مجلة التربوي
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معامل التأثير العربي 1.5
العدد 20

مجلة التربوي
مجلة علمية محكمة تصدر عن كلية التربية
جامعة المرقب

العدد العشرون
يناير 2022م

- **المجلة ترحب بما يرد عليها من أبحاث وعلى استعداد لنشرها بعد التحكيم .**
- **المجلة تحترم كل الاحترام آراء المحكمين وتعمل بمقتضاها .**
- **كافة الآراء والأفكار المنشورة تعبر عن آراء أصحابها ولا تتحمل المجلة تبعاتها .**
- **يتحمل الباحث مسؤولية الأمانة العلمية وهو المسؤول عما ينشر له .**
- **البحوث المقدمة للنشر لا ترد لأصحابها نشرت أو لم تنشر .**

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ضوابط النشر:

يشترط في البحوث العلمية المقدمة للنشر أن يراعى فيها ما يأتي :

- أصول البحث العلمي وقواعده .
- ألا تكون المادة العلمية قد سبق نشرها أو كانت جزءا من رسالة علمية .
- يرفق بالبحث تزكية لغوية وفق أنموذج معد .
- تعدل البحوث المقبولة وتصحح وفق ما يراه المحكمون .
- التزام الباحث بالضوابط التي وضعتها المجلة من عدد الصفحات ، ونوع الخط ورقمه ، والفترات الزمنية الممنوحة للتعديل ، وما يستجد من ضوابط تضعها المجلة مستقبلا .

تنبيهات :

- للمجلة الحق في تعديل البحث أو طلب تعديله أو رفضه .
- يخضع البحث في النشر لأولويات المجلة وسياستها .
- البحوث المنشورة تعبر عن وجهة نظر أصحابها ، ولا تعبر عن وجهة نظر المجلة .

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IDENTIFICATION THE OPTIMUM PRODUCTION PROCESS OF THE HYDROGEN GAS

Fadela M. Elzalet[(1)] , Sami A. S. Noba and omar M. A. kaboukah.

[1]Department of Chemical and Petroleum Engineering, El-Mergab University
elzaletfadela@gmail.com

Abstract

This project is concerned Comparative study of hydrogen production technologies, with the production assumed capacity of plant is about 500 kg/day of hydrogen gas .Due to the importance of hydrogen gas, there is a need for significant comparison between the production processes to select the optimum process. Therefore this project offers an overview of the most two important technologies for hydrogen production. These technologies which to be discussed are: Reforming of Natural Gas, and Water Electrolysis Decomposition, with the same assumed daily production capacity of hydrogen gas which is (500 Kg/Day). The first one steam methane reforming process that is called SMR, and the second one is the water electrolysis. This comparison Studies the differences between these two technologies , by doing the calculation which is the material balance ,that includes: the differences such as flow charts , the type and the quantities of raw materials are to be used, or the reactants and the amounts of materials products. The second step is the energy balance, this is important point that is determination the amounts of the energies for all streams in the processes. It has been considered that the optimum one is the process with low consumed energy. Moreover the most important comparison that includes, studying the economically side after design, by Selection the low capital costs .from the results the amount of the cost for these processes SMR ,and electrolysis water receptively are (816288.3$ cost, 13875968$ cost). Therefore, it can be said that the appropriate production process must be with (high purity of hydrogen ,the low total cost, and the low energy consumed from this process ,even though with the rough operating conditions such as high temperatures and pressure).

***Key words**: hydrogen; Reforming; methane ;electrolysis; SMR; material balance; energy balance; capital cost; flow chart.*

1. Introduction

Hydrogen is a chemical element with the symbol H and atomic number1, it is located in the periodic table within the elements of the first cycle and above the elements of the first group. Hydrogen is a colorless and odorless gas, flammable, nontoxic gas, in the standard conditions of pressure and heat,. Hydrogen is very active gas which consists of only one proton without neutrons in the nucleus.

it is the lightest and most abundant chemical element in the universe, accounting for 75% of the universe's size [1]. Most of the hydrogen on Earth is molecularly shaped by entering a covalent bond in the structure of water and most organic compounds. Hydrogen is not available on the earth. Therefore, it is available as chemical compounds of oxygen and carbon. For example, hydrogen is present in water; fossil hydrocarbons such as coal, petroleum, natural gas; and biomass process. This gas has both similarities and differences when compared to the conventional fuels such as methane (natural gas), liquefied petroleum gases (LPG), and liquid fuels such as gasoline .This study gives the comprehensive view of the optimum and best method to produce the hydrogen gas, because this gas too important and friendly uses in the vehicles as fuel .

