Hydrogen Generation by Electrical Discharge through Metal/Water System

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Abstract

Hydrogen generation by dissociation of water is described. The major force for the dissociation comes from the oxidation potential of the reactive metal reacting with water whereas the minor role is played by electrical discharge which helps sustain the reaction. A premixed reactive metal/water system undergoes a fast hydrogen generation upon the ignition by an electrical pulse. In another method the reactive metal can be fed into the reaction as a consumable electrode whose tip is activated by electrical discharge. Some characteristics of the methods are discussed.

1. Introduction

Generation or storage of hydrogen molecules for the use in vehicular applications, as seen in fuel cells, imposes a very important but formidable technological challenge to face. Traditional methods include a reformer which utilizes a hydrocarbon fuel, storage in the form of liquid or high pressured gas or of metal hydride. Technologically sound as each method may appear there are still many technical problems to be solved, particularly reducing size or weight of the generation or storage device, fast utilization, purification of the product gas.

The hydrogen generation based on electrical discharge through reactive metal/water system has been reported for such applications as a fast hydrogen generator(1) or a vehicular fuel source(2). Most commonly used metal is aluminum. These methods are in principle very simple. It is well known that although aluminum has high oxidation potential, the passive oxide film prevents a further oxidation. By raising temperature or adding chemicals such as NaOH the oxidation reaction proceeds. The electrical discharge is , in a sense, a replacement of the chemical effect. But unlike the chemical method, the electrical discharge method provides a "hot" reaction zone which is confined in a local region or spreads into the entire system with time. The major technical problem to be solved is to improve the electrical energy efficiency defined as the ratio of the metal consumed to the electrical energy input. For the fast generation method(1) in which the aluminum fuel is premixed with water, the energy efficiency already exceeds 100. In the method described in the reference 2, aluminum fuel takes the form of a consumable electrode through which electrical discharge is applied. The energy efficiency seen in this method is yet to be improved.

The difficulty with the method 2 is ascribed to that a stable reaction zone is not easily established. The condition for the establishment is the coupling of the aluminum-water chemical reaction to the electrical discharge. Unless the reaction takes place continuously the discharge alone can not drive the metal/water reaction. Then the continuous reaction can be warranted only when many experimental variables such as the voltage-current shape and the metal feeding rate are optimized.

Another factor which will determine the success of the electrical method is the cost of the reactive metal fuel. Assuming that the electrical energy efficiency is optimized, the cost of aluminum fuel is about 3~4 times higher than that of fossil fuel on the basis of equal energy output. Methods such as recycling of the metal oxide the reaction product and utilization of the heat from the reaction in further dissociation of water could improve the practical feasibility of the method. Some features of each method will be discussed.

2. Experimental Methods

The simple electrical circuits for the methods for hydrogen generation are shown in Figure 1-(a) & (b). The method 1 which uses a premixed aluminum/water system (R in the Figure 1-(a)) generates hydrogen in very fast time schedule(within 1 msec) by discharging the electrical energy stored in the capacitor bank C by closing the fast switch S_1. Switch S_2 is used to control the electrical energy input. The details of the premixed reactants and the reaction chamber are shown in Figure 2. The aluminum power, $<40\mu m$ in average diameter, is purchased from Alfa products. The powder and water were mixed in the stoichiometric ratio. The reaction in the mixture was initiated by embedding a copper or aluminum trigger wire in it and applying an electrical pulse through the wire.

In the method 2 the aluminum fuel takes the wire shape which is consumed during the reaction with water. Facing the wire electrode and distancing about 2~3mm from it is placed the planar anode made of stainless steel or aluminum. The reaction chamber enclosing the electrodes was filled with deionized water ($R \geq 18M\Omega$-cm). The DC power supply provides two modes of power - the high voltage/low current mode to cause the electrical breakdown between the electrodes and the low voltage/high current mode to activate the metal wire tip. A DC motor was attached to the aluminum wire feeder to control the feeding rate. The product gas was determined by pressure measurements, gas analysis or volume measurements.

