EMISSION CONTROL FOR A GLOW PLUG DIRECT INJECTION CI ENGINE USING PREHEATED COCONUT OIL BLENDED DIESEL

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Abstract— **This paper discusses the experimental study on the reduction of energy utilization and thereby abiding an indirect control on the emission strategies for a CI engine. Three different methods for the control of emission were carried out and the results were compared. The first method was to improve the combustion by incorporating a copper perforated medium beneath the atomized fuel spray and thereby improve the combustion through vaporisation. The second method was to use coconut oil directly as an additive to diesel. The last method was to preheat the coconut oil blended diesel. The analysis showed that of all the coconut blends, namely, 10% to 50%, 20% blended ratio found a good place in both fuel efficiency and reduced emissions. Similarly, the preheated blends showed still drastic reductions in emissions even for higher proportions of coconut oil.**

Index Terms— **engine, emission control, blended fuel, coconut oil.**

Notation

SEC: Specific energy consumption, kJ/kWh
SFC: Specific fuel consumption, kg/kWh
TFC: Total fuel consumption, kg/h

I. INTRODUCTION

The world is presently confronted with the twin crises of fossil fuels depletion and environmental degradation. Indiscriminate extraction and lavish consumption of fossil fuels have led to the reduction in hydrocarbon resources underground. The search for an alternative fuel, which promises a harmonious correlation with sustainable development, energy conservation, management, efficiency and environmental preservation, has become highly pronounced in the present day context. For developing countries of the world, fuels of bio-origin can provide a feasible solution to the crisis. The fuels of bio-origin may be alcohol, vegetable oils, biomass and biogas. Some of these fuels can be used directly while others need to be formulated to bring the relevant properties close to those of conventional fuels. Considering the recent wide spread use of diesel fuel in various sectors, this study focuses on assessing the feasibility of using coconut oil blended preheated diesel oils in the existing diesel engines with minor modifications in the existing design.

Unlike other vegetable oils, coconut oil has a special feature of readily mixing with diesel. It remains a white crystalline solid at temperatures below 20°C, but it is a clear liquid when it is blended with ordinary diesel fuel (ODF). Further, apart from other vegetable oils, the fraction of coconut oil in blends did not create any separation or form any layers on the inside wall of the fuel tank. This was investigated by Masjuki *et al.* [1] in Malaysia, where the ambient environmental temperature is 23°C to 33°C. As a result, the possible cold temperature fuel filter problems and injection line blocking have been ignored. However, researchers faced problems due to minor variation in viscosities, which is nullified in this work using a pre-heated coconut oil blended diesel.

Three different methods for the control of emission and their corresponding improvement in engine performance were experimented. The first method was to improve the combustion by incorporating a perforated copper medium beneath the atomized fuel spray. This improves the combustion through vaporisation and reducing the physical delay period of the first phase of combustion. In the second method, coconut oil was used as an additive to diesel because of its oxygen content in the molecular structure. The last method was to preheat the coconut oil blended diesel, to reduce the negligible viscosity variations leading to an improvement in the performance.

Test Engine Specifications

Make	:	Field Marshal
Class	:	single cylinder, 4-stroke, direct injection type
Power output, kW	:	3.7 (5 Bhp)
SFC, g/kWh	:	240
Speed, rpm	:	1500
Fuel	:	high speed diesel
Bore, mm f	:	80
Swept volume, cc	:	553
Valve timing	:	IVO–5° BTDC
		IVC–27.8° ATDC
		EVO–38° BBDC

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II. CONTROL METHODS

Combustion through a Perforated Medium An experimental study had been carried out using porous medium by Durst and Weclas2 of Germany and the performance of an indirect injection Hartz diesel engine had improved with reductions in emissions. A similar work had been experimented using perforated copper medium in a direction injection engine.

The aim was to incorporate heat capacitance material, such as, copper or brass in the form of perforated sheet beneath the fuel atomizer. The heat absorbed during combustion in the previous cycle gets stored in the medium which will then vaporise the incoming fuel spray. The physical delay phase of combustion is reduced thereby improving the combustion characteristics. Care should be taken in positioning the perforated medium so that the well-atomized fuel spray is undisturbed. However, the expected results could not be achieved in this test engine because of the difficulty in incorporating the perforated medium that affected the spray characteristics and thereby could not contribute any improvement in emissions.

