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EXPERIMENTAL INVESTIGATION STRATEGIES TO AUGMENT THE DIESEL ENGINE PERFORMANCE AND REDUCTION OF EMISSION CHARACTERISTICS BY THE EFFECT OF WASTE PLASTIC OIL

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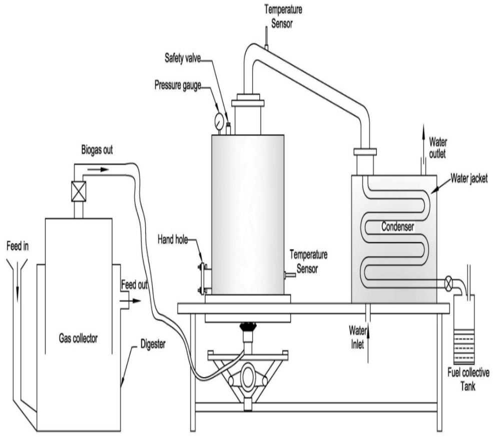
Graphical abstract



Abstract

The need for biomass to waste plastic oil (WPO) in recent years, as the desire to diversify feedstock and reduce industrial emissions has grown. The technologies for converting biomass to conventional WPO are investigated in this paper. Biomass likes as cow dung and kitchen waste was used as a feed for the anaerobe to generate biogas. This biogas can be effectively utilized for heating purpose of synthesis WPO from waste plastic. WPO conversion process fly ash is used as catalyst with 0.1 cat/pol. WPO blend with different percentages with diesel like 25 % to 100 % WPO ((WPO 25), (WPO 50), (WPO 75) and (WPO 100)) by volume with pure diesel and run the KIRLOSKAR TV -1 engine. At various engine loads, the impact of WPO blends on engine performance and exhaust emissions were investigated. The results are validated to those of a standard diesel fuel operation. WPO has a greater fuel concept and brake thermal efficiency than diesel. The engine functioned better with WPO25 mix. It is discovered that the NOx, HC, CO_2, and smoke emissions are greater than those of diesel.

Keywords: Waste plastic oil, Biogas, Biomass, C.I. Engine, Performance.

1.0 INTRODUCTION

Current rises in the cost of fossil fuels – particularly oil, in addition to their tendency to become increasingly unpredictable, are also driving the formation of a new “flexi-fuel” economy and novel material production techniques, such as the biomass-to-WPO route [1]. The claimed better sustainability of the biomass-to-WPO process, as well as the qualified low-cost investments due to previously developed technology for the growing gas-based petrochemistry industry, will have to be investigated [2].

Cogeneration is an age-old and well-proven procedure. However, due to the current energy crisis, there has been a resurgence of interest in cogeneration for commercial buildings, industrial locations, and rural applications in recent days [3].

The potential of cogeneration systems to improve fuel efficiency is their primary technological advantage. A cogeneration facility uses more fuel to produce both thermal and electric energy than would be necessary to produce either type of energy alone. In the near future, it will be vital to manufacture biogas from waste, leftovers, and energy crops. For both electricity generation and transportation fuel, biogas is an excellent renewable alternative to fossil fuels [4]. Biogas produced through anaerobic digestion has a number of advantages over other types of bioenergy generation. is considered to be one of the most efficient and sustainable bioenergy production systems on the market [5].

Cogeneration systems based on biomass are becoming more common, and various studies have been undertaken in this area. Bianchi et al. (2006) investigated the use of natural wastes from an accessible rooster industry as fuel, taking into account various plant layouts, in order to utilize the oil as well as the animal protein and bone meal, which are spin-offs of the chicken cooking process. Gustavsson and Johansson (1994) discussed Sweden's bioenergy potential and compared various bioenergy applications in the electricity, heating, and transportation sectors.

From an environmental standpoint, it is vital to dispose of waste plastic that has collected in landfills. The energy embodied in waste plastic might be well again as WPO and recycled as a diesel engine fuel via catalytic pyrolysis [8]. WPO is among the most promising diesel substitutes because it shares many of the identical characteristics [9]. By way of the manufacture of fuel from plastic wastes, the difficulties of waste management and the growing fuel emergency can be addressed [10].

