Theoretical Investigation on Ammonia as a Secondary fuel for IC Engines

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***Abstract* - Ammonia or azane is a compound of nitrogen and hydrogen with formula of NH3. It is a colorless gas with a characteristic pungent smell. It contributes to the nutritional needs of terrestrial organisms in the form of food and fertilizers. It is also a building block for the synthesis of pharmaceutical products and also in many commercial cleaning products. In these we use gasoline (petrol) as primary fuel and ammonia as secondary fuel. Ammonia has a lower explosive limit (LEL\LFL)is 15% and upper explosive limit(LEL\UFL)is 28%.**

During the combustion process the spark plug ignites the air fuel conflation containing ammonia. Here ammonia is miscible with gasoline thus making the mixture environmental friendly. Hence ammonia acts as a positive catalyst , which promotes the combustion in IC engine. Thus it can concluded that hydrogen energy can stored as gasoline-ammonia fuel blends and reclaim back successfully without any strenuous revamping to existing cadre and end user accoutrements or deportment.

Keywords: Ammonia, Secondary fuel, Environmental friendly, Catalyst, IC engine.

1. INTRODUCTION

Ammonia was first used by the alchemist in the early 8th century. The idea behind using ammonia as a fuel in the IC engine is to enhance or promote the combustion. It was alone used as a fuel for motor buses in Belgium during the year 1943.Ammonia has high octane rating about 120 when compared to gasoline at 86-93.It has relatively low energy density per gallon - about half of gasoline. Ammonia can be used in both gasoline and diesel engines with little modification. Its chemical composition.

Formula: NH_3

IUPAC ID: Azane

Molar mass: 17.031 g/mol

Boiling point: -33.34 °C

Density: 0.73 kg/m³

Melting point: -77.73 °C

Ammonia is a colorless alkaline gas with a characteristic sharp smell. Ammonia is one of the most abundant nitrogen-containing compounds in the atmosphere. It is an irritant with a characteristic pungent odour, which is widely used in industry. It is lighter than air, its density being 0.589 times that of air. It is easily liquefied due to the strong hydrogen bonding between molecules. Ammonia can be produced at an affordable cost using any energy source, including fossil fuels, such as relatively clean natural gas, since the infrastructure for large-scale production and distribution of ammonia already exists worldwide and gasoline vehicles can be retrofitted to run on mostly ammonia at a modest cost.

Fossil fuel as an energy source is not a sustainable solution to future energy requirements and continuously high level of demand for it. Replacing fossil fuels with alternative and renewable fuels will eradicate/decrease the issue of carbon emissions and support a sustainable future. One option is to counter the increase of carbon emissions is the use of bio-fuels, but it may have its side effects when considering deforestation, emissions from pesticide use and also loss of carbon stock. Another option is ammonia that is carbon-free.

The search for alternative fuels (ammonia in this case) paused for a while after 1960: s, but is becoming an interesting area of research again. Ammonia as a fuel has the benefit of being carbon-free. Internal combustion engines, both Spark Ignition and Compression Ignition, have been tested with ammonia as fuel, but ammonia has it´s disadvantages as a fuel. Presently the disadvantages related to ammonia as fuel for an internal combustion engine are Very high auto-ignition temperature (651 °C) Low flame

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speed, High heat of vaporization, Narrow flammability limits (16-25% by volume in air), Toxic.

Ammonia is also used as IC engine fuel due to absence of carbon so that it will reduce Unburnt Hydro Carbon Emissions. Ammonia when combined with gasoline in IC engine results in the promotion of combustion rate thereby reducing the emission of greenhouse gases.

2. PHASES OF AMMONIA

Ammonia are present in three phase but only two phase of Ammonia can be used as fuel.The phase which can be used are liquid phase and gaseous phase. The main reason for not using solid phase is they may form sediment inside the fuel tank and affect the engine. Using other two types will be useful because they undergo combustion easily and they do not need any solute to dissolve it in to liquid phase.

2.1. Liquid fuel

Liquid fuels are combustible or energy-generating molecules that can be harnessed to create mechanical energy, usually producing kinetic energy; they also must take the shape of their container. It is the fumes of liquid fuels that are flammable instead of the fluid. Ammonia as a liquid fuel is a good carrier of hydrogen .Liquid ammonia contains more hydrogen by volume than compressed hydrogen or liquid hydrogen. For example, ammonia is over 50% more energy dense per gallon than liquid hydrogen. So ammonia can be stored and distributed easier than elemental hydrogen. Fueling stations are much easier to convert to dispensing ammonia than elemental hydrogen. Ammonia as a liquid fuel can be used as a liquid combustion promoter thereby increasing the efficiency of the engine.

