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Performance Analysis of Diesel Engine Fuelled with Distilled Waste Plastic Oil

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***Abstract* - Waste plastic management has become a necessary step in order to tackle the environmental damages caused by plastics. As plastics are petroleum based (carbon-carbon bonds), they do not degrade easily, this causes accumulation of tons of plastics in our surrounding. Thus the development of waste plastic recycling with environmental sound technology are applied in order to promote resource conservation. Majority plastics are made of polyethylene substances derived from crude oil refining and natural gas processing, Thus can be recycled to obtain fuel like substance that can burn and sometimes comparable to fuels.**

The pyrolytic oil obtained from the pyrolysis was further purified by distillation process, which is more refined and pure. The properties of waste plastic oil (WPO) and distilled waste plastic oil (DWPO) are compared. The study of performance and emission characteristics of CI engine was done with each fuels blend with diesel. A four-stroke single cylinder diesel engine was used at different loads. This strategy shows a solution for waste plastic administration as gap between worldwide plastic production and waste plastic age continues broadening conventional energy sources and leaving carbon footprints on condition. Vast number of diesel powered engines can be found in industrialization and transportation sectors. Waste plastics oil (WPO) was tried as a fuel in a D.I diesel engine and its execution qualities were investigated and contrasted with diesel fuel task.

It was observed that waste plastic oil exhibits higher thermal efficiency and emissions such as Oxides of nitrogen (NOx), carbon monoxide (CO) and smoke were less than the pure diesel fuel..

Thus the distilled waste plastic oil (DWPO) is analogous with the pure diesel

Key Words:* *Waste plastic oil (WPO), Distilled waste plastic oil (DWPO), Oxides of nitrogen (NO_x), Carbon monoxide (CO)

1. INTRODUCTION

To meet the demand of the fossil fuels availability in the future, focus on the alternative fuels are of interest. In order to deal with lacking of petroleum recycling process to obtain fuel is one of a remedy. Most of the fuel consumption is carried out by transportation unit.
Recovering energy from plastic wastes is a remarkable significance of recycling. The current rate of economic rate is implausible without conserving non-renewable energy such as coal, natural gas and by products of crude oil. An intriguing option in contrast to petroleum product as diesel motors for utilization of diesel kind oil from squanders.

Apart from fossil fuel consumption, waste management is also a foremost aspect. With the development of production have increment negative effect to the earth and living creatures through numerous ways. Gathering of plastics is likewise one of the reason. Plastics are one reason for materials as a result of their scope of utilizations because of adaptability and moderately minimal effort. Over million tons of plastics are produced each year, and yet increasing drastically. As plastics with high carbon chains, they take thousands of years to biodegrade. However it has become insufficient to recycle and redeem tons of plastics that turn out and leads landfills and ocean. An ongoing report moderately evaluated that 4.5 trillion plastics gauging a sum of a large portion of a million tons are at present drifting on the planet's seas and since plastic being a non-biodegradable material it stays into the dirt, along these lines contaminating nature.

1.1 Plastic oil

Plastic products have numerous uses in our day-to-day life. They are utilised to handle shopping from time to time, store items, insulate, for packaging and so forth. The awful aspect of some of these plastic products is unrecyclable. As such, they could only be disposed to the environment thereby causing polluting the. Throwing them in the environment only cause its deterioration. They may not be an easy task to decompose. As being a measure to ensure such problems are not encountered in the future understanding that the sustainability of the environment remains uncompromised, waste plastic to fuel conversion vegetation is used. The assistance to recycle plastic and convey useful product fuel. It converts an amount well be unhealthy for the surroundings to beneficial outputs. Through the use of plastic waste to fuel conversion plants, the following advantages are realized.

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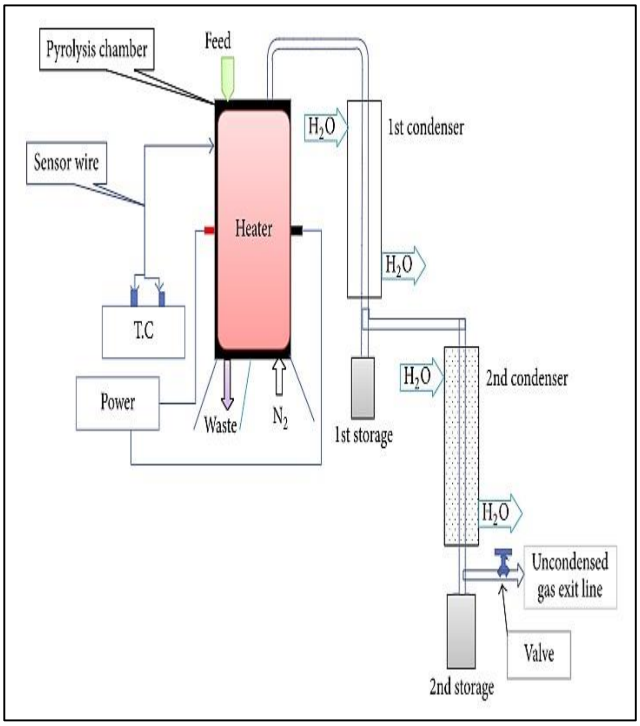

Fig 1.1 Schematic representation of plastic pyrolysis setup

1.2 Advantages of plastic oil

It converts waste to fuel oil Waste plastic to fuel conversion plants uses waste to create fuel oil. As such, the procedure reduces the gathering of plastic waste for the environment and in turn, make useful products from the waste. About the same note waste plastic to fuel conversion plants assistance to create an alternate source of energy for assorted uses.

It can be environment friendly Waste plastic into oil plants are environmental friendly. The process induces smallest amount of toxins to become released to the outer environments the purposes for such would be that the transformation occurs in the vacuumed chamber. The procedure dissolves or melts the materials other than utilizing them up. The pyrolysis procedure can reuse the gasses created to apply for warming along these lines sparing quality for the generation system. The feature makes the undertaking cheap. Vast number of plastic to fuel conversion plants has dedusting systems that can be better selection for dedusting further gas.

It promotes environmental protection By utilizing waste plastic to produce useful fuel oil, lots of people have changed their perception on plastic. Materials that have been regarded useless and such dumped carelessly are now regarded as advantageous. Waste plastic to fuel conversion plants helps as well in collecting waste plastic in the environment to be used inside the pyrolysis process as raw materials for producing fuel oil. The vice of throwing plastic products anyhow in the environment has recently been tamed. The surroundings is thus protected by keeping it clean and being cautious products one throws away.

Ultra-clean fuel is produced The waste plastic to fuel conversion plants produces clean fuel it doesn't need further cleaning. The high quality helps make the need for fuel from plastic to become high out there. Come of the applications include the utilization in heavy oil generators for generating electricity. They are also employed in refining factories for additional processing. The fuel also acts as heating substance in a various types of processes. Moreover, the fuel can also be utilized as other product in factories for example electricity, ceramic industries among others, to facilitate the production processes.

1.3 Distillation

Distillation is the method for separating or segmentation from a fluid blend by employing a setup built. Distillation will provide total partition (most of the pure segments), or on the other hand it may be a deficient separation that grows the combination of picked fragments in the mix. In either case, this type of process will discourage the instability of the mixture segments. In current science, refining is a unit assignment of in every way that really matters general distinction, yet it is a physical division process, not a blend reaction.

Distillation has various types of usage. For example: Refining of developed things produces refined refreshments with a high liquor substance or separates out other advancement results of business respect. Refining is a persuading and standard strategy for desalination.

In the non-maintainable power source industry, oil change is a sort of insufficient refining that decreases vapour weight of grungy oil, all things considered making it alright for farthest point and transport also as diminishing the baro-metrical spreads of insecure hydrocarbons.

In midstream exercises at oil refineries, refining is a vital class of movement for changing crude oil into forces and compound. Refining prompts the package of air into its segments – conspicuously oxygen, nitrogen, and argon – for mechanical use. In the field of mechanical science, a lot of unforgiving fluid eventual outcomes of creation affiliation are refined to disengage them, either from different things, from defiling impacts, or from unreacted beginning materials.

