Original Article: Design and Optimization of Hydrogen Production Systems in Fuel Cells

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ABSTRACT

A fuel cell is a device that converts the chemical energy of the fuel directly into electrical energy. Hydrogen gas is used as an ideal fuel in a fuel cell due to its high reactivity, abundance and lack of environmental pollution. In order to produce energy with optimal efficiency, the fuel cell series requires additional equipment called the fuel cell system, which optimal performance conditions for the fuel cell include fuel purity, the amount of air and fuel entering the fuel cell series, gas humidity and water management, temperature control and finally control the gas pressure in the fuel cell system and series. According to the type of fuel cell and its application, these systems are simple or complex, for example, in power plant fuel cells, the fuel converter part that converts fossil fuels, biomass into pure hydrogen, is the main and complex part of the fuel system. In automotive applications, the refueling system can take the following two forms depending on the type of fuel infrastructure: If hydrogen is produced at the refueling station, the vehicle fuel storage system can use different methods such as hydrogen storage in pressure tanks, Use of nanotubes, use of metal hydride absorbers, use of chemical hydrides. In case of hydrogen production in the car, the fuel converter (especially the gasoline and methanol converter) that can be installed on the car is the main and complex part of the fuel system in the car.

Introduction

Fuel cells directly convert the chemical energy of a fuel into electrical energy. Fuel cells, due to their high-power density [1], harmless by-products for the environment and fast recharging, are considered as one of the new technologies for energy production in the future and a suitable alternative for energy production from conventional methods [2]. The most important advantage of fuel cells, compared to reciprocating and sterling engines, is the possibility of achieving higher efficiency in converting fuel into electricity [3], which is especially suitable in polluted areas. A fuel cell system can be divided into three main parts, including the fuel supply part (fuel converter and hydrogen storage system), the energy production part, including the fuel cell series and the humidity, pressure, temperature [4], and gas flow control system, and finally, the energy conversion part, which is related to the season between the fuel cell and the electricity consumer is divided to convert the electricity

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current and voltage into the appropriate voltage and current [5].

For fuel cells, hydrogen is the preferred fuel. The advantage of using hydrogen in a fuel cell is its high reactivity for the electrochemical reaction of the anode and its non-polluting nature. However, hydrogen does not exist as a gaseous product in nature. For this reason, water, fossil fuels and other materials with high hydrogen density must be used [6], which can be a difficult and expensive process. Also, storing hydrogen, especially for use in vehicles and household applications, is not yet easily possible. For this purpose, the use of fuel processing systems has been suggested to produce hydrogen needed for fuel cells on site. The use of these fuel processing systems makes it possible to combine the high energy density of fuels and the high-power density of the fuel cell and creates a system with high efficiency. So far, a lot of research has been done to investigate fuel processing systems in the form of laboratory work and modeling [7].

There are three reforming methods for hydrogen production, including steam reforming (SR) [8], partial oxidation (POX) [9] and auto thermal reforming (ATR) [10]. Steam reforming is endothermic and partial oxidation is an exothermic process. Reactants for self-heating reforming include steam, oxygen and fuel. In fact, self-heating reforming is a combination of reforming with steam and partial oxidation. Self-heating reforming is the preferred method for use in a vehicle due to the lack of an external heat source and the formation of smaller amounts of soot. In this study, with the help of Computational Fluid Dynamics (CFD) [11] auto thermal reformer of methane has been modeled. Many researchers have been done for auto thermal reforming of methane on conventional catalysts such as nickel, platinum, and palladium. In many of these studies, the catalyst used for partial oxidation and steam reforming is different. The modeling done in this research is mainly based on the relationship of reaction rates on conventional catalysts. In the search conducted by the author, so far, the modeling of self-heating reforming of methane on 5% catalyst in a monolithic reactor has not been done [12]. The aim of this research is to model auto thermal reforming of methane on 5% catalyst with the help of computational fluid dynamics. The advantage of using 5% catalyst is that it can promote both partial oxidation and steam reforming reactions. In the modeling, modified speed equations for 5% catalyst have been used. The reactor selected in this research is a monolithic catalytic reactor [13]. Monolithic reactors consist of a large number of parallel flow channels separated by solid walls. Monolithic reactors are suitable for mobile applications due to their high surface-to-volume ratio and low pressure drop.

