

## *Retraction*

# **Retracted: Effect of Rotating Magnetic Field on Hydrogen Production from Electrolytic Water**

### **Shock and Vibration**

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

- (1) Discrepancies in scope
- (2) Discrepancies in the description of the research reported
- (3) Discrepancies between the availability of data and the research described
- (4) Inappropriate citations
- (5) Incoherent, meaningless and/or irrelevant content included in the article
- (6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

### **References**

- [1] H. Guo and S. Kim, "Effect of Rotating Magnetic Field on Hydrogen Production from Electrolytic Water," *Shock and Vibration*, vol. 2022, Article ID 9085721, 11 pages, 2022.

## Research Article

# Effect of Rotating Magnetic Field on Hydrogen Production from Electrolytic Water

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In order to reveal the influence of magnetic field on electrochemical machining, a research method of the influence of rotating magnetic field on hydrogen production from electrolytic water is proposed in this paper. Firstly, taking pure water as electrolyte, this paper selects rigid SPCE water molecular model, constructs the molecular dynamics model under the action of magnetic field, and simulates it. In this paper, the thermodynamics, electric power principle, and electrolytic reaction of hydrogen production from electrolytic water are analyzed, and the working processes of alkaline electrolytic cell, solid oxide electrolytic cell, and solid polymer electrolytic cell are analyzed. Based on solid polymer electrolytic cell, the effects of membrane electrode performance, diffusion layer material, contact electrode plate, electrolytic temperature, and electrolyte types on hydrogen production are analyzed. The experimental results show that the heteroions in the lake electrolyte significantly affect the performance of the membrane electrode, and the number of heteroions in the electrolyte should be controlled during the experiment. The hydrogen production capacity and energy efficiency ratio of the unit are basically not affected by different water flow dispersion. When dilute sulfuric acid electrolyte is selected in the experiment, the concentration should be 0.1%–0.2%; After the proton exchange membrane enters the stable period after the activation period, with the increase of the electrolysis time of tap water, (24 h) the membrane electrode will weaken the catalyst activity and reduce the electrolysis efficiency in the electrolysis process. Furthermore, the correctness of rotating magnetic field on hydrogen production from electrolytic water is verified.

## 1. Introduction

Developing sustainable energy strategies and solving future energy problems have become the consensus of all countries. Among them, the important thing is to use sustainable fuels or energy instead of traditional energy such as oil, natural gas, and coal, change the energy structure based on limited fossil fuels, and strive to move towards a sustainable and sustainable energy structure [1]. Hydrogen energy is an efficient, clean, and environment-friendly energy. The development of hydrogen energy in China has important strategic significance. Hydrogen storage, especially in the form of compounds, is rich in water on Earth. By integrating hydrogen into the current energy system, we can solve the problems of fuel resistance, waste emission, and waste, meet

the high energy demand of modern society, reduce previous energy resources, and deal with the serious environmental problems caused by fossil fuel combustion. Hydrogen is the lowest density gas on Earth. Under standard conditions, the density of hydrogen is 0.0899 g/L, which is 1/14 of the air quality. Hydrogen is the lightest and most common element in nature [2]. Under normal temperature, the nature of hydrogen is very stable, it is not easy to dissolve in water, and it is not easy to have chemical reaction with other substances. Under some conditions, such as adsorption on metals such as handlebars or platinum, hydrogen has a strong effect and is easy to explode when touching flame. Hydrogen energy has high energy density. When it is used as a fuel carrier to provide energy, it does not produce air pollutants and can realize carbon-free emission [3, 4].

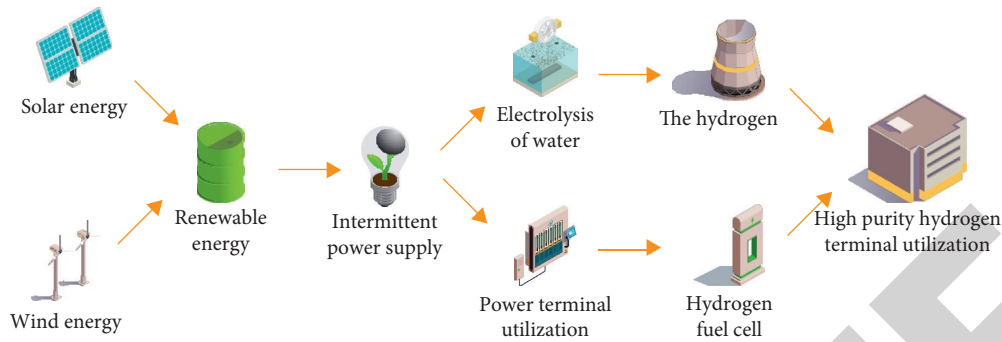


FIGURE 1: Distributed continuous clean energy supply system with hydrogen production from electrolytic water as the medium.