Most of the researches have degrade the waste plastic by electrical and LPG heating. In this work energy from biodegradable waste is used to convert the non-biodegradable waste into hydrocarbon. The biodegradable cow dung and kitchen wastes are converted into biogas. This biogas is used as a heating agent in the catalytic reactor. This heat is used to crack the waste plastic and convert it into gases and liquids. Furthermore, WPO performance as fuel was tested and analysed by using diesel engine. The effects of WPO/diesel blends of [75D25W (75%Diesel + 25%WPO), 50D50W (50%Diesel + 50 %WPO), 25D75W (25%Diesel + 75%WPO), 100W (0%Diesel + 100%WPO) and 100D0W (100%+0WPO)] were then compared towards diesel engine performance and gas emissions produced.

2.0 METHODOLOGY

2.1 Materials And Methods

The biodigester employed in this study is a 750-liter syntax tank digester (Figure 1), and the research was conducted at Annamalai University in Tamil Nadu, India. The waste materials employed in this investigation were cow dung and kitchen waste. Fresh cow dung and kitchen wastes were collected from the Municipal waste collecting yard located at Annamalai Nagar. Other supplies used included a 500-liter calibrated plastic bucket, a top-loading balance (15 kg), a thermometer, and a digital pH meter. Waste plastic that has been unused is changed into liquid hydrocarbons. HDPE plastics are sliced by cutting machines. As a catalyst, lignite fly ash is employed. Al (Aluminum), Si (Silica), and O (Oxygen) have all been found in fly ash (oxygen). Fly ash can be utilised as a catalyst for the breakdown of waste plastics because silica and alumina have been widely employed as catalysts [11]. Waste plastic and fly ash are mixed together.

Figure 1 Biodigester tank

2.2 Description of the Distillation Unit

Figure 2 depicts the reactor plant layout for catalytic conversion. The reactor was a stainless steel cylindrical cylinder with a diameter of 1.3 m. The reactor was heated with biogas

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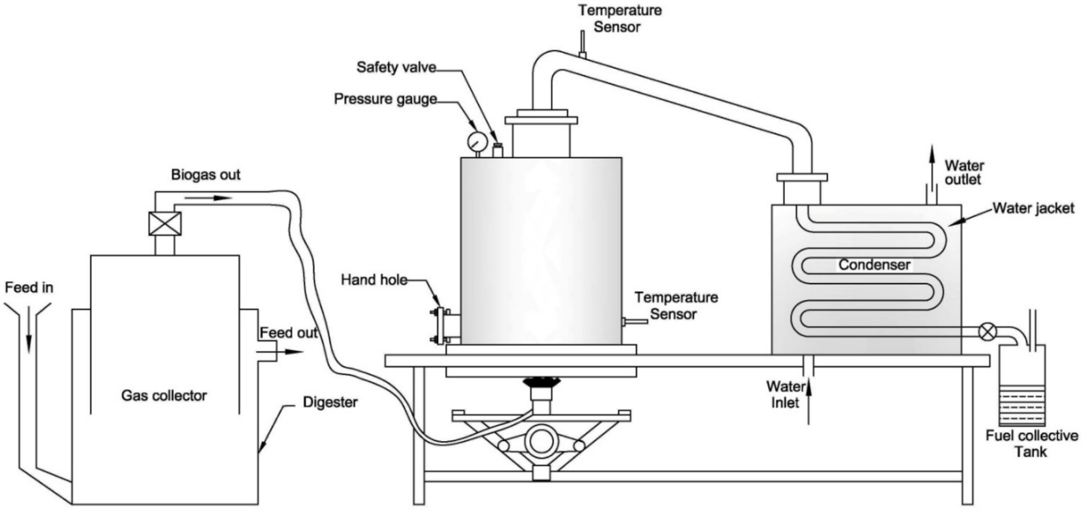

