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Performance of Biodiesel based Diesel Engines additive with Zirconium Oxide Nanoparticles

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Abstract *- The use of biodiesel as an alternative fuel has gained significant attention due to its renewability, environmental benefits, and reduced carbon emissions. However, biodiesel exhibits lower calorific value, higher viscosity, and incomplete combustion, which can affect engine efficiency and performance. This study investigates the impact of zirconium oxide (ZrO_2) nanoparticles as fuel additives to enhance the combustion, performance, and emission characteristics of a diesel engine running on biodiesel.*
A series of experimental tests are conducted using different concentrations of ZrO_2 nanoparticles blended with biodiesel. Engine performance parameters such as brake thermal efficiency (BTE), brake specific fuel consumption (BSFC), and combustion characteristics are analyzed. Additionally, emission characteristics including NO_x, CO, HC, and particulate matter are evaluated to assess environmental impact.
The results indicate that the addition of ZrO_2 nanoparticles improves combustion efficiency, reduces emissions, and enhances overall engine performance by acting as a catalyst for better fuel atomization and oxidation. This research highlights the potential of nanotechnology in biofuel applications, contributing to cleaner and more efficient diesel engine operation.
Keywords: *Bio-fuel, nano-particles, Jatropha oil.*

I. INTRODUCTION

Since the industrial revolution, different forms of energy have become essential for human beings to maintain a standard of living and to conserve economic growth. In the past few decades, fossil fuels, mainly petroleum-based liquid fuels, natural gas and coal have played an important role in fulfilling this energy demand. However, because of their non-renewable nature, these fossil fuels are projected to be exhausted in the near future. This situation has worsened with the rapid increase in energy demand with significant worldwide population growth. Therefore, the demand for clean, reliable, and yet economically feasible renewable energy sources have led researchers to search for new sources. In this context, biodiesel derived from vegetable oil has drawn attention as a potential alternative for diesel fuel for diesel engines.

II. CURREBT ENERGY SCENARIO

Global energy demand is increasing dramatically because of rising population. In 1980, fuel consumption was 6630 million tons of oil equivalents. It almost doubled in 2012 at 12,239 million tons of oil equivalents. According to the International Energy Agency estimation, global energy demand is expected to increase by 53% by 2030. Currently, a major part of energy demand (88.6%) is fulfilled by fossil fuels, in which crude oil accounts for 33.7%, coal for 30.5%, and natural gas for 24.4%. Conversely, nu-clear energy and hydroelectric energy contribute only small pro-portions at 4.6% and 6.8%, respectively. Over the past 25 years, total energy supply has increased steadily.

A. Biodiesel

It is well known that a considerable amount of biodiesel is produced from edible oils. However, the extensive use of edible oils might lead to some negative impacts such as starvation and higher food prices in developing countries. For instance, in Malaysia the biodiesel refineries have created shortages in palm oil. Therefore the price of palm oil for cooking has risen by 70%. The rising food prices may be beneficial to the poor farm producers but at the same time they are unlikely to benefit the urban poor. Some researchers have pointed out that developing the technology to convert cellulosic materials into biofuels will significantly reduce food shortage problems. In addition to this, the waste edible oil may be made primary feedstock and the fresh edible and non-edible oils should be made supplement feedstock. This may reduce the food shortages significantly. However, many of the researchers agree that non-edible oils are the suitable alternative to edible oils for biodiesel production. Hence, the recent focus is to find non-edible oil feedstock for biodiesel production.

Many of the reviewing papers have tried to report the necessity and feasibility of non-edible oils for biodiesel production. A lot of work is being carried out on biodiesel production from Jatropha oil in countries like India, Malaysia and Indonesia.

However, recent trends and technologies for the production of biodiesel from non-edible oils and the impact of price rise of the food commodities due to the consumption of edible oils for biodiesel have not yet attracted the attention they deserve.

Biodiesel is a renewable and clean burning combustible fuel for diesel engines. It is nontoxic, biodegradable, and virtually free from aromatics and sulfur contents. This is because its primary components are domestic renewable resources such as vegetable oil and animal fats consisting of long-chain alkyl (methyl, ethyl, or propyl) esters. Biodiesel is the mono-alkyl esters of fatty acids that result from animal fats or vegetable oils. In other words, biodiesel (fatty acid ester) is the end result of the chemical reaction caused by mixing vegetable oil or animal fat with an alcohol such as methanol. Together these ingredients produce a compound recognized as a fatty acid alkyl ester. A catalyst such as sodium hydroxide is also necessary in order for the biodiesel to be considered a finished product, and is added with the new compounds to produce biodiesel.

