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PERFORMANCE ANALYSIS AND FEASIBILITY STUDY OF BIO-BUTANOL AS A POTENTIAL SUBSTITUTE TO GASOLINE IN SPARK IGNITION ENGINE

SUHAIL SHAMSUDHEEN[1], SHARIQUE MN[2], NIHAL CP[3], MUHAMMED FASIL VP[4], JOHN PAUL[5]

[1,2,3,4]Students, Department of Mechanical Engineering, MES College of Engineering, Kuttippuram, Kerala
[5]*Assistant Professor, Department of Mechanical Engineering, MES College of Engineering, Kuttippuram, Kerala*

Abstract - *The demands of energy consumption, exaggerate depletion of fossil fuels energy sources and serious environmental issues are the main common problems to be debated currently in the world. So the main objective of this project is to replace the current gasoline by biobutanol. Biobutanol can be produced by A-B-E process and by alcoholic fermentation of feedstock. Since the properties of biobutanol are approximately similar to that that of gasoline. We can also transform food waste and feedstock to a useful fuel. Biobutanol fuels are more environment friendly than gasoline. If the production of biobutanol is increasd, the cost of biobutanol can be given at lower price than gasoline. So energy can be easily decentralized. The main aim of this paper is to analyze the performance, emission characteristics and road testing of 100% biobutanol in SI engine and replace the gasoline by biobutanol which is more promising way of waste management.*

Key Words: *A-B-E Process, Applications, Biofuel, Decentralization, Substitute, Waste management etc.*

1. INTRODUCTION

Butanol from biomass is called biobutanol. It can be used in unmodified gasoline engines. Butanol (C_4H_9OH) is a colourless, flammable alcohol. It is widely used in industry, as a solvent. *Biobutanol* is a four-carbon alcohol produced by the fermentation of biomass. Its properties are similar to that of gasoline. Some gasoline-powered vehicles can even use biobutanol without being modified. Biobutanol can be blended with gasoline in concentrations up to 11.5% by volume. Biobutanol exhibits the potential to reduce carbon emissions by 85% when compared to gasoline, thus making it a viable and suitable alternative to gasoline and gasoline-ethanol blended fuels. The production of biobutanol can be carried out in ethanol production facilities.

Biobutanol is an emerging type of biofuel that can be utilised in the modern era as a potential substitute to gasoline and it is also show a great characteristic features in emission standards. It is produced from the corn stalks, beer wastes, sugar wastes and also municipal food wastes. This project can be applied for the enhancement of sustainable development by paving way to use the degradation of waste in an efficient manner and produces the fuel which is economical and eco-friendly that will aid for development of the nation.

1.1 APPLICATIONS OF BIOBUTANOL

- Biobutanol can also be used as an industrial solvent and chemical feedstock.
- Possible other applications may include paints/coatings, resins, plasticizers, pharmaceuticals, food grade extractants, chemical intermediates and herbicides.

2. PREPARATION OF BIOBUTANOL

Biobutanol is produced by microbial fermentation, similar to bioethanol, and can be made from the same range of sugar, starch or cellulosic feedstocks. The most common method of producing biobutanol is the fermentation of simple sugars in biomass feedstock. Butanol is a by-product of this process in addition to ethanol and acetone. The process, known as ABE (Acetone Butanol Ethanol), uses the microbial species Clostridium acetobutylicum.

In addition to butanol, these organisms also produce acetone and ethanol, so the process is often referred to as the "ABE fermentation". The main concern with *Clostridium acetobutylicum* is that it easily gets poisoned at concentrations above 2% of biobutanol in the fermenting mixture. This hinders the production of bio-butanol in economically viable quantities.