Figure 2 Schematic Diagram of WPO Degradation Plant

A thin cylindrical sheet was used to encase the reactor. Between the reactor vessel and the thin layer, glass wool was placed. Insulation is provided by the glass wool. A safety valve, a pressure monitor, an intake with an airtight stopcock for feeding waste plastic, and an output connected to the water-cooled condenser were all located on the top of the reactor. Pressures of up to 500 kg/m^2 can be handled by the safety valve. A hand hole with an airtight stopcock was provided at the bottom of the reactor to remove the materials once they had cracked. A thermocouple was inserted into the bottom of the reactor to measure the interior temperature. A cooling coil and a water jacket were used in the condenser. The condenser was made from a stainless steel coil with a diameter of 0.2 m [12]. This coil, which had a height of 0.5 m and a diameter of 0.3 m, was reserved within the water jacket. An intake was provided at the bottom of the water jacket, and an outlet was supplied at the top. The entrance and outflow were used to circulate water in the jacket. In a stainless steel tank, the condensed oil was together and accumulated [9].

2.3 Procedure for Load Test

The Kirlosker TV-I diesel engine, which runs on diesel fuel, has undergone the following tests like performance, emission and combustion. Table 1 shows the specifications of Engine. To achieve steady state conditions with the least amount of load, the engine was allowed to run for nearly 30 minutes on nothing but diesel fuel at a constant 1500 rpm speed. In order to minimize their impact on the findings, the temperature of the engine cooling water and lubricating oil were kept constant throughout the investigation. Fuel injection was used to stabilize the engine's operation so that the lubricating oil and cooling water reached temperatures of 65°C and 70°C, respectively.

Table 1 Specification of the KIRLOSKARTV -1 Engine

Type	Water cooled, Vertical, Four Stroke Diesel Engine
Number of Cylinder	One
Stroke	110 mm
Bore	87.50 mm
Maximum Power	5.20 kW
Compression ratio	17.5:1
Dynamometer	Eddy Current
Speed	1600 rpm
Injection Pressure	2.20 kg/mm^2
Injection timing	23 ° before TDC

The flow of cooling water was kept constant. The flow of cooling water was kept at 7L/min. then, for concordance, the following variables were established twice: 1. The duration of the 10 mL fuel consumption (s) Smoke density 2. (HSU) 3. NOx production (ppm) 4. Carbon dioxide emissions (ppm) 5. Burning conditions (analyzed by the use of AVL combustion analyzer) Following the completion of the tests with pure diesel fuel, additional tests were carried out using various 75D 25W 50D 50W 25B 75W oil blends. The engine was run with each blend at a variety of load percentages, including 20%, 40%, 60%, 80%, and maximum load. Tests for combustion, emissions, and performance were run. Readings that corresponded to the performance and emission characteristics of each load were recorded.

3.0 RESULTS AND DISCUSSION

3.1 Biogas Production

The digester was stimulated with 6.0 kg of cow dung and 12 kg of water in a 1:2 waste-to-water ratio, and the slurry was thoroughly churned [11]. A thermometer was used to record the daily slurry and ambient temperatures. The pH values were checked every morning three times and averaged to identify the action of methanogens, which use the acids, carbon dioxide, and hydrogen created by non-methane generating bacteria [13]. After a period of one week, waste biomass from kitchen waste is feed into the digester in the ratio of 5:1 i.e., 5 kg of kitchen waste and 1 kg of cow dung [14]. Every five days, to increase one kg of cow dung and decrease one kg of kitchen waste. After the 25th day, feed cow dung and kitchen waste in equal proportions 6:6 i.e., 6 kg of kitchen waste and 6 kg of cow dung [15]. Table 2 shows the summary of the biogas production. Biogas contain in the region of 55 -65 % of methane, 30 – 40 % of CO_2 and calorific value of biogas is noticeably elevated 5000 – 5500 kcal/kg.

Table 2 Production of Biogas

S.No	Days	Quantity of Biomass (kg)		Quantity of Water (ltrs)	pH	Temperature °C	Volume of gas (L)	Cumulative Volume of gas (L)
		Cow dung	Kitchen Waste					
1.	1	1	5	10	6.8	28	0	0
2.	5	2	4	10	5.83	30	0.4	0.4
3.	10	3	3	10	7.18	30	1.1	1.5
4.	15	4	2	10	7.52	31	2.4	3.9
5.	20	5	1	10	7.3	32	3.2	7.1
6.	25	6	6	10	7.16	34	4.1	11.2

3.2 Synthesis of WPO

The Biogas knob was turned on, and a lighter was used to light the burner. A stop watch was used to keep track of the time.

