Scientific Journal Impact Factor (SJIF) : 3.518
International Journal of Modern Trends in Engineering and Research
ISSN (ONLINE) : 2349 - 9745 ISSN (PRINT) : 2393 - 8161

PERFORMANCE AND EMISSION ANALYSIS OF COTTONSEED OIL METHYL ESTER IN A DIESEL ENGINE

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Abstract-In this study, performance and emissions of cottonseed oil methyl ester in a diesel engine was experimentally investigated. For the study, cottonseed oil methyl ester (CSOME) was added to diesel fuel, numbered D2, by volume of 5%(B5), 20%(B20), 50%(B50) and 75%(B75) as well as pure CSOME (B100). Fuels were tested in a single cylinder, direct injection, air cooled diesel engine. The effects of CSOME-diesel blends on engine performance and exhaust emissions were examined at various engine speeds and full loaded engine. The effect of B5, B20, B50, B75, B100 and D2 on the engine power, engine torque, bsfc's and exhaust gasses temperature were clarified by the performance tests. The influences of blends on CO, NO_x, SO_2 and smoke opacity were investigated by emission tests. The experimental results showed that the use of the lower blends (B5) slightly increases the engine torque at medium and higher speeds in compression ignition engines. However, there were no significant differences in performance values of B5, B20 and diesel fuel. Also with the increase of the biodiesel in blends, the exhaust emissions were reduced. The experimental results showed that the lower contents of CSOME in the blends can partially be substituted for the diesel fuel without any modifications in diesel engines.

I. ALTERNATIVE FUELS

It is known as non-conventional or advanced fuels, are any materials or substances that can be used as fuels, other than conventional fuels. Conventional fuels include: *fossil fuels* (petroleum (oil), coal, propane, and natural gas), as well as nuclear materials such as uranium and thorium, as well as artificial radioisotope fuels that are made in nuclear reactors.

Some well-known alternative fuels include biodiesel, bio-alcohol (methanol, ethanol, butanol), chemically stored electricity (batteries and fuel cells), hydrogen, non-fossil methane, non-fossil natural gas, vegetable oil, and other biomass sources.

Biodiesel

Biodiesel is made from animal fats or vegetable oils, renewable resources that come from plants such as, soybean, sunflowers, corn, olive, peanut, palm, coconut, safflower, canola, sesame, cottonseed, etc. Once these fats or oils are filtered from their hydrocarbons and then combined with alcohol like methanol, biodiesel is brought to life from this chemical reaction. These raw materials can either be mixed with pure diesel to make various proportions, or used alone. Despite one’s mixture preference, biodiesel will release smaller number of pollutants (carbon monoxide particulates and hydrocarbons) than conventional diesel, because biodiesel burns both cleanly and more efficiently. Even with regular diesel’s reduced quantity of sulfur from the ULSD (ultra-low sulfur diesel) invention, biodiesel exceeds those levels because it is sulfur-free.[4]

Hydrogen

Main article: Hydrogen fuel

Hydrogen is an emission less fuel. The byproduct of hydrogen burning is water, although some mono-nitrogen oxides NOx are produced when hydrogen is burned with air.

HCNG

Main article: HCNG

HCNG (or H2CNG) is a mixture of compressed natural gas and 4-9 percent hydrogen by energy.

Liquid nitrogen

Liquid nitrogen is another type of emission less fuel.

Compressed air

The air engine is an emission-free piston engine using compressed air as fuel. Unlike hydrogen, compressed air is about one-tenth as expensive as fossil oil, making it an economically attractive alternative fuel.

Natural Gas Vehicles

Compressed natural gas (CNG) and Liquefied Natural Gas (LNG) are two a cleaner combusting alternatives to conventional liquid automobile fuels.

CNG Fuel Types

CNG vehicles can use both renewable CNG and non-renewable CNG.

Conventional CNG is produced from the many underground natural gas reserves are in widespread production worldwide today. New technologies such as horizontal drilling and hydraulic fracturing to economically access unconventional gas resources, appear to have increased the supply of natural gas in a fundamental way.

II. COTTONSEED OIL

Cottonseed oil is a cooking oil extracted from the seeds of cotton plants of various species, mainly *Gossypium hirsutum* and *Gossypium herbaceum*, that are grown for cotton fiber, animal feed, and oil. Cotton seed has a similar structure to other oilseeds such as sunflower seed, having an oil-bearing kernel surrounded by a hard outer hull; in processing, the oil is extracted from the kernel. Cottonseed oil is used for salad oil, mayonnaise, salad dressing, and similar products because of its flavor stability.