Test with coconut oil blends

Coconut oil's special feature of readily mixing with diesel has been described already. There is a high production of coconut oil in tropical countries like India, Sri Lanka and Malaysia and so it could be a good partial replacement for conventional ODF. One major drawback is that the price of coconut oil is slightly higher than that of conventional petroleum fuels. But it could be the least cost alternative in terms of the global emissions management because coconut oil based fuels produce reduced exhaust emissions. Suitable proportions of 10% to 80% coconut oil blended diesel were prepared and the test engine was run for a long period of time using these samples.

Specific energy consumption tests

When fuels of different origin are to be studied and compared for their performance the specific energy values will give the exact inference [5]. The results of the tests conducted with ODF were taken as reference for comparison with various blends of (10% to 80%) coconut oil. These blended fuels were used to run the test engine for prolonged periods under the same operating conditions. The variation in the specific gravity, because of the blending was taken care of and calculated (Table-1). Using these calculated values the TFC values were computed. The overall output of the system was calculated and hence the SFC value when multiplied with corresponding calorific value would result in SEC value. The calculated values were plotted on a graph (Figure-1, without heating).

Emission tests

A testing method similar to the fuel consumption tests was adopted for emission tests also. The emission tests were also conducted using a Kane-May flue gas analyser. The engine was warmed up for a long period of time. By keeping all the engine parameters constant, the fuel alone was modified to various blends. The gas analyser was first calibrated. The probe of the analyser was properly introduced into the exhaust pipe so that the tip of the probe did not touch the wall of the exhaust pipe and also fixed at the centre of the exhaust pipe so that maximum temperature of exhaust gas was exposed to the probe. These settings were periodically checked during the entire period of the experiments. The result of experiments, namely, CO concentration, NOx concentration were noted down and analyzed graphically.

Test with preheated coconut oil blends

The problems associated with most vegetable oils are the large variation of viscosities than that of the ODF, which lead to flow related problems. However, such problems could be overcome by transesterification, micro-emulsion, pyrolysis, dilution, which reduce the viscosities of the vegetable oils. Alternatively this difficulty could also be overcome by preheating. This method was adopted in this project and the performance and emission tests were carried out and compared with that of ODF. From Figures 4 to 6 it can be inferred that preheating decreases the SEC values.

Engine modification

A 12V, 15W glow plug was fixed using an adapter in the high pressure tube between the injector and fuel injection pump and close to the fuel injector. The glow plug was fixed with an aim of preheating the fuel before the combustion, to reduce the viscosity and physical delay of combustion. Care was taken in fixing the glow plug in the adapter so as not touch the inner walls of the tubes and minimizing heat loss. The performance test was then carried out under the same operating condition and the procedure followed for testing of coconut oil blends without heater was repeated. The performance and emission test were started using 100% ODF and then the fuel was replaced by blended fuels. The results were plotted graphically and compared (Figures 4 to 6).

III. RESULTS AND DISCUSSIONS

Out of the three methods suggested to improve the performance and emission reduction, the perforated medium combustion technique was not found feasible due to fabrication difficulties in positioning the perforated medium. The suggested principle of operation was to preheat and vaporise the atomized diesel spray. To achieve this depth of combustion chamber should have been higher than the length of spray. But, in this case the depth of the chamber could not be increased beyond a certain limit as it blocked the cooling system of the engine.

The second method suggested was to use direct coconut oil blends. Experiments were conducted using various vegetable oils and it was proved that engine running using vegetable oils increased the power output and reduced emissions. Moreover, vegetable oils were renewable energy sources and were nontoxic and biodegradable. It was noticed that most vegetable oils contained substantial amount of oxygen in their molecular structure and sulphur content was almost negligible. The various characteristic curves and emissions curves of coconut oil are shown in Figures 1 to 6. The values of SEC for 20% and 30% coconut oil are far below the 100% diesel line and for 10% and other higher values of blending it are quite higher.

