# "Efficient use of Hydrogen generated by the Reaction of Water with Aluminum Alloy"

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## ABSTRACT

*Energy plays an important role in improving country's economy. To decrease the pollution and global warming we need new sustainable methods, which full fill the on growing demand of energy without destroying the ecological balance of the nature. The use of hydrogen is among the ways in which a green fuel is used. Hydrogen can be made by splitting water by reaction with aluminum alloy on demand in automobiles replacing conventional fossil fuel engine and fuel tank by hydrogen engine and water tank. Today as the need of the petroleum products is increasing with increase in population and industrialization, the depletion of fossil fuels (eg. Petrol, Diesel, Coal etc.) from earth is a harbinger of the energy crisis of the future, so to come out of this problem we find a technology in which we used aluminum which is mixed with some other metals like gallium, indium and tin which splits the water in hydrogen and oxygen. This hydrogen than used as a fuel in vehicles. Now a day's due to fuel depletion the hydrogen produced is used as fuel instead of diesel which will bring the new revolution in the field of this sector. So in future the water will be the only source, which is present abundantly on earth. This technology will help to reduce the usage of fuels and reduce the pollution which also improves the economic condition of the country like India. Solid alloy of aluminum, gallium, indium and tin have been shown to react with water at room temperature to produce hydrogen and aluminum oxide in a exothermic reaction. This aluminum oxide can be recycled into aluminum. Apart from that aluminum metal is abundant on earth. The recycling is less expensive then mining aluminum-containing ore bauxite. After recycling the aluminum oxide back to aluminum 60 times the cost of producing energy would reduce to 10 cents per KW hour or Rs 6.33 per KW hour.*

## INTRODUCTION

February 19, 2008 Purdue University, the engineers of the Purdue University have developed a new aluminum-rich alloy that produces hydrogen by splitting water and is economically competitive with conventional fuels for transportation and power generation. The two major barriers to realizing a viable large-scale hydrogen economy are hydrogen storage and economically viable "green" hydrogen production. This is an economically viable process for producing hydrogen on-demand for vehicles.

The new alloy contains major percentage of aluminum and some percent of an alloy that is made of the metals gallium, indium and tin. Because the new alloy contains significantly less of the more expensive gallium than previous forms of the alloy, hydrogen can be produced less expensively.

When submerged, the aluminum alloy would instantly split water into its two constituents, and only produce aluminum hydroxide, which can be disposed in a landfill or recycled, to re-extract aluminum. The aluminum splits water by reacting with the oxygen atoms in water molecules, liberating hydrogen in the process. The gallium-indium-tin alloy is a critical component because it hinders the formation of a "passivating" aluminum oxide skin normally created on pure aluminum's surface after bonding with oxygen, in a process called oxidation. This skin usually acts as a barrier and prevents oxygen from reacting with bulk aluminum. Reducing the skin's protective properties allows the reaction to continue until all of the aluminum is used to generate hydrogen.

**$2Al + 6\ H_2O \rightarrow 3H_2 + 2Al(OH)_3$**

In June 2011 Utah University, a thesis on the water splitting by Yizaho Lang is approved by The University. In his thesis he said that among the materials for chemical methods, aluminum could be utilized as an efficient and environmental friendly energy carrier via the production of hydrogen from water. However, it requires the reaction between aluminum and water to be complete, controllable and does not require the involvement of acids and/or alkali. Such direct reaction between aluminum and neutral water, once considered impractical due to the passivation of aluminum surface in water, is enabled with the relatively recent use of catalytic gallium-based liquid alloys. The rate of hydrogen production from each aluminum-water reaction was measured as a function of time. The theoretical ability of one kilogram of aluminum to generate hydrogen is 1245 liter but due to the formation of amorphous oxide layer, whose thickness is several nanometers, forms on surface of aluminum metal which prevents its further reaction with water.
Ga-In eutectic alloys can be useful to activate aluminum powders for generating hydrogen. Ga and In are both nontoxic and already widely used in various fields of science and technology. Their eutectic has a melting point lower than room temperature and the alloy is very easy to generate from Ga metal and In metal.

This reaction rate depends on the temperature of water and surface area. High temperature water is more reactive due to kinetic reasons. This reaction gives the abundant heat energy and the hydrogen gas which can be used in the cars as a fuel instead of diesel.

## 2. LITERATURE REVIEW

Alessandro Volta built a toy in early 1780s, it is an electric pistol in which an electric spark exploded a mixture of air and hydrogen, firing a cork from the end of the gun.

In 1807 Swiss engineer François Isaac de Rivaz built an internal combustion engine powered by a hydrogen and oxygen mixture, and ignited by electric spark.