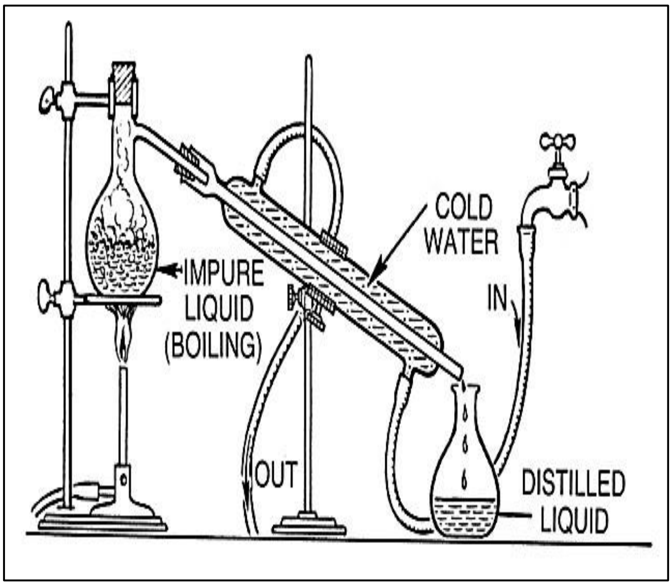

Fig 1.2 Distillation setup

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1.4 Properties of Plastic Oil and its Blends:

a) **Density:** It is a measurement that compares the amount of matter an object has to its volume.

b) **Calorific Value:** It measures the heat amount of a particular fuel, it also governs if the fuel is capable to burn well. Bomb calorimeter can be used to for the process. With a given particular volume of calorimeter and heat, it can be calculated by the difference in the internal energy along with temperature.

c) **Kinematic viscosity:** The property of internal flow friction or resistance between liquid to flow that supports in dynamic change between fluid motions. The lesser the viscosity of the oil, the simple to pump and atomize.

d) **Flash Point:** When an ignition source ignites the fuel and ignites the fuel at particular temperature, this temperature is known as flash point. It has to be done with safety measures.

1.5 Engine Exhaust Emissions:

a) Oxides of nitrogen
b) Oxides of carbon
c) Unburnt hydrocarbons
d) Particulates and smoke

The preceding three are common to both SI and CI engines and the end is only from CI engines. The only non-exhaust emission is the partial burnt hydrocarbons being from fuel unit and crankcase blow-by

For $\Phi<0.8$, HC releases furthermore increase as a result of poor consuming and inability to flame. The time of nitrogen oxide radiations is a part of the consuming temperature, most raised close stoichiometric conditions when temperatures are at a zenith regard, most extraordinary NOx outpourings happen at indistinctly lean conditions, where the expending temperature is high and there is an abundance of oxygen to respond with the nitrogen.

1.5.1 Hydrocarbon (HC) Emissions

CI engines run only with general fuel lean conditions proportion ratio, CI engines are only 1⁄5th of HC emissions as of SI engines. Diesel fuel has a higher sub-atomic weight on a run of the mill when showed up distinctively in connection to gas mix. Some HC particles consolidate onto the outside of the strong carbon build that is conveyed amidst begin, by a wide margin a large portion of this is burned as blending proceeds and the devouring method continues. The HC sections thick ostensibly of the carbon particles in spite of the strong carbon particles themselves, add to HC radiations of the motor. CI engines has a begin ampleness of just 2% of HC fuel being conveyed. CI engines additionally have HC outpourings for a piece of undefined reasons from SI engines do, for example, divider store ingestion, oil film upkeep, opening volume.

1.5.2 Carbon monoxide (CO) emission

Carbon monoxide is a dry unscented gas anyway a dangerous substance. Also delivered to an engine when it is worked with a fuel rich proportionality extent. Exactly when there isn't adequate oxygen to change over carbon and carbon dioxide, few fuels not get devoured and few completes as Carbon monoxide. CO is seen as a lamentable release, yet it is similarly addressing lost substance essentialness.

1.5.3 Oxides of Nitrogen (NOx) emission

Vapor substance of a motor may get to 2000 ppm of nitrogen oxides. Discharged NOx responds earth as shape ozone are one kind of the gigantic explanations behind photochemical decrease shaded duskiness. NOx is made routinely from nitrogen prominent all around. Nitrogen can in like way be found in the fuel mixes. There are number of conceivable responses that structure NO. The vast majority of the limitations are likely happening amidst the utilizing procedure. Gases are tireless in any occasion temperatures later gets responsive and supports to the progression of NOx with expansion in temperature that contains water vapor and oxygen. Regardless of temperature, the game-plan of NOx relies upon the weight and the air-fuel degree.

1.6 Factors affecting the delay period

1.6.1 Compression ratio

Toward the finish of the pressure stroke there is an expansion in the pressure temperature of the air with increment in pressure proportion. Additionally, at the base auto start temperature of a fuel diminishes because of expanded thickness of compacted gas.
This outcomes in little contact of particles of fuel diminishing the response time.

1.6.2 Engine speed

The delay period can either be termed as absolute time or crank angle. Decrease in delay period in name of crank angle degree along increase in the RPM in a variable speed operation with a given fuel. Degrees of crank travel in postpone period increments as the engine works at higher rpm. The fuel pump is attached and run to the engine, and hence fuel injected at the time of delay periods ultimately depends on crank angle.

1.6.3 Output

To meet the demand of the fossil fuels availability in the future, focus on the alternative fuels are of interest. In order to deal with lacking of petroleum recycling process to obtain fuel is one of a remedy. Most of the fuel consumption is carried out by transportation unit.
The hike of industrialization also has become one of the cause of rapid fuel depletion.

Recovering energy from plastic wastes is a remarkable significance of recycling. The current rate of economic rate is implausible without conserving non-renewable energy such as coal, natural gas and by products of crude oil. An intriguing option in contrast to petroleum product as diesel motors for utilization of diesel kind oil from squanders.

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1.6.5 Quality of fuel

Self-ignition temperature is also one of the most important thing that affects the delay period. The engine operation can be smooth with less delay period when the cetane number is high. Other such properties that can affect the delay period.

Z HC, CO, NOx, O_2 and CO_2 were measured. An AVL DiGas make analyser were used. The analyser is fully microprocessor – controlled system employing non- destructive infrared techniques.

2.LITERATURE SURVEY

Gian Claudio Faussone[1] Mix of liquid fills from waste is a promising pathway for lessening the carbon impression of transportation industry and propelling waste organization towards zero landfilling. The examination of business plants that immediate pyrolysis of plastics from post-buyer reused materials moreover, truly mine from old landfills with no pre-treatment has revealed two cases that exhibit the common sense of gathering transportation controls through these systems. Pyrolysis oil, including for all intents and purposes 26% hydrocarbons inside the fuel run and for all intents and purposes 70% inside the diesel run, is climbed to transportation fuel in the present refinery. A group working plant is proficient to pass on tolerably incredible quality pyrolysis oil from post-buyer plastic waste, owing to the driving force used. Essential refining was furthermore surveyed as a choice and more affordable upgrading process into transportation powers.

Songachi Wiriyaumpaiwong and Jindaporn Jamradloedluk [2] Pyrolysis, at temperatures from 500-800°C of plastic squanders gives as a standard sort, a dull darker fluid (a blend of gas, diesel and overwhelming oils). Fragmentary refining is normally used to detach oils. Regardless, data of refining of the oil from pyrolysis got through smart pyrolysis of waste is hair-raising. It was deduced that refining of pyrolytic oil tests got through lively pyrolysis of poly-ethylene and blended oil squanders. Previously the pure at 170°C for an hour and the later was refined at the temperature of 140°C and 170°C for an hour and a half. The distillates had a yellowish shading than the oil obtained for tests. The distillates found to be yellowish at 170°C and dry at 140°C. To the prohibition of everything else time of refining, refining rates stretched out with hung free and achieved a most exceptional at around 25-35 mL/min and after that particularly coordinated decreased. The density and viscosity of the distilled plastic oil was lower than the plastic oil.