Table 3 WPO production at different temperature and time

S.No	Time (min)	Temperature of the sample within the reactor chamber in °C	The temperature of the sample vapour inside the reactor chamber in °C	The amount of oil obtained in (ml)
1.	0	27	25	-
2.	10	58	46	-
3.	20	104	63	-
4.	30	150	79	-
5.	40	198	101	10
6.	50	209	106	35
7.	60	231	112	75
8.	70	259	124	165
9.	80	285	135	240
10.	90	314	151	390
11.	100	336	189	495
12.	110	355	204	560
13.	120	351	197	620
14.	130	343	191	640
15.	140	335	182	650

Table 4 Properties of Diesel & WPO

S.No	Properties	Diesel	WPO (100%)	75D25W (75%Diesel + 25%WPO)	50D50W (50%Diesel + 50%WPO)	25D75W (25%Diesel + 75%WPO)
1.	Density 15 °C (kg/m^3)	0.8451	0.8878	0.8513	0.8655	0.8761
2.	Specific gravity @ 15/15 °C	0.8345	0.8915	0.8518	0.8625	0.8717
2.	Kinematic Viscosity at 40 °C (cSt)	3.16	4.45	3.42	3.75	3.99
3.	Flash Point (°C)	44.5	118	61.5	70.5	93.3
4.	Fire Point (°C)	49.6	131.2	67	79.4	104
5.	Pour Point (°C)	-21.5	-10	-19.2	-15.5	-14.5
6.	Grass calorific value (kJ/kg)	44000	41982.5	43911.5	42758.5	42201.5
7.	Cetane number	53	52.15	51.15	52.1	52.95

The water-cooled condenser was used to condense the vapour produced by the plastic cracking. The liquid condensed from the condensable vapour and was collected in the collecting tank. As a result of the heating, the temperature inside the reactor progressively rises.The temperature as well as the time when oil production began was noted. When the reactor's temperature was gradually raised, the cracking process became more intense. As a result, greater WPO was achieved [9]. The temperatures at which the oil first began to form and then ceased were recorded. The amount of oil obtained in 650 ml at reactor chamber in °C 335. WPO observations are shown in Table 2.

3.3 WPO Blend With Diesel

WPO-Diesel blends of 25, 50, and 75% were made using a normal technique and employed in a diesel engine test. 75D25W, 50D50W, and 25D75W are the designations for these blends, with the number indicating the percentage of WPO in the blend. Table 4 summarises the characteristics of diesel and catalytic WPO produced from medicinal wastes.

3.4 Brake-Specific Fuel Consumption

Figure 3 shows how ternary blends affect brake-specific fuel utilisation at various load conditions. From low to full load, brake-specific fuel consumption for diesel, WPO, 75D25W, 50DW50, and 25D75W ranges from 0.5569 to 0.3219 kg/kW-h, 0.4921 to 0.2901 kg/kW-h, 0.3892 to 0.2542 kg/kW-h, 0.4353 to 0.2179 kg/kW-h, and 0.4041 to 0.2595 kg/kW-h, in that sequence. Figure 3 indicates that for all test fuels, brake-specific fuel consumption reduces as load increases. Simultaneously, the amount of brake-specific fuel used increases as the ratio of diesel to WPO in the WPO-Diesel blend increases [16]. When employing mixtures, the engine will consume more gasoline due to the low calorific value of WPO [17].