Its fatty acid profile generally consists of 70% unsaturated fatty acids (18% monounsaturated, and 52% polyunsaturated), 26% saturated fatty acids. When it is fully hydrogenated, its profile is 94% saturated fat and 2% unsaturated fatty acids (1.5% monounsaturated, and 0.5% polyunsaturated). According to the cottonseed oil industry, cottonseed oil does not need to be hydrogenated as much as other polyunsaturated oils to achieve similar results.

Properties of cotton seed oil and other fuel

s.no	PROPERTIES	COTTON SEED OIL 100%	JATROPHA (B100)	DIESEL
1.	Specific gravity	0.91	0.8621	
2.	Density (Kg/m^3)	912	856	828
3.	Flash point (oc)	207	174	56
4.	Fire point (oc)	230	180	63
5.	Kinematic viscosity	55.61	5.37	2.68
6.	Calorific value (Mj/Kg)	38.0	39.174	42.96
7.	Melting point	-1		

8.	Iodine value	105	60 to 135	
9.	Cetane no	52.0	46 to 70	51

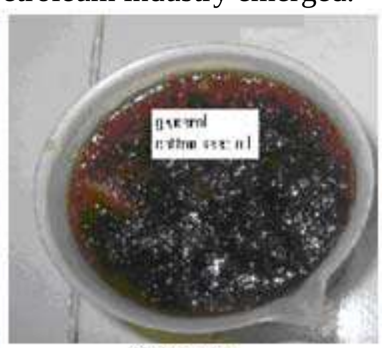
III. HISTORY

The by-product of cotton processing, cottonseed was considered virtually worthless before the late 19th century. While cotton production expanded throughout the 17th, 18th, and mid 19th centuries, a largely worthless stock of cottonseed grew. Although some of the seed was used for planting, fertilizer, and animal feed, the majority was left to rot or was illegally dumped into rivers.

In the 1820s and 1830s Europe experienced fats and oils shortages due to rapid population expansion during the Industrial Revolution and the English blockade during the Napoleonic Wars. The increased demand for fats and oils, coupled with a decreasing supply caused prices to rise sharply. Consequently, many Europeans could not afford to buy the fats and oils they had used for cooking and for lighting. Many United States entrepreneurs tried to take advantage of the increasing European demand for oils and America's increasingly large supply of cottonseed by crushing the seed for oil.

But separating the seed hull from the seed meat proved difficult and most of these ventures failed within a few years. This problem was resolved in 1857, when William Fee invented a huller, which effectively separated the tough hulls from the meats of cottonseed. With this new invention, cottonseed oil began to be used for illumination purposes in lamps to supplement increasingly expensive whale oil and lard. But by 1859, this use came to end as the petroleum industry emerged.

Bio-diesel



Glycerol

Production of cotton seed oil

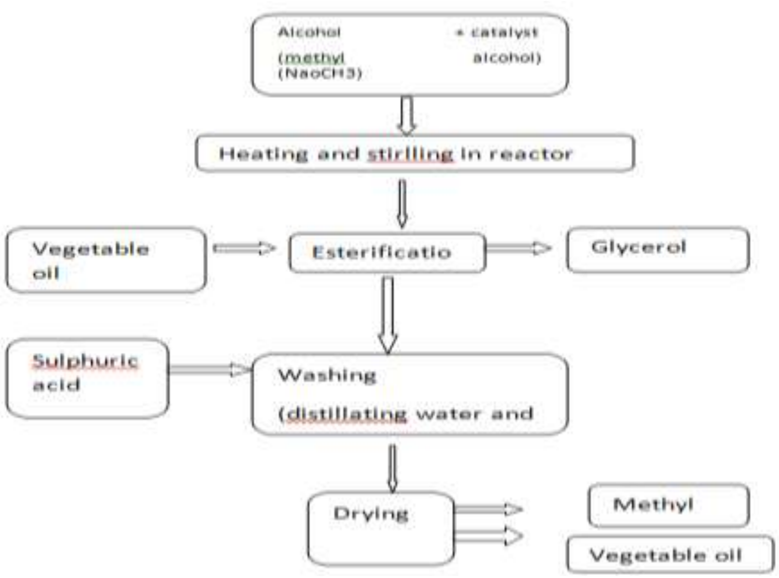


Figure 1. (a) Chemical Equation of Transesterification Process, (b) Crude, Transesterified (Biodiesel) Cotton Seed Oil and its by-product, (c) The flowchart of the cotton seed oil methyl ester (CSOME) production processes

