixture of hydrogen and oxygen gases, which can be used as a supplementary fuel in engines and other applications.

The performance of HHO generators depends on various factors, including electrode design, electrolyte concentration, applied voltage, and system configuration [4], [15]. Increasing the number of electrode plates and optimizing the spacing between them can significantly improve gas production efficiency.

The use of multiple electrode plates in electrolysis systems enhances the surface area available for electrochemical reactions, leading to increased hydrogen production [25], [39]. In addition, proper arrangement of plates ensures uniform current distribution and efficient operation. The design of the electrolysis chamber, including inlet and outlet ports, also affects the performance and stability of the system. Efficient gas collection and flow management are essential to ensure continuous and safe operation.

The incorporation of safety components is a critical aspect of hydrogen generator design. A bubbler is used to filter the generated gas and act as a barrier to prevent flame propagation. Similarly, a flashback arrestor is used to stop the reverse flow of flame, ensuring safe operation of the system [6], [23]. These components are essential in preventing accidents and improving the overall reliability of the hydrogen generator.

The objective of this project is to design and fabricate a hydrogen generator using water electrolysis. The system is developed using multiple stainless steel electrode plates to enhance hydrogen production efficiency. A suitable electrolyte, potassium hydroxide (KOH), is used to improve conductivity and facilitate the electrolysis process. The generated gas is passed through a bubbler and flashback arrestor to ensure safe operation. The performance of the system is evaluated based on gas generation and operational stability.

This project aims to demonstrate a simple, cost-effective, and efficient method for hydrogen generation using water electrolysis. The developed system can be used for small-scale applications and serves as a practical approach towards clean energy utilization. The study also highlights the importance of safety and design optimization in hydrogen generation systems, contributing to the advancement of sustainable energy technologies.

Experimental Setup

5.1 Overview of the Setup

The experimental setup was designed and fabricated to produce hydrogen–oxygen (HHO) gas through the electrolysis of water. The system comprises an electrolysis chamber, a direct current (DC) power supply, an electrolyte solution, and essential safety components including a bubbler and a flashback arrestor.

The electrolysis chamber serves as the primary unit where the electrochemical reaction takes place. When a DC voltage is applied across the electrodes immersed in the electrolyte, water molecules dissociate into hydrogen and oxygen gases. The generated gas mixture is subsequently directed through a controlled flow path for further handling.

To ensure operational safety, the gas produced is passed through a bubbler unit, which acts as a gas purification and flame arresting medium. In addition, a flashback arrestor is incorporated downstream to prevent reverse flame propagation into the system. All components are interconnected using properly sealed pipelines to maintain leak-proof operation.

The overall configuration of the setup is compact and systematically arranged to facilitate efficient gas generation, controlled flow, and safe operation under experimental conditions.

Figure 1. Schematic representation of the hydrogen generator experimental setup

5.2 Electrolysis Chamber

The electrolysis chamber is the primary component of the hydrogen generator, designed to facilitate the electrochemical decomposition of water into hydrogen and oxygen gases. The chamber is constructed using a non-conductive and chemically resistant container to prevent electrical leakage and corrosion during operation.

The chamber is provided with an inlet port for introducing the electrolyte solution and an outlet port for the discharge of the generated gas. The internal structure is designed to securely hold the electrode plates in a fixed position while maintaining proper spacing between them.

The material selection and structural design of the chamber ensure that it can withstand the operating conditions, including the effects of electrolyte concentration and gas pressure. Proper sealing of the chamber is maintained to prevent leakage of gas and electrolyte, thereby ensuring safe and efficient operation.

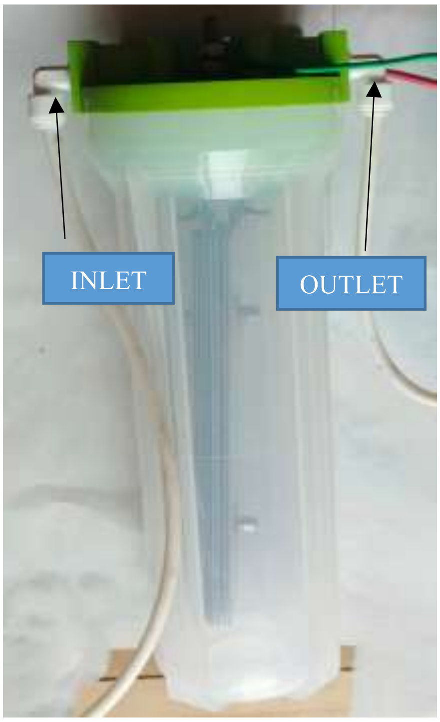

Figure 2. Electrolysis chamber showing inlet and outlet ports

5.3 Electrode Configuration

The electrode system consists of eight stainless steel plates arranged in a parallel configuration within the electrolysis chamber. These plates function as the anode and cathode, facilitating the electrochemical reactions required for hydrogen and oxygen generation.

The plates are electrically connected to the DC power supply with alternating polarity to ensure uniform current distribution across the electrodes. Proper spacing between the plates is maintained to allow efficient movement of ions within the electrolyte and to minimize electrical resistance.