Table 1 Comparison of properties of coconut oil and diesel

Properties	Fuel blend									
	100% diesel	100% coconut oil	Diesel + percentage coconut oil							
			10	20	30	40	50	60	0	0
Cal value kJ/kg	42500.00	37260.000	41976.000	41452.000	40928.000	40404.000	39880.000	39356.000	8832.000	8308.00
Specific gravity	0.83	0.918	0.838	0.847	0.856	0.865	0.874	0.882	0.891	0.90
Sulphur, wt, %	0.10	0.009	0.090	0.081	0.071	0.060	0.040	—	—	—
Cetane number	52.00	37.000	49.000	47.000	46.000	44.000	44.000	—	—	—
Cost (approx), Rs/kg	18.00	40.000	20.200	22.400	24.600	26.800	29.000	31.200	3.400	5.60
Kinematic viscosity, Cst 40°C	3.60	26.220	3.700	3.930	4.700	4.800	5.300	—	—	—

Optimum performance was obtained for 20% coconut oil blend (Figure-1). The possible reasons for increased thermal efficiency or reduced SEC values are more complete combustion and additional lubricity of coconut oil. Tests conducted using coconut oil blends showed that frictional horsepower losses in the engine followed a declining trend. The reduction in frictional losses was also reflected in SEC values followed by the unaccounted losses. So, the energy saved by decreased frictional horse power made additional contribution towards useful energy, cooling losses and exhaust losses.

In general CI engines show reduced percentage of CO due to their excess air operation. The emission curves (Figure-2) show reduction in CO concentration for all values of blending ratios. Here also the 20% coconut oil line shows the minimum value of carbon monoxide percentage. There are two main reasons, the higher thermal efficiency, better and complete combustion. The reason for the complete combustion is that the molecules of coconut oil contain some amount of oxygen that takes part in combustion. For diesel engines the most important pollutant is NOx which is temperature dependent. It was noticed from NOx curves (Figure-3) that NOx value decreased as coconut oil percentage was increased. This is because coconut oil blends produce lower heat release rate at the premix combustion phase, which lowers the peak combustion temperature and hence reduces NOx emissions. The production of the lower combustion temperature by vegetable oil as well as by coconut oil is due to their chemical bond and its properties.

The exhaust temperature decreased with increasing coconut oil blends. The exhaust temperature is lower because oxidation of hydrocarbons is occurring during the expansion stroke rather than in the exhaust. Hence, a positive sign glows in this method. The third method suggested was to preheat the fuel before injection into the cylinder. It was mainly aimed at reducing viscosity to get rid of flow related problems. Experiments were conducted using preheated diesel and blended coconut oil. The various characteristic curves and emission curves for different blends of coconut oil are shown in Figures 4 to 6.

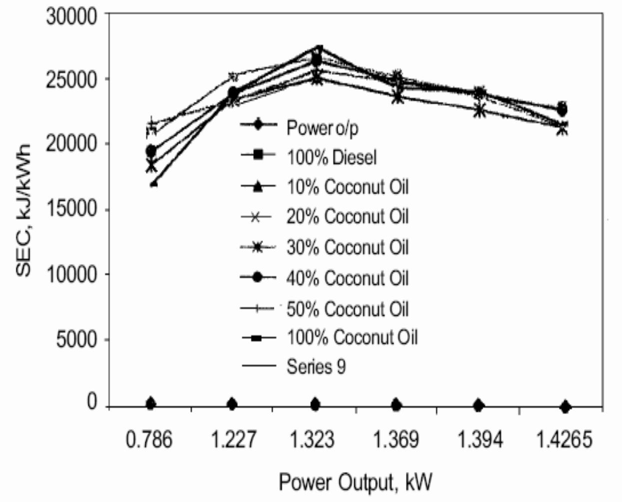

Figure 1 Power output against SEC (without heater)

The trend of the SEC curve had improved for preheated fuel from 100% diesel to 50% coconut oil. Optimum performance was obtained for 50% coconut oil (Figure-4), whereas, for blended coconut oil without heater it is only 20% (Figure-1). So, preheating decreases the SEC as a whole and it is less than nonpreheated diesel. When the blending ratio was increased more than 50% it starts increasing.