Cottonseed oil then began to be used illegally to fortify animal fats and lards. Initially, meat packers secretly added cottonseed oil to the pure fats, but this practice was uncovered in 1884. Armour and Company, an American meatpacking and food processing company, sought to corner the lard market and realized that it had purchased more lard than the existing hog population could have produced. A congressional investigation followed, and legislation was passed that required products fortified with cottonseed oil to be labeled as ‘‘lard compound.” Similarly, cottonseed oil was often blended with olive oil. Once the practice was exposed, many countries put import tariffs on American olive oil and Italy banned the product completely in 1883. Both of these regulatory schemes depressed cottonseed oil sales and exports, once again creating an oversupply of cottonseed oil, which decreased its value.

It was cottonseeds depressed values that lead a newly formed Procter & Gamble to utilize its oil. The Panic of 1837 caused the two brothers-in-law to merge their candlestick and soap manufacturing businesses in an effort to minimize costs and weather the bear market. Looking for a replacement for expensive animal fats in production, the brothers finally settled on cottonseed oil. Procter & Gamble cornered the cottonseed oil market to circumvent the meat packer's monopoly on the price. But as electricity emerged, the demand for candles decreased. Procter and Gamble then found an edible use for cottonseed oil. Through patented technology, the brothers were able to hydrogenate cottonseed oil and develop a substance that closely resembled lard. In 1911, Procter & Gamble launched an aggressive marketing campaign to publicize its new product, Crisco, a vegetable shortening that could be used in place of lard. Crisco placed ads in major newspapers advertising that the product was "easier on digestion...a healthier alternative to cooking with animal fats. . . and more economical than butter.” The company also gave away free cookbooks, with every recipe calling for Crisco. By the 1920s the company developed cookbooks for specific ethnicities in their native tongues. Additionally, Crisco starting airing radio cooking programs. Similarly, in 1899 David Wesson, a food chemist, developed deodorized cottonseed oil, Wesson cooking oil. Wesson Oil also was marketed heavily and became quite popular too.

Over the next 30 years cottonseed oil became the pre-eminent oil in the United States. Crisco and Wesson oil became direct substitutes for lard and other more expensive oils in baking, frying, sautéing, and salad dressings. But by World War Two cottonseed oil shortages forced the utilization of another direct substitute, soybean oil. By 1944, soybean oil production outranked cottonseed oil production due to cottonseed shortages and soybean oil costs falling below that of cottonseed oil. By 1950, soybean oil replaced cottonseed oil in the use of shortenings like Crisco due to soybeans comparatively low price. Prices for cottonseed were also increased by the replacement of cotton acreage by corn and soybeans, a trend fueled in large part by the boom in demand for corn syrup and ethanol. Cottonseed oil and production continued to decline throughout the mid and late 20th century.

In the mild to late 2000s, the consumer trend of avoiding trans-fats, and mandatory labeling of trans-fats in some jurisdictions, sparked an increase in the consumption of cottonseed oil, with some health experts and public health agencies recommending it as a healthy oil. Crisco and other producers have been able to reformulate cottonseed oil so it contains little to no trans-fats. Still, some health experts claim that cottonseed oil’s high ratio of polyunsaturated fats to monounsaturated fats and processed nature makes it unhealthy.