The use of multiple plates increases the effective surface area available for the electrolysis process, thereby enhancing the rate of gas production. Stainless steel is selected as the electrode material due to its good electrical conductivity, corrosion resistance, and durability under alkaline conditions.

The configuration of the electrode assembly plays a critical role in determining the overall efficiency of the hydrogen generation system, as it directly influences current density and gas evolution rate.

Figure 3. Arrangement of stainless steel electrode plates inside the electrolysis chamber

5.4 Electrolyte Preparation

The electrolyte solution used in the experimental setup is prepared by dissolving potassium hydroxide (KOH) in distilled water. The addition of KOH enhances the electrical conductivity of water, which is essential for efficient electrolysis.

A suitable concentration of KOH is maintained to ensure optimal ion mobility and stable operation of the system. The solution is prepared by gradually adding KOH to distilled water under controlled conditions to ensure complete dissolution and uniform mixing.

The prepared electrolyte is introduced into the electrolysis chamber through the inlet port, ensuring that the electrode plates are fully immersed. Proper handling of the electrolyte is maintained due to the highly alkaline nature of potassium hydroxide.

The concentration and quality of the electrolyte significantly influence the efficiency of gas generation, as they directly affect the current flow and rate of the electrochemical reaction.

5.5 Power Supply

A direct current (DC) power supply is employed to provide the անհրաժեշտ electrical energy required for the electrolysis process. The power supply is connected to the electrode plates with proper polarity, where the positive terminal is connected to the anode and the negative terminal to the cathode.

The applied voltage and current are maintained within a suitable range to ensure efficient gas generation while preventing excessive heating of the system. Stable power input is essential for maintaining a consistent rate of electrolysis and uniform gas production.

Electrical connections are made using insulated wires to avoid short circuits and ensure operator safety. The power supply unit plays a critical role in controlling the overall performance of the hydrogen generator, as variations in voltage and current directly affect the rate of hydrogen and oxygen evolution.

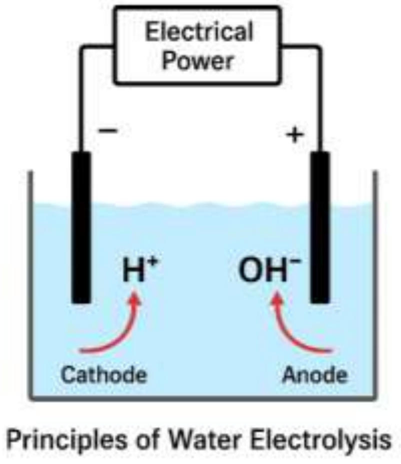

Figure 5. Electrical connection of DC power supply to the electrode system

5.6 Gas Flow Path

The gas flow path is designed to ensure the safe and efficient transfer of the generated hydrogen–oxygen (HHO) gas from the electrolysis chamber to the final output. The gas produced within the chamber exits through the outlet port and is directed through a series of interconnected components.

The flow of gas is maintained in a single direction using properly aligned pipes and fittings. This controlled pathway ensures that the gas passes sequentially through the safety units, including the bubbler and flashback arrestor, before reaching the output.

All connections in the gas flow path are sealed to prevent leakage and maintain system efficiency. The design of the flow path minimizes pressure loss and ensures continuous gas movement during operation.

The proper arrangement of the gas flow system is essential for maintaining stability, safety, and consistent performance of the hydrogen generator.

5.7 Bubbler Unit

The bubbler unit is incorporated into the system as a safety and gas purification component. It consists of a container partially filled with water, through which the generated hydrogen–oxygen (HHO) gas is passed.

As the gas enters the bubbler, it is forced to pass through the water medium, which helps in removing impurities and moisture content present in the gas. Additionally, the bubbler acts as a protective barrier by preventing the propagation of flame back into the electrolysis chamber.

The water column in the bubbler absorbs any sudden pressure fluctuations and provides stability to the gas flow. This makes the bubbler an essential component for ensuring safe operation of the hydrogen generator system.

The design and placement of the bubbler are critical, as it serves as the first level of protection against backfire and enhances the overall safety of the setup.

Figure 7. Bubbler unit showing gas inlet and outlet arrangement

5.8 Flashback Arrestor

The flashback arrestor is a critical safety component installed in the gas flow line after the bubbler unit. Its primary function is to prevent the reverse propagation of flame into the hydrogen generation system.

In the event of ignition at the output, the flashback arrestor effectively blocks the flame from traveling back through the pipeline toward the electrolysis chamber. This is achieved through its internal design, which dissipates heat and interrupts the flame path.

The inclusion of a flashback arrestor significantly enhances the operational safety of the system by minimizing the risk of explosion or damage to the equipment. It acts as a secondary level of protection following the bubbler unit.

Proper installation and positioning of the flashback arrestor are essential to ensure reliable performance and safe handling of the generated HHO gas.

Figure 8. Flashback arrestor used in the hydrogen generator system

5.9 Final Output and System Integration

The final stage of the experimental setup involves the collection and utilization of the generated hydrogen–oxygen (HHO) gas after passing through all safety components. The gas exiting the flashback arrestor is considered purified and safe for controlled use.