Biodiesel offers many advantages as it is,
- Renewable and energy efficient
- Usable in most diesel engines with no or only minor modifications
- Nontoxic, biodegradable and suitable for sensitive environments

Apart from the above advantages, following are the disadvantages of biodiesel
- Biodiesel has 12% lower energy content than diesel.
- Due to the high oxygen content in biodiesel, it produces relatively higher NOx.
- Biodiesel can cause corrosion in vehicle material.

III. PRODUCTION TECHNOLOGIES

Globally, there are many efforts to develop and improve vegetable oil properties in order to approximate the properties of diesel fuels. It has been remarked that high viscosity, low volatility and polyunsaturated characters are the mostly associated problems with crude vegetable oils. These problems can be overcome by four methods; pyrolysis, dilution with hydrocarbons blending, Micro-emulsion, and transesterification.

A. Pyrolysis

Pyrolysis is the thermal decomposition of the organic mat-ters in the absence of oxygen and in the presence of a catalyst. The paralyzed material can be vegetable oils, animal fats, natural fatty acids or methyl esters of fatty acids. Many investigators have studied the pyrolysis of triglycerides to obtain suitable fuels for diesel engine. Thermal decomposition of triglycerides pro-duces alkanes, alkenes, alkadines, aromatics and carboxylic. It has been observed that pyrolysis process is effective, simple, wasteless and pollution free.

B. Dilution

Mainly, vegetable oils are diluted with diesel to reduce the viscosity and improve the performance of the engine. This method does not require any chemical process. However a blend of 20% vegetable oil and 80% diesel fuel was successful. The use of blends of diesel fuel with sunflower oil, coconut oil, African pear seed, rice bran oil, PP (Pistachia Palestine), waste cooking oil, palm oil, soybean oil, cottonseed oil, rubber seed oil, rapeseed oil, J. curcas oil, P. pinnata oil has been widely used.

C. Micro-emulsion

A micro-emulsion is defined as a colloidal equilibrium dispersion of optically isotropic fluid microstructure with dimensions generally into 1–150 nm range formed spontaneously from two normally immiscible liquids and one and more ionic or more ionic amphiphiles. Micro-emulsions using solvents such as methanol, ethanol, hexanol, butanol and 1- butanol have been investigated by many researchers. Micro-emulsion with these solvents has met the maximum viscosity requirement for diesel fuel.

D. Transesterification

Transesterification is regarded as the best method among other approaches due to its low cost and simplicity. Biodiesel is the main product of this process. Transesterification consists of a number of consecutive, reversible reactions. In these reactions, the triglycerides are converted step wise to diglycerides, monoglyceride and finally glycerol which sinks to the bottom and biodiesel which floats on top. Glycerol is an important by-product and can be burned for heat or be used as feedstock in the cosmetic industry. In this reaction, methanol and ethanol are the two main light alcohols used for transesterification process due to their relatively low cost. However, propanol, isopropanol, tert-butanol, branched alcohols and octanol and butanol can also be employed but the cost is much higher.

In this reaction, 100 lb of fat or oil are reacted with 10 lb of a short chain alcohol in the presence of a catalyst to produce 10 lb of glycerin and 100 lb of biodiesel. Generally, transesterification process includes two main processes; catalytic and non-catalytic method. A catalyst is used to commence the reaction. The catalyst is vital as alcohol is barely soluble in oil or fat. The catalyst enhances the solubility of alcohol and thus increases the reaction rate. Alkaline catalysts include catalysts such as NaOH, NaOCH3, KOCH3, KOH, NaMeO and K2 CO3. Most of the biodiesel producers use sodium hydroxide or potassium hydroxide. . An alkaline catalyst proceeds at around 4000 times faster than with the same amount of acid catalyst. Moreover, this method can achieve high purity and yield of biodiesel product in a short time (30–60 min). Therefore, it dominates the current biodiesel production methods. However, to use alkaline catalysts, free fatty acid (FFA) level should be below a desired limit (ranging from less than 0.5% to less than 3%). Beyond this limit the reaction will not take place and the product formed will be soap and water instead of esters and the yield of esters will be too less. In addition to, this reaction has several drawbacks; it is energy intensive; recovery of glycerol is difficult; the catalyst has to be removed from the product; alkaline wastewater requires treatment and the level of free fatty acids and water greatly interfere with the reaction