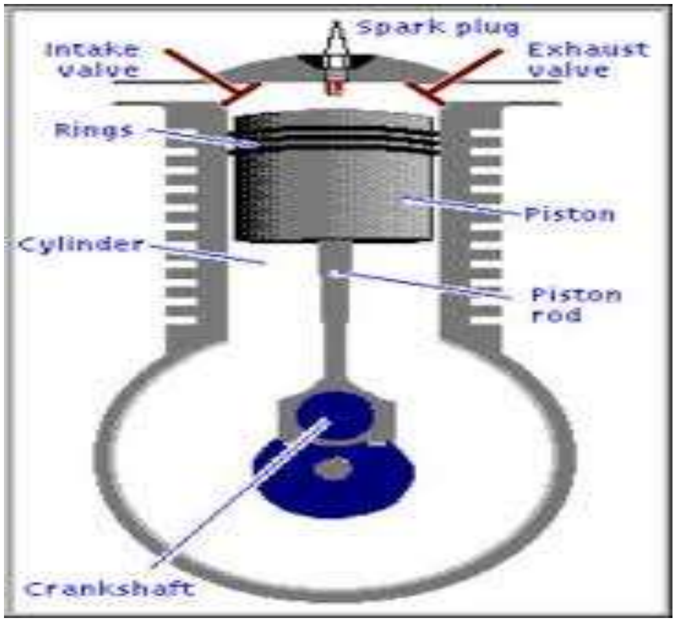
IV. FOUR STROKE DIESEL ENGINE

A diesel engine (also known as a compression-ignition engine) is an internal combustion engine that uses the heat of compression to initiate ignition and burn the fuel that has been injected into the combustion chamber. This contrasts with spark-ignition engines such as a petrol engine (gasoline engine) or gas engine (using a gaseous fuel as opposed to gasoline), which use a spark plug to ignite an air-fuel mixture. The engine was developed by German inventor Rudolf Diesel in 1893.

The diesel engine has the highest thermal efficiency of any standard internal or external combustion engine due to its very high compression ratio. Low-speed diesel engines (as used in ships and other applications where overall engine weight is relatively unimportant) can have a thermal efficiency that exceeds 50%.

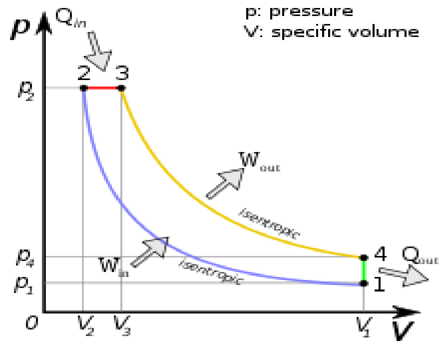
The diesel internal combustion engine differs from the gasoline powered Otto cycle by using highly compressed hot air to ignite the fuel rather than using a spark plug (*compression ignition* rather than *spark ignition*).

In the true diesel engine, only air is initially introduced into the combustion chamber. The air is then compressed with a compression ratio typically between 15:1 and 22:1 resulting in 40-bar (4.0 MPa; 580 psi) pressure compared to 8 to 14



bars (0.80 to 1.4 MPa; 120 to 200 psi) in the petrol engine. This high compression heats the air to 550 °C (1,022 °F). At about the top of the compression stroke, fuel is injected directly into the compressed air in the combustion chamber. This may be into a (typically toroidal) void in the top of the piston or a *pre-chamber* depending upon the design of the engine. The fuel injector ensures that the fuel is broken down into small droplets, and that the fuel is distributed evenly. The heat of the compressed air vaporizes fuel from the surface of the droplets. The vapour is then ignited by the heat from the compressed air in the combustion chamber, the droplets continue to vapourise from their surfaces and burn, getting smaller, until all the fuel in the droplets has been burnt. The start of vaporization causes a delay period during ignition and the characteristic diesel knocking sound as the vapour reaches ignition temperature and causes an abrupt increase in pressure above the piston. The rapid expansion of combustion gases then drives the piston downward, supplying power to the crankshaft.

As well as the high level of compression allowing combustion to take place without a separate ignition system, a high compression ratio greatly increases the engine's efficiency. Increasing the compression ratio in a spark-ignition engine where fuel and air are mixed before entry to the cylinder is limited by the need to prevent damaging pre-ignition. Since only air is compressed in a diesel engine, and fuel is not introduced into the cylinder until shortly before top dead centre (TDC), premature detonation is not an issue and compression ratios are much higher.



p-V Diagram for the Ideal Diesel cycle. The cycle follows the numbers 1-4 in clockwise direction. In the diesel cycle the combustion occurs at almost constant pressure and the exhaust occurs at constant volume. On this diagram the work that is generated for each cycle corresponds to the area within the loop.

Diesel engine model, left side

Diesel engine model, right side

Different vegetable oils such as soybean oil, castor oil, rapeseed oil, jatropha curcas oil, cottonseed oil are considered as alternative fuels for diesel engines. The important advantages of vegetable oils as fuel are that they are renewable, can be produced locally, cheap and less pollutant for environment compared to diesel fuel.

