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Novel Techniques Of Generating Huge Amount Of Hydrogen Gas Using Microwave And Radiowave Energy

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ABSTRACT : This research revealed that exposure of methane and/or steam to radiowave (RW) and microwave (MW) energy using copper and rhodium catalysts produced hydrogen gas in high quantity. The feasible pathways of chemical reactions leading to its production are shown below ;

$$CH_4 + 2H_2O + \text{MW or RW} + \text{catalyst} \rightarrow CO_2 + 4H_2$$
$$4H_2O + \text{MW or RW} + \text{catalyst} \rightarrow 2O_2 + 4H_2$$

The generation of hydrogen gas was true for both sources of energy whether separately or in combination. The amount of hydrogen produced using RW energy was however, greater by more than 53 % as compared to the output of hydrogen using MW energy. MW at 1, 145 W power using 18.3 g rhodium catalyst yielded an average of 15,000 ppm hydrogen. Using RW energy, the same quantity of rhodium catalyst net a very high yield of 542,151 ppm hydrogen. Using 153.3 g copper catalyst, RW produced an average amount of 30,820 ppm hydrogen gas. For RW the optimum conditions for the above reactions to move forward and yield the highest amount of hydrogen gas, were the following; methane average gas flow rates of 1.0 ml/s, average steam flow rates of 5 g/s, radiowave coil glow time of 1 minute and /or greater. For MW, time range of 4 to 5 minutes at a power of 500 to 600 W was observed optimum. RW generator at 475 kHz and a coil glow time of 1 minute and higher gave peak of hydrogen gas generation. In general, methane as well as, steam or in right combinations studied on both, when subjected to MW and/or RW energy in the presence of catalyst(s) produced continuous generation of hydrogen gas.

Keywords : Hydrogen gas, methane, radiowave, microwave, Haldor Topsoe process, copper catalyst, rhodium catalyst, steam reforming process, radiowave induction, methanation reaction and thermodynamics.

1 INTRODUCTION

TAKING into account the stoichiometric air – fuel ratio of the currently available fuels being used nowadays, hydrogen is the one that has by far the widest air – fuel ratio (1 : 34), and has more than three times higher heating capacity than that of gasoline (Plymouth Univ., 2007). Thus its use as future source of sustainable energy is gaining more and more research and popularity. In fact, almost all automotive vehicle companies worldwide had been consistently testing trial hybrids and/or fuel cell vehicles which has its fuel base on hydrogen gas. Producing this gas, however, using the traditional Topsoe Steam Reforming process, TSRP (also called Haldor-Topsoe process) using natural gas by means of tubular reformer, and partial oxidation of fuel oils and coal, requires a whole facility similar in size to an oil refinery and engulfs tremendous amount of energy requiring temperature as high as 1,200 ^{o}C. The alternative process is researched herewith by subjecting steam and/or methane to two types of wave energy and catalysts. Various conditions were observed and optimized to generate the highest amount of hydrogen gas. The heat supply was via non contact, 'inside out' method as offered by microwave technology and induction heating through radio frequency.

2 MATERIALS AND METHODOLOGY

2.1 Materials used in the research

Specific equipment used in the experiment with brands and specifications are listed in Table 1.

TABLE 1
EQUIPMENT USED IN THE RESEARCH

	Properties and Specifications
Ammeter	*Escort Digital Ammeter model ECT – 620N*
Analytical balance	*Mettler PC4400 Delta Range, ACS calibrated*
Automatic Signal Scanner	*Dataplex 10 Omega Engineering Inc.*
Flowmeters	*Sho-Rate Flow rate Meter, Model 1355EYZZPGV5A by Brooks Instrument Emerson Co. Range 0 –150 & 0.01-5.0 ml/s*
High Frequency Monitor	*Philips high resolution frequency monitor, model PM 6670*
Microwave oven	*Panasonic NN-S553 Inverter Technology, 1,100 W, 4.9 A, 2,450 MHz, Oven dimension (HXWXD) = 225 X 375 X 386 mm*
Precision RF generator	*Hyforce 6 DMI, 380 – 490 kHz frequency range, Cheltenham 3192 Australia*
Rhodium catalyst	*18.3 g melting point of 1,964 degrees Centigrade*
Steam generator	*Piranha brand model MS-312, 1350 W*
Temperature Monitor	*10 Channel Wide Visibility Temp Monitor, Amalgamated Instrument Co. Pty. Ltd.*
Thermometer, Laser Infrared	*Raytek PM Plus, model RAYRPM20L2G*
Thermocouples	*Type K*
Hydrogen Gas Analyzer	*Drager Hydrogen Monitor, TC detector, with additional oxygen sensor. Sicherheitstechnik Germany GmbH*
Autotransformer	*Variac WIOHMT3 General Radio Co.*