Acid catalysts include sulfuric, hydrochloric, ferric sulfate, phosphoric and organic sulfonic acid. Some researchers have claimed that acid catalysts are more tolerant than alkaline catalysts for vegetable oils having high free fatty acids and water. Therefore, acid catalyst is used to reduce the free fatty acids contents to a level safe enough for alkaline transesterification which is preferred over the acid catalyst after the acid value is reduced to the desired limit. It has been reported that acid-catalyzed reaction gives very high yield in esters. However, the reaction is slow (3–48 h). It has been reported that the homogeneous transesterification consumes large amount of water for wet washing to remove the salt produced from the neutralization process, and the residual acid or base catalyst. Nevertheless, there are many companies around the world commercializing this technology because of its relatively lower energy.

IV. BIODIESEL- VARIOUS SOURCES

A. ‘Biodiesel from non-edible sources

It is estimated that about 84% of the biodiesel production is obtained globally by rapeseed oil, which happens to be edible oil. Similarly other edible oils such as sunflower oil, palm oil and soybean oil also contribute substantially. Since more than 95% of biodiesel is produced from edible oils, many activists are claiming that it is not only conversion of edible oil into biodiesel but also conversion of food into fuel. Recently, non-governmental organizations and social and environmental activists have started to argue the harmful effects of biodiesel production, not only from edible oils but from non-edible oils as well. They argue that usage of edible oils would lead to food starvation and that of non-edible oils would cause deforestation and destruction of the ecosystem. However, to overcome this devastating situation or at least to minimize food shortages, researches have been focused toward production of biodiesel from non-edible feedstock. Several ever-green trees producing non-edible oils can be cultivated in non-arable land. In fact, many Indian states have decided to reserve a total of 1.72 million hectares of land for the cultivation of Jatropha. Furthermore, small quantities of Jatropha biodiesel are already being used successfully by state public transport buses including the railways. Following are few non-edible feedstock.

B. Jatropha Curcas

Jatropha curcas is a draught-resistant tree mainly found in Central and South America, South-east Asia, India and Africa. It is a plant with multipurpose uses and considerable potential for biodiesel production. The high free fatty acid contents of the jatropha crude oil could be reduced by esterification. Transesterification of the esterified oil gives yield of jatropha biodiesel above 99%. The biodiesel produced from Jatropha curcas L. does have similar properties to that of petroleum diesel.

C. Pongamia Pinnata

Pongamia pinnata is a fast growing leguminous tree with a high potential for oil and growth on marginal land. It is an underutilized plant which grows in many parts of India. Applying dual-step transesterification would result in a yield of 96.6–97% biodiesel. The important fuel properties lie within the limit set by ASTM standards and German biodiesel standards. The large-scale cultivation of the Pongamia pinnata could make the non-edible feedstock cheaper for biodiesel production*Jatropha Curcas*

D. Madhuka Indica

Madhuca indica is a non-edible oil with higher free fatty acid contents (19%) available largely in central and northern plains and forests of India. Madhuca has two major species, indica and longifolia. The methyl esters of Madhuca indica could be used as fuel for internal combustion engines in place of diesel without any modifications on the engines.

E. Michelia Champaka

Jatropha Michelia champaca is a tall evergreen tree found in China, Burma and throughout India. It is also known as svarna champa. The seeds of michelia are a rich source of oil (45%). The flowers of the tree possess excellent fragrance and hence are used in perfume industry also. The saponification values (SV), iodine value (IV) and cetane number (CN) of the methyl esters Michelia champaca indicate its suitability for biodiesel production.