In order to improve the accuracy of ECM, compound ECM is proposed, which includes laser assisted electrochemical spraying technology and magnetic field assisted ECM technology. Magnetic field assisted electrochemical machining technology is proposed based on the principle of the interaction between magnetic field and electric field. Because adding an external magnetic field is equivalent to adding Lorentz force, at this time, Lorentz force can change the physical characteristics of charged particles in electrolyte, such as velocity and position. Secondly, there is always an electric field in the electrochemical machining process. At this time, the external magnetic field and electric field interact to improve the machining accuracy by changing the movement direction and trajectory of ions. According to the current experimental research results, through the magnetic circuit design, magnetic field assisted electrochemical machining can effectively reduce stray corrosion, improve surface roughness, shape and position accuracy, and improve the material removal rate. However, this technology is only studied from the perspective of technology, and the research object is also for specific shape workpieces or workpiece materials, so the research results have great limitations. Moreover, this technology faces some shortcomings, such as lack of micromechanism research and difficulty to control precision. Therefore, based on the microbasic theoretical research of this technology, this subject plans to build the microstructure model of electrolyte under the condition of magnetic field, study the influence of microdiffusion characteristics of electrolyte under the action of magnetic field by using molecular dynamics simulation technology, reveal the microbehavior mechanism of electrolyte in magnetic field assisted electrochemical machining, and finally verify and modify the model through experimental methods to provide theoretical basis and process scheme for magnetic field assisted electrochemical machining technology [5, 6]. In the conceptual distributed clean energy production, conversion, storage, and community use system shown in Figure 1, hydrogen produced by electrolytic water can play an important role as an energy storage medium in the system.

## 2. Literature Review

The advantages of ECM are that it can process difficult materials, no cathode loss, high machining efficiency, and no

residual stress on the machined surface. Because the machining process of ECM corrodes material ions, it has the ability of precision machining. However, due to many influencing factors, including electrochemical reaction, flow field, and electric field, it is difficult to control effectively and the machining accuracy is not easy to control. Therefore, more and more experimental studies tend to composite field assisted electrochemical machining technology. PR and others applied the rotating magnetic assisted ultrasonic electrochemical finishing technology and obtained that this technology helps to reduce the processing time and make the workpiece surface smooth and bright [7]. Koponen and others used the electrochemical machining technology embedded in magnetic circuit to improve the ability of centralized etching and effectively reduce stray corrosion. Water is the raw material of hydrogen production from electrolytic water. Because it is colorless and pollution-free in the process of production, its development prospect will be wider and wider with the development of science and technology and the treatment of air. Hydrogen production from electrolytic water originates from alkaline electrolytic cell. The technology is relatively simple and the cost of hydrogen production is low, but the efficiency of hydrogen production is low and the purity of hydrogen is not high. At the same time, there are safety problems in alkaline electrolyte. The current research mainly focuses on the integration of electrode and membrane, ensuring the close connection between anode and cathode, replacing toxic cotton, and improving the activity of electrocatalyst to reduce the reaction overpotential [8]. The diaphragm of the electrolytic cell is made of polyimide membrane to separate the high concentration of alkali and acid in the electrolytic cell. Proost proposed the hydrogen production method of acid-base amphoteric electrolytic water by membrane method. This method improves the electrochemical reaction activity, reduces the overpotential of hydrogen evolution, and reduces the energy consumption of hydrogen production [9]. Based on the battery theory, the step-by-step method of electrode reaction, that is, the highly reversible charging and discharging process of secondary battery electrode, is used to realize the cache of ions and electrons. Wang and others proposed to split the electrolytic water process into separate steps of hydrogen and oxygen production, so as to realize the production of hydrogen and oxygen without membrane [10]. Koponen and others

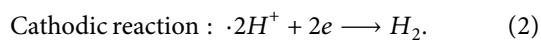
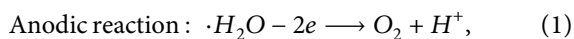
pointed out that the calcite type oxide material can greatly reduce the traditional fuel reaction activity range by reducing the polarity resistance of the material, greatly improve the catalytic activity of oxygen at medium and low temperature, and guide the electrode electrolytic gas to the full electrode interface. The material also has excellent oxygen mobility, low coefficient of thermal expansion, abnormal catalytic activity, higher antioxidant substances, and higher resistance [11]. Horikoshi and others systematically summarized the research progress of disulfide key based hydrogen evolution catalysts, compared pure disulfide key, base electrocatalyst and self-supporting electrocatalyst, and analyzed the two ways of active site regulation and improving conductivity. It shows that the disulfide key has great potential as an electrocatalyst for hydrogen evolution under acidic conditions [12].

Based on this research, a study on the effect of rotating magnetic field on hydrogen production from electrolytic water is proposed in this paper. This topic plans to build the potential energy model of electrolyte in ECM under the action of external magnetic field, that is, adding electrostatic field and different magnetic field strength to the potential energy model. The electrolyte adopts pure aqueous solution and NaCl solution with mass fraction of 3.5%. The molecular dynamics simulation method is used to analyze the influence of the microdiffusion characteristics of the electrolyte under the action of external magnetic field and complete the calculation of the properties of the electrolyte under the action of magnetic field. Finally, the experimental verification is carried out through macroexperiment (i.e., infrared spectroscopy technology), so as to provide theoretical basis and process scheme for magnetic field assisted electrochemical machining technology.

### 3. Research Methods

**3.1. Basic Theory of Hydrogen Production from Electrolytic Water.** Hydrogen is a renewable and clean energy, which can be widely used in all walks of life as industrial raw materials and energy carriers. Therefore, low-cost and efficient hydrogen production technology from electrolytic water is extremely important and has a very broad market prospect and research value.