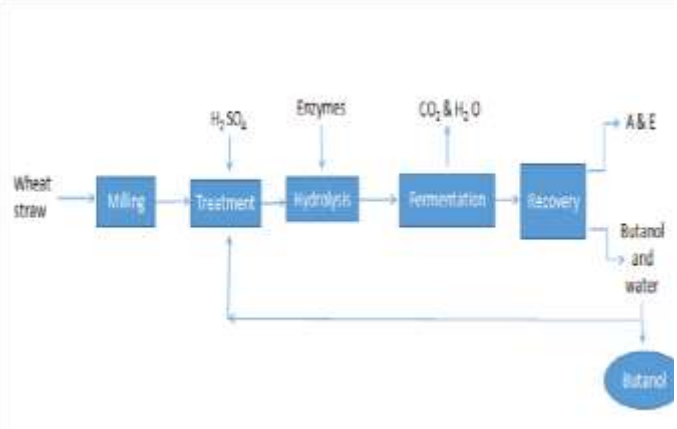


Fig 1. A-B-E Process

2.1 YIELD OF BIOBUTANOL

The biobutanol is produced from the biological waste residues like starch and food materials. Normally the household wastes are mainly considered for this and it can be received from other sources like hotels and wastes from the sugarcane industries and glucose manufacturing plants. The starch or glucose, which is produced from the wastes, varies based on its features and physical features. The yield also depends upon the raw materials used in the process. The pure sugar, molasses, corn, cane juices are used for the preparation.

- Total Solvent produced = 11.3 g/L.
- Biobutanol present in the solvent = 4.8 to 7.6 g/L.
- Total sugar yield obtained after biomass pretreatment = 56 g/L.(1 kg of paddy stalk was pretreated with 0.094 kg of chemical catalyst and 4.63 kg of water for four hour.)
- Quantity of inoculant to produce biobutanol from hydrolysate = 0.463 kg.
- Residual sugar = 21.25 g/L
- Biobutanol yield = 0.14 kg.

Consider an example: The solvent produced by the acid hydrolysis contains 11.3 grams of sugar in a 1000 ml of the total solvent. The biobutanol present in the total of the solvent will be 4.8 to 7.6 gram that can be separated by the distillation of the distilled acid mixture. It is a tedious and careful procedure so that only the required amount of pre biobutanol is produced. The sugar that is present in the total solvent will be 56 grams per litre. If one kilogram of paddy is pretreated with the chemical catalysts like hydrolysate 10 g, beef extract 10 g, yeast extract 3 g, dextrose 5 g, sodium chloride 5 g, sodium acetate 3 g, soluble starch 1 g, Lcysteine hydrochloride 0.5 g and a 4.63 kg of water is added to the prepared solution. The inoculants whisch is the acetobacterium butylicum mixture needed for the biobutanol separation is 0.463 kg. Then the residual sugar obtained is 21.25 grams per litre. The biobutanol extracted from the total solution is 0.14 kg.

3. BIOBUTANOL AS A FUEL

Biobutanol is an alcohol obtained from fermentation of feedstocks and other wastes. The properties of biobutanol make it an efficient substitute to gasoline in Spark Ignition engines. Biobutanol contains four carbon atom ,thus it can improve their fuel properties like RON, LHV etc.,

Biobutanol has relatively high-energy content among other gasoline alternatives. When compared with ethanol, bio butanol has a lower vapor pressure, which means lower volatility and evaporative emissions. Biobutanol can be produced domestically from a variety of feedstocks and this has increased the energy security. Carbon dioxide captured by growing feedstocks reduces overall greenhouse gas emissions by balancing carbon dioxide released from burning biobutanol.

The various properties like flash and fire point, dynamic viscosity, self ignition temperature and calorific value of gasoline, bio butanol, ethanol and diesel were determined and the results obtained suggests that gasoline has a much similar properties to that of bio butanol and hence we came to establish that bio butanol will be the best suitable alternative to gasoline. The test results are given in table 1.

Table 1. Comparison of properties

Properties	Gasoline	Diesel	Butanol	Ethanol
Flash point(°C)	-43	52	35	16.6
Fire point(°C)	-23	78	45	26

Dynamic viscosity (mPa.s)	1.11	3.35	2.5	.983
Calorific value(MJ/Kg)	46.6	45.5	37.3	29.7
Self ignition temperature (°C)	280	256	343	363

3.1 METHODOLOGY

In this stage, focus is given on using the bio butanol in SI engines. The methodology is much similar to that of gasoline in SI engines. The fuel from the fuel tank is passed to the carburetor from where air-fuel mixing takes place. The required air-fuel ratio is 11.2. Then this mixture is moved through a preheater. The purpose of preheater is to heat the mixture prior to its entry into the combustion chamber. This preheating is done in order to reduce the viscosity otherwise which may affect the flow and smooth injection of air-fuel mixture. The variation of density with temperature is shown in Fig.3.The preheater is powered by the battery installed in the vehicle. The combustion is similar to that of gasoline in SI engine. The diagrammatic representation of the entire process is given in Fig.3.