However, monolithic reactor modeling is very costly and time-consuming. For this reason, the behavior of one channel of the monolithic reactor is assumed to be almost the same as the behavior of the entire monolithic reactor, and the geometry of a channel is chosen as the computational domain. This modeling includes a three-dimensional model for the reactor [14], which includes the equations of conservation of mass, momentum, energy, and the survival of chemical species, as well as a model to consider the mechanism and speed relationship of reactions. These equations have been solved with the help of Fluent 6.3.26 software, which is based on finite volume calculations [15]. To consider the reaction speed relationship, programming in C++ environment has been used, which can be used for similar tasks. The results of this modeling have been compared with the laboratory work done for auto thermal reforming of methane on 5% catalyst. In the following, the effect of changing operating parameters on the amount of hydrogen and carbon monoxide produced and the temperature profile inside the reactor have been investigated. The investigated operating parameters include the molar ratio of oxygen to methane (O_2/CH_4), the molar ratio of water vapor to methane (H_2O/CH_4) and the temperature of the gas entering the reactor [16].

Fuel supply department

The fuel supply section in power generators sometimes consists of different parts such as fuel converter reactor, aeration system, compressor, pressure tanks. The fuel converter reactor, which is the main component in the power supply department, converts existing hydrocarbon fuels into hydrogen-rich gas, which is the fuel cell feed. A fuel converter in a vehicle's fuel cell system makes the system a bit more complicated, but has the advantage of using fuels that are available in the current infrastructure and distribution networks. As mentioned, when pure hydrogen fuel is produced outside the car and loaded into cars, the fuel cell system will be much simpler [17].

Fuel converter

The low energy density of hydrogen in the gas state makes it difficult to use hydrogen as an energy carrier. This means that compared to liquid fuels such as gasoline or methanol, it has little energy per unit volume. Therefore, loading gaseous hydrogen (under medium and low pressure) in an amount that provides an acceptable range of motion for a fuel cell vehicle seems to be a difficult task. Liquid hydrogen has a good energy density (about 120.7 kilojoules per kilogram) [18], but it must be stored at very low temperatures (253 degrees Celsius below zero) and high pressures, which makes storage and transportation difficult.

Common fuels such as natural gas, propane and gasoline and fuels such as methanol and ethanol all have hydrogen in their molecular structure. By using the converter installed on the vehicle (onboard) or the converters installed in the refueling places, the hydrogen in these fuels can be separated and used as fuel in the fuel cell [19]. In this way, the problem of hydrogen storage and distribution is almost completely solved. The work of the fuel converter is to provide the hydrogen required by the fuel cell using fuels that are available and easy to transport. Fuel converters must be able to do this with minimum pollution and highest efficiency. The function of fuel converters in simple language is to convert fuel rich in hydrogen into hydrogen and other by-products. One of the important problems in the field of making converters is the size and weight of the converter. To improve the level of efficiency [20], it is necessary to reduce the weight and volume of converters per unit of electrical energy from the system as much as possible. In the same way, the cost of making converters should also be kept low so that the high cost of this technology does not prevent the mass production of cars. The second most important problem in this field is the purity of the hydrogen produced from the converters. Pollutants such as carbon monoxide (and in some types of fuel, sulfides) are byproducts of the conversion process [21]. Meanwhile, a large amount of carbon monoxide can cause the fuel cell catalyst to become toxic. Therefore, it is necessary to remove the carbon monoxide before entering the fuel into the fuel cell. Although there are many types of fuel converters, often resulting from the combination of different technologies, the main types of converters that are common in the field are:

Converter with steam system

The steam-assisted conversion process is a two-step process as follows: In the first reaction, oxygen in hot water vapor (usually more than 500 degrees Celsius) is used to separate carbon from hydrogen and produce hydrogen molecules and carbon oxides. At the same time as this reaction (depending on the temperature of the steam), in the second reaction carbon monoxide is converted to carbon dioxide and thus more hydrogen is released. The purification step of the exhaust gas from the steam system converter is very important [22], because usually the exhaust gas from the converters is not pure and free of waste materials and it cannot be sent directly into the fuel cell as fuel [23].

These impurities include: carbon monoxide and carbon dioxide resulting from reactions inside the converter, fuel residue (such as methanol or gasoline), nitrogen oxides, sulfur oxides, and volatile organic compounds, all of which actually originate from the primary fuel. Therefore, it is necessary to separate these impurities from the final output gas of the converter. Especially in the case of carbon monoxide separation, the standard level for fuel cells that work at low temperatures is less than 10 ppm in order to avoid the poisoning of the catalyst in the fuel cell, especially the polymer fuel cell [24].

In order to produce energy with optimal efficiency, a fuel cell needs continuous feeding of fuel and oxidizer, the release of water produced from the electrochemical reaction inside the cell, keeping the membrane moist by keeping the incoming gases moist, temperature and pressure control. The equipment and accessories that provide these optimal conditions for the fuel cell are called the fuel cell system. A fuel cell system can generally be divided into the following main components: the fuel system which includes the fuel converter or the hydrogen storage system. The air supply system or oxidizer that provides the oxygen needed by the fuel cell. Water and heat management system, which includes humidification system for incoming gases, cooling system, system or pressure control valves and indicators [25].

Electronics - power (Power Electronic) which is related to the interface between the fuel cell and the electricity consumer to convert the electricity current and voltage to the appropriate voltage and current. The electronic control system that controls temperature, pressure, power output from the battery, charging storage batteries, coordinating between the fuel system and the fuel cell and the power electronic department.

Fuel cells for portable electronic devices

Batteries are inconvenient for many portable devices such as laptop computers and cell phones. They are expensive, heavy and annoying and often need charging at the worst possible times. Recent advances in fuel cell technology may solve this problem. Several research groups are developing "Micro fuel cells" that allow cell phones to run on standby for weeks. Fuel cells are simple devices that are basically composed of non-metallic conductors called electrolyte that are placed between two electrodes [26]. Hydrogen from a fuel such as methanol flows through the electrolyte and mixes with an oxidizing agent, such as oxygen in the air, and an electric current is established between the two electrodes from the chemical reaction. The batteries can be easily and quickly refilled by adding more fuel. Fuel cells are also environmentally clean because their main byproduct is water from the combination of hydrogen and oxygen. Whereas batteries that eventually wear out from repeated charging have a disposal problem. Now, one of the researchers of the Alamos National Laboratory has invented a micro fuel cell and predicts that the power of his cell will be 50 times more than half the weight of conventional nickel-cadmium batteries at the same size and price. This researcher predicts that mobile phones can work continuously for 40 days in this way, consuming less than 60 grams of methanol. This invention is more of an engineering triumph than a scientific wonder. In the construction of this battery, he used new methods for the construction of the electronic circuit and applied them in the technology of fuel cells [27].

The key factor is in the packaging. While most researchers start by designing electrolytes and electrodes, this researcher found that the best way to achieve miniaturization and mass production is to use a thin plastic film as the base container for microscopic fuel cells. The plastic membrane with a thickness of only 25 microns is bombarded with nuclear particles, in this way the chemical etching causes the creation of small pores where the liquid electrolyte is poured. The metal plates of the electrode, the catalyst and a conduction network that connects the individual cells are layered and etched on the plastic structure using practical chip-making methods such as vacuum deposition. According to researchers, "Fuel cells are basically made like printed circuits" [28].