**3.1.1. Hydrogen Production Raw Materials.** Thermodynamic principles: hydrogen production by electrolyzing water is powered by electric energy to electrolyze water molecules into hydrogen and oxygen at the anode and cathode of the device. The reaction equations are as follows:



If the electrolytic cell works at a certain temperature and pressure, the energy required for the reaction of electrolytic water is determined by baking  $\Delta H$ . The Gibbs-free energy  $\Delta G$  is equivalent to the necessary heat  $Q$  and the external electric energy. The heat  $Q$  is equal to the product of the

temperature  $T$  in the reaction process and the direct change  $\Delta S$  before and after the reaction. Then the thermodynamic equation can be expressed as follows:

$$\Delta G = \Delta H - Q = \Delta H - T^* \Delta S, \quad (3)$$

where, at 298.15 K and 1 atm, the enthalpy change  $\Delta H$  is 285.84 kJ/mol, the entropy change  $\Delta S$  is 163.1 J/mol, the free energy  $\Delta G$  is 237.2 1 kJ/mol, and the unit of process temperature  $T$  is kelvin K.

The external power supply provides power for the electrolytic reaction. The minimum voltage required for the electrolytic reaction of water molecules in the electrolytic cell is the equilibrium potential  $V_{rev}$ . The relationship between Gibbs-free energy  $\Delta G$  and the equilibrium potential  $V_{re}$  is shown in the following:

$$\begin{aligned} V_{rev} &= \frac{\Delta G}{z * F} \\ &= 226.21 \times \frac{102(J/mol)}{2 \times 95376} \\ &= 1.218V, \end{aligned} \quad (4)$$

where  $Z$  is the number of electrons required for each mole of hydrogen produced by the reaction and  $F$  is Faraday constant, 95374 C/mol.

If the phase state of water changes from liquid to gas due to the change of temperature in the electrolytic reaction, the heat  $Q$  required in the phase state transformation process is provided by electric energy. At 298.15 K, 1 atm, for the electrolytic cell with phase change process, the minimum voltage required for electrolytic reaction is recorded as thermal neutral electrolytic voltage  $V_{tn}$ , as shown in the following:

$$\begin{aligned} V_{tn} &= V \Delta H \\ &= \frac{\Delta H}{(z * F)} \\ &= + \frac{274.73(kJ/mol)}{2 \times 95376} \\ &= 1.371V. \end{aligned} \quad (5)$$

**3.1.2. Principles of Electricity.** The completion of electrolytic reaction requires electric energy from external power supply. When the generation rate of hydrogen in the cell increases or the electrolytic current increases, the cell voltage  $V_{cell}$  of the cell will also increase. Moreover, due to the electrolytic cell device and equipment, the electrolytic cell has the contact resistance between various components and the activation resistance generated by the energy barrier in the electron migration process during the electrolytic reaction between the anode and the cathode electrodes. Due to the different transmission dispersion of electrolyte in the electrolytic reaction, the concentration at the interface of two electrodes and in the solvent is inconsistent, and the resulting

concentration polarization will affect the actual voltage, so that the voltage value of the cell in the electrolytic process is greater than the voltage value required for water electrolysis in theory [13, 14]. The relationship of various voltage values in the electrolytic cell is shown in the following:

$$V_{\text{cell}} = V_{\text{rev}} + V_{\text{ohm}} + V_{\text{act}} + V_{\text{con}}, \quad (6)$$

where  $V_{\text{rev}}$  is equilibrium voltage of electrolytic cell reaction, unit: V;  $V_{\text{ohm}}$  is contact resistance voltage of electrolytic cell, unit: V;  $V_{\text{act}}$  is activated overpotential of electrolytic cell, unit: V; and  $V_{\text{con}}$  is concentration overpotential of electrolytic cell, unit: V.

Theoretically, the concentration overpotential  $V_{\text{con}}$  is often small in the electrolytic cell and is much smaller than the contact resistance voltage  $V_{\text{ohm}}$  and the activation overpotential  $V_{\text{act}}$ .

When studying the energy efficiency of the electrolytic cell, the current efficiency of the electrolytic cell can be calculated by comparing the output of hydrogen per unit time with the electrolytic current per unit time. Ideally, according to Faraday's law, the generation rate of hydrogen should be in direct proportion to the input electrolytic current [15]. Therefore, under a certain electrolytic current, the hydrogen generation rate  $f_{H_2}$  (unit:  $\text{m}^3/\text{h}$ ) of the electrolytic cell can be shown in the following:

$$f_{H_2} = \left( \eta_F \times N_{\text{cell}} \times \frac{I_{\text{cell}}}{z \times F} \right) \times \left( 21.31 \times \frac{3500}{1000} \right), \quad (7)$$

where  $\eta_g$  is current efficiency of electrolytic cell;  $N_{\text{cell}}$  is number of electrolytic cells, unit: piece; and  $I_{\text{cell}}$  is input current of electrolytic cell, unit: a.

Considering the actual influencing factors, the electric energy consumed by the actual electrolytic reaction of the electrolytic cell is compared with the electric energy consumed by the electrolytic reaction in the ideal state, which is recorded as the electrolytic efficiency of the actual electrolytic cell. The formula is expressed as

$$\eta_E = \frac{C_F}{C_E}, \quad (8)$$

where  $\eta_g$  is overall electrolytic efficiency of electrolytic cell;  $C_F$  is electric energy required to produce hydrogen per unit time when the electrolytic cell reacts; and  $C_E$  is electric energy consumed by hydrogen production per unit time in the actual electrolysis process.