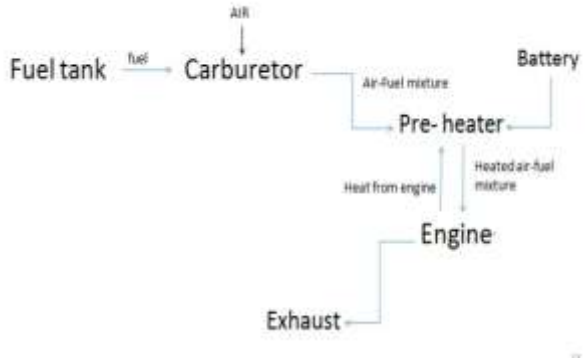


Fig 2. Process Layout

4. TESTING OF BIOBUTANOL

To study the properties of biobutanol several tests were conducted on it. The tests are done in order to identify the physical and chemical properties of biobutanol as a fuel. The tests that we have done include the following:

4.1 DETERMINATION OF RELATIVE AND KINEMATIC VISCOSITIES USING REDWOOD VISCOMETER.

Density of water was found at room temperature using specific gravity bottle method. The oil is filled at measured level. The orifice is opened and time taken to collect specific amount was found. After filling the oil to required level, the temperature of oil was kept constant and time to collect 50cc of oil was noted. The experiment is repeated for different temperature of oil.

Inference: Kinematic viscosity and absolute viscosity decreases with increase in temperature. This is due to increase in temperature cause kinematic energy of oil molecules to get increased and hence become more mobile.

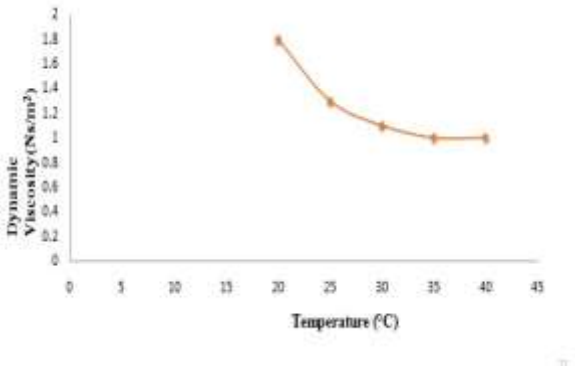


Fig 3. Dynamic Viscosity Vs Temperature graph

4.2 FLASH AND FIRE POINT USING PENSKY MARTENS CLOSED CUP APPARATUS

The flash point of any oil is defined as the lowest temperature at which it forms vapors and produces combustible mixture with air. The higher flash point temperature is always desirable for any lubricating oil and lower flash point for any fuel. If the oil has the lower value of the flash point temperature, it will burn easily and forms the carbon deposits on the moving parts. The minimum flash temperature of the oil used in I.C engines varies from 200°Cto 250°CWhen the oil is tested by using the open cup apparatus, the temperature is slightly more than the above temperatures.

The fire point of any oil is the lowest temperature at which oil just begins to burn continuously. Flash and

fire point temperature differs by 3°Cto 5°Cwhen it is tested. However a greater difference may be obtained if some additives are mixed with oil .The flash and the fire point temperatures depends upon the volatility of the oil.

Fire and flash points are good indication of relative flammability of the oil and also limits the operating temperature of oil. Except for the safety from fire hazards, they do not have any significance for engine operation.