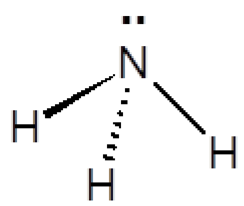
2.2. Gaseous fuel

Gaseous fuel or fuel gas is any one of a number of fuels that under ordinary conditions are gaseous. Many fuel gas are comprised of hydrocarbons such as methane or propane. Ammonia as a gaseous fuel can be used as a transportation fuel. It also has its application in gas turbines and ammonia based fuel cell. Anhydrous ammonia is used extensively in the nitrogen fertilizer industry where it can be applied directly as anhydrous ammonia or can be used as feed stock in liquid nitrogen solutions. Along with hydrogen ammonia is the only gas which on combustion has no carbon emission, as it does not contain carbon. It may contribute to small amount of NOx emissions which can be controlled. Ammonia can also be used in Internal Combustion engines with some minor modifications which would eventually increase its efficiency

3. AMMONIA AS A TRANSPORTATION FUEL

Anhydrous ammonia (ammonia without water)can be a substitute for petroleum as a transportation fuel. It has the potential to make the hydrogen economy, a reality in the near-term, at an affordable cost. It is an energy form that can be made from all primary energy sources. Production sources can be diversified or production can focus on the cheapest, cleanest and greenest source. Ammonia can be used in internal combustion engines with minor modifications. Ammonia itself isn't exactly cheap; it has to be adjusted for its energy content. It can be used in gas turbines and ammonia fuel cells are being developed. Substantial ammonia distribution infrastructure already exists in the Midwest. Other existing infrastructure can be converted. The necessary to support the infrastructure for retail distribution does not exist. This is a problem which should be revamped no matter what direction we chose to move with regard to the fuel that will power our future. As far as safety issues concerns with ammonia, the issues are no more severe than those with gasoline and diesel fuel.Driving the NH3 vehicle is does not make any difference as a driver but to fill up the tanks,where gasoline and ammonia are mixed in the same tank.
Although we've already used with gasoline, it's a remarkable substance. It has a tremendous amount of energy in a small volume, and it's flammable. It bursts into flame or explodes easily under the proper conditions. Ammonia is a much less active fuel. It doesn't combust easily on its own. But, with a small amount of combustion enhancer (gasoline, diesel or pure hydrogen) mixed in, it burns and releases enough energy to drive the engine.
The control system technology makes the NH3 vehicle possible which manages the perfect mixture of fuel for the amount of work the engine does. At start and idle, the engine requires the flammable properties of gasoline, but as the vehicle accelerates (increasing the load) the fuel mixture transitions to predominately ammonia. Rocket engines have also been fueled by ammonia. Similar to propane, anhydrous ammonia boils below room temperature when at atmospheric pressure. So it can be stored and transported as a liquid but used as a gas.

Formula and structure: The chemical formula of ammonia is NH_3, and its molar mass is 17.03 g/mol.



The ammonia molecule has a trigonal pyramidal shape, with nitrogen connected to the three hydrogen atoms. The nitrogen atom has a lone electron pair, which makes ammonia a base. NH_3 is a polar molecule which readily forms hydrogen bonds, making it highly miscible with water.
Occurrence: Ammonia occurs naturally in the body, and is secreted by the kidneys to neutralize excess acid. It is also found in small amounts in rainwater, volcanic areas, and even the atmosphere.

3.1 Ammonia powered Reciprocating Engines

Gasoline and diesel fuel internal combustion engines can be converted to run on ammonia. Reciprocating engines include both diesel and spark-ignition configurations. They are important for both transportation and for stationary uses. The long history of technical development and high production levels have contributed to making reciprocating

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engines a rugged, reliable, and economic choice as a prime mover for CHP applications. Ammonia has a high octane rating. So it does not need an octane enhancer and can be used in high compression engines. However, it has a relatively low energy density per gallon – about half of gasoline. The fuel mileage of ammonia is about half of gasoline's mileage. Along with hydrogen, ammonia is the only fuel that has no carbon emission when combusted because it doesn't contain carbon. It may contribute a small amount of nitrous oxide emission, which can be controlled. Ammonia can also be used in diesel engines. However, ammonia will not compression ignite except at very high pressures. So a small amount of high-cetane (the combustion quality during compression ignition) fuel is added. Research show that a 5 percent biodiesel and 95 percent ammonia blend works well in farm machinery.