Because : Hydrogen gas is called green fuel because it releases only H2O rather CO2 which causes pollution problems ,therefore the (H_2) is being used in combustion engines and fuel cell electric vehicles. When combusted (oxidized) it releases only water vapor as a by-product. And produces the small amount of CO and CO2 and Using this gas reduces the global world warming and all types of pollution, the hydrogen as fuel has highest amount of heat value.

1.1 The Objectives of this work:

This work offers an overview of the most two important technologies for hydrogen production, these technologies which to be discussed are:
I-Reforming of natural gas, and **II** - the Water electrolysis decomposition.

The comparison will between the two with the same assumed daily capacity 500 Kg/Day. Also the optimization between them to improve the plant efficiencies, to select the best method to produce this gas:

1-Becauce of the importance of hydrogen gas, there is need for significant comparison between the two production processes: the first one reforming process SMR and the second the water electrolysis.

2 -Studying the differences between the two processes that it includes these most important points such as: the flow charts, the type of raw materials to be used, the reactants and produces material from the reactions and the mechanism of them. , also the amounts of materials which are in or out; "material balance ".

3- Energy issue: selection the process with low consumed energy by Doing the energy balance, and determination the quantities of heats that enter or exit from systems and reactions.

4-The design of equipment's , special design of device may be required ,and the comparison includes studying the economically side after design .and selection the low capital costs process.

5-The optimum method that will produce the gas with high purity.

6-The pollution issue is to be considered (the best process can be selected with low polluted exits), also the recommended solutions must be included for any selected process that, has low cost and high purity of hydrogen gas and same time caused high pollution to environments.

8-modifiying for these processes to make them more economic and effective.

9- Discussing the point view of this comparison on our country Libya, due to importance of gas hydrogen that may be used as alternative gas in future.

1. Hydrogen gas production processes:

The comparison will be between the most important production processes to produce the hydrogen gas which are:

2.1 Steam Methane Reforming process (SMR)

Steam Methane Reforming (SMR) is a chemical process used in the gas manufacturing industry to produce hydrogen on a large scale. This process contains two chemical reactions which ultimately convert water and methane into pure hydrogen and carbon dioxide. The hydrogen gas is then further

purified to a quality specified by the customer, the method of producing hydrogen (almost 48% of the world's hydrogen is produced from SMR). There are two basic steps in steam methane reforming. The first one involves the mixing of methane with steam to produce a gaseous mixture CO, CO2 and the hydrogen.

The next step is called water gas shift reaction which involves combining the carbon monoxide with water to produce hydrogen gas and carbon dioxide. The reactor WGR uses iron-based catalyst, This process results in mostly CO2 and H2 as gas outputs, methane, water and other gases.. Hydrogen is separated from carbon dioxide and other gases using Pressure Swing Absorption (PSA), which results in pure (>99.995%) hydrogen [4]

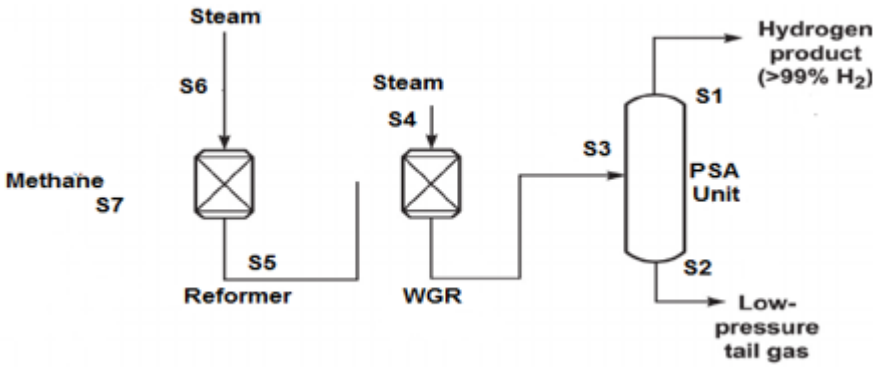

Figure (1): Flow diagram steam methane reforming

2.2 The Electrolysis of Water process:

Electrolysis and the Electrolytic Cell.
Electrolysis of water is process where current is passed through an electrolyte causing water to break up into its hydrogen and oxygen constituent elements. It is essentially the fuel cell in reverse and a very useful method of producing pure hydrogen for local or commercial use. Hydrogen gas is produced at the cathode (negative electrode) and the chemical equation for the reduction of water at this electrode is:
H2O + 2e- → H2 + O2 (1)
Oxygen gas is produced at the anode (positive electrode)and the donation of electrons due to oxidation at the electrode
is expressed as:
H2O → ½O2 + 2H+ + 2e-(2) [2]

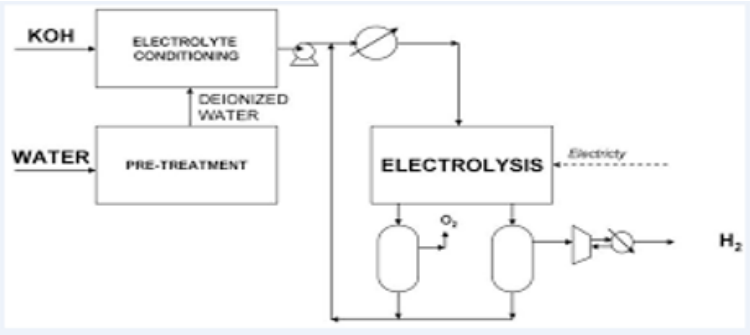

Figure: (2) electrolysis water process.