**3.1.3. Type of Electrolytic Cell.** Hydrogen production from electrolytic water starts from alkaline electrolysis technology. The hydrogen production equipment from electrolytic water in front of mouth mainly includes alkaline electrolytic cell, polymer film electrolytic cell, and solid oxide electrolytic cell. Hydrogen production by alkaline electrolytic cell is the longest and most mature technology. Hydrogen production from solid oxide is still in the research and development stage because the electrolysis process requires high temperature conditions and relatively harsh application conditions. Hydrogen production by solid polymer electrolysis

has attracted more and more attention because of its compact structure, small volume, and high adaptability to electrolysis conditions [16].

### 3.2. Effect of Magnetic Field on Water Electrolysis Process.

In industrial electrolytic cells, the electrode layout and electrode form are generally optimized, or the flow of electrolyte is mechanically driven to accelerate mass transfer and discharge of gaseous products, so as to reduce ohmic voltage drop and electrode overpotential. In recent years, with the demand of industrial application and the in-depth development of relevant scientific research, more and more new methods have garnered increasing attention. The most significant methods include the use of catalysts to reduce the activation energy of hydrogen electrolysis reaction and the methods of external energy field, such as ultrasonic oscillation and hypergravity field. It has been found that the effect of magnetic field outside the electrolytic cell can significantly affect the mass transfer process and change the movement of gas-phase products, resulting in the reduction of electrode potential. The provision of static magnetic field does not require additional energy input. NdFeB permanent magnet can produce a strong enough magnetic field to meet the requirements. At the same time, the magnetic field device is cheaper and easier to use than electrocatalyst. In the process of water electrolysis, different electrode forms, magnetic fields, and different electrode layout can introduce different forms of electromagnetic forces into the electrolyte, mainly manifested in MHD (magnetohydrodynamic) and micro-MHD (micro-magneto-hydrodynamic) effects driven by Lorentz force [17].

#### 3.2.1. Simulation of Bubble Growth Behavior on Electrode Surface.

The formation of bubbles on the electrode surface will have a direct impact on the whole electrochemical reaction process, whether it is the gas-phase product or side reaction product we want to obtain by electrolysis. Bubble growth is a mass transfer process through the phase interface. Simulating its evolution behavior from the single bubble scale can help us deeply understand the gas-liquid mass transfer process on the electrode surface and the influence of bubble formation on the local flow field and concentration field. The bubble core initially growing on the electrode surface carries out interphase mass transfer driven by the concentration difference inside and outside the gas-liquid interface. In this process, it involves the control of the electrochemical reaction rate of hydrogen on the electrode surface, the transmission of hydrogen components in the liquid phase, and a reasonable mass transfer rate model at the gas-liquid interface. With the growth of bubbles, bubbles are subject to the combined action of two forces that inhibit their detachment and promote their detachment. When bubbles grow in acidic environment, their contact angle changes constantly, so the simulation of bubble growth needs to provide reasonable contact angle change input as boundary conditions. For the simulation of single bubble growth, VOF method and gas-liquid mass transfer rate model are used to compile the changes of electrode surface

electrochemical reaction rate, interfacial mass transfer rate, and dynamic contact angle into fluent computing platform through UDF. The mass transfer model and bubble evolution behavior are compared with the experimental results [18–20]. For the observation of bubble behavior and the influence of magnetic field on electrode potential difference, the experiment is carried out on the same experimental platform. The experimental platform includes the experimental section composed of permanent magnet and electrolytic cell, power control system, and bubble behavior recording system. Different electrolytic cells and electrodes are used for different experiments, and the layout direction of magnetic field, electrolytic cell, and electrode needs to be changed. The experimental system is shown in Figure 2.

**3.3. Molecular Dynamics Simulation of the Effect of Magnetic Field on the Microstructure of Electrolyte in Electrochemical Machining.** According to the results of molecular dynamics simulation, a trajectory related to the velocity and position of particles in the simulation system can be obtained, and various physical quantities can be extracted through this trajectory. In the third chapter, the influence of magnetic field on the microdiffusion characteristics of water molecules and ions in pure aqueous solution and NaCl solution in ECM is obtained by using this simulation method. It is pointed out that the effect of external magnetic field has a certain influence on its diffusion coefficient. This chapter attempts to further explain this phenomenon by using the influence of law of magnetic field on the radial distribution function of electrolyte and the number of hydrated ions in ECM [21, 22].

**3.3.1. Simulation Results and Discussion of Radial Distribution Function of Magnetic Field on Electrolyte in ECM.** Radial distribution function (RDF), also known as pair correlation function, can be defined as the average number density of molecules in the volume element with a distance of  $r + \delta r$  from the central ion. Therefore, the radial distribution function describes the aggregation characteristics of molecules or ions in the solution, so we can understand the structure of the liquid. Then the expression of the function is as follows:

$$g(r) = \frac{1}{\rho 4\pi r^2 \delta r} \frac{\sum_{T=1}^T \sum_{j=1}^t \Delta N(r \rightarrow r + \delta t)}{N \times T}, \quad (9)$$

where  $N$  is number of molecules in the system and  $T$  is total number of simulated steps.