Hydrogen production with environmentally friendly methods is under investigation. One of these methods is the use of solar energy and water in contact with active and long-lived catalysts. Research has focused on using sunlight to generate the heat needed to break down water into usable hydrogen and oxygen. Another method of hydrogen production, using water vapor and natural gas to produce hydrogen and carbon dioxide, also has special attractions. This method increases the energy content of natural gas by 20% using solar energy. Under certain conditions, some microscopic green algae use sunlight to generate electricity in the summer. An interesting idea is to generate enough solar electricity in the summer to electrolyze water and produce hydrogen [29]. This hydrogen can be converted into electricity in a fuel cell and provide the energy needed in winter. Then this cycle repeats. For example, a self-reliant solar energy house has been built in Germany. This house supplies all the electricity it needs without connecting to the electricity grid.

Table 1. The advantages and disadvantages of diesel fuel, fuel cell and electric batteries

Property	Diesel Fuel	Fuel Cell	Electric Batteries
Production of greenhouse gases	×	*	*
Long distances	*	*	×
Fast refueling	*	*	×
Low impact of climatic conditions	*	*	×
Can be used in all cars	*	*	×
High efficiency	*	*	*
Constant torque	×	*	*
No noise pollution	×	*	*
Domestic sources of fuel	×	*	*

Fuel cell design

Fuel cells are electrochemical devices. This equipment produces electricity by combining hydrogen and oxygen by creating an electric charge along a membrane. This equipment produces electricity at a constant and stable rate without having a rotating part. The fuel cell system with the possibility of fuel reformer can use other types of fuel such as diesel, natural gas or methanol. Of course, there is more natural gas than oil in the ground. So far, natural gas has been used in a limited way. Natural gas is likely to be used more than other fuels in the 21st century. This fuel can be considered as a bridge for hydrogen production until hydrogen production from water becomes affordable [30].

The future of fuel cells

In space applications, hydrogen provides all the electricity a spacecraft needs. As a result of burning hydrogen, drinking water needed by astronauts is prepared. The near future application of fuel cell is to use this technology to produce electricity in hybrid cars. A fuel cell can constantly supply the electricity required by the car engine. Hydrogen is suitable for long distances due to its high energy density. Meanwhile, the electric battery has a suitable power density for accelerating the car. In a hybrid car, both technologies are used [31].

Now, a research group led by Professor Shao Minwa from the Department of Chemical and Biological Engineering of the Hong Kong University of Science and Technology has achieved a new formula that not only reduces the amount of platinum used by 80%, but also in terms of the durability of the fuel cell has created a new quota [32]. This fuel cell showed no signs of performance degradation in a test with 200 hours of operation. One of the reasons for this good performance is that this new fuel cell has three active sites, unlike the previous examples that had one active site. Shao said: Hydrogen fuel cell is an energy conversion device that aims to achieve a world free of polluting gas emissions. Carbon is essential. We will try to further improve this fuel cell to be competitive with fuel cells and other electrochemical devices [33].

Optimization of process parameters

The first category, which refers to the optimization in construction, refers to things such as the type of flow channel, channel geometry, material of the pile members and also a suitable configuration. Although these parameters are very important and effective parameters, they cannot be changed in any way during the process and are fixed throughout the process. The second category, which is related to functional parameters or process parameters, includes parameters such as anode side pressure, cathode side pressure [34], fuel cell operating temperature, input flow rate on the anode and cathode sides, which are flexible and can change during the process. Due to the problems in optimizing the geometrical parameters, the current research has focused on the optimization of three parameters: Anode side pressure, cathode side pressure, and fuel cell operating temperature, which are extremely important among the process parameters. In genetic algorithms, the base two coding method is usually used for parameter values, but for ease of work and to create more speed in the used algorithm, the real number coding method has been used, as well as to avoid the loss of elegant answers in the middle generations. An elitist algorithm is used. The table below shows the values obtained for the above three parameters as well as the optimal values reported from the article by Suleiman and his colleagues [35]. The value obtained for the operating temperature of the battery shows that the increase in temperature has a positive effect on the efficiency of the battery to some extent, but if the temperature exceeds a certain value, the efficiency of the battery will decrease significantly, which can be explained due to excessive drying of the membrane [36].

