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Determining Performance Characteristics of Diesel Blends with Plastic Pyrolysis Oil

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Abstract: ***Recent population explosions and an improved standard of living has resulted in an increased demand for fossil fuels. The increased levels of pollution generated by plastic wastes are nearly uncontrollable. The non-detrimental nature of plastic doesn't allow it to decompose even over a very long period of time. The oil derived from the waste plastic is hence tested to acknowledge both these major intimidations with one solution. The project focuses in comparing the performance parameters of the blends of diesel and plastic pyrolysis oil with diesel itself over a series of loading conditions on a single cylinder CI engine using a rope brake dynamo-meter. It was found that the thermal efficiency and brake specific fuel consumption values were at par with diesel, and the differences were insignificant. Also, it was seen that for all the blends, the values of mechanical efficiency were always greater than diesel. But there was no pattern visible with an increase in the percentage blending of the two fuels.***

Keywords: Diesel blends, Plastic pyrolysis oil, Engine performance

1. Introduction

The world population growth has risen exponentially over the past few decades, and so has the quality of living. This has resulted in an increased demand for automotive vehicles, which in turn have increased the demand of fossil fuels worldwide. Moreover the increasing population has resulted in an increased level of carbon footprints per individual and has had a very detrimental effect on the environment.

The need to look for alternatives to fossil fuel has never been this high. The ultimate solution to the issue definitely lies in the concepts of electric drive lines. But, for the time being the lack of electric charging outlets and the convenience of purchasing electric vehicles, requires an intermediate solution. The project hence, takes a small step towards the development of alternatives to fossil fuels.

Plastic pyrolysis oil is derived from waste plastics, including plastic bottles, containers, bags, etc. It undergoes a process known as thermal depolymerisation. It is a thermochemical decomposition which takes place in the presence of water. It uses hydrous pyrolysis to reduce complex organic materials into light crude oil. It mimics the natural geographic processes involved in the production of fossil fuels. Under pressure and heat, long chain polymers of hydrogen, oxygen, and carbon decompose into short chain petroleum hydrocarbons with a maximum length of around 18 carbons.

In thermal depolymerisation the feed is first broken down in chunks and then water is added to the waste. The feed stock thus prepared is then fed to a pressure vessel, where it is heated at around 250 degrees Celsius at constant volume. The pressure in the vessel rises to around 600 psi (4 MPa). This stage is left for 15 minutes, after which the pressure is released very rapidly. Due to this, the water gets evaporated and the leftover consists of hydrocarbons and sold minerals. The minerals are removed and the hydrocarbons are fed to another pressure vessel where they are heated at 500 degrees Celsius, further breaking them down. The resulting crude oil, then undergoes fractional distillation and refining for finished oil.The project aims at determining the performance characteristics of diesel blends with the waste plastic pyrolysis oil manufactured by the process. It further compares the costs at which the various blends tested and proposes the ideal blending ratio among the tested set of blends.

2. Literature Survey

C. Wongkhorsub [1], stated that, by creating a sustainable energy and environment, alternative energy is needed to be developed instead of using fossil fuels. This research describe a comparison of the use of pyrolysis oils which are the tire pyrolysis oil, plastic pyrolysis oil and diesel oil in the assessment of engine performance, and feasibility analysis. Pyrolysis oils from waste tire and waste plastic are studied to apply with one cylinder multipurpose agriculture diesel engine. It is found that without engine modification, the tire pyrolysis offers better engine performance whereas the heating value of the plastic pyrolysis oil is higher. The plastic pyrolysis oil could improve performance by modifying engine. The economic analysis shows that the pyrolysis oil is able to replace diesel in terms of engine performance and energy output if the price of pyrolysis oil is not greater than 85% of diesel oil.

PawarHarshal R. [2], quoted that eenvironmental concern and availability of petroleum fuels have caused interests in the search for alternate fuels for internal combustion engines. Conversion of waste to energy is one of the recent trends in minimizing not only the waste disposal but also could be used as an alternate fuel for internal combustion engines. Waste plastics are indispensable materials in the modern world and application in the industrial field is continually increasing. In this context, waste plastics are currently receiving renewed interest. As an alternative, non-biodegradable, and renewable fuel, waste plastic oil is receiving increasing attention. In the present paper waste plastic pyrolysis oil, waste plastic pyrolysis oil and its blend with diesel has been introduced as an alternative fuel. In this study, a review of research papers on various operating parameters have been prepared for better understanding of operating conditions and constrains for waste plastic pyrolysis oil and its blends fuelled compression ignition engine.

SenthilkumarTamilkolundu[3], set the aim of his paper is present the preparation of blend of diesel with 5% volume proportion of waste plastic oil produced from the thermal pyrolysis. The quality of blending process is analyzed with FTIR spectrum. The viscosity and density of these blends were analyzed in relation with regular diesel fuel. The feasibility of the waste plastic oils derived from PVC plastics as an alternate fuel for transportation is also checked by conducting performance test on a single cylinder Kirlosker diesel engine equipped with electrical loading at 50% of the engine maximum load i.e., at 3.7 kW. Total Fuel Consumption and Specific Fuel consumption is found to decrease while brake thermal efficiency is found to increase with the use of waste plastic oil/diesel blend.

