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Potential of Bio ButanolDriven Petrol Engines and Solid Oxide Fuel Cells

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ABSTRACT

As the demand for fuel is constantly increasing, petroleum reserves are on a constant decline. This scenario has called for the requirement of an alternative fuel to replace the likes of petrol (gasoline) and possibly an alternative propulsion system for the benefit of environment. This paper assesses the potential of n-butanol as an alternative to petrol (gasoline) to be used in solid oxide fuel cells and petrol engines. It explores various methods, both relatively newer and more traditional for obtaining n-butanol. The paper evaluates these processes for sustainability in the long term.Scope of using n-butanol as a fuel for solid oxide fuel cells is also examined and merits as well as demerits of such a system are presented.

Keywords

Butanol, n-butanol, solid oxide fuel cells, SOFC, alternative fuel

INTRODUCTION

Recent years have witnessed a steep growth in consumption of petroleum based fuels such as petrol, diesel and kerosene. The requirement for energy is projected to sore and so will the demand for fuels. But with petroleum slated to get extinct from the earth, a need for alternative fuel(s) which can be sustainably and economically be produced in sufficient quantity and quality to quench the entire demand is being widely felt.

In light of the adverse effects on environment caused by combustion of petroleum based fuels, the alternative fuel(s) coupled with the alternative propulsion system must produce relatively less harmful or toxic emissions as compared to the system currently in use.

In short, a system which has the capability to address the shortcomings of the currently employed system and which can be sustained in the long run is the need of the hour.

Current Scenario of Alcohol Fuels

Currently, Ethanol is a very popular alcohol fuel worldwide. It is mixed with gasoline to varying extents in many countries. Various ethanol-gasoline blends are currently in use such from ED-5 to ED-95 or more where the number denotes the percentage of ethanol present in the blend.

In light of the advantages and growing popularity of such blends, India has also initiated a Ethanol Blending Program (EBP) in which 5% ethanol is blended in petrol.

Issues with Gasoline-Ethanol blends

Despite its many advantages, blending ethanol with gasoline also poses some issues which need to be addressed.

Ethanol is hygroscopic in nature meaning that it tends to absorb moisture from air. This nature of ethanol makes it corrosive. It also tends to be incompatible with some fuel system components. One such incompatibility arises with vehicles using capacitance fuel level gauging. Alcohol fuels may cause erroneous gas gauge readings in vehicles which employ such systems.

Another issue is the low energy density of ethanol. This factor reduces the overall energy density of the fuel when mixed with gasoline. Also, insufficient vaporization is a known problem in alcohol fuels. The heat of vaporization of ethanol sits at 0.92 MJ/kg which makes it harder to start the engine at lower temperatures while using an ethanol blended fuel.

n-butanol as an alternative

n-butanol is the straight chain isomer of butanol, a four carbon alcohol. It is also known as 1-butanol or butan-1-ol.n-butanol offers many advantages over ethanol when blended with gasoline. It may also be used directly in unmodified petrol engines, albeit with some decrease in efficiency, as has already been demonstrated.

Advantages over ethanol

n-butanol provides many advantages over the popular ethanol blend such as :

- A larger carbon chain makes it fairly non polar. Similar Research and Motor Octane Numbers (RON & MON) to gasoline allow for higher blends than ethanol. Less corrosive nature than ethanol also makes it more compatible with fuel system components.
- Energy density of n-butanol is only slightly less than gasoline and significantly more than ethanol. Kinematic viscosity is also far higher than that of gasoline.
- One very important advantage of n-butanol is that existing technology allows for n-butanol to be used to drive Solid Oxide Fuel Cells.

Solid Oxide Fuel Cells

According to hydrogenics.com, a fuel cell is a device that converts chemical potential energy into electrical energy with an efficiency of about 60% and operating temperatures are about 1,000 degrees C. These cells tend to be rather large and such high operating temperatures limit its applications.

Using butanol for Fuel Cells

Butanol also has a capability to be used in fuel cells which offer a cleaner and greener source of energy. By using the same fuel for both petrol engines and fuel cells will bring uniformity in the supply line and may eventually lower the cost.Due to size and operating temperatures, fuel cells may not be able to find application in every place. So petrol engines optimized for running on butanol or on a combination of butanol and gasoline can be the solution there. Such a blend for petrol engines may also include ethanol along with butanol and gasoline to benefit from its higher octane number which allows for better compression ratio and efficiency.

Advantages of Fuel Cells in Marine Propulsion

A study conducted by Jing Sung of Department of Naval Architecture and Marine Engineering of University of Michigan along with John Stebe and ColenKennell of Center for Innovation in Ship Design, Naval Surface Warfare Centre, Carderock Division proposes principal parameters of notional SOFC power plant as follows-

Output power- 5MW

Efficiency- 50%

Fuel utilization- 85%

Air utilization- 25%

Air/fuel inlet temperature- 600 deg.C

Four such cells were coupled with a gas turbine to obtain a total output of 24MW.