**3.3.2. Effect of Magnetic Field Intensity on Radial Distribution Function of Pure Water.** In ECM, the radial distribution functions  $g_{O-H}(r)$  and  $g_{O-O}(r)$  of pure water under the action of magnetic field are shown in Figures 3 and 4. In  $g_{O-H}(r)$ , the first peak represents the hydrogen oxygen covalent bond within water molecules in pure aqueous solution, while the second peak represents the hydrogen bond between water molecules in pure aqueous solution. It

can be seen from the figure that when  $R < 1.55a$ ,  $g_{O-H}(r) = 0$ , indicating that the distance between water molecules in the simulation system should be 1.55 larger. When  $r = 5.75 \text{ \AA}$ ,  $g_{O-H}(r) = 1$ , indicating that when the distance between two water molecules is greater than 5.75, it has the same properties as a uniform liquid [23, 24].

In Figure 4, the main peak represents the nearest distance between two water molecules. The secondary peak represents the distance between two water molecules connected to the same water molecule through hydrogen bond. It can be seen from the figure that the nearest distance between two water molecules is 3.35 Å. Under the action of magnetic field, the first peak of the two diagrams of  $g_{O-H}(r)$  and  $g_{O-O}(r)$  is obviously large, which leads to the increase of the number of water molecules in the first coordination ring, the enhancement of structural stability, and the decrease of the diffusion coefficient of water molecules in the solution. However, the first peak position does not change, indicating that the nearest distance between the two water molecules to form hydrogen bond has little effect on the external field.

**3.3.3. Effect of Magnetic Field Intensity on Radial Distribution Function of 3.5% NaCl Solution.** Analyze the radial distribution function between ions and water molecules in NaCl solution with mass fraction of 3.5% under the action of magnetic field (0 T and 5 T), as shown in Figures 5 and 6. The maximum peak of the radial distribution function appears at  $r = 2.25 \text{ \AA}$  and  $r = 2.7 \text{ \AA}$ , which indicates that it is most likely to present other molecules or atoms near molecules  $r = 2.25 \text{ \AA}$  and  $r = 2.7 \text{ \AA}$ . When  $r < 1.9 \text{ \AA}$ , the radial distribution function is zero, indicating that the nearest distance between two atoms should be greater than 1.9 Å. The first peak value of  $g_{Na-o}(r)$  is obviously greater than  $g_{Cl-H}(r)$  under the action of magnetic field or no magnetic field, indicating that sodium ions have strong hydration ability. However, under the action of magnetic field, the first peak value of radial distribution function curve between ions and water molecules decreases, indicating that the interaction between ions and water molecules decreases and the number of ion hydration decreases; this is because the mobility of ions is enhanced, the number of hydrogen bonds between water molecules in the solution is reduced, the action is weakened, and the relatively stable structure of water molecules is destroyed [25].

The radial distribution function  $g_{Na-Cl}(r)$  of sodium ion and chloride ion in the solution is shown in Figure 7. When the magnetic field intensity is 5 T, the first peak value of  $g_{Na-Cl}(r)$  is at the same position as that without external magnetic field; that is, both are at  $r = 2.7 \text{ \AA}$ . Under the action of magnetic field, the first peak value of radial distribution function  $g_{Na-Cl}(r)$  of electrolyte increases, which is because the mobility of ions is increased under the stirring of Lorentz force, the possibility of ions appearing around them is increased, and the interaction with water molecules is weakened. The second peak decreased significantly, which means that the interaction between ions and water molecules in the solution is weakened.

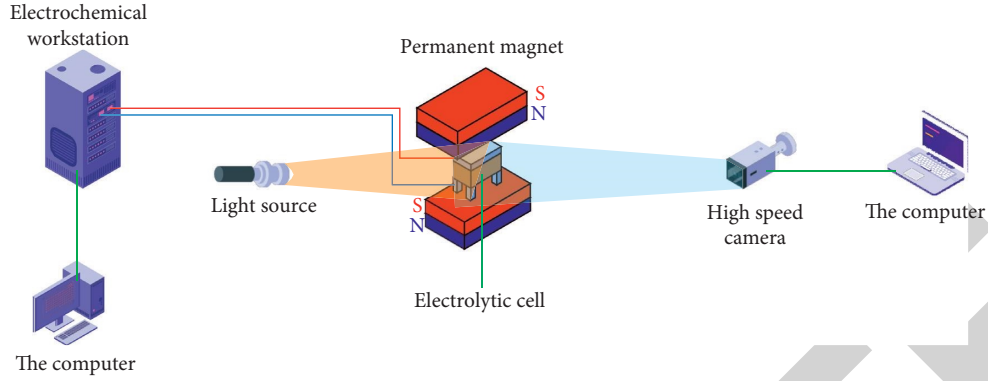


FIGURE 2: Experimental system diagram.

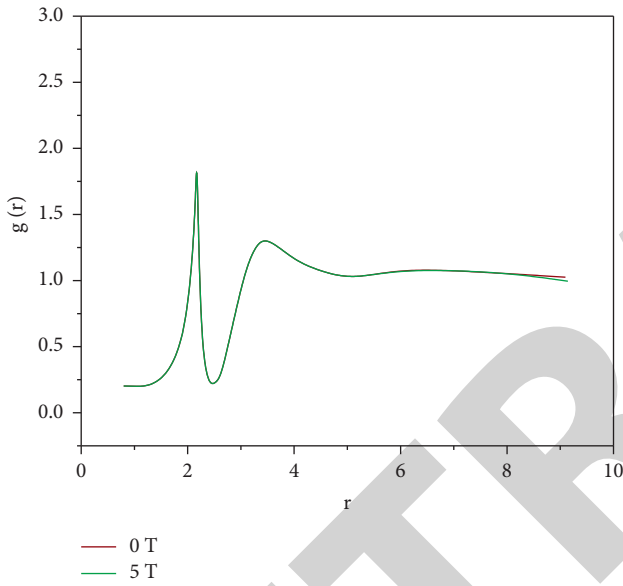


FIGURE 3: Effect of magnetic field on microstructure of pure water  $g_{O-H}(r)$ .