Design of fuel cell power system

Distributed generation generally means small generators, from a few kilowatts to 10 megawatts, either connected to the main grid or used independently in island mode. Typically, small DGs, in the power range of 5 to 250 kW, can supply electricity to large residential buildings (either in island mode or connected to the grid). DG technologies can be divided into renewable and non-renewable DGs. In general, renewable energy technologies are sustainable (i.e., their energy source will not run out) and do not cause environmental problems [37]; These include solar photovoltaic, solar thermal, wind, geothermal, tidal, low (small) hydropower, biomass and biogas, and hydrogen fuel cells (hydrogen produced from renewable sources). Non-renewable energy technologies refer to sources that use a type of fossil fuel such as gasoline, diesel, oil, propane, methane, natural gas or coal as their energy source. Fossil fuel-based DGs are not considered sustainable power generation sources because their energy source is exhaustible [38]. These include the internal combustion engine (ICE), combustion turbine, gas turbine, micro turbine, and fuel cells (which use some form of fossil fuel, such as natural gas, to produce hydrogen). Both types of DGs (renewable and non-renewable) are widely used all over the world. The disadvantage of renewable DG sources is the intermittent and occasional nature of their renewable energy source, and the disadvantage of fossil fuel-based DGs is that they pollute the environment and, in some cases, produce toxic exhaust gases such as SO_2 and NOx, which are similar to pollutants. centralized power plants are common. However, considering the increase in electricity demand, the advantages of non-renewable DG technologies with low pollution of polluting gases outweigh their disadvantages and it is expected that they will be used in the near future [39].

Fuel cell technology can be placed in both categories mentioned above. If the hydrogen fuel needed to supply fuel cell energy is produced from a renewable source, that fuel cell power generating unit is a renewable energy technology product, that is, wind and solar energy are used to produce hydrogen to supply fuel for a fuel cell assembly. Conversely, if hydrogen is produced from a fossil fuel source (for example, natural gas or methane), that fuel cell is a non-renewable energy technology product. By careful design, selected fossil fuel-fired DGs can be made to oxidize some of the fossil fuel (combined with oxygen) to produce heat [40]. Such ways of working, whether in electromechanical systems (cycling) or electrochemical systems (fuel cell), are called "Combined heat and power" (CHP) operating mode. Most new DG technologies have power electronics to provide usable output power. These DGs are often called DGs connected to power electronics. Highly optimized power control of these power sources is possible by controlling units connected to power electronics [41]. In a common method, the output voltage of these dc or ac power generation devices is converted into a controlled output voltage. Among the types of distributed generation technologies, fuel cells are considered as potential sources of electricity generation. Fuel cells have several advantages that make them superior compared to other technologies. The integration (connection) of the fuel cell system is to provide continuous electricity to the load based on demand. In the fuel cell energy system used for distributed generation applications, the source is combined with a DC-DC boost converter to stabilize the fuel cell voltage. Then, the output of the boost converter is fed to a three-phase PWM inverter to obtain a three-phase ac voltage for grid-connected applications [42].

Discuss

Today, hydrogen is mainly used in ammonia production, oil refining and methanol production. Hydrogen is also used in NASA's space program, as a fuel in spacecraft and in fuel cells that produce heat, electricity and drinking water for astronauts. Fuel cells are devices that convert hydrogen directly into electricity. In the future, hydrogen can be used as a fuel for cars and airplanes, and by using this element, we can provide electricity for homes and offices [43].