Table 2. Results of Flash and Fire point test

Sl. No	Temperature of Biobutanol in ^{O}C	Observation-No Flash/Flash/Fire
1	30	No Flash
2	32	No Flash
3	33	No Flash
3	34	No Flash
4	35	Flash
5	40	No Fire
6	41	No Fire
7	42	No Fire
8	43	No Fire
9	44	No Fire
10	45	Fire

Thus,

- The flash point temperature of the given sample of oil is **35^{o}** C
- The fire point temperature is of the given sample of oil is **45^{o}C**

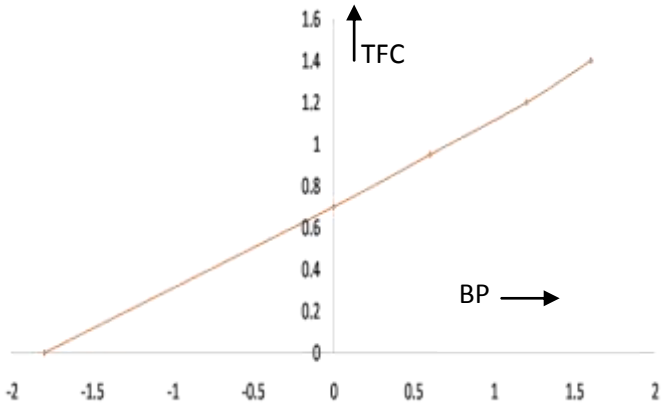
4.3 LOAD TEST ON SI ENGINE

The load test has been conducted to analyse the fuel properties and to calculate the efficiencies like brake power, mechanical, thermal, indicated power etc. From the data observed we can conclude that the bio butanol has a great fuel properties and it satisfies the conditions necessary for a fuel to be used in an automobile engine. The brake power gives the details about the efficiency of the internal combustion engines with the shaft ouput. It gives the rate of fuel consumption to the power produced.

From the specific fuel consumption data it provides details like the amount about the fuel efficiency of any engine that burns the fuel to produce a specific output. From the data obtained by running biobutanol as prime fuel in S.l engine it shows a great similarity with the gasoline. We can observe that the bio butanol runs smoothly and it does not show any kind of error or any problems in the working and also in the aftermath. The fuel consumed by the engine is particularly lesser than the gasoline. The emission of CO and other pollutant is way lesser than using other fuels.

When the brake power increases simultaneously the fuel consumption also increases linearly. From the SFC and brake power analysis it gives a parabolic curve which shows that increasing torque reduces the fuel efficiency. The thermal efficiency is also increased by the raise in brake power because increasing load will more work to be done and it will increase the heat emission of the engine. The indicated thermal efficiency first increases but later, it decreases.

Fig 4. TFC v/s BP Graph



Inference: The graphs were plotted based on the datas from the experiments. In TFC Vs BP graph (Fig 4), the TFC is proportional to Brake power and uniformly varies according to load which is applied uniformly applied and here BP is not uniform which causes SFC to be non-uniform as shown in Fig 5. The indicated

thermal efficiency obtained from experiment is high due to the effect of frictional power, Fig 6.

Initially the indicated thermal efficiency is increasing with increasing brake power. After a certain period the indicated thermal efficiency falls down, this is because the engine gets heated up when it runs for a particular time after the starting and this causes the engine's indicated thermal efficiency to fall down or decrease.

Fig 5. SFC v/s B.P Graph

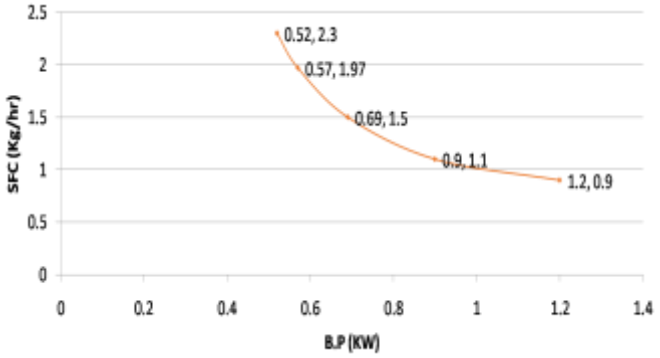
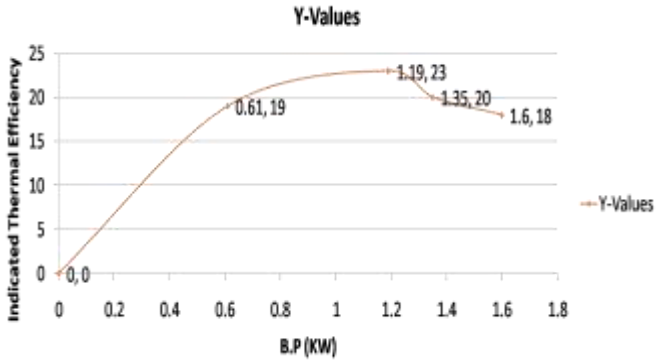