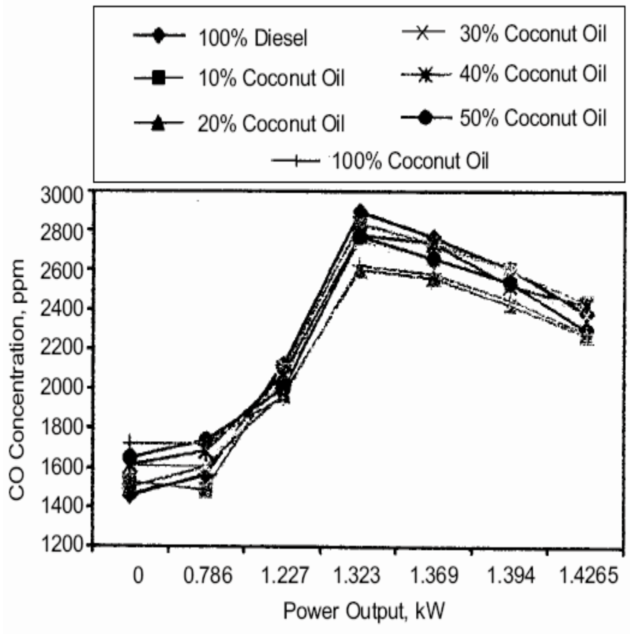

Figure 2 Power output against CO concentration (without heater)

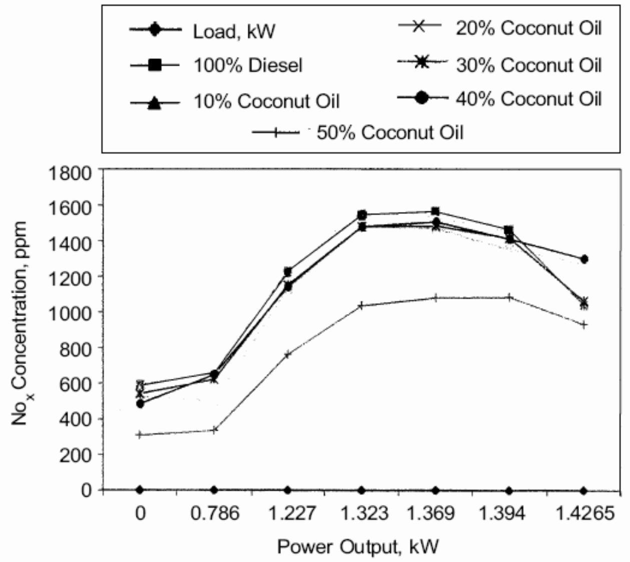

Figure 3 Power output against NO_X concentration (without heater)

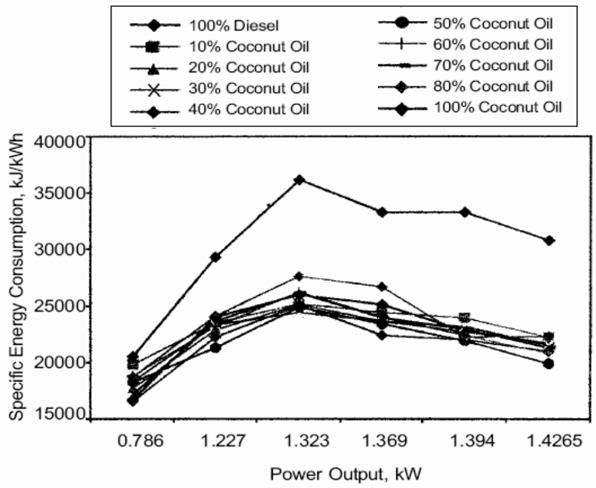

Figure 4 Power output against specific energy concentration (without heater)