4. Gasoline-ammonia fuel blend internal combustion engine

The time taken by gasoline for combustion in IC engine is low when compared to hydrogen. The temperature rises up to 600 degree Celsius and pressure raises between 32 to 50 bars. The compression ratio for gasoline varies from 10:1 to 14:1. Using bi-fuel in engine containing nearly about 30% of ammonia would result in the production of ideal amount of power. Ammonia in general has very high auto ignition temperature, low flame speed narrow flammability limits, high heat of vaporization but when combine with gasoline as secondary fuel these properties may enhance the efficiency of engine.

Initially Ammonia is mixed with Gasoline in fuel tank and this mixture is allowed to enter the combustion chamber through the intake valve. The spark plug will ignite the mixture where the hydrogen content present in Ammonia will boost up the combustion rate thereby increasing the flame speed eventually increasing the efficiency of engine. The final goal of this study is to implement a methodology to ignite Gasoline-Ammonia mixture and have complete combustion thereby reducing the use of conventional fuel.

4.1 Extraction Process of Ammonia

Preparation:

Ammonia is produced commercially by the Haber-Bosch process, in which elemental hydrogen and elemental nitrogen are reacted in the presence of a metal catalyst to give ammonia gas. The reaction is performed at high pressures and high temperature (400–550 °C).

$N_2 + 3H_2 \rightarrow 2NH_3$

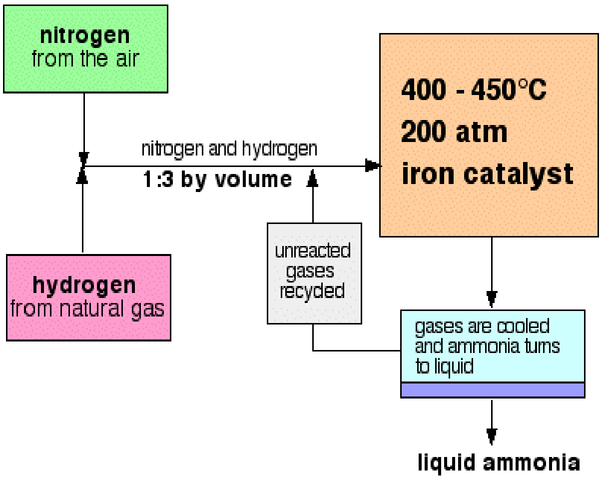

Fig: 4.1 Extraction of Ammonia

4.2 Properties for Ammonia

Physical properties:

Ammonia is a colorless gas with a sharp, penetrating odor. Its boiling point is -33.35 °C, and its freezing point is -77.7 °C. NH_3 gas can be liquefied, however, due to its extremely low boiling point, liquid ammonia must be stored at low temperature and high pressure.

Chemical properties:

Ammonia is a weak base. It combines with various acids to form ammonium salts, which are important chemicals in many industries. Ammonia readily dissolves in water in an exothermic reaction, to form aqueous ammonia solution, also called as ammonium hydroxide (NH_4OH).

$NH_3 + H_2O \rightarrow NH_4OH$

Liquid ammonia is an important non-aqueous solvent, which can dissolve many alkali and alkaline-earth metals to produce blue-colored conductive solutions.

4.3 Uses

Ammonia is the precursor to various important nitrogen compounds, such as urea, amino acids, phenol, acrylonitrile, hydrogen cyanide, soda ash, nitric acid, and many others. It is also used for the production of fertilizers, polymers, synthetic fibers (nylon, rayon), explosives (TNT, nitroglycerin), cleaning agents, and refrigerants.

4.4 Health hazards/ health effects

Although it is widely available in nature and used for many household purposes, ammonia is considered toxic by inhalation. NH_3 fumes have a sharp and pungent odor which can seriously irritate the eyes, nose, mucous membranes and skin, and damage the respiratory tract. At high concentrations, exposure to ammonia gas can cause permanent lung damage and death.

4.5 Safety and Precautions

Ammonia is safer than propane and gasoline thus can be used as transportation. It has strong odors thus the leakage can be detected easily. Ammonia is not carcinogenic. It is less likely to cause fire explosion .Ammonia does not contain carbon thus cannot produce soot while Gasoline can produce carbon soot particles that are hazardous when breathing.