**3.4. Ion Hydration Number.** In fact, the number of ions in the hydration solution can be calculated by simulating the number of ions in the water around NaCl, which is the first number of ions in the hydration solution. Integrating the radial distribution function of sodium ion oxygen to the first peak and valley, the hydrate number of the first hydration circle of ions can be calculated, and the expression is as follows:

$$n = \rho_w \int_0^r g_{io}(r) 4\pi r^2 dr, \quad (10)$$

where  $n$  is the hydration number,  $\rho_w$  is the density of the solution, and  $R$  is the first minimum value of  $g_{io}(r)$ ; the hydration number of sodium ions without and with magnetic field is obtained from formula (10), as shown in Table 1.

It is found that the number of sodium ions hydrated decreases under the action of magnetic field. This is because the Lorentz force has a stirring effect on the ions in the solution, which increases the probability of collision between

ions, weakens the interaction with water molecules, reduces the number of hydrogen bonds formed between water molecules, qualitatively destroys the stability of water molecules, and then increases its diffusion coefficient.

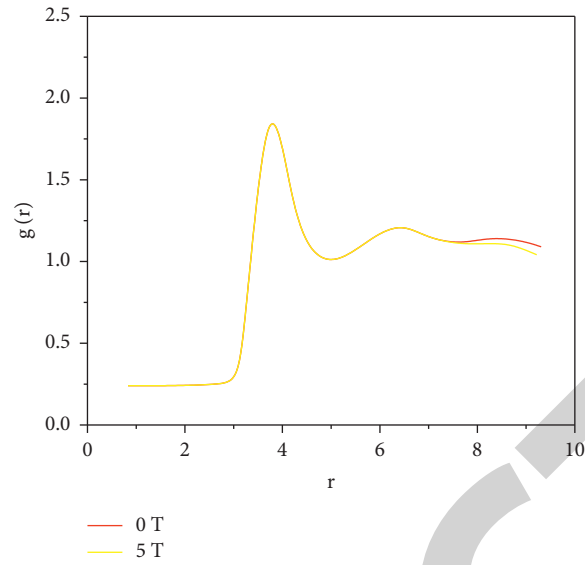
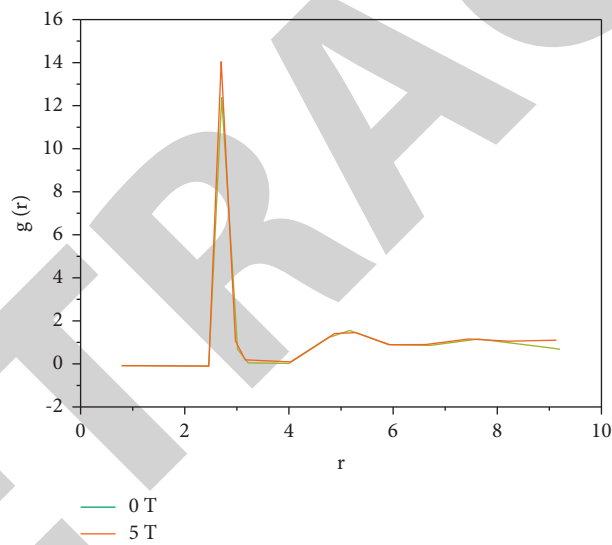
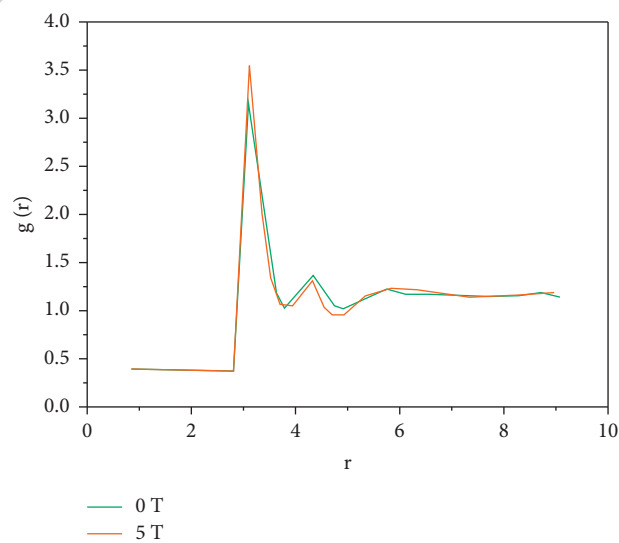
## 4. Result Discussion

**4.1. Comparative Analysis of Tap Water and Lake Water.** It can be seen from Figure 8 that the hydrogen production amount is in direct proportion to the current, and the water quality does not affect the linear growth relationship between the hydrogen production amount and the current during the electrolysis process. After standing, the lake water is full of miscellaneous ions. Although the amount of hydrogen production increases linearly, it is significantly lower than that of tap water, and the increase of temperature has little effect on the difference of hydrogen production between them. Therefore, the amount of miscellaneous ions affects the hydrogen production rate of the electrolytic cell.