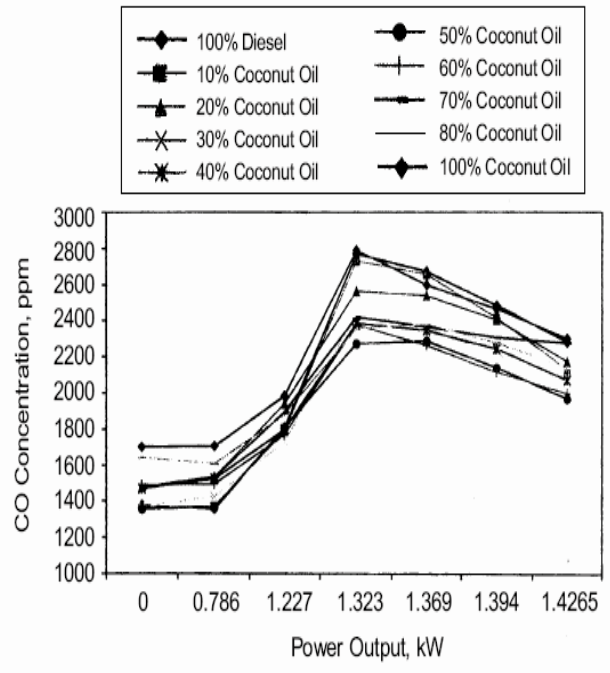

Figure 5 Power output against CO concentration (without heater)

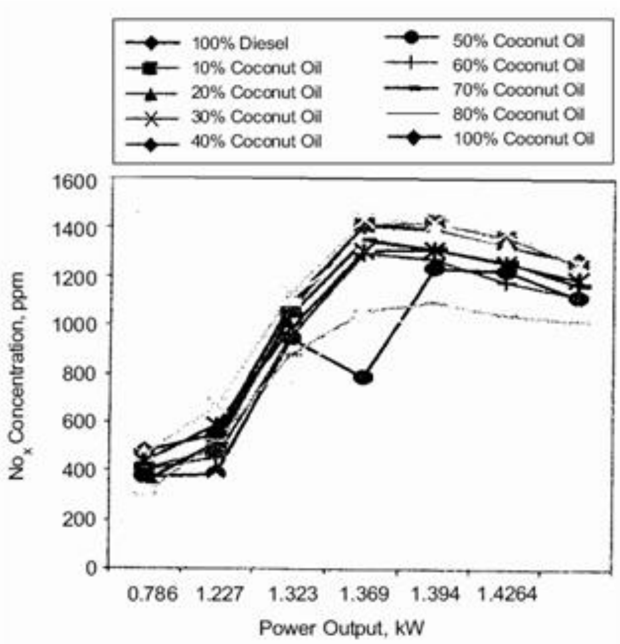

Figure 6 Power output against NO_x (with heater)

The possible reason for increased thermal efficiency could be the reduction in viscosity of the injected fuel and shortened physical delay of combustion. Preheated fuel improves spray characteristics because of reduced viscosity and density. So, atomized droplets readily mix with air and hence the physical delay is reduced. The emission curves with preheating showed reduction in CO concentration (Figure 5) when coconut oil percentage was increased. Emission curves showed reduction in NOx when blending of coconut oil was increased (Figure-6). The possible reasons could be the contribution of reduced SEC values due to preheating blends.

However, the measurements for particulate matter and unburned hydrocarbons have not been included. Since, the engine adapted for experiment is of a lean-burn engine, the hydrocarbon emission will be negligible and NOx emissions will be predominating. Also, highly refined coconut oil reduces the particulate matter. The emission of particulate matter is also influenced by the sulphur content of fuel. Since, the sulphur content in coconut oil is negligible; the particulate matter emissions will also needfully be reduced. The wear characteristics of the engine will be improved due to the viscosity of the coconut oil and also due to the presence of fatty acids, which acts as a corrosion resistant material.

IV Conclusion

Based on the exhaustive engine tests, it can be concluded that coconut oil can be adapted as an alternative fuel for the existing conventional diesel engines without major modifications. Preheated (50%) coconut oil blends were found to be better in terms of both emission and performance. Without preheating 20% coconut oil blends gave optimum results, but SEC and emissions were higher than those of preheated blends. With respect to the cost analysis, even though the cost of coconut oil is higher than that of diesel, under emission management scenario, this could be a least cost alternative to the existing system.

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