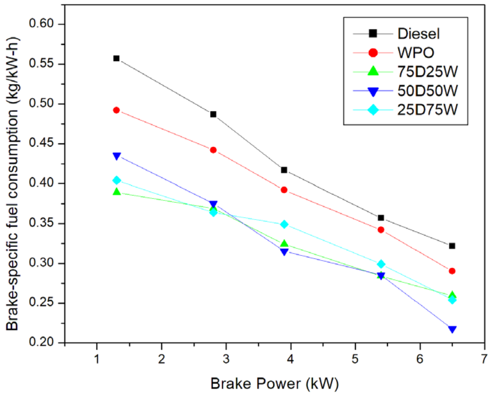

Figure 3 Variation of Brake-specific fuel consumption with brake power

3.5 Brake thermal efficiency (BTE)

The change in brake thermal efficiency as an occupation of engine load is depicted in Figure 4. When compared to diesel, using WPO as a fuel leads to a slight increase in thermal efficiency, as shown in the graph. The engine's thermal efficiency at full load is 27.18 percent for diesel and 28.31 percent for WPO. Figure 4 also indicates that a 75D25W outperforms all other combinations, with the benefit in efficiency being greater at full load. Conversely, when the percentage of WPO is greater than 25%, however, efficiency suffers. This could be because a higher proportion of WPO in a diesel mix causes increased viscosity and lower density in the blended fuels as well as a lower entire heat discharge rate as compared to diesel, influencing fuel atomization and vaporisation and, as a result, a lower BTE [18]. This could also be attributed to the reduced calorific value of WPO-diesel blends, as WPO has a lower calorific value than diesel.

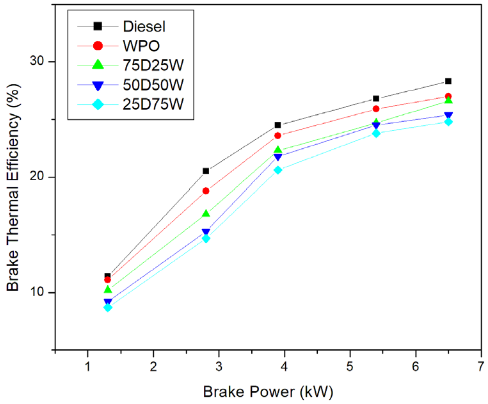

Figure 4 Variation of BTE with brake power

3.6 NOx Emission

The change in nitrogen oxides with load for the WPO-Diesel blend and diesel is exposed in Figure 5. When comparing WPO and diesel operation, it can be shown that NOx emissions for WPO are superior throughout the load range. In addition, with a rise in the amount of WPO in the blend, NOx emissions rise. This could be credited to a longer combustion impediment period as a result of the WPO's longer hydrocarbon chain. Diesel NOx concentrations range from 6.52 g/kW-h at low load to 13.36 g/kW-h at full load, whereas WPO NOx concentrations range from 9.43 g/kW-h at low load to 16.87 g/kW-h at full load. It ranges from 7.85 g/kW-h at low load to 14.16 g/kW-h at maximum load for 75D25W. For 50D50W, NOx levels range from 8.3 g/kW-h at low load to 14.86 g/kW-h at full load, whereas for 25D75W, NOx levels range from 8.81 g/kW-h at low load to 15.38 g/kW-h at full load. NOx value enhance with enhance in load [19]. Because of the better combustion, the flue gas temperature is higher with increasing amounts of plastic blend in the fuel. There is a direct relationship between NOx and flue gas temperature. Both are proportional to each other in a direct relationship [20].

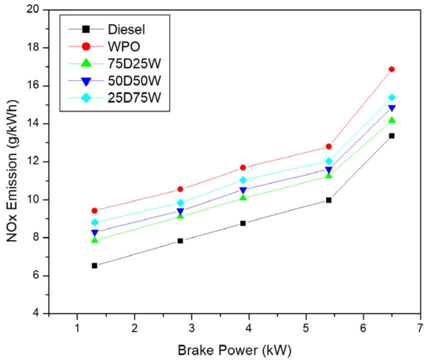

Figure 5 Variation of NOx with brake power

3.7 Unburned Hydrocarbon

Figure 6 illustrates the unburned hydrocarbon (HC) emission for all test blends in relation to engine brake power. With a higher amount of WPO in the blend, HC emissions rise. For diesel, WPO, 75D25W, 50DW50, and 25D75W, HC emission ranges from 17.5 to 46.5 ppm, 49.2 to 74.1 ppm, 33.2 to 63.4 ppm, 38.2 to 66.6 ppm, and 38.8 to 72.2 ppm, respectively, from low to full load. Due to higher fuel intake, there is more hydrocarbon at no load, less unburned hydrocarbon at lighter loads due to charge uniformity, and more unburned hydrocarbon at rising load ranges [21]. There are two possible explanations for the greater HC emission in blends evaluated compared to diesel. One possibility is that the WPO contains unsaturated hydrocarbons that are unbreakable throughout the burning process. Another issue is that the fuel spray does not penetrate far enough into the combustion chamber, leaving unburned gaseous hydrocarbons on the cylinder wall and in the crevice volume [22].