DipakAhire [4], Waste plastic from municipal solid waste were collected it was stored based on the types like HDPE, LDPE, PVC, etc. They were graded into nearly uniform size by crusher, cutter and shredder. The graded feed was heated just to melt it so that irrelevant impurities such as hard metal, clay, sand, glass, etc. settles in the bottom of the melter, which was removed sometimes. The gaseous product during melting can be either dissolved in suitable solvent or incinerate to produce heat. The modern plastic along with catalyst it sent to a reactor which is maintained at temperature between 350-600 degree Celsius and impressive pressure. The vapor which come out of the reactor can be distilled to obtain different fraction of petroleum product. The different fraction dependent upon type of feed, catalyst /feed ratio, temperature and time of heating. Catalyst and different products are characterized for these usefulness. The various properties of the product obtained were then tested and compared with the actual values for the petroleum range product.

Mani M. [5], Increase in energy demand, stringent emission norms and depletion of oil resources have led the researchers to find alternative fuels for internal combustion engines. On the other hand waste plastic pose a very serious environment challenge because of their disposal problems all over the world. Plastics have now become indispensable materials in the modern world and application in the industrial field is continually increasing. In this context, waste plastic solid is currently receiving renewed interest. The properties of the oil derived from waste plastics were analyzed and compared with the petroleum products and found that it has properties similar to that of diesel. In the present work, waste plastic oil was used as an alternate fuel in a DI diesel engine without any modification. The present investigation was to study the performance, emission and combustion characteristics of a single cylinder, four-stroke, air-cooled DI diesel engine run with waste plastic oil. The experimental results have showed a stable performance with brake thermal efficiency similar to that of diesel. Carbon dioxide and unburned hydrocarbon were marginally higher than that of the diesel baseline. The toxic gas carbon monoxide emission of waste plastic oil was higher than diesel. Smoke reduced by about 40% to 50% in waste plastic oil at all loads.

On reviewing the papers it was found that almost all the types of pyrolysis oil were able to run the engine on their own. Though various papers compared two types of pyrolysis oil manufactured from either waste tires or waste plastic. On further research it was found that waste tire pyrolysis oil manufacturing was banned due to excessive pollution levels during the process. Hence, plastic pyrolysis oil was selected and moreover the results or performance of the oil were never as satisfactory as desired. It turned out to be a potential subject for further research on the main motive of the project, alternative fuels.

3. Methodology

A series of lab tests were performed to find the chemical composition of the plastic pyrolysis oil and its blend with diesel. The three blend used were 20%, 30% and 40% plastic pyrolysis oil with diesel respectively. The lab results are as shown.

Table 1: Chemical composition of tested fuels

PROPERTIES	METHOD	DIESEL	PPO	PPO:DIESEL (20:80)	PPO:DIESEL (30:70)	PPO:DIESEL (40:60)
Calorific Value (kcal/kg)	Bomb Calorimeter	10000	10084	10011	10042	10085
Kinematic Viscosity @ 40 degrees(cSt)	U-tube	3.61	2.2	3.5	3.2	2.8
Density @ 25 degrees (kg/litre)	Gravimetery	0.820	0.804	0.832	0.827	0.822
Ash Content(% w/w)	Gravimetery	0.01	0.01	0.008	0.006	0.007
Sulphur Content(% w/w)	Spectrophotometry	0.005	0.0054	0.0055	0.0048	0.0040
Flash Point(degree Celsius)	Closed cup method	64	26	45	37	31
Water Content(% w/v)	Karl Fischer method	0.05	0.05	0.05	0.06	0.04
Carbon Residue(% w/w)	Gravimetery	0.3	0.85	0.21	0.24	0.25

Engine testing was done for a fixed set of output performance parameters. The dynamic apparatus consists of a single cylinder engine, vertical diesel engine mounted over a sturdy frame. Loading arrangement used is rope brake which is connected to engine through coupling. A digital multi-channel temperature indicator measures temperatures at various points. Various measurements provided enables to evaluate the performance of engine at various loads.

Engine Specifications: -

1) Engine- single cylinder, vertical, water cooled self-governed diesel engine, developing 5 horsepower at 1500 revolutions per minute.

2) Brake- Rope brake with loading springs and loading screws. Effective radius of 0.141 metres.
3) Measurements-
   a) Calibrated fuel burette for fuel consumption measurement.
   b) Orifice meter, fitted to air inlet tank with manometer for air intake measurement.
   c) Multi-channel digital temperature indicator for measuring temperatures at various points.
   d) Exhaust gas calorimeter to measure heat carried away by exhaust gases.

After the tests were completed for the blends, the calculations for various efficiencies and specific fuel consumption were done. The comparison charts for diesel and various blends were plotted.

4. Results

Table 2: Thermal efficiency results

Thermal efficiency:

LOAD	DIESEL	PPO:DIESEL20:80	PPO:DIESEL30:70	PPO:DIESEL40:60
2 kg	9.39%	9.33%	9.33%	9.45%
4 kg	15.77%	15.76%	15.53%	17.07%
6 kg	21.29%	20.49%	19.70%	20.49%
8 kg	25.76%	24.72%	23.65%	25.23%

Table 3: Brake specific fuel consumption

Brake specific fuel consumption: -

LOAD	DIESEL	PPO:DIESEL20:80	PPO:DIESEL30:70	PPO:DIESEL40:60
2 kg	0.898	0.910	0.910	0.898
4 kg	0.538	0.539	0.547	0.497
6 kg	0.399	0.414	0.431	0.414
8 kg	0.3298	0.343	0.359	0.336

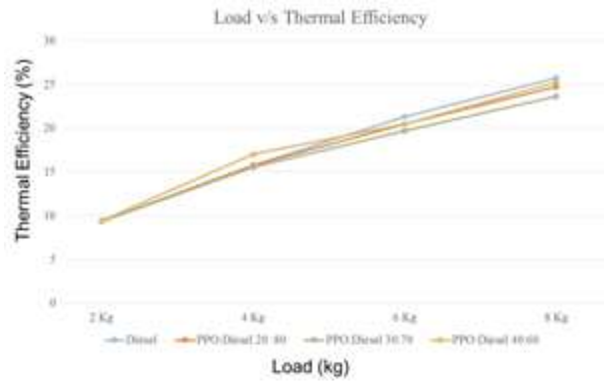
Table 4: Mechanical efficiency results

Mechanical efficiency

LOAD	DIESEL	PPO:DIESEL20:80	PPO:DIESEL30:70	PPO:DIESEL40:60
2 kg	15.75%	20.72%	21.33%	20.80%
4 kg	27.24%	34.33%	35.17%	34.42%
6 kg	35.96%	43.95%	44.86%	44.01%
8 kg	42.81%	51.13%	52.05%	51.23%

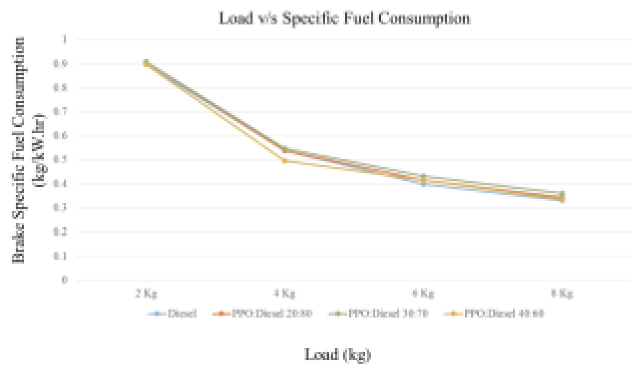
The plotted graphs are as follows:-

i) Load v/s thermal efficiency



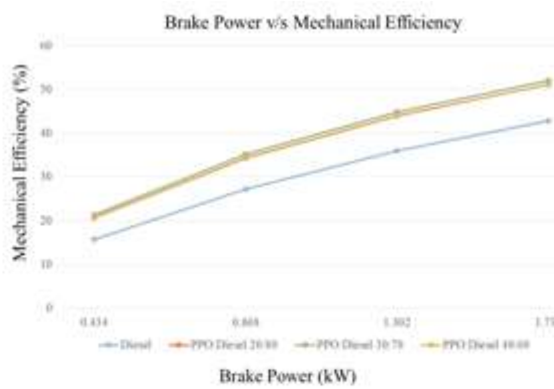
Graph 1: Load v/s thermal efficiency

ii) Load v/s specific fuel consumption



Graph 2: Load v/s specific fuel consumption

iii) Brake power v/s mechanical efficiency



Graph 3: Brake power v/s mechanical efficiency

The results indicate similar behavior of the blends in terms of the thermal efficiency and the specific fuel consumption with respect to diesel. On the other hand, all the three blends indicated higher mechanical efficiency than diesel at the tested brake power. This was mainly as a result of reduced friction power loss with the addition of plastic pyrolysis oil.

5. Conclusions

It can be concluded that, from the above results, the ideal blend to be used would be 30% of plastic pyrolysis oil in diesel. This is because it has and almost identical set of values for brake thermal efficiency and specific fuel consumption to that of diesel. Moreover, it has the highest set of values for mechanical efficiency among the tested fuels and blends. When we calculate the overall cost of the blend as was available during the project, it comes to around 54.7 rupees per litre. This value is more than 10% cheaper to that of the current cost of pure diesel per litre.

6. Future Scope

In the current automobile industry there is an urgent need to replace the propulsion source. With electric cars the ideal solution to the problem, there is still a lot of work that needs to be done before the vision becomes practical. Hybrid sources are the proposed solution to the current situation. Hence, the scope of blended fuels in the immediate future is vast. The raw plastic pyrolysis oil that is being obtained from plastic waste need to be refined to improve its nature, thereby improving the life of the engine. Also, with the emission norms becoming stricter, a new exhaust system may be developed to counter the harmful exhaust gases emitted by the blended fuel.

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