Fig 6. Indicated Thermal Efficiency v/s B.P graph



4.4 PHYSICOCHEMICAL PROPERTIES OF GASOLINE, BIOETHANOL AND BIOBUTANOL

Biobutanol is considered to be a superior biofuel when compared to ethanol and has a larger potential than ethanol for gasoline replacement, due to superior fuel properties. The physicochemical properties indicate the quality of fuel to be combusted in SI engine

4.4.1 OXYGEN CONTENT

The oxygenated fuel i.e. alcohol fuel has higher oxygen content i.e. biobutanol has 21.59% oxygen and bioethanol has 34.73% oxygen promotes higher complete combustion and lower exhaust emissions.

4.4.2 OCTANE NUMBER

Bioethanol has higher octane number compared to biobutanol and gasoline. High-octane fuel prevents the premature ignition that causes knocking which can damage the engine.

The higher octane rating gives bioethanol advantages in improving the thermal efficiency. However, it emits 2-4 times higher of acetaldehydes than gasoline hence it is highly corrosive.

4.4.3 REID VAPOUR PRESSURE

Alcohol fuels, i.e. bioethanol and biobutanol have lower RVP as compared to gasoline, thus they bring problems when starting cold engine especially during cold weather. However, bioethanol is easier to evaporate relative to biobutanol. It means that it emits more volatile organic compound into atmosphere as pollution especially during summer hot day.

This volatile organic compound along with NO_x gases is converted by ultraviolet radiation into ground ozone pollution. Thus, lower vapour pressure of biofuel brings both beneficial and consequences to the performances.

4.4.4 LOWER HEATING VALUE

Carbon, C and hydrogen, H are liable to raise the heating value when the oxygen is declining during combustion. The energy content of biobutanol is approximately 82% of gasoline energy, while bioethanol has 65% of gasoline energy. Therefore, these biofuels give higher fuel consumption as compared to gasoline.

4.4.5 DENSITY

Density of bioethanol and biobutanol are 794 Kg/m^3 and 809 Kg/ m^3 respectively which are higher than gasoline, results in enhancing the volumetric fuel economy fairly.

4.4.6 BOILING POINT

As the carbon chain length increases, the boiling point of alcohols increases. The boiling point of biobutanol and bioethanol are 117°C and 78.3°C respectively. The boiling point of each alcohol influences their evaporative behaviour.

4.4.7 HEAT OF VAPORIZATION

HoV of bioethanol and biobutanol are quite higher than gasoline, thus reducing the air-fuel mixture temperature during intake stroke. Higher HoV improves knock resistance and achieves better volumetric efficiency of the engine. However, higher HoV of bioethanol and biobutanol leads to problems when engine start-up including when running cold engine especially during cold weather due to the cooling effect of the air-fuel mixture at ambient temperature. Besides that, higher latent HoV promotes higher emissions of organic gases.

4.4.8 VISCOSITY

Viscosity of biobutanol and bioethanol is higher than gasoline. These properties may attribute the fuel injection system due to higher flow resistance at lower temperature combusted in SI engine.

4.4 ROAD TEST USING BIOBUTANOL

We have conducted a road test by using biobutanol as a fuel. The bike on which we performed the road test is Discover model which is manufactured by Bajaj Automobiles. During the road test we found no issues during running. There was a slight decrease in pulling of the vehicle but it doesn't affect the performance of the bike. We also find it hard to start the engine, this is because biobutanol is having a higher viscosity. This problem can be solved by preheating the fuel. When the temperature rises the viscosity decreases and hence the smooth running can be achieved.