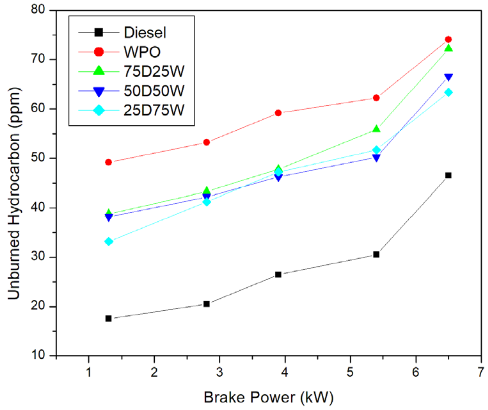

Figure 6 Variation of Unburned hydrocarbonwith brake power

3.8 CO_2 Emission

Figure 7 depicts the variation in carbon dioxide emissions with engine load during combustion for diesel and WPO blends. For similar patterns in NOx, the results show that CO_2 emissions increase modestly with increasing load. The findings demonstrated that increasing the concentration of WPO in diesel resulted in CO_2 emissions that were marginally equivalent to or greater than diesel at all loads. This could be because the combined fuels' exhaust temperatures are higher, resulting in improved combustion [23].

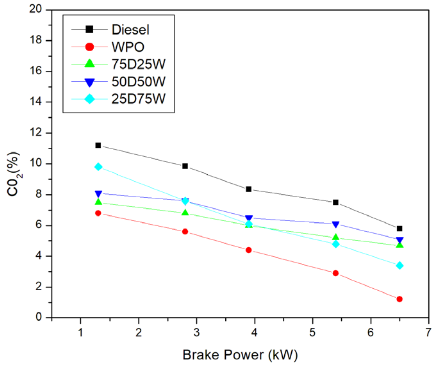

Figure 7 Variation of $CO_2$with brake power

3.9 Smoke Density

Figure 8 depicts the smoke variances for all test fuels. The amount of smoke produced by WPO is 13.5% more than that produced by diesel. When the smoke emissions of 75D25W, 50DW50, and 25D75W are compared, the smoke emission of 25D75W is 9.2 % greater than the other WPO. Smoke emissions are increased due to WPO's higher viscosity and slow burning during the combustion phase [9]. This could result in the creation of rich mixed patches due to a variation in spray atomization.

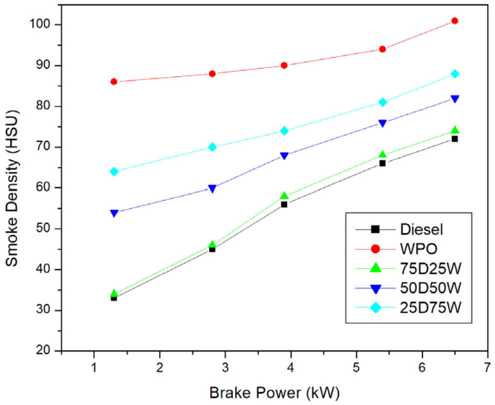

Figure 8 Variation of Smoke Densitywith brake power

4.0 CONCLUSION

The results of this study on the production of flammable biogas from cow dung and kitchen garbage showed that anaerobic digestion can produce flammable biogas from both wastes. This biogas was used as a heat source for the synthesis of WPO from waste plastic. Also in this study, WPO blended with diesel and conducted performance and emission tests.

It was discovered that the engine could run at a maximum of 100% WPO (without blending diesel) and WPO blend with different percentages with diesel like 25, 50 & 75%75% Diesel 25 WPO blend, the engine performed better. Up to full load, the blend's brake thermal efficiency 5.8 % is higher than diesel. NOx is higher by about 7 % for WPO operation than that of diesel operation CO_2 emission increased by 5% in WPO compared to diesel operation.

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