3. The methodology

The methodology of this work depends on the results have been calculated and presented in tables of comparisons that have been done between the two chosen processes by considering the points below:

1-Determination the quantities of required material (in mass) by using the general equation balance, the accumulation of these processes equal =0, because the two processes are steady state. These quantities of the input and output materials can be estimated by using the same assumed production capacity 500Kg/day for each process , the production capacity that is assumed for each process is not too much because the main reason, that is no need to produce a high quantity of hydrogen gas per day. Therefore the utilizations of this gas as fuel at the filling station is low, for example the majority of gas stations actually run at no more than 5 percent of their theoretical maximum throughput-or fewer than 100 cars a day where uses the hydrogen as fuel just about up to 25 cars[9].

2-Calculation the quantities of energy for all streams (input and output) by doing the Energy balance and focusing on the consuming energy for each process.

3-The next important step after doing the energy and material balances, which is the cost determinations that would be for each machine of the two processes flow charts, also the cost is the most conclusive step to choose the optimum production process after doing the calculations.

4- The best process will be chosen by making the comparison tables (material, energy, the cost, and the operation conditions such as pressure, temperature). Results are obtained from the calculations of balances, that will explain ,the optimization of gas production process have to be included (low capital cost, low quantity of consumed energy, high purity), and the consideration of the rough operating conditions such as high temperatures and pressures should be taken in the account . And the results of energy balance showed in table (1)

Table (1): The energy balance of the two processes

The process	Type of energy	Devices Which occur the (heating) in the process	Amount of added energy	The Consumption of energy (The energy which is supplied to the system)	No .of devices can be needed
1- Steam Methane Reformer	Thermal Energy.	Reformer + Heat exchangers	Heat exchangers and reformer= $31*10^5$kJ/hr	Reformer ,WGR and heat exchangers (thermal energy)	One device per equipment.
2- WATER- Electrolysis	Electrical Energy	Electrolysis Cell	Power= 0.6298 MW	Cell(electricity energy)	Number of cells =94 [7]

Table (2): Overall comparison based on production capacity of hydrogen:

The process	Type of Raw material and availability of the feed	products	Side Products	Purity of Hydrogen	Amount of materials Kg/hr	Catalyst to be used	Purification process	Pollutions issue CO2 emissions	The type of fuel Related to the source of feed
SMR	H2O (Too available CH4 (not available this can be obtained from N.G) & crude oil)[2]	CO CO2 H2	CO CO2	99.995% [2]	Methane and steam =36kg/hr ,Carbone dioxide CO2=97.17 kg/hr	(Nickel), in the reformer (Cr2O3) in the WGR. And (zeolite) in(absorbers) tower PSA .	Adsorber tower (PSA)	(high quantity of CO2) Causes environmental problems.	Fossil fuel Which is named (blue hydrogen)
Water Electrolysis	WATER Cheep too available	H2 O2	No side products	98%[3]	Water =187.4 kg/hr No carbon dioxide CO2 emissions	Using the KOH 30% in the cell And Nickel (electrodes) [4]	No purification device – needed Drying to remove HO2 & KOH	No Co2 emissions Friendly process.	Renewable fuel which is named (green hydrogen) .

Table (3): The final comparison between the two processes (SMR & Water electrolysis)

Process	Total cost	Life span	Quantity of consumed Energy / hr	special design device	Product purity %	Pollution issue Environmental friendly	The process Difficulties	The problems during the production
SMR	816288.3$	30 years Year[6]	861kW	PSA needs to special design causes(from high pressure and Temp)	High purity 99.995% [6]	Not friendly with the environment, because there are a lot of gases such as co2 and co release into environment cause the pollution	There is a hazards in the operation due to conditions(high pressure and temperature & type of the feed which is natural gas at 900 c and steam and 25 bar)[2]	Un reacted methane may causes the cook as side product that decreases the production of hydrogen.
Water Electrolysis by alkaline cell	13,87596$	20-30 Years [10]	0.628 MW	Cell also needs to special design causes from complicated manufacturi ng.	Less than SMR 98%[3]	It is friendly with the environment and there is no gases product from this method	No _hazards in operation -no difficult in operation because the water enters to cell at 25 c and (1)bar low pressures[3]	No side product.