During our road testing we tried riding the bike through various topographies and in varying speed conditions. We were able to achieve a speed around 75km/hr without any issues. The performance of the bike in climbing a hilly road were also found to be satisfactory. Hence we can use this fuel as a potential substitute to gasoline.

4.6 EMMISSION TEST

Exhaust emission consists of undesirable foreign substance i.e. flue gas that emitted and discharged into the air as a result of fuel combustion in the internal combustion engine. Excessive release of the undesirable foreign substances into the air will aggravate the air quality, which can causes acid rain, health problem to human and also cause damages to the ecosystem. The combustion gases consist of non-toxic gases, i.e. nitrogen (N_2), water vapour (H_20) and also carbon dioxide (CO_2) that contributes to global warming. The other little parts of unpleasant gases which are toxic and very harmful such as carbon monoxide (CO) discharged from incomplete combustion, hydrocarbon (HC) exhibits from unburned fuel, nitrogen oxides, NO_x reveals from extra combustion temperatures, ozone (O_3) and also particulate matters (PMs), i.e. soot.In spite of that, the amounts of these emissions also depend on the engine design including operating condition.

Table 3. Emmission Test on SI Engine

	EMISSION TEST ON SI ENGINE		
	BUTANOL ACTUAL	PETROL ACTUAL	REGULATION VALUE
CO	2.939	0.133	3.5
HC	4314	1212	4500
O_2	5.478	0.27	0
CO_2	22.341	14.84	0

5. ADVANTAGES AND DISADVANTAGES

5.1 Advantages

- Helps to transform the domestic waste and feed-stock to a useful fuel there by reducing waste management and dependency on fossil fuels.
- Decentralization of energy.
- Reduced carbon emission.
- Vehicles requires less or no modification.
- It's good for global farmers.
- Promotes sustainability.

5.2 Disadvantages

- Less availability and higher cost of bio-butanol due to its low production.
- Alcohol based fuels are not compatible with some fuel system component.

6. FUTURE SCOPE

- Gasoline can be completely replaced by biobutanol in the future.

- For large scale production of biobutanol distillaries should be constructed, so that cost of biobutanol can be reduced significantly.
- Cooperative societies should be encouraged for the collection of grain stalks (paddy, corn, wheat etc.) and sugar yielding crops, so wastage of crops can be reduced.
- Biobutanol fuels are more ecofriendly than gasoline.

7. CONCLUSION

The demands of energy consumption, exaggerate depletion of fossil fuels energy sources and serious environmental issues are the main common problems to be debated currently. In our project, a new promising biobutanol gives a great attraction due to its competitive properties compared to gasoline.

This project indicate that the biobutanol can be completely replaced by gasoline without any modification which helps in improving engine performance and reducing exhaust emission.

Biobutanol contains higher carbon number than bioethanol thus it may improve the fuel properties i.e. RON, LHV, etc. Besides that, the higher flame speed of biobutanol gives higher ICP and HRR than gasoline. Biobutanol fuels are more environmental friendly than gasoline influences to the engine durability and lubricating oil.

The biobutanol gives main problems to the engine such as corrosion on engine parts and contaminated lubricating oil that contributes engine failure. The main disadvantage is that its availability and higher cost due to very low production of biobutanol.

Through the project we gained a lot of practical knowledge regarding biofuels commonly used and its characteristics properties. We feel that the project work is a good solution as it leads to the complete replacement of gasoline by biobutanol in the foregoing future. And we are proud that the future of energy consumption can be solved by our project.

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BIOGRAPHIES

	Suhail Shamsudheen Student, Department of Mechanical Engineering MESCE Kuttippuram.
	Sharique MN Student, Department of Mechanical Engineering MESCE Kuttippuram.
	Nihal CP Student, Department of Mechanical Engineering MESCE Kuttippuram.
	Muhammed Fasil VP Student, Department of Mechanical Engineering MESCE Kuttippuram.

Er. John Paul
Assistant Professor, Department of Mechanical Engineering MESCE Kuttippuram.