5. RESULT AND DISCUSSION

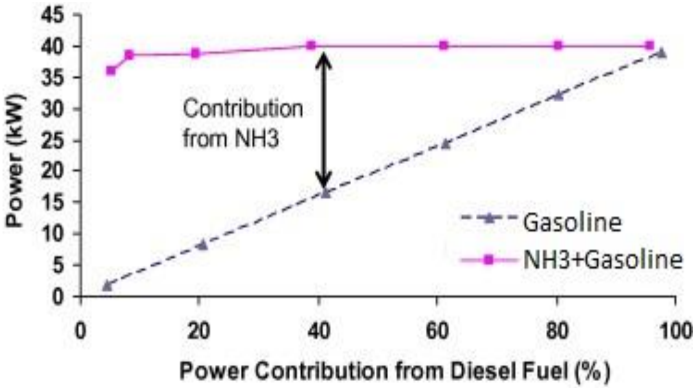

Fig: 5.1 Contribution of Ammonia

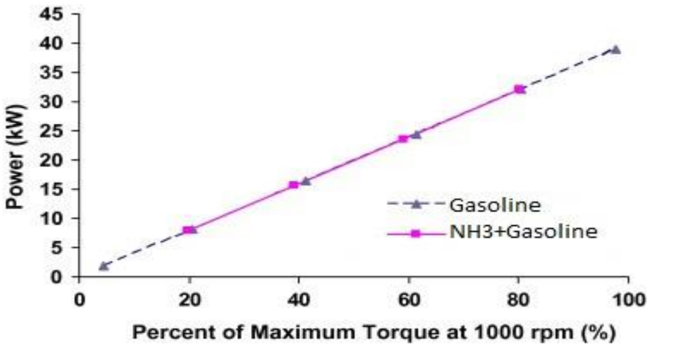

Fig: 5.2 Maximum Torque

Ammonia-gasoline fuel blend system needs minimal equipment modification. This system needs a high pressured single fuel tank to store the fuel blend and leak proof re-filling system. Dual fuel storage systems inject ammonia in to the combustion chamber at the point of injection or on-board catalytic reforming of hydrogen from ammonia. Two major drawbacks of this system is the new injector system and the necessity to have second on board fuel storage tank for ammonia. The third system uses metal amine complexes to store ammonia on board and then uses heating and decomposing mechanism to release ammonia from the metal amine complex and break part of released ammonia in to hydrogen and nitrogen. There are several drawback of this system when compared to other two. It needs two additional systems to provide fuel and also the initial energy needed for these systems has to be obtained from a secondary energy source. When all these three system are considered, it is evident ammoniagasoline fuel blend system requires least amount of new mechanisms/equipment to be utilized. Therefore it can be concluded that ammonia-gasoline fuel blends could be used to commercialize ammonia as an alternative energy source in a short period of time.

6. CONCLUSION

The current study demonstrates that Ammonia fueled vehicles could be a promising near-term alternative for light delivering vehicle because of its significant contribution in reducing carbon di oxide emission compared with vehicles of carbon based fuels. Ammonia does not produce any solid waste during combustion in current ICEs. Due to Haber's process, potential production of Ammonia is possible. Car and truck engines designed specifically to operated on Ammonia fuel are fuel efficient than even the best gas and diesel engines of today, this means more miles per litters for all future vehicles. The effect of combustion of hydrogen generated by an ammonia dissociation catalyst on engine performance and exhaust emissions in a spark-ignition engine using ammonia-gasoline was investigated. An ammonia dissociation catalyst coated with 2% ruthenium on 3.175-mm alumina pellets were used in order to analyze the effect of the catalyst as an ammonia cracker to decompose ammonia into hydrogen and nitrogen. Results show that combustion of hydrogen generated by an ammonia dissociation catalyst resulted in improved engine performance and reduced exhaust emissions. The conversion rate of ammonia into hydrogen was affected by the flow rate of ammonia, and the catalyst was very effective at low to medium flow rates, resulting in significantly increased engine power and decreased fuel consumption. With the use of the catalyst, emissions of CO, HC, NH_3 and NOx were reduced considerably. Overall, it was demonstrated the ammonia dissociation catalyst can enable ammonia to be used as a hydrogen carrier for use in internal combustion engines effectively

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