3. Results and Discussions

It was reported in reference 1 that the energy efficiency seen in the method 1 already exceeds 100. This means that the cost of electrical energy input is negligible compared to that of aluminum fuel. Critical to warrant a high energy efficiency is the physical confinement of the reaction chamber enclosing the premixture during the electrical pulse application. Most of the metal fuel underwent the reaction (over 90%). Implementing this generation method into a practical device waits an engineering solution which ensures a continuous provision and the physical confinement of the mixture during the pulse application.

Among the many experimental variables associated with this method the surface coverage of the wire and the electrical components of the discharge circuit were examined. It was found that during the high voltage mode application the electrolysis taking place at the side of the wire is detrimental to ignition of the reaction. Adding extra L (over $1MH$) components outside the DC power supply lengthens the low voltage discharge time so that the portion of aluminum fuel engaged in the reaction increases by a factor of move than 10. Thus far it has been found that the experimental variables dictating the sustained reaction include the surface are of the wire electrode subject to electrolysis, the temperature of water, the feeding rate and the shape of the discharge voltage and current, and finally the agitation of the reaction region. The feeding rate should be the function of the current density. Thus far we have only found the right range of RLC values of the discharge circuit in prolonging the reaction time. The electrical energy efficiency is still very low compared to the method 1.

4. Conclusions

The dissociation of water employing reactive metals and electrical discharge is a viable method for generating hydrogen fuel, particularly for on-demand applications such as vehicular fuel source. Electrical discharge through a premixed aluminum/water system generates hydrogen gas with the energy efficiency exceeding 100. Another method based on feeding the aluminum fuel as a consumable electrode has yet to optimize many experimental variables. Thus far the values of electrical components like L, R, C in the discharge circuit turn out to be crucial to sustain the reaction.

References

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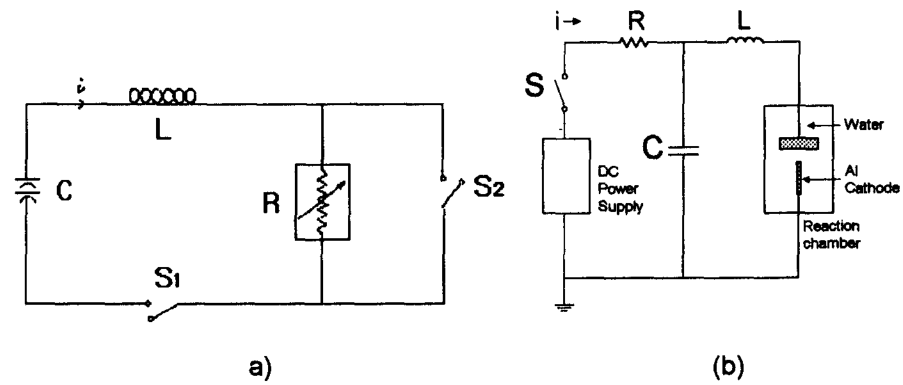

Fig. 1. Electrical circuit for (a) method 1 (premixed aluminum/water) and (b) method 2 (consumable aluminum wire cathode)

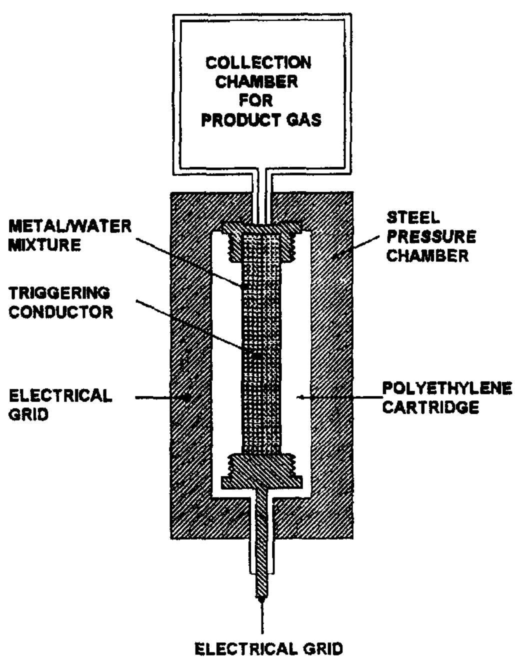

Fig. 2. Details of the reaction chamber used in the method 1.