A mission endurance analysis was done by taking example of US Military Sealift Command's Ro-Ro cargo vessel. Mission endurance was measured by the distance travelled with 90% of full fuel capacity at peak speed of 24 knots.The fuel cell powered ship was found to have an endurance advantage of 25% over diesel systems and 57% over gas turbine system.The cells used in the analysis and no such system currently exists which can deliver an output of 5MW but the authors believe that the technology will be achievable in the next 15-20 years. The study, although based on a notional system, shows the potential of fuel cells as a cleaner and more efficient option for marine propulsion.

Methods for production of Butanol

Traditional methods of production such as Acetone-Butanol-Ethanol fermentation do not yieldbutanol in a large enough quantity to address the cureent and growing demand. Another method for production can also be employed using sugarcane leftovers. This method will only use leftovers from sugarcane harvesting and will thus not hamper production of other commodities from sugarcane.

If 1 ton of sugarcane is crush 10-11 liters of ethanol can be obtain from it.

This ethanol can then be directly converted to butanol by using Ruthenium diphosphile catalyst or genetically engineered clostridium bacteria.

Taking India's example,

Sugarcane production in India in the year 2014-15 was estimated to be 342.79 million tones.

Taking the conservative values of 340 million tons and 10 liters,

Total ethanol obtained= 34 million tons.

Now considering 94% efficiency of Ruthenium diphosphine

Total butanol obtained= 31.96 million tons.

Now, the total petroleum consumption of India in 2014 was 3,735,000 barrels per day. That equals to 12,313,275,000 barrels in a year considering 365 days.

1 metric ton = 7.15 barrels

So total consumption of India in the year in metric tons = 12,313,275,000/7.15 = 1,722,136,363.64 or 1.722 billion metric tons.

Another discovery made at Tulane University by David Mullin and his team in the Department of Cell and Molecular Biology provides us with another way to improve butanol yield.

The bacteria TU-103 was discovered in animal feaces and was then cultivated for butanol production. The bacteria is a new strain of Clostridium bacteria and has been found to produce butanol directly from cellulose and can also do so in an oxygen filled environment.

Conclusion

By optimizing butanol production and improving ways to produce it, higher yield can be obtained which may be capable of quenching the world's needs of fuel and driving fuel cells from it will provide energy in a greener way for the benefit of the planet.

Figures

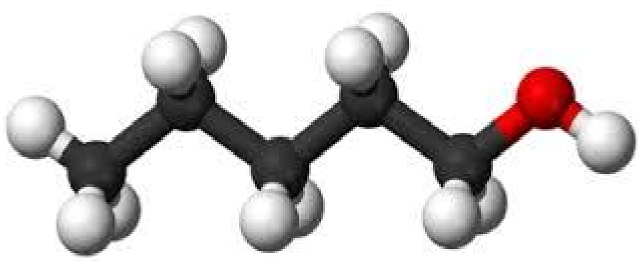

Figure 1. n-butanol

Christine & Scott Gable. Mar 2017. BiobutanolThe Production, Process and Pros and Cons.

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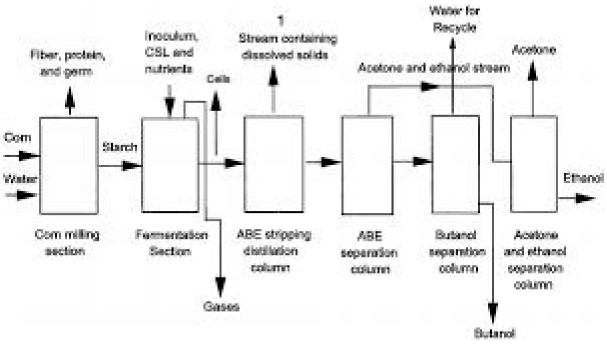

Figure 2. Acetone-Butanol-Ethanol (ABE) Fermentation

N Qureshi, H.P. Balschek. Dec 2001. ABE Production from Corn: A Recent Economic Evaluation.

Fuel	Energy density	Air-fuel ratio	Specific energy	Heat of vaporization	RON	MON
Gasoline and biogasoline	32 MJ/L	14.6	2.9 MJ/kg air	0.36 MJ/kg	91–99	81–89
Butanol fuel	29.2 MJ/L	11.1	3.2 MJ/kg air	0.43 MJ/kg	96	78
Ethanol fuel	19.6 MJ/L	9.0	3.0 MJ/kg air	0.92 MJ/kg	107	89
Methanol	16 MJ/L	6.4	3.1 MJ/kg air	1.2 MJ/kg	106	92

Figure 3. Comparison between different fuels

Matthew Humphries. Aug. 31, 2011. New bacteria promises sustainable gasoline replacement from waste paper, plant matter.

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