2.2 Methodology

The process of subjecting methane gas and/or steam to these two forms of energy followed the pathways in the experimental

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rig shown in Fig 1. Reagent grade methane gas from Liquid Air Aus. and steam from distilled water through steam generator quantified precisely by analytical balance, were used. Flow meters monitor the gases passing through catalysts (copper and rhodium) subjected to induction heater and microwave energy. Conditions like flowrates, temperature, microwave power, gas combinations and induction radiowave coil glow time were adjusted to observe the effects on hydrogen gas production. The amount of hydrogen gas produced were measured precisely using Sicherheitstechnik Deutch Drager hydrogen gas analyzer and monitor with TC detector. The flow of gases and steam has two pathways as shown schematically in the experimental rig, Fig 1. Both process follow beginning and ending pathways until reaching the measurement instruments. One process passed through a micro-

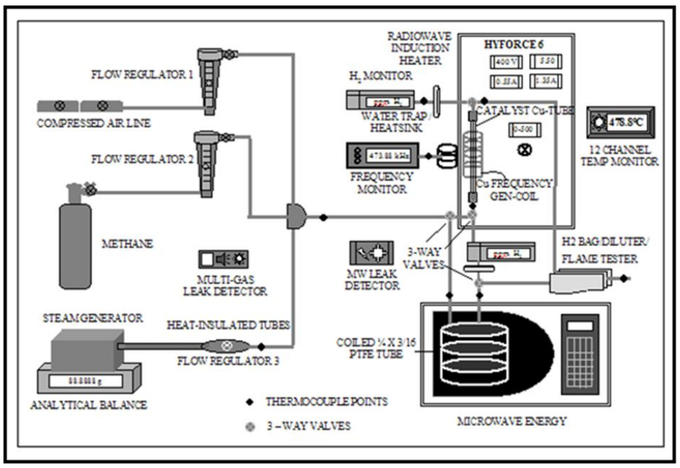

Fig 1: *The experimental rig used in the research*

wave machine as source of MW energy and the other through inductive radio frequency generator as source of RW energy as shown in Fig 2.

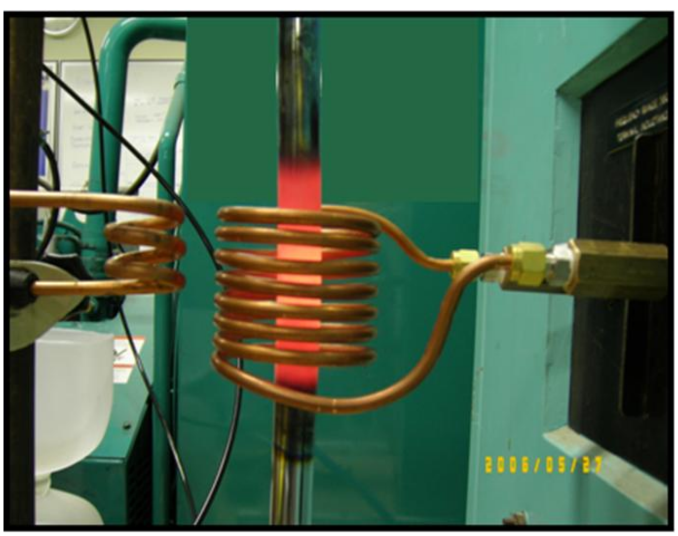

Fig 2: *Subjecting the flow of gases through catalysts shown in the middle column heated to amber glow by radiowave induction generator*

3 Results and Discussion

Gradually incrementing the time of exposure of 0.1 g/s steam to a microwave power of 1145 W, peak production of hydrogen gas was observed at 5.8 minutes as shown in Fig 3. A maximum 15,000 ppm was measured at the tube output.