TABLE I. FUEL PROPERTIES

SL.NO	FUEL PROPERTIES	DIESEL	JATROPHA SEED OIL
1	SPECIFIC GRAVITY	0.842	0.9186
2	DENSITY (KG/M3)	840	917
3	KINEMATIC VISCOSITY CST@40 °C	2.44	35.98
4	KINEMATIC VISCOSITY CST@80 °C	71	229
5	FIRE POINT (°C)	103	273
6	CETANE VALUE	46	23-41
7	CALORIFIC VALUE (MJ/KG)	45.343	39.071

Fig. 1. Scanning Electron Microsscope(SEM) image of Zirconia nano additives

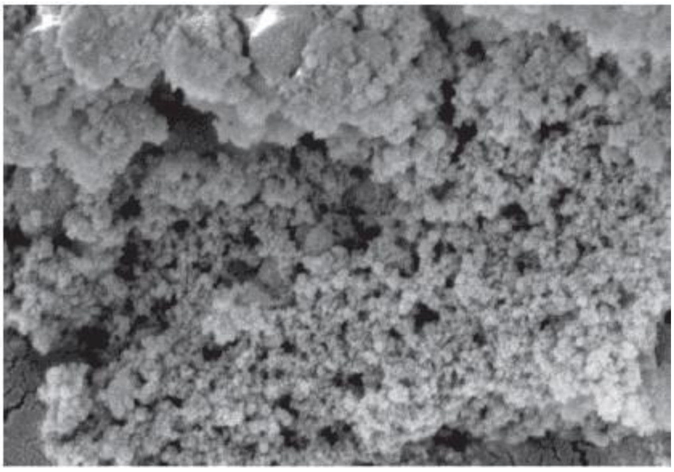
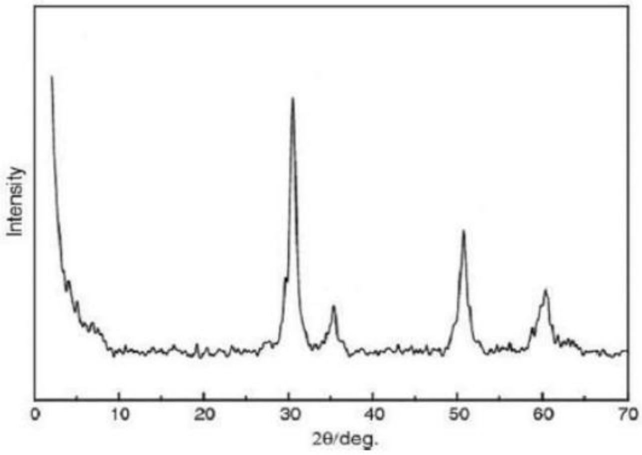


Fig. 2. XRD pattern for zirconium oxide nanoparticles



REFERENCES

[1]. Nadir Yilmaz, "Performance and emission characteristics of a diesel engine fuelled with biodiesel–ethanol and biodiesel–methanol blends at elevated air temperature''. Fuel 94 (2012) 440-443

[2]. Nadir Yilmaz, Tomas M.Sanchez '' Analysis of operating a diesel engine on biodiesel–ethanol and biodiesel–methanol blends'' Energy 46 (2012) 126-129

[3]. Jincheng Huang , Yaodong Wang, Shuangding Li , Anthony P, Roskilly , Hongdong Yu , Huifen Li" Experimental investigation on the performance and emissions of a dieselengine fuelled with ethanol– diesel blends" Applied Thermal Engineering 29 (2009) 2484–2490.

[4]. J.Sadhik Basha and R.B. Anand. "Effects of nanoparticle additive in the water-diesel emulsion fuel on the performance, emission and combustion characteristics of diesel engine" International Journal of vehicle design. 2012 Vol 59, No. 2/3, pp.164-181

[5]. J.Sadhik Basha and R.B. Anand. "Role of nanoadditive blended biodiesel emulsion fuel on the working characteristics of a diesel engine" Journal of renewable sustainable energy 3, 023106 (2011)

[6]. S. Imtenan , H.H. Masjuki, M. Varman, M.A. Kalam , M.I. Arbab, H. Sajjad, S.M. Ashrafur Rahman "Impact of oxygenated additives to palm and jatropha biodiesel blends in the context of performance and emissions characteristics of a light-duty diesel engine" Energy Conversion and Management 83 (2014) 149–158.

[7]. H.K. Rashedul , H.H. Masjuki, M.A. Kalam, A.M. Ashraful, S.M. Ashrafur Rahman, S.A. Shahir "The effect of additives on properties, performance and emission of biodiesel fuelled compression ignition engine" Energy Conversion and Management 88 (2014) 348–364. .