Discussion

It can be discussed , through the comparison tables (material , energy ,and the cost), the results which are obtained from the comparison which show the optimum process to produce the hydrogen gas, with (low capital cost ,low quantity of consumed energy ,high purity) is the STEAM REFORMING METHANE PROCESS (SMR) by using the methane , that why the researches in the USA and the other industrial countries prefer the STEAM REFORMING METHANE PROCESS (SMR), and the 92%[2] production of hydrogen gas from this process, and just 4% from water electrolysis, even though with the rough operating conditions such as high temperatures and pressures.

On the other hand, this process can be unfriendly process to the environments, because high quantity of the carbon oxide CO2. The global warming potential is highest in SMR of hydrogen production, but there are a lot of techniques to decrease the CO2 from this process (the solutions).
Also the raw material of this process is methane CH4, it can be very expensive , when it compared to the water, in electrolysis process, this gas can't be easily obtained especially in the non- petroleum countries such as USA and the Europe countries , for this reason ,the SMR process is selected method , in these countries.

The energy consumed from this process is lower than water electrolysis process; this is very important point, because it can be added extra cost to the cost estimation of the process.

Application this comparison in the Libya

This is a very clear the Libya is petroleum country, it has a big amount of natural gas and crude oil , therefore the SMR process is very good method to produce this gas ,because the raw material is too easy to be obtained .

From the point of view, the collected information, that shows the electrical energy is too cheap in Libya is about 0.031 Libyan diner while the USA is = 15 cent [**8**] ,when it is compared to the USA and other countries. Therefore the water electrolysis can be a desirable process as well, due to raw material is too available and cheap and the electrical energy isn’t expensive.

The Solutions:

It can be recommend to improve the production of hydrogen gas is studying the weakness points for each method , therefore the steam reforming process

SMR has a lot of problems due to the high amount of carbon dioxide ,that products from the reactions , so there is strongly needing to convert the reminded of CO2 and CO into the material which is methane the CH4, so this step can be provide extra amount of the raw material and the same time decrease the emission of CO2 and CO in to the environment . The adding step to be recommended is the Recycle carbon dioxide to reactor for two reasons:

1- Reduction of air pollution

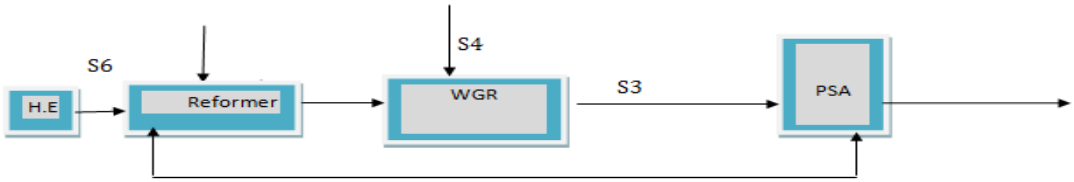

Figure (3): the steam reforming methane after modification

2-Recycling the carbon dioxide to reformer to be converted into methane (CH4), that it increases the quantity of the feed which is CH4.
3-Collection the carbon dioxide to produce poly carbonate.
-For the water electrolysis, the modifications can be take place in to process for these reasons:
1-Some units will be added to improve hydrogen purity
2-The deoxidizer should be added to this process to separate the hydrogen gas from the calcium hydroxide.
3-providing the dryer unit to increase the purity of hydrogen.

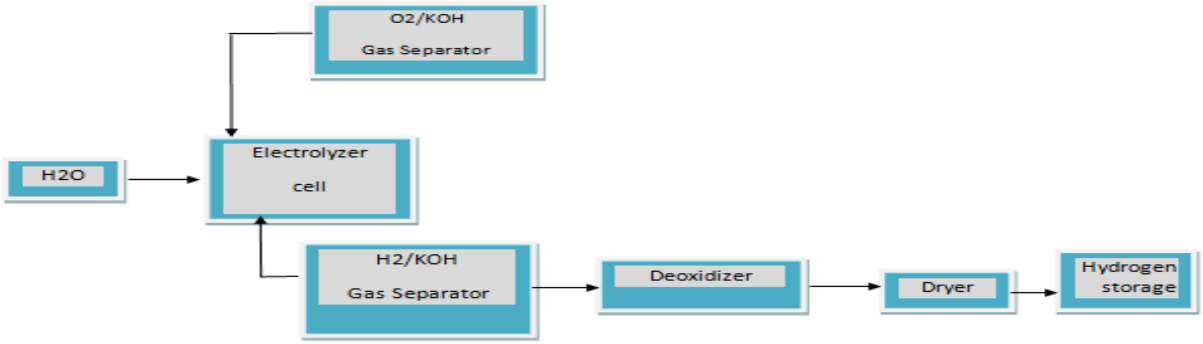

Figure (4): water electrolysis after modification

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