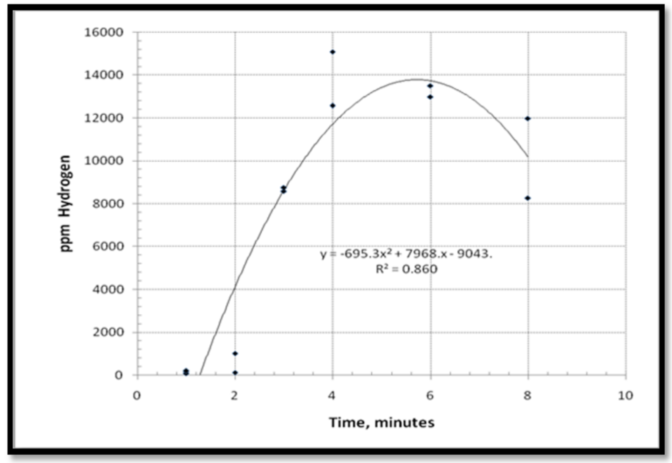

Fig 3 *: Generation of hydrogen gas with time on continuous exposure to microwave energy of 1145 watts.*

Extending microwave exposure time after 6 min to know the peak of production of hydrogen gave declining gas production.

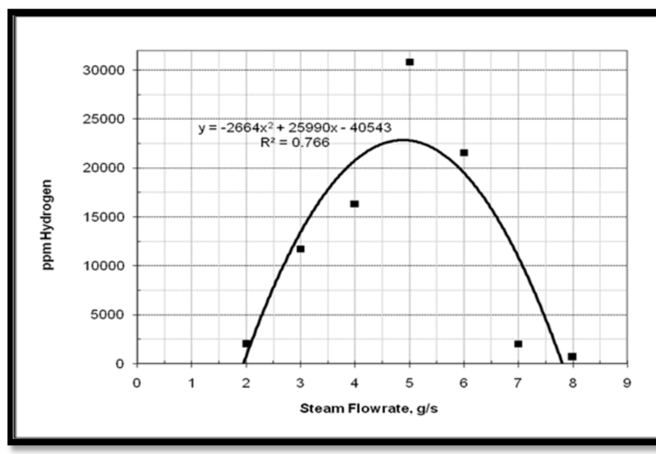

Fig 4: *Steam flow rate as it affects production of hydrogen gas.*

The relationship of steam flow rates with the amount of hydrogen gas generated is shown in Fig 4. This used 230 g copper catalyst exposed to a temperature of 500 ^oC at methane flow rate of 5ml/s with Hyforce RW Frequency of 473 kHz and a coil glow time of 1 min. Higher than 5 g/s flow rate decrement gas production and slowly extinguished it. Shown in Fig 5 below was the results of the determination of peak of hydrogen gas production by varying the glow time of catalyst exposed to 473 kHz radiofrequency. At this condition of 230 g copper catalyst with a temperature of 508 ^oC, air flow rate 10 ml/s and no methane, highest peak was observed after 1.75 minutes. Further extending the time of exposure gave declining results.