Hydrogen can be obtained by heating hydrocarbon molecules in a process known as hydrogen "Conversion". In this process, hydrogen is obtained from natural gas. With the use of electric current, water can be separated into its components, i.e. oxygen and hydrogen, in a process called electrolysis. Some algae and bacteria use sunlight as an energy source and release hydrogen under certain conditions. Hydrogen as a fuel has a lot of energy, at the same time, a car fueled by pure hydrogen does not produce any pollution [4]. NASA has been using liquid hydrogen to power rockets since the 1970s, and now to send spacecraft into orbit. Hydrogen fuel cells provide the necessary power for the spacecraft's electrical systems, and the byproduct of this process is pure water, which is used as drinking water by the crew members [5]. You can think of a fuel cell like a battery that can be continuously recharged by adding fuel so that it never runs out of charge. Hydrogen is one of the most abundant elements on Earth. This element does not exist in nature in pure form, but it can be obtained from other elements in different ways. Hydrogen is the most important option as a new energy carrier. Compared to other fuels, this material can be converted into other forms of energy with higher efficiency and very clean combustion.

Fuel cells are a promising technology that can be used as a source of heat and electricity in buildings and as a source of electrical power in vehicles. Car companies are already working on making cars and trucks equipped with fuel cells [6]. In a car's fuel cell, there is an electrochemical device that converts hydrogen (stored in the system board) and oxygen in the air into electricity, driving the car's electric motor and providing its power. Although the use of these ideal applications for pure hydrogen seems a little far-fetched, but on a real scale and close to it, we can refer to fuels such as natural gas, methanol or even gasoline [4]. Modifying these types of fuels to produce hydrogen allows us to use it in many current energy infrastructures such as gas stations, natural gas pipelines, etc. This is while the use of fuel cells is in the exploitation stage. In the future, hydrogen can be considered as an important energy carrier like electricity. The energy carrier stores and transfers energy and provides it to consumers in a usable form. Some experts believe that hydrogen will form the main energy infrastructure in the future and replace natural gas, oil, coal and current power plants. They believe that the "New hydrogen economy" could replace the current "Fossil fuel economy", although this plan is probably in the distant future [8].

Hydrogen is a very important raw material in the oil, gas and petrochemical industries. The current annual production of hydrogen in the world is about 50 million tons per year. Meanwhile, 99% of hydrogen is produced by the process of reforming fossil fuels (mainly natural gas) with steam. 97% of this amount of production is in the same places of consumption (petrochemicals, refineries) and about 3% is produced commercially and for sale. The main uses of hydrogen can be mentioned in refineries for the hydrogenation process, petrochemical units for the production of ammonia and methanol, as well as the conversion of paraffin's into olefins. Simultaneously with the increasing pressure of the responsible organizations to prevent further warming of the earth due to the emission of greenhouse gases caused by from burning fossil fuels, there has been a lot of focus on the production and use of hydrogen gas as an energy source. The hidden value of using hydrogen gas as a fuel or energy carrier is that in the place where this burning gas is consumed, only water vapor is produced and it may cause very little or no pollution at all [9]. What should be said about hydrogen in this regard is that hydrogen, like fossil fuels and natural gas, is not readily available in nature, and therefore its production requires the expenditure of primary energy, which must be available from certain sources in abundance and at a competitive price. produced in any case, the use of hydrogen as a common source of energy has technological and instrumental limitations. Another point is that hydrogen gas is burned with maximum combustion efficiency and its combustion reaction is relatively complete. In this way, from two important economic and environmental aspects, the application of hydrogen as an energy source is important [8].