**4.2. Influence Analysis of Acid Solution at Different Temperatures.** The same set of electrolytic device is used in the experiment. The dilute sulfuric acid solution with the concentration of 0.5% is used as the electrolyte. The input current of the system is changed to 0.13 A–0.9 A. the electrolyte temperature is adjusted and set through the constant temperature water bath. The electrolyte temperature is set to 30°C = 40°C and 50°C, respectively. The average value of the three groups is taken, and the voltage and electrolytic water loss rate of the device are recorded.

It can be seen from Figure 9 that, under the working condition of 0.5% dilute sulfuric acid, when the electrolysis temperature is 30°C, 40°C, and 50°C, there is basically no difference in the hydrogen production capacity of the electrolytic cell. Changing the temperature of acid electrolyte has little effect on hydrogen production.

It can be seen from Figure 10 that the energy efficiency ratio of the same concentration of sulfuric acid at different temperatures varies greatly. When the current is in the range of 0.13 A–0.5 A, the influence of temperature on the energy efficiency ratio is obvious. The energy efficiency ratio at 40°C and 50°C is high, and the energy efficiency ratio at 30°C is the lowest. In the current region of 0.6A–0.9 A, the influence of

FIGURE 4: Effect of magnetic field on microstructure of pure water  $g_{O-O}(r)$ .FIGURE 5: Effect of magnetic field on microstructure of 3.5% NaCl solution  $g_{Na-o}(r)$ .FIGURE 6: Effect of magnetic field on microstructure of 3.5% NaCl solution  $g_{Cl-H}(r)$ .



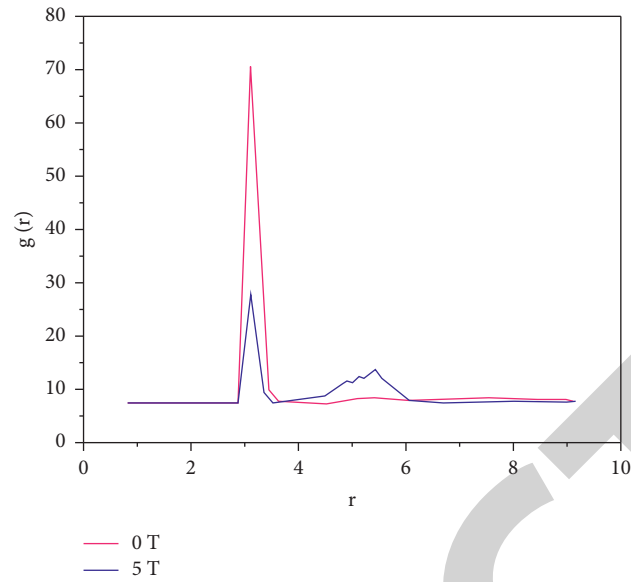


FIGURE 7: Effect of magnetic field on microstructure of 3.5% NaCl solution  $g_{\text{Na-Cl}}(r)$ .

TABLE 1: Ion hydration number of salt ion pairs in solution.

Magnetic field intensity (T)	0	5
Ion hydration number	6.54	6.34

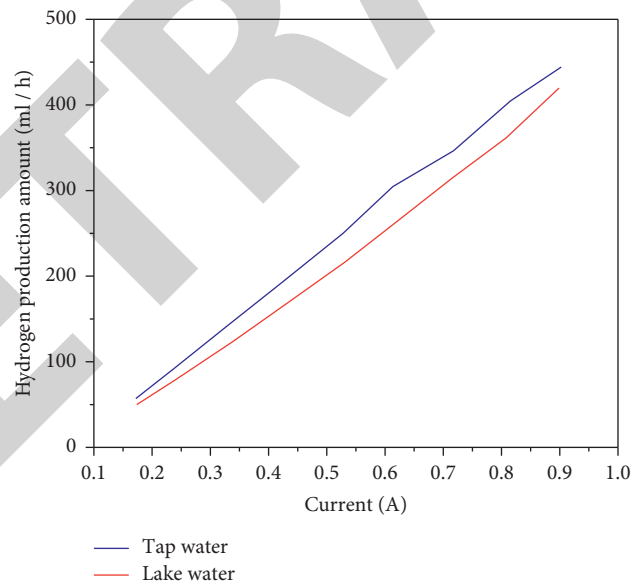


FIGURE 8: Variation of hydrogen production from electrolytic water with tap water and lake water.

temperature on the energy efficiency ratio is not obvious, and the energy efficiency ratio corresponding to the three temperatures has little difference. In conclusion, under low electrolytic current, the increase of temperature is conducive to hydrogen production reaction, and the hydrogen production rate of electrolytic cell is improved, but, under high electrolytic current, the influence of temperature on hydrogen production rate is weakened. In the experiment, the

increase of acid and electrolyte temperature should not be considered, and the corrosion of electrolyte at room temperature should not be considered.