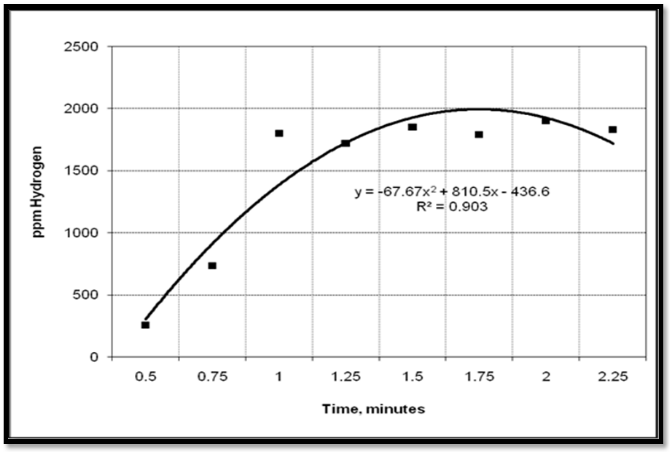

Fig 5: *Varying glow time of catalyst*

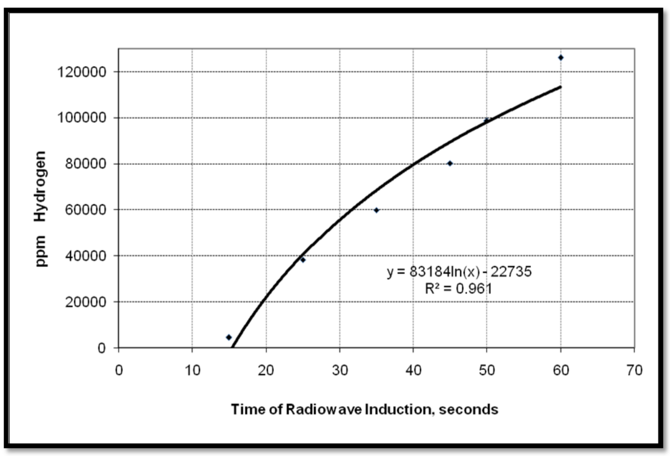

Fig 6 *: Increasing RW Induction energy produced huge amount of hydrogen gas.*

Hydrogen trend was recorded continuously increasing with time of heat Induction or glow time. At steam flow rate of 0.059 g/s using 18.3 g rhodium catalyst , at temperature of 475 ^oC and Hyforce frequency of 474 kHz and with emphasis only in the presence of steam (no air and no methane), hydrogen gas can be produced continuously even getting results at 543K ppm reaching the maxima of the instruments' measurements capability.

5 Conclusion and Recommendations

The research have concluded that hydrogen gas can be produced from methane and/or steam using both microwave and radiowave energy sources. Microwave gave peak production of 15,080 ppm. A higher generation of 210, 664 ppm was produced by using radiowave. Using suppression method by varying reactants, conditions and radiowave generator's parameters, the optimum production of hydrogen was recorded at 542,151 ppm. Base on feasible chemical reaction paths, the research indicated that it follows Rostrup-Nielsen's [3], [4], [5] methanation reactions (1) and (2), but not reaction (3) in the articles, as data collected showed oxygen to even suppress production of hydrogen. The potential likelihood however, of the reaction leading to the optimum production of hydrogen was primarily ;

$2H_2O$ + MW or RW energy + Rh or Cu → O_2 + $4H_2$

This reaction has never been seen in any literature, but the reactants were known and the products were identified by hydrogen gas analyzer and was validated to follow Le Chatelier principle of reactions. It was also highlighted that the addition of small quantity of methane at 1 ml/s, augmented the production of hydrogen tremendously. It is however, recommended that this reaction be authenticated and verified in further research.The optimum conditions determined for both microwave and radiowave induction energy that produce maximum hydrogen output were namely;

- Rhodium > copper catalyst
- High steam flow rate of 5 g/s and low methane flow rates of 1 ml/s was found optimum gas combination.
- Radiowave coil glowtime of 1 minute or more at frequency of 473 kHz
- Hydrogen peaked at 4 minutes exposure to microwave energy
- Catalyst temperature range of 475 ^oC to 508 ^oC

Whether this is due to temperature or to vibrational spin or both, remains to be validated. One thing is revealed however, it used lower temperature to produce hydrogen which is less than half as compared to the conventional Topsoe Haldor Steam Reforming process of 1,200 ^oC. The impact of this research, being economical, faster and easier to produce, these two new methods will decrease the cost of hydrogen fuel. The overall contribution of this is that, it scientifically validated that hydrogen can be produced using much simpler method that consumed less energy as compared to the current manufacturing process which uses gigantic facilities and devour huge amount of energy. There is also that possibility in the near future, that a reactor following this principle can be incorporated in motor vehicles which can make sea water replace petroleum as fuel. Maybe a possibility of this reactor in tandem with fuel cell reactor built-in fuel cell vehicles, will eliminate hydrogen depot alongside petrol stations. Instead of dwindling petroleum, seawater will just be filled in the vehicle's fuel tank. A sequel and follow up to this research is therefore highly recommended.

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