In 1860 Belgian Jean Joseph Etienne Lenoir (1822–1900) produced a gas-fired internal combustion engine similar in appearance to a horizontal double-acting steam engine, with cylinders, pistons, connecting rods, and flywheel in which the gas essentially took the place of the steam.

In 1892 Dr. Rudolf Diesel developed his Carnot heat engine type motor and in 1893 February 23 Rudolf Diesel received a patent for his compression ignition (diesel) engine.

In 1903 EgidiusElling builds a gas turbine using a centrifugal compressor which runs under its own power.

In March, 1937 The HeinkelHeS 1 experimental hydrogen fueled centrifugal jet engine is tested at Hirth.
From 1991 to 2007 Mazda has developed Wankel engines that burn hydrogen.

In 2002 and 2007 BMW tested a supercar named the BMW Hydrogen 7, powered by a hydrogen ICE, which achieved 301 km/h (187 mph) in tests. At least two of these concepts have been manufactured.

Earlier the splitting of water is done by Electrolysis, Photo-electrochemical water splitting, Photo-electrocatalytic water splitting and Photo-biological water splitting.

**ANALYSIS**

It is analyze that storing of hydrogen is difficult task, especially in vehicles, pumps etc. so we find a new way to produce hydrogen on demand in vehicles as per requirement. We mount a system on board in which the hydrogen is produced which can be collected in different tank. This system contains the aluminum powder with the liquid alloy of gallium indium and tin. When the water falls on the mixture of alloy the water molecules get split into the molecules of the hydrogen and oxygen. This paper focuses on an innovative idea of making of hydrogen within the vehicle by decomposition of water into it's constituent molecules i.e. $H_2$ and $O_2$ by its reaction with aluminum.

Although the rate of reaction is slow but in presence of gallium, indium and tin, there can be a rapid rise in the rate of reaction. Alternatively this reaction can be catalyzed by presence of zinc also. This can be further become the field of research.

$$2Al + 6H_2O \rightarrow 2Al(OH)_3 + 3H_2 + heat$$

**The energy released in this reaction = 861.1 KJ**
**And the energy released after burning of $H_2$ produced = 857.4 kJ**

**Energy Density-**

**As hydrogen produce from splitting water,**

1. **1 Kg $H_2$: 142 MJ = 39.4 KWh combustible energy**
2. **1 Kg Al makes 111g $H_2$ from 2 Kg of $H_2O$ = 4.4 KWh**
3. **1 gal(10 Kg) Al makes 44 KWh as Hydrogen**
4. **1 gal diesel makes 37.5 KWh**
5. **1 gal liquid hydrogen makes 10 KWh.**

**As heat from splitting water,**
**1) 1 Kg Al : 4.4 KWh**

**Therefore, total energy obtained from 1 Kg Aluminum: 8.8 KWh (1Kg coal: 6.7 KWh)**

Further the rate of reaction can be greatly enhanced by the use of hot water substituting the cold one. Although it looks costlier but it will be of no cost if we design the engine in such a manner that at first the water can be used as a coolant for engine and afterwards it can be used as a working fluid for producing hydrogen. So we have hot water at no cost (ignoring the cost of circulating the water through the engine). From the analysis we found that water of temperature greater than $70^oC$ is highly reactive. The efficiency of aluminum to produce $H_2$ increases as temperature of water increases.

Variation of Mass of hydrogen produced at different temperature with respect to time
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Theoretical efficiency of Al is 1245 Liter of hydrogen but practically due to formation of aluminum hydroxide it decreases. At $70^oC$ the efficiency of Al is 58% of the theoretical value and as the temperature of water increases the efficiency increases.

The aluminum hydroxide [$Al(OH_3)$] produced is totally nontoxic, non-ignitable, non-explosive solid and harmless. So it can be used as a land fill and also can be recycled. The cost of recycle is less than the cost of Al extraction from the ore.

## CONCLUSIVE REMARKS

Most of the industrial equipment's and transportation media use fossil fuels as a source of energy. As the demand of energy, keep on increasing, but the fossil fuel is a non-renewable source of energy, so cannot be recycled. Thus we need alternative fuel to full fill the on growing demand of energy.

Our study suggests a very efficient substitute i.e. Hydrogen derived from water and aluminum. The paper suggests the use of $H_2O$ and Al in a very efficient manner. The inbuilt (Al & water) looks very attractive option for future. The use of alloying elements and hot water is suggested in paper which will increase the rate of $H_2$ generation when the vehicle is idle. The $H_2$ is continue to produce and get stored in its chamber and can be utilized during running condition.

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