By controlling the electrolyte temperature, membrane electrode, diffusion layer, and contact electrode plate, the hydrogen production capacity of high-purity water and 1% acid solution is large, but the energy efficiency ratio is low. When the concentration is 0.1%–0.5%, there is basically no

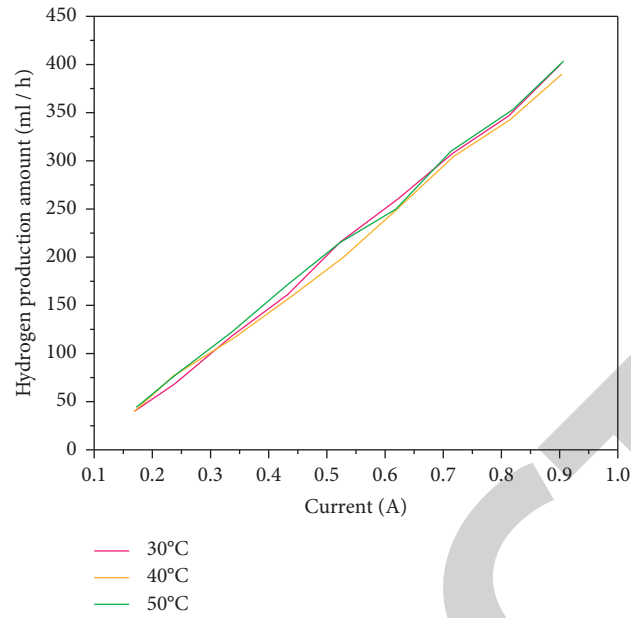


FIGURE 9: Variation of hydrogen production from electrolytic water with temperature under the condition of 0.5% dilute sulfuric acid.

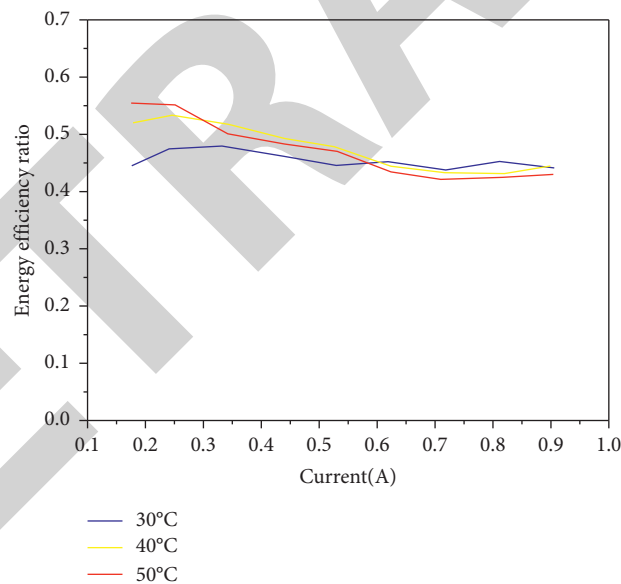


FIGURE 10: Variation of energy efficiency ratio of electrolytic water with temperature under the working condition of 0.5% dilute sulfuric acid.

difference in hydrogen production, but the difference in energy efficiency ratio is large. The increase of acid temperature has little effect on hydrogen production and energy efficiency ratio. Comprehensively, the concentration of acid electrolyte in the experiment should be 0.1%–0.2%, and it is more suitable at room temperature.

## 5. Conclusion

This paper mainly focuses on the generation and movement of hydrogen bubbles in the process of water electrolysis, and the driving mechanism of external magnetic field for gas products. Through experiments and numerical simulation,

the effects of different scale magnetic convection on the growth behavior of single bubble and the distribution of gas products are revealed. It involves many aspects, such as electrochemical reaction kinetics, gas-liquid two-phase flow, interphase mass transfer, and bubble dynamics. In this paper, the microchannel membrane SPE electrolytic water hydrogen production system is used, and the influencing factors of electrolytic water hydrogen production are analyzed and studied by using the method of controlling variables. The influencing factors of electrolytic water hydrogen production are analyzed and studied by changing the electrolytic current, electrolytic temperature, material of contact electrode plate and channel slot width, material of diffusion layer, water flow confusion, electrolyte type, and concentration of dilute sulfuric acid of the experimental system. The following conclusions are drawn.

Electrolyte solution: the hydrogen production rate and energy efficiency ratio of lake water are lower than those of tap water. The heteroions in lake water electrolyte significantly affect the performance of membrane electrode, so the number of heteroions in electrolyte should be controlled during the experiment. When dilute sulfuric acid is used as acid electrolyte, considering the factors of hydrogen production and energy efficiency ratio, the optimal concentration is 0.1%–0.2%. When the electrolysis temperature is 30°C–50°C, the temperature rise has a positive impact on the hydrogen production efficiency under the current of 0.13 a–0.5 a, and the hydrogen production efficiency under the current of 0.6 a–0.9 A is not obvious. The simulation results show that the diffusion coefficient of water molecules in pure water decreases with the increase of magnetic field intensity. This is because the combination of external magnetic field and electric field makes many water molecules combine through hydrogen bonds to form different forms of water molecular chains or rings and then form a hydrogen bond grid composed of many water molecules, making the structure of water molecules more compact. Therefore, the diffusion coefficient of water molecules in pure water decreases with the increase of magnetic field intensity.

As hot clean energy, hydrogen is of great significance for new energy vehicles and oxyhydrogen fuel cells to study the influencing factors of hydrogen production from electrolytic water. In this paper, some influencing factors of electrolytic water device are experimentally studied. There are still many factors to be deeply studied in SPE electrolytic water hydrogen production system.

### Data Availability

The labeled data set used to support the findings of this study is available from the corresponding author upon request.

### Conflicts of Interest

The author declares that there are no conflicts of interest.

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