Experimental Setup

A single cylinder, water cooled, four stroke direct injection compression ignition engine with a compression ratio of 17.5: 1 and developing 5.2 kW power at 1500 rpm was used for this work. Fuels used were diesel, cottonseed oil and blends of cottonseed oil-diesel pre heated to 70°C.The cylinder pressure and top dead centre (TDC) signals were acquired and stored using a high-speed computer based digital data acquisition system. The stored signals were processed with specially designed software to obtain the performance and combustion parameters. Viscosity of the fuel was measured with a Say bolt viscometer. ACRYPTON exhaust gas analyzer was used to measure carbon monoxide (CO) and hydrocarbon (HC) levels. The analyzer is a fully microprocessor controlled system employing nondestructive infrared techniques. Smoke level was measured using a standard BOSCH smoke measuring .

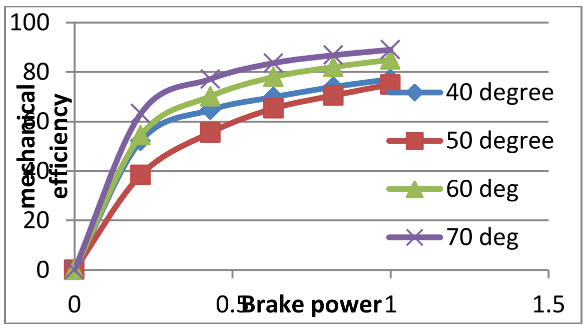
Experimental Procedure

During all the tests, the rated power and speed of the engine (5.2 kW @ 1500 rpm) were maintained. Load was changed in 5 levels, 20%, 40%, 60%, 80% and 100%. Load, speed, air flow rate, fuel flow rate, exhaust gas temperature, exhaust emissions of HC, CO and smoke were stored in the computer at all load conditions. Cylinder pressure and TDC position signals were also recorded to obtain combustion parameters.

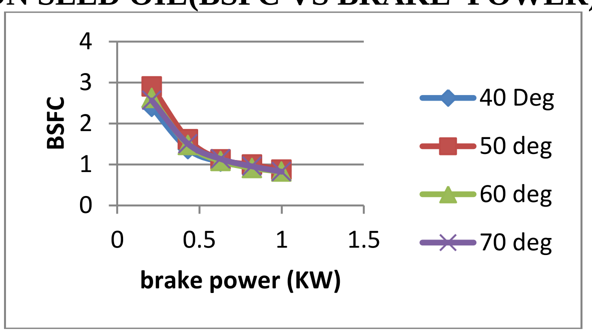
Graphical Presentation of diesel – cottonseed oil and its performance

- Brake Power (BP) VS Brake Thermal Efficiency(at 40^0 c, 50^0 c, 60^0 c, 70^0 c)
- Brake Power (BP) VS Brake Specific Fuel Consumption (BSFC) (at 40^0 c, 50^0 c, 60^0 c, 70^0 c)
- Brake Power (BP) VS Mechanical Efficiency (at 40^0 c, 50^0 c, 60^0 c, 70^0 c)
- Comparison Of Diesel Vs Cottonseed Oil (Iso Thermal Efficiencies) (at 40^0 c, 50^0 c, 60^0 c, 70^0 c)

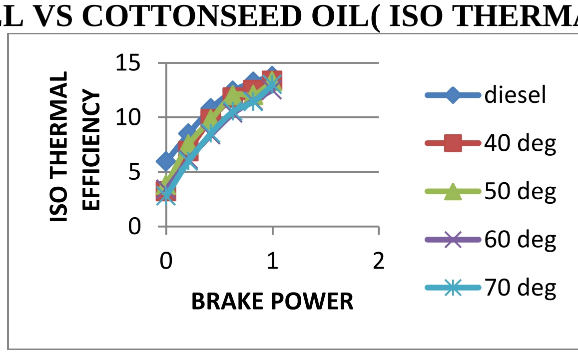
PREHEATING OF COTTON SEED OIL(MECHANICAL EFFICIENCY VS BRAKE POWER)



PREHEATING OF COTTON SEED OIL(BSFC VS BRAKE POWER)



COMPARISON OF DIESEL VS COTTONSEED OIL(ISO THERMAL EFFICIENCIES)



V. CONCLUSION

The project has been carried out successfully and it was found the diesel engine is performing well with cottonseed oil alone as the fuel. Cotton seed oil when preheated gave better results in terms of total fuel consumption, specific fuel consumption and the brake thermal efficiency.Cotton seed oil methyl ester , can be used only during the crisis of diesel because of the relatively higher cost of cotton seed oil compared to diesel.

However among the other vegetable oils found suitable to run the diesel engines, cotton seed oil suits as an attractive alternative fuel because of its less cost compared to other vegetable oils.