All components of the system, including the electrolysis chamber, gas flow lines, bubbler, and flashback arrestor, are integrated in a sequential and compact arrangement. This integration ensures a continuous and uninterrupted flow of gas from generation to output.

The system is designed to operate under controlled conditions with minimal leakage and stable performance. Proper alignment and secure connections between components contribute to the overall efficiency and reliability of the setup.

The integrated configuration of the hydrogen generator demonstrates a simple, cost-effective, and safe approach for small-scale hydrogen production using water electrolysis.

Figure 9. Final integrated hydrogen generator system

6. Results and Discussion

The performance of the fabricated hydrogen generator was analysed through experimental testing. The gas output was measured using the water displacement method under controlled conditions. The obtained results were used to evaluate the efficiency, stability, and overall behaviour of the system. Multiple trials were conducted to ensure accuracy and consistency in the measurements.

6.1 Gas Output Measurement

The gas output from the hydrogen generator was measured using the water displacement method. In this method, a water-filled bottle was inverted and connected to the gas outlet of the system. As gas was produced, it displaced the water inside the bottle, and the corresponding volume of gas collected was recorded.

The experiment was conducted at a constant voltage of 12 V. Three trials were performed under identical conditions to ensure the reliability of the results. The volumes of gas collected were 638 ml, 652 ml, and 643 ml over a duration of 60 seconds.

Table 1: Gas Output Measurement Results

Trial	Voltage (V)	Time (s)	Volume (ml)	Flow Rate (ml/s)
1	12	60	638	10.63
2	12	60	652	10.87
3	12	60	643	10.71

Calculation of Gas Flow Rate

The gas flow rate was calculated using the relation:

Flow Rate = Gas Collected / Time

The average volume of gas collected from the three trials was determined to be **644.3 ml**.

Since the time duration is 60 seconds, the average flow rate is:

Flow Rate = 644.3 / 60 = **10.74 ml/s**

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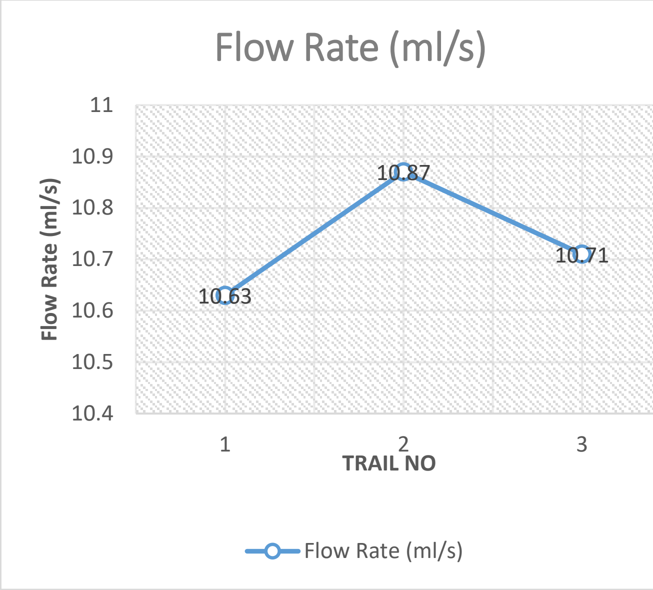

Figure 1: Comparison of gas flow rate for different trials

The graph shows that the gas flow rate remains nearly uniform across all trials, indicating stable performance of the system.

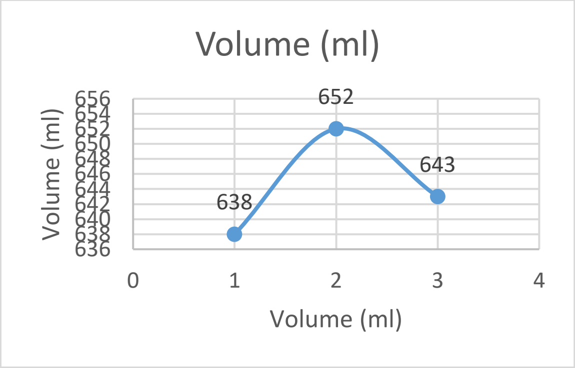

Figure 2: Volume of gas collected for different trials

The graph indicates slight variation in the volume of gas collected, which may be attributed to minor experimental uncertainties.

7. Conclusion

In this project, a hydrogen (HHO) generator was successfully designed and developed using the principle of water electrolysis. The system was tested under a constant voltage of 12 V, and the gas output was measured using the water displacement method.

The experimental results showed that the generator produced a consistent gas output, with an average flow rate of 10.74 ml/s. The slight variations observed in the readings were minimal and can be attributed to minor experimental errors.

The overall performance of the system was found to be stable and reliable. This demonstrates the feasibility of hydrogen generation using a simple and cost-effective setup.

Furthermore, the developed system has potential applications in clean energy systems. Future improvements can be made by optimizing electrode materials, electrolyte concentration, and system efficiency.

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