Although hydrogen as an energy carrier can create a lot of flexibility in energy consumption patterns in the world and improve them, it should be noted that there is still no large commercial market for hydrogen as an energy carrier and its main applications are for consumption in oil and petrochemical industries and other chemical production units are limited and the only direct use of hydrogen gas as an energy supply factor is in fuel cells, which is produced by burning hydrogen in electric power cells, and now these cells are used in large automobile industries. Fuel as a driving factor has received serious attention and has actually become a strategic program. Large-scale fuel cells are also of interest, which are used as electric generators in support cases. Therefore, although currently hydrogen is not widely consumed in commercial energy applications in the world, it is time for hydrogen to find its proper place in the world energy market. Hydrogen can be used as gas fuel in city gas networks like natural gas. It is also possible to mix hydrogen gas with natural gas and use it. A practical experience has shown that about 10 to 15% of hydrogen gas volume to the municipal gas fuel network did not cause any particular problem, while it significantly reduced the emission of carbon dioxide gas [4]. Another example in the city of Montreal, about 5% by volume, equivalent to 15% of the energy content, hydrogen was added to the fuel system of gas-burning vehicles (natural gas) and after their engine was adjusted for optimal performance, compared to burning natural gas. The reduction of nitrogen oxides and volatile organic substances in exhaust gases has been very significant. Also, in the Netherlands, in a plan that was followed and implemented by the government, a gas network was created for the distribution and consumption of hydrogen as urban fuel. Plastic pipe lines were used for the distribution network [41]. Also, hydrogen can have a profitable market in the transportation industry. The use of hydrogen as a vehicle fuel can significantly reduce these atmospheric pollutants. Regarding the use of hydrogen as a carrier of fuel energy, there are two major problems that are the subject of many study-research projects. First, hydrogen is not widely available at a competitive price. Second, storing fuel with the vehicle is not yet easily possible, and storing it in the right volume is currently a major problem [10]. Another field that is prone to the use of hydrogen as an energy source is the production of urban electricity. In this method, hydrogen gas may be produced in different ways that are not currently common and then used in turbines that have not been modeled to generate electricity. A big project in Japan to build these turbines is running. This turbine is supposed to use liquid hydrogen fuel and have an electricity generation capacity of about 500 megawatts. The development of other applications of hydrogen in the future is in the aerospace and aviation industries [5]. Currently, it is used in the aerospace industry in some cases, and airplane companies have also started activities to build airplanes with hydrogen fuel, which is very compatible with the atmosphere.

Conclusion

Due to the ever-increasing energy consumption and production of greenhouse gases, as well as global warming, the best solution is to use renewable energy sources such as solar energy and use clean and high-efficiency technologies such as fuel cells to produce energy from hydrogen. With the increase in the use of fuel cells in the industry and as an on-site application, there is a need to develop on-site hydrogen production units. In this research, a monolithic catalytic reformer in which auto thermal reforming of methane takes place is modeled in three dimensions. The catalyst used in this modeling is 5%. This modeling includes the simultaneous solution of the survival equations, in which the reactions that have taken place are also given an effect. One channel of this monolithic reactor has been used as a computing domain. The results of this modeling are in good agreement with the laboratory data available in the sources. This model has been used to estimate the performance of the reformer in other operating conditions. The investigated parameters include the molar ratio of oxygen to methane input (O_2/CH_4), the molar ratio of water vapor to input methane (H_2O/CH_4) and the temperature of the input gas to the reformer. Finally, after examining the effects of the mentioned parameters, it was concluded that in order to achieve the maximum amount of hydrogen in the investigated range in terms of operational parameters, the molar ratios of O_2/CH_4 and H_2O/CH_4 input to the reactor were chosen as 0.445 and 3.8, respectively. The use of hydrogen has many limitations, one of the first of these limitations is the resistance of public opinion because this fuel has not yet gained a foothold among the people and people do not accept it as a fuel. It is possible to produce cars that use hydrogen fuel, as well as easy access to hydrogen, another limitation is the storage of hydrogen in cars. Because storing hydrogen in a car requires a large volume, solutions have been provided for this problem, which include compressing hydrogen and cold storage of liquid hydrogen and absorption on metal heaters.

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