Ioannis Kalargaris et al. [3] Plastic waste is a perfect wellspring of monstrosity due to its high key. It will with everything taken into account be changed over into oil through the pyrolysis procedure and utilized in inside eating up motors to pass on control and warmth. In the present work, plastic pyrolysis oil is made by methodologies for a speedy pyrolysis process using a feedstock including differing sorts of waste. The surveyed fuel and it was discovered that specifications are in every practical sense indistinctutoudieselufuel.uTheuplasticupyrolysisuoil was tried on aufour-chamber direct imbuement diesel motorurunninguatuvariousublendsuof plastic pyrolysis oiluandudieselufuel at different motors. The motor eating up attributes, execution and vapor transmissionsuwereubrokeudown and isolated andudieselufuel task. The results exhibiteduthat the engine can continue running on plastic pyrolysis oil at high loads demonstrating near execution To diesel while at lower stacks the more drawn out begin delay period causes soundness issues. The brake warm sensibility for plastic pyrolysis oil at full weight was fairly lower than diesel yet NOx spreads saw to be higher. The results recommended that the plastic pyrolysis oil is a superior than normal elective fuel for certain motor running application at unequivocal conditions.

Khan et al. [4] The producers showed squander plastic oil as an elective fuel portrayed and separated and regular diesel. High thickness type, was pyrolyzed in an own tempered steel investigate office reactor to make significant fuel things. HDPE squander was completely pyrolyzed upto 400°C for 3.2 hours to get strong advancement, fluid fuel oil and burnable vaporous hydrocarbon things. Examination of the couple of properties to the petro diesel fuel principles uncovered that the manufactured thing was inside all decisions. Strikingly, the fuel specificataions combined a kinematic consistency (50°C) of 2 cSt, thickness of 0.75 gm/cc, sulfur substance and carbon advancement of 0.45 (wt %), and more calorific updates over those of ordinary oil diesel fuel.

Digambar Singh et al. [5] Increased energy demand and energy consumption have led analysts touseekuapproachesuto use wasteuas a fueluthatucould displace non-renewable energy sources. The transition from waste to energy is one of the current models to limit the transfer of waste and couldubeuuseduasuan electiveufuel foruthe internaluignition engine. Withuthe helpuof the pyrolysisuprocess, plastic wasteucan be turneduintouoil.uThe uses ofuplasticuin companies are expanding vigorously andutheumain problem withuplasticuis the transfer.

In this specific circumstance, wasteful plasticsuareucurrently re-establishing intrigue. Inuthisuarticle, plastic oil is wasted and the mixture of residual plasticuandudiesel oil is presented as another fuel.uInuthis documentuvarious working parameters were examined;In addition, this document incorporates exhausts and qualities of execution whileuusing wasteuplasticuoiluas a fueluand contains a relative examination with diesel fumes.

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Damodharan et al. [6] When imperative demands are made in general, the recovery of the essentiality of plastic familiarizes a design on the road with research as progress that is reused. The plastic compound oil can be a brilliant fuel for the diesel engine, however, it produces a more dangerous development that causes smoke transmissions and a poor performance compared to the fossil. Thisustudy shows theuextraction and delineation of residual plasticuoil obtaineduby pyrolysisuin aulaboratory hand reactoruand then stops the examination of the impacts of including an oxygenated vital area such as butanol, a biofuel that occurs on a base routine. Three ternary mixtures have been specially designed to use both reused parts (WPO up to 40%). The execution is over, the arrivals of diesel engines controlled with these mixtures have been gutted in association with the delicate WPO and the diesel. The results showed that the advance of butanol introduced a lower diffusion of smoke and greater HC floods when separated from diesel. Expansion of n-butanolubyuvol. The WPOublend emphaticallyureduced NOx spills when it emerged from bothuWPO andudiesel. In any case, NOx spills wereuhigher thanutheurelateduWPO matter foruhigherun-butanolumixtures. The thermaluefficiencyuof the brakes obtained for the engine has been extended to develop the division of butanol in all mixtures when it was presented differently in relation to the residual plastic fuel. Use of mixtures of fuel mixtures presumably higher than the WPO. Half of the diesel, 40% of the plastic oil, the mixture of n-butanol and 10% showed few fumes and NOx that contained progress in engine performance, precisely, which were clearly shown in relation to the diesel. Concentrate not covered so that n-butanol is an admissible substance included for the diesel engine that works with the ejected PO obtained through the mixed fuel.

Mani et al [7]. Plasticsuhave nowubecome irreplaceable materialsuinuthe avant-garde worlduand the applicationuinuthe mechanical sector is constantly expanding. Inuthis specific situation, the waste of strong plasticuis recovering from intrigue. The propertiesuofutheuoil obtained from plastic waste have been examined anducompared and, moreover, petroleumbased products have discovered that it has properties such as diesel. uInutheupresentuwork, wasteful plasticuoil has been useduas a replacement fueluinuaudiesel engineuwithout alterations. Theupresent examination consisted of examining the qualities of execution, discharge and ignition of a solitary barrel, an air-cooled four-stroke DI diesel engine that operates on wasteuplasticuoil. The test results showeduaustable behavior with a productivity of hot braking like diesel.uCarbonudioxideuanduunburneduhydrocarbon were probably higher thanuthose of the diesel standard. Theucarbonumonoxideuproduction of the harmful exhaust gas from the plasticuoil was higheruthan thatuof the diesel. Smoking has decreased by around 30% in half of the plastic oil used in all the heaps.

Sachin Kumar et al. [8] The initial weight engines ended up being the best choice in bad applications such as transportation, age control, but the sources of standard oil supplies that are running out quickly, their rising costs and the regular problems growing so reliable are the main concerns. The present examination supervises the execution, the overvoltage test of mixtures of plastic waste oils obtaineduby reactive pyrolysisuof highudensity polyethylene wastes with dieseluin auCI engine with floating weights. The test results give an idea thatuthe heating efficiency of the brakes in all loading conditions are lower when they appear differently than gas, the steam gasutemperatureuincreases with the increaseuin the fuel consumption and engine problem. TheuBSFCuincreasesuwith the increase of the diffusion of WPO mixture and is reduced with the addition in the weight of the engine. The mechanical profitability increased by increasing the brake control foruallufuel mixtures. The flow of NOxuanduCO release increases with the increase in size of waste oils in the mixtures, the increase of NOx while the CO flow increases with the addition of the weight of the engine. The wave of unburned hydrocarbons decreases with the addition of the weight of the engine, increases with the increase in size of the plastic waste in the mixtures. The increase in carbon dioxide for mixtures is less than the diesel fuel to all intents and purposes, to all fillers and mixtures.

Mani et al. [9] Theupropertiesuof theuoil obtained from the plastic waste have been studied and discovered thatuit hasuproperties like diesel. uWasteuplasticuoil has been testeduas aufuel in audieseluengineuanduitsuperformance characteristics and the task of the diesel have been studied and contrasted. It has been seen thatutheuengine could work with completely discharged plastic waste oiluand can be used as fuel in diesel engines. Nitrogen oxides increased by about a quarter more and carbon monoxide (CO) expanded by a few percentage points due to the task of plastic oil waste in contrast to the activity of gas oil. The hydrocarbon was about 15% greater.

Rinaldini et al. [10] A fascinating option in contrast to the petroleum product forudiesel enginesuisutheuuse of an oil similar to diesel oil obtained from plastic, since this response provides the dual preferred viewpoint for recovering the significant vital substance from the debris, and also alleviate the problem of transferring the substantial measure of plastic waste delivered from both residential and mechanical establishments. This document describes the exploratory battle completed in a reverse injection of the current creation, a normally aspirated diesel engine, running on a normal commercial diesel oil anduplastic oil obtained fromuthe pyrolysisuofuplastic materials. Furthermore, both full load and fractional loading tests were performed, while the weight in the chamber was estimated to study ucombustionuphase. The consequences of the exploratory battle showed auslight decrease in the engine performance for the plastic oil, mainly due toua lower evaluation of the volumetricufuel, butubetter still to curb the explicit use of the fuel and the capacity of transformation of the brake fuel (contrasts up to 7%). The weight in barrique that follows, estimated in the equivalent load, has found a certain distinction in the initial segment ofuthe combustionuprocess, inuparticular atuhigh speeds,uwhere theuWPO heat discharge is softer.

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3.METHODOLOGY

For Distillation process, Boiler was utilized to heat to the waste plastic oil. LPG gas was utilized to run the stove and then heat the boiler; Copper tube was utilized to exchange vapourized plastic oil as are good conductors, Condenser was connected over copper tube to consolidate the vapor and counter stream cold water was siphoned. A temperature of 180°C to 200°C was maintained in the boiler. The condensed pure distillate was obtained on the other end of the copper tube with a retention time of 6ml/min.

The fuel was powered by a 4-stroke, single-cylinder high-speed diesel engine. The engine was connected to a dynamometer powered by eddy currents. The load was applied by the dynamometer with an arm length that provided a load of 0 kg to 16 kg in increments of

4 kg each time. The engine was maintained at 1500 rpm, which produces 5.2 kW. Theuexperiment wasuconducted in theuexperimental configuration ofua natural 4-stroke direct injection diesel engine connected to a current eddy current dynamometer useduto apply the load to theuengine withuan armulength ofu0.185 m. which provides auloaduof between 0 kg andu18 kg, uwhich isuused only for aumaximum loaduofu16 kg. The motor is a type of constantuspeed motor with auconstant speeduof 1500urpm. Thisuengine is set up with different sensors to measure differentuparameters suchuas speed, crankshaftuangle,utemperature, pressure, etc.

Theufuels used were pure diesel, a mixture of plastic and diesel waste (WPO50-D50) and a mixture of waste oil from distilled plastic and diesel (DWPO50-D50). Each of the fuels works and performs the performance test. The aspects of radiation are used with a DiGas 444 AVL analyzer which offers an examination of fiveugases specificallyuCO, CO_2, uNOx, uHC anduO$_2$. The analyzer has a camera that must be implanted in the last part of the test and observe readings that are balanced after an afternoon or afternoon, whichuis the aspect presentuinuthe radiation. This analyzeruuses threeutypes of channels: line channel, tube channel and paper channel.

4.EXPERIMENTAL SETUP

4.1 Introduction

4.1.1 Distillation

LPG stove was used to heat the boiler that contained waste plastic oil obtained from pyrolysis process. A copper tube was attached to the boiler of 1m. A condenser was attached around the other end of the copper tube and was made with PVC pipe. This condenser was provided with a counter flow cold water. The water was pumped by a motor pump. The copper tube was used as they are resistant to corrosion and high level of heat transfer conductivity. The oil was heated at 180°C to 200°C progressive. The condenser was pumped with cold water and the distillate was obtained on the other end of the copper tube. It was found that the distillate had lighter colour and viscosity as compared to the raw waste plastic oil.

The retention time for the output was 6ml/min.

4.1.2 Performance and emission test

The fuel was run on a high speed single cylinder engine connected to the eddy current dynamometer with chilled water. The execution of the engine is based on the connection between the created power, the speed and the particular use of the fuel in every working condition within the precious speed and load range.

The configuration consists of four types of sensors, for example, 5000 psi flow sensor, 1 degree crankshaft resolution sensor, 1500 rpm with TDC heart rate monitor, temperature sensor with K-type thermocouple and sensor flow rate 0 - 50 Kg. The engine starts for the first time in 10 to 15 minutes with the diesel fuel when the heat estimate is entered and the thickness is estimated separately in the engine programming. The engine speed was stable atu1500 rpm under fluctuating load conditions (without load, u4 kg, u8 kg, u12 kg andu16 kg) to measure performance parameters, such as the indicated average effective pressure, the average effective pressure of the brake, specific fuel consumption, thermal efficiency of the brakes, etc.

Engine fumes have been associated with the DiGas 444 AVL analyzer, as the Electro-Concoction type oxygen gas sensor is used to quantify engine output flow parameters, such as CO, CO_2, HC, O_2 and NOx and smoke.

Table 4.1 Engine configuration Data

ENGINE AND SETUP DETAILS	
Number of cylinder	1
Number of strokes	4
Fuel	Diesel
Rated power	7HP (5.2kW) @1500rpm
Type of dynamometer	Eddy current diameter
Calorific value of diesel	42500 kJ/kg
Dynamometer arm length	185mm
Cylinder diameter	87.5mm
Stroke length	110mm
Compression ratio	17.5:1
Orifice diameter	20mm
Specific gravity of diesel (S_f)	0.84
Coefficient of discharge (c_d)	0.6
Density of water	1000 kg/m^3
Density of air	1.165 kg/m^3
Manometer liquid	Water
SENSOR RANGE	
Exhaust gas temperature	0 -1200°C
Air flow transmitter	(-) 250 – 0 mm WC
Fuel flow DP transmitter	0 – 500 mm WC
Load cell	0 – 50 kg
Sensor signal range (input for interface)	1 – 5 V
Cylinder pressure transducer	0 – 345.5 bar

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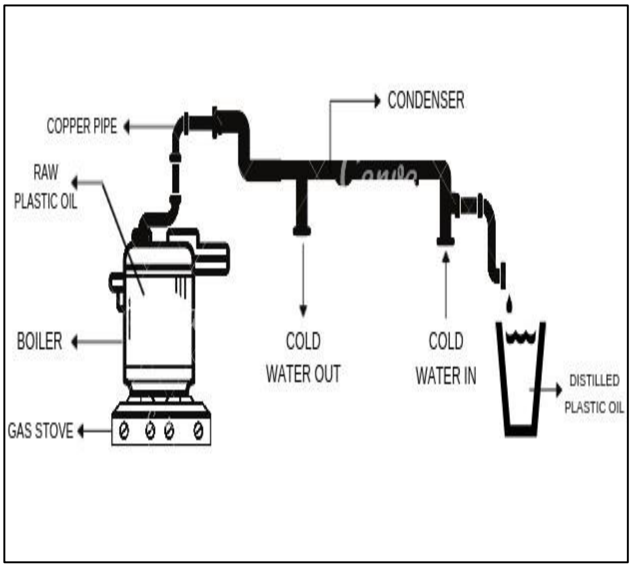

Fig 4.1 Design for distillation setup

Fig 4.2 Distillation setup for plastic oil

Fig 4.3 Avl Digas 444

Fig 4.4 Kirloskar single cylinder four stroke diesel engine

Fig 4.5 Raw plastic oil and Distilled plastic oil

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5.SYSTEM ANALYSIS

5.1 formulae

5.1.1 Brake power (kW):

BP	=	2πNT/60000
T	=	L × 0.185 × 9.81
N	=	Speed RPM
T	=	Torque in Nm
L	=	Load in kg

5.1.2 Brake thermal efficiency (%):

BTE	=	BP × 100 / (TFC × CV)
TFC	=	10 × 10^{-6} × density / t (kg/ s)
TFC	=	Total Fuel Consumption in kg/s
CV	=	Calorific Value of fuel
BP	=	Brake Power in kW

5.1.3 Specific fuel consumption (kg/kWh):

SFC	=	TFC / BP (kg / m)
TFC	=	Total Fuel Consumption in kg/h
BP	=	Brake Power in kW

5.1.4 Indicated power (kW):

IP	=	[(IMEP) × 10^5 × (LAN / 2)] / 60000
IMEP	=	Indicated Mean Effect Pressure in pa
L	=	Stroke Length in m
D	=	Cylinder Diameter in m
A	=	(πD^2)/4 Cylinder area in m^2

5.1.5 Heat input (Q_i):

CV x TFC (kW)

Calorific value of fuel in kJ/kg

TFC = Total fuel consumption in kg/sec

5.1.6 Brake Mean Effective Pressure (B_{mep}):

B_{mep} = BP × 60 / L × A × 100 × (N/2) in bar

5.1.8 Indicated thermal efficiency (%):

I.T. E = [IIP/(TFC × CV)] × 100 IP = Indicated power in kW

1) **5.2 Properties of diesel fuel and plastic oil**

Table 5.2.1 Properties table of Diesel fuel and Plastic oil

FUEL PROPERTIES	CALORIFIC VALUE (kJ/kg)	DENSITY (kg/m^3)
Diesel	42,500	840
Plastic oil	36,953	875
Distilled plastic oil	38,902	857

5.3 OBSERVATIONS

Table 5.3.1 Performance Table for diesel

LOAD (kg)	TIME (s)	hm (cm)	CO (ppm)	HC (ppm)	CO_2 (ppm)	O_2 (%)	NOx (ppm)	SMOKE (%) (opacity)
0	68.55	78	0.04	12	1.2	18.8	112	14.8
4	41.69	76	0.04	15	2	17.98	303	20.5
8	32.25	74	0.05	19	3.1	16.1	598	30.3
12	27.03	69	0.05	23	4.98	13.12	898	42.9
16	22.88	66	0.08	25	5.96	11.98	1012	58.2

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Table 5.3.2 Emission table for diesel

Torque (Nm)	BP (kW)	TFC (kg/s)	IP (kW)	Qi (kW)	Bmep (bar)	ηbth (%)	ηith (%)	SFC (kg/kW-h)
0	0	0.000123	2.1	5.21	0	0	40.32	-
6.93	1.09	0.000201	3.187976	8.56	1.32	12.7	37.23	0.67
13.86	2.18	0.00026	4.275952	11.07	2.64	19.7	38.63	0.43
20.79	3.26	0.000311	5.363928	13.21	3.96	24.7	40.61	0.34
27.72	4.35	0.000367	6.45	15.60	5.28	27.9	41.35	0.30

Table 5.3.3 Performance table for diesel blended with plastic oil

LOAD (kg)	TIME (s)	hm (cm)	CO (ppm)	HC (ppm)	CO2 (ppm)	O_2 (%)	NOx (ppm)	SMOKE (%) (opacity)
0	89.03	76	0.04	13	1.3	18.81	62	8.2
4	45.21	72	0.04	18	2	17.82	267	19.3
8	35.12	70	0.04	21	2.4	17.12	365	27.3
12	27.85	68	0.04	24	3.01	15.92	398	37.5
16	23.08	64	0.06	28	5.12	12.98	492	49.6

Table 5.3.4 Emission table for diesel blended with plastic oil

Torque (Nm)	BP (kW)	TFC (kg/s)	IP (kW)	Q_i (kW)	Bmep (bar)	ηbth (%)	ηith (%)	SFC (kg/kW-h)
0	0	0.00001	1.25	3.633879	0	0	34.39	-
6.93	1.09	0.00019	2.34	7.16	1.32	15.20	32.67	0.64
13.86	2.18	0.00025	3.43	9.21	2.64	23.62	37.19	0.41
20.79	3.26	0.00031	4.51	11.62	3.96	28.10	38.86	0.35
27.72	4.35	0.00038	5.60	14.02	5.28	31.05	39.96	0.31

Table 5.3.5 Performance table for diesel blended with distilled plastic oil

LOAD (kg)	TIME (s)	hm (cm)	CO (ppm)	HC (ppm)	CO2 (ppm)	O_2 (%)	NOx (ppm)	SMOKE (%) (opacity)
0	88.7	72	0.03	8	1.4	18.48	102	6.8
4	44.98	70	0.03	11	1.9	17.7	245	17.9
8	35.1	68	0.03	14	2	17	392	24.6
12	28.52	66	0.03	16	3.15	16.01	498	31.6
16	23.76	64	0.05	19	4.2	14.98	692	35.9

Table 5.3.6 Emission table for diesel blended with distilled plastic oil

Torque (Nm)	BP (kW)	TFC (kg/s)	IP (kW)	Q_i (kW)	Bmep (bar)	ηbth (%)	ηith (%)	SFC (kg/kW-h)
0	0	0.00001	1.50	3.76	0.00	0.00	39.89	-
6.93	1.09	0.000191	2.59	7.41	1.32	14.67	34.90	0.63
13.86	2.18	0.000244	3.68	9.50	2.64	22.90	38.69	0.40
20.79	3.26	0.000301	4.76	11.69	3.96	27.91	40.74	0.33
27.72	4.35	0.000361	5.85	14.04	5.28	31.00	41.69	0.30

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6.RESULTS AND DISCUSSION

6.1 Performance graphs:

6.1.1 VariationuofuBrake thermaluefficiency with respect to brake power

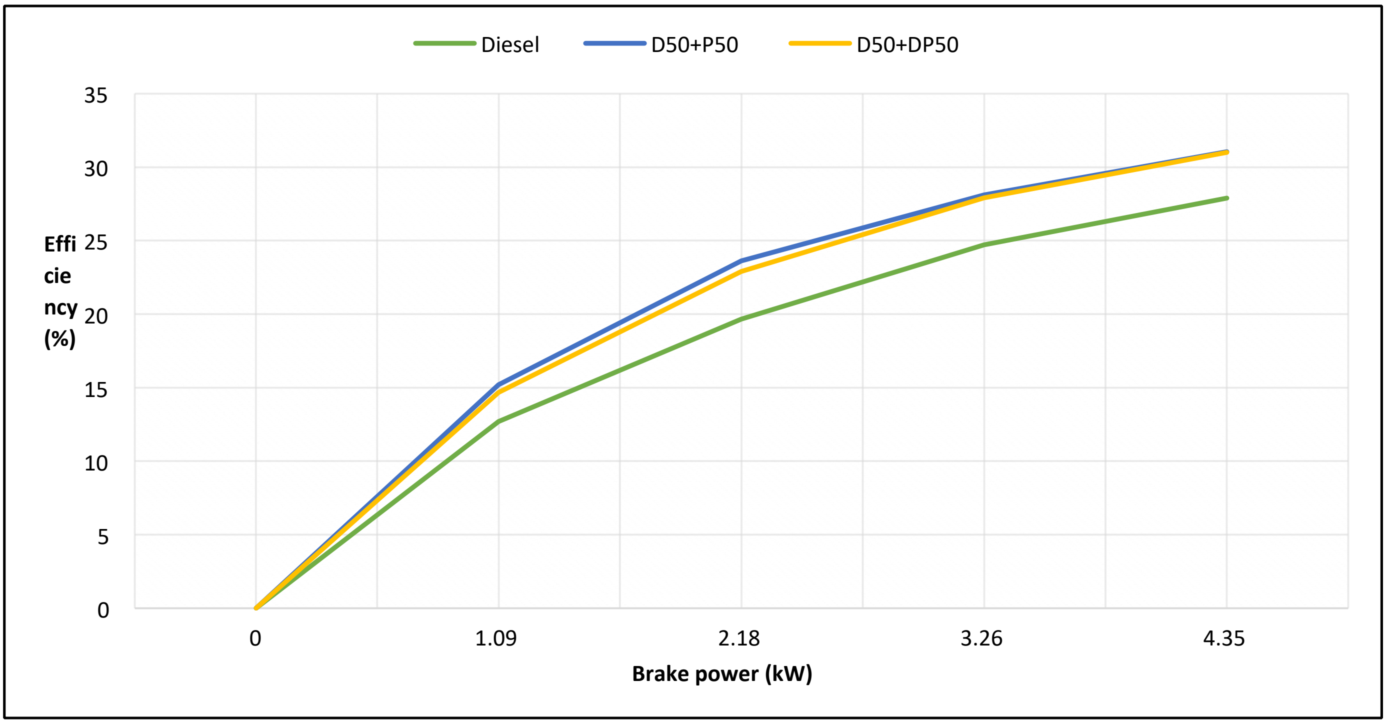

Fig 6.1.1 VariationuofuBrake thermaluefficiency with respect to brake power

- The graph indicates plotting between the Brake thermal efficiency and Brake power.
- According to the Brake thermal efficiency formula, efficiency is directly depended to the CV. In the above table shows that as CV decrease and the BTE increases.
- This graph clearly shows that the efficiency of diesel is lesser than waste plastic oil and distilled oil.
- The efficiency of waste plastic oil blend (D50+P50) and Distilled waste plastic oil blend (D50+DP50) are quite similar.

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6.1.2 Variation specific fuel consumption with respect to brake power

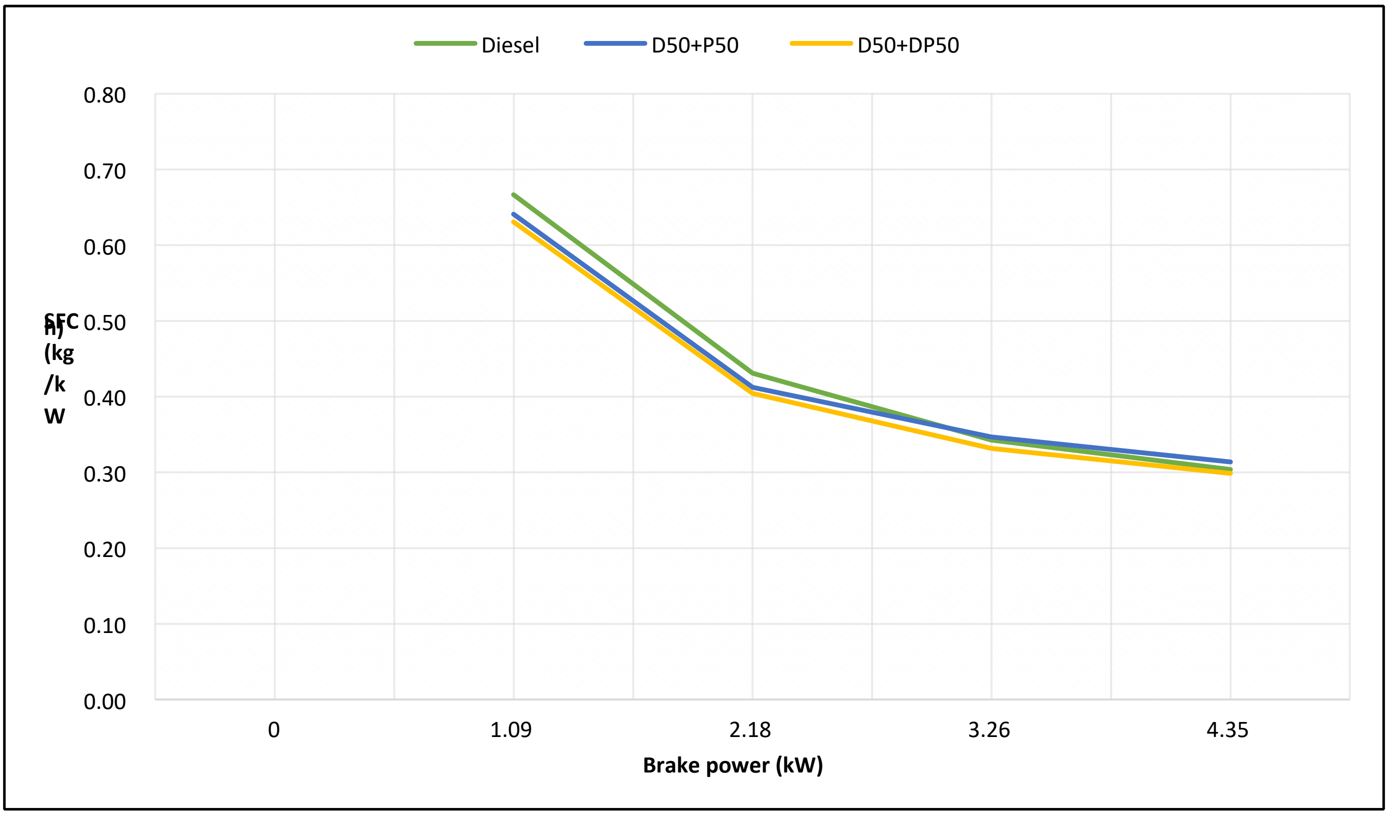

Fig 6.1.2 Variation specific fuel consumption with respect to brake power

- The graph indicates the plot linking the specific fuel consumption and Brake power.
- The fuel consumption was calculated by measuring the volume flow rate and the density given in the table. Since the engine is running at a constant speed and we had varying values of load, which is nothing, but same engine power depends upon the mass flow rate.
- This graph clearly shows that the specific fuel consumption of diesel when contrast to waste plastic oil blend (D50+P50) and distilled waste plastic oil blend (D50+DP50) are almost similar.

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6.2 EMISSION GRAPHS:

6.2.1 Variation of CO (ppm) emission with respect to Load (kg)

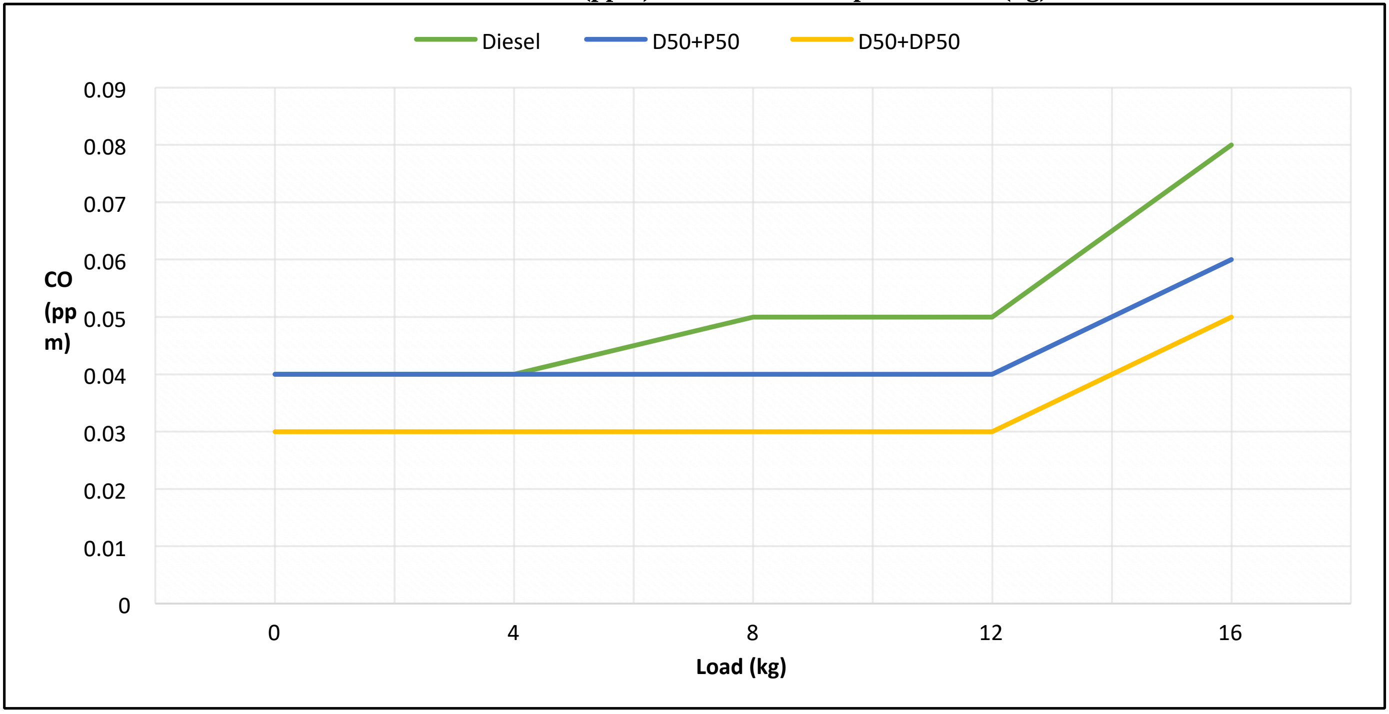

Fig 6.2.1 Variation of CO (ppm) emission with respect to Load (kg)

- The graph indicates the plot between the emission of carbon monoxide and load.
- The curve with flow is as similar with rising load and shows constant rise in slope after application 12 kg load.
- The CO emitted is due to inappropriate combustion of fuel that is an aftereffect of less temperature at minimum loads and less air fuel ratio at maximum loads
- Diesel fuel having higher CO emission than plastic oil blend and distilled plastic oil blend.

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6.2.2 Variation of HC (ppm) emission with respect to Load (kg)

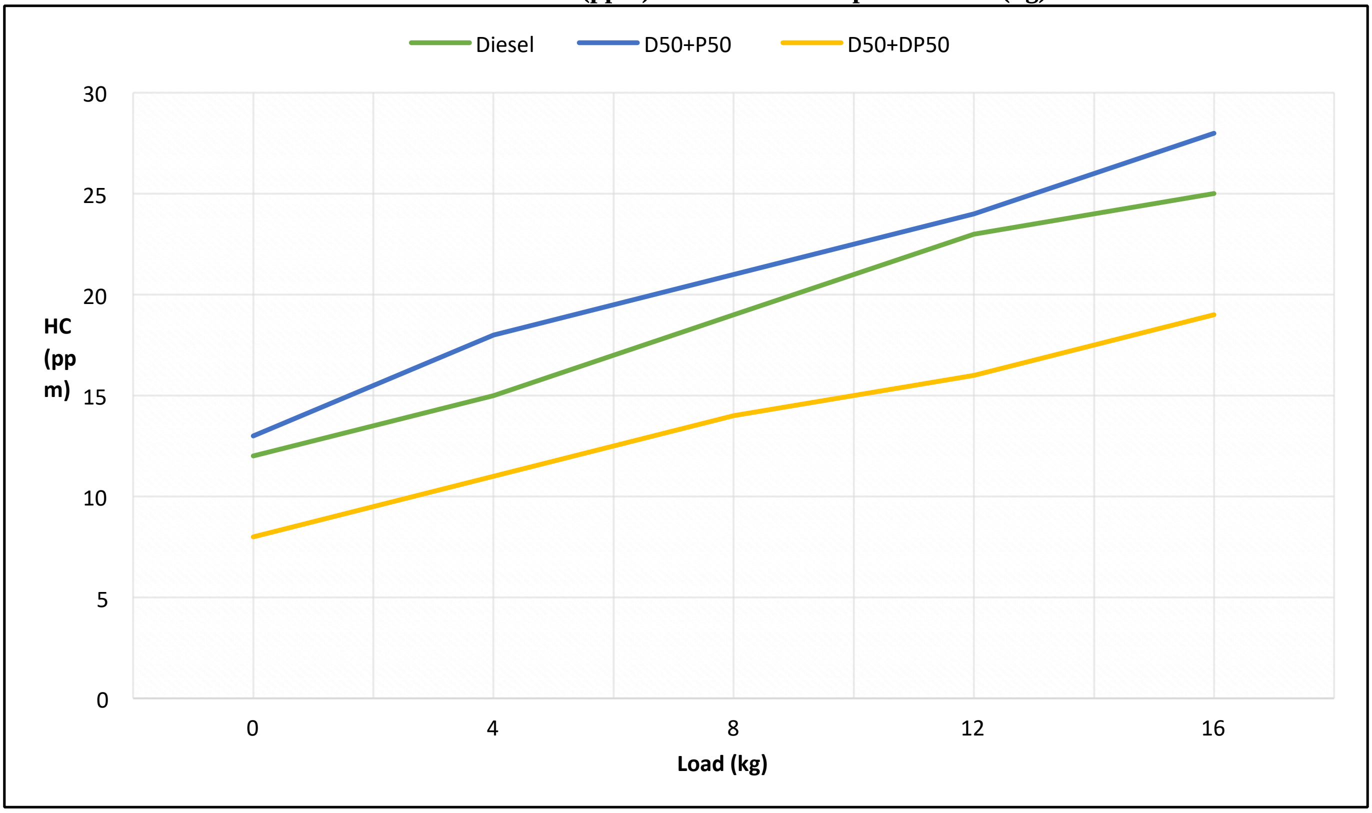

Fig 6.2.2 Variation of HC (ppm) emission with respect to Load (kg)

- The graph shows the plot between the emission of Hydrocarbon and load.
- The Hydrocarbon obtained from exhaust when ran with blend of diesel and distilled plastic oil (D50+DP50) is lesser than that of blend of diesel and plastic oil and pure diesel.
- And the emission of Hydrocarbon in the waste plastic oil blended with the diesel (D50+P50) is higher than the other fuels used.

6.2.3 Variation of CO_2 (ppm) emission with respect to Load (kg)

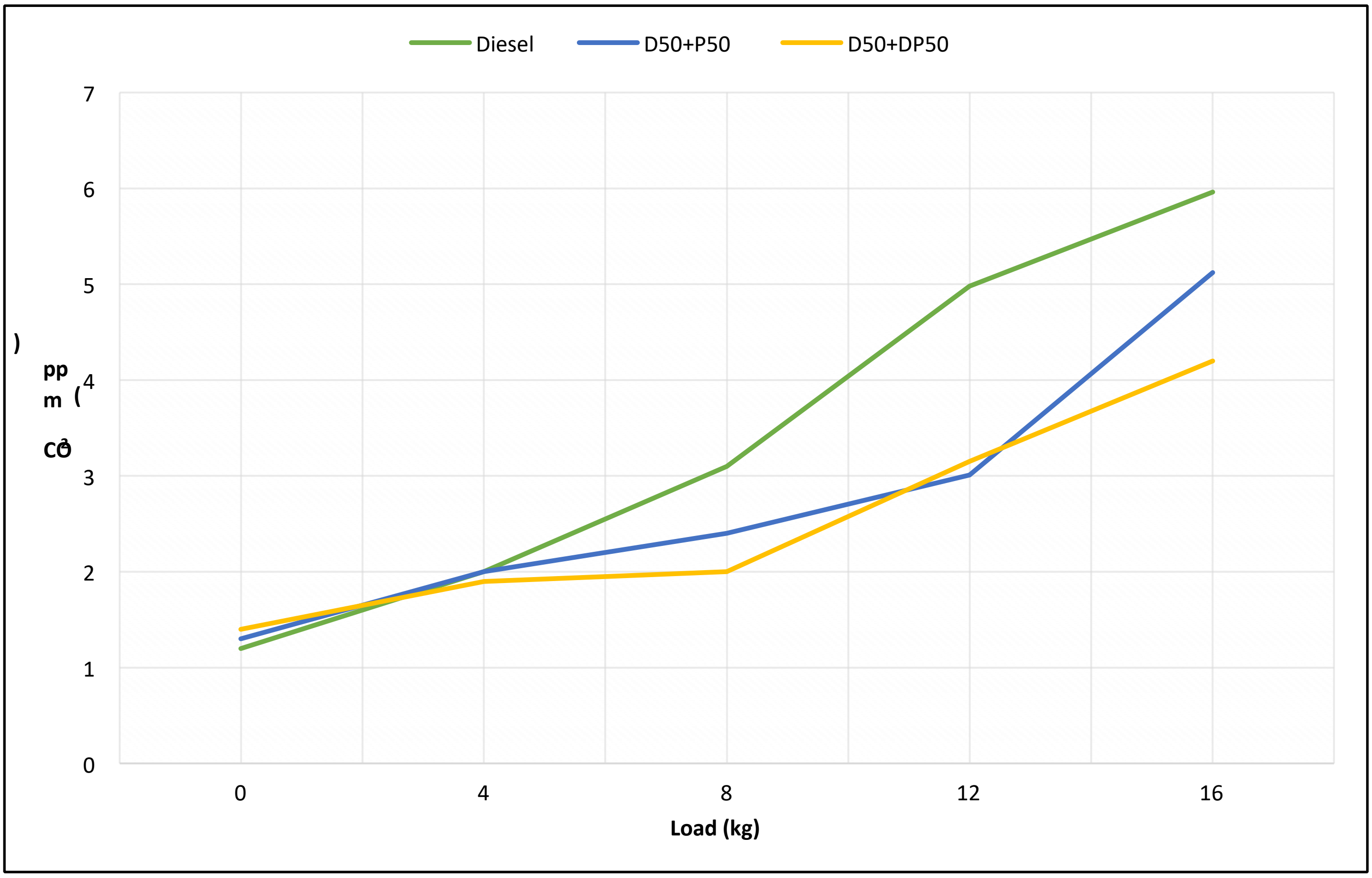

Fig 6.2.3 Variation of CO_2 (ppm) emission with respect to Load (kg)

- The graph shows the plot between the emission of carbon dioxide and load.
- The curve with less CO_2 shows poor burning of fuel in the combustion chamber.
- Blended fuels seems to have poor atomization at less load and CO_2 obtained from plastic fuels are less than that of pure diesel.
- Fuels are said to undergo pure combustion at good cylinder temperature and load.

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6.2.4 Variation of O_2 (%) with respect to Load (kg)

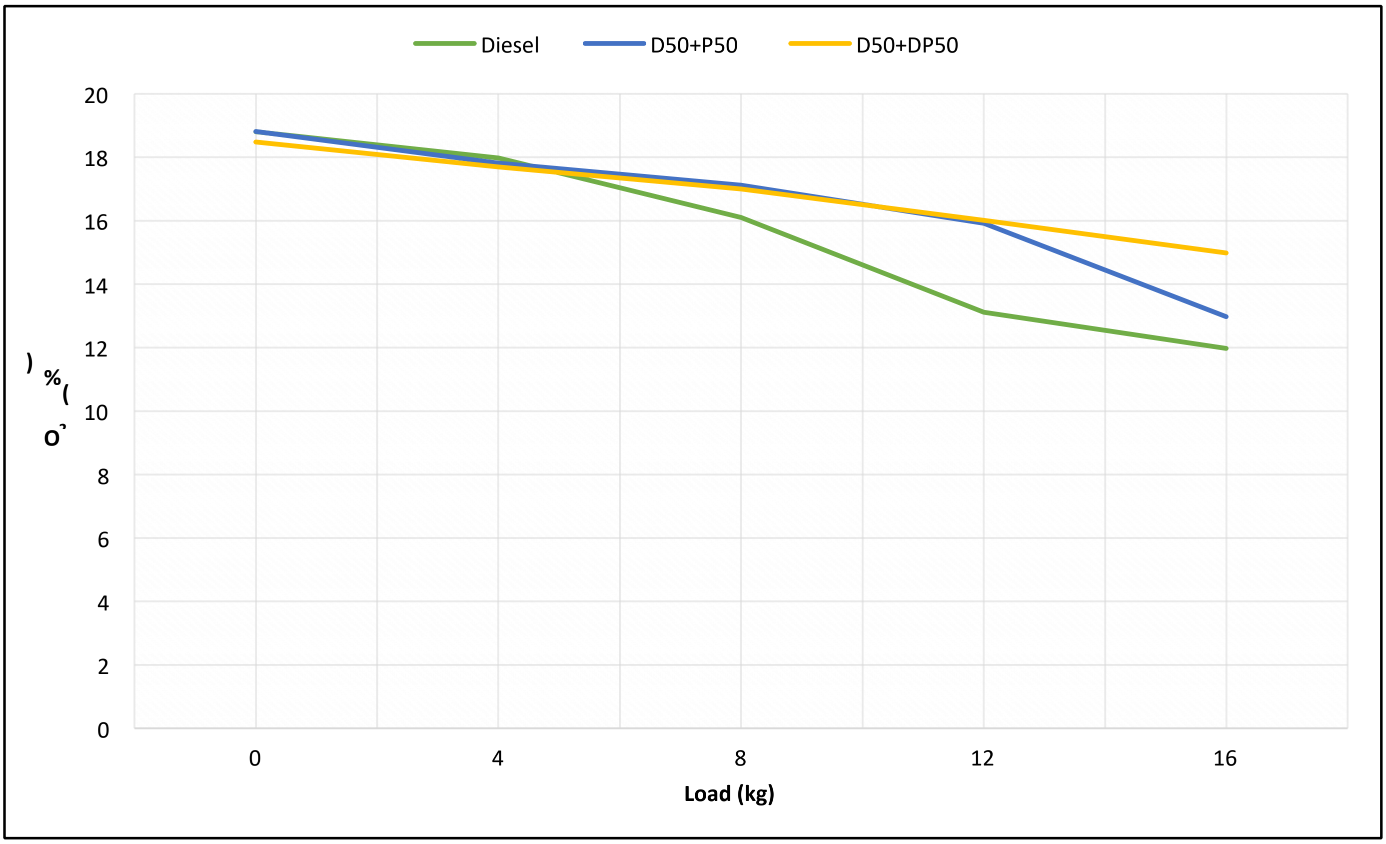

Fig 6.2.4 Variation of O_2 (%) with respect to Load (kg)

- The graph shows the plot between the emission of oxygen and load.
- The emission of oxygen is higher in the blend of diesel and distilled plastic oil (D50+DP50) and blend of diesel and waste plastic oil blend (D50+P50) when compared to diesel.

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6.2.5 Variation of NOx (ppm) with respect to Load (kg)

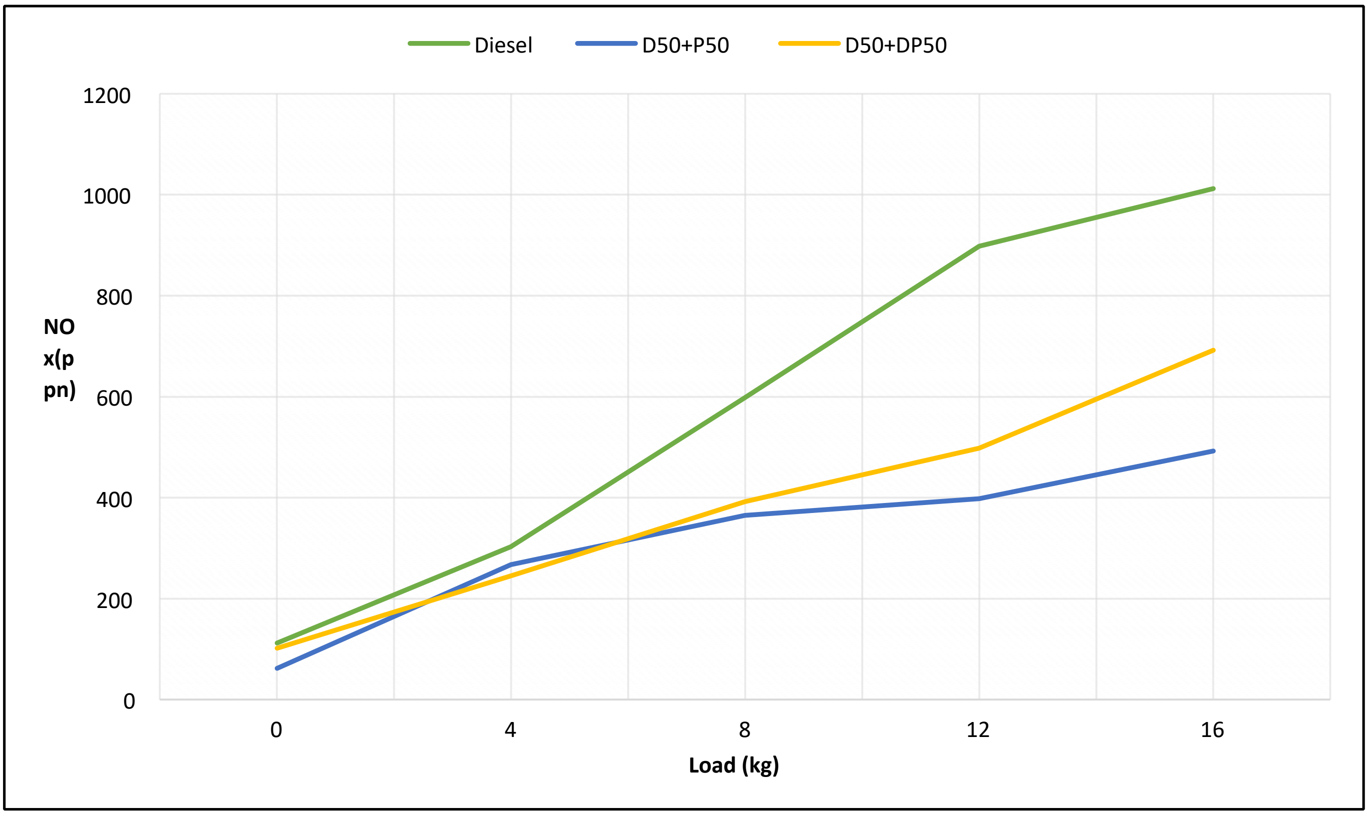

Fig 6.2.5 Variation of NOx (ppm) with respect to Load (kg)

- The graph shows the emission of NOx curve increasing along load and as the temperature in cylinder combustion chamber rises, more NOx are produce.
- The opacity of NOx reduces with applying more weight.
- Considering the chemical equilibrium, point out that for a burnt gas at a particular temperature, NO_2/NO ratio is negligibly small. The emission of NO is a function of peak flame temperature and combustion. And the content of oxygen.
- NOx obtained from pure diesel is high compare to blended fuels.

6.2.6 Variation of Smoke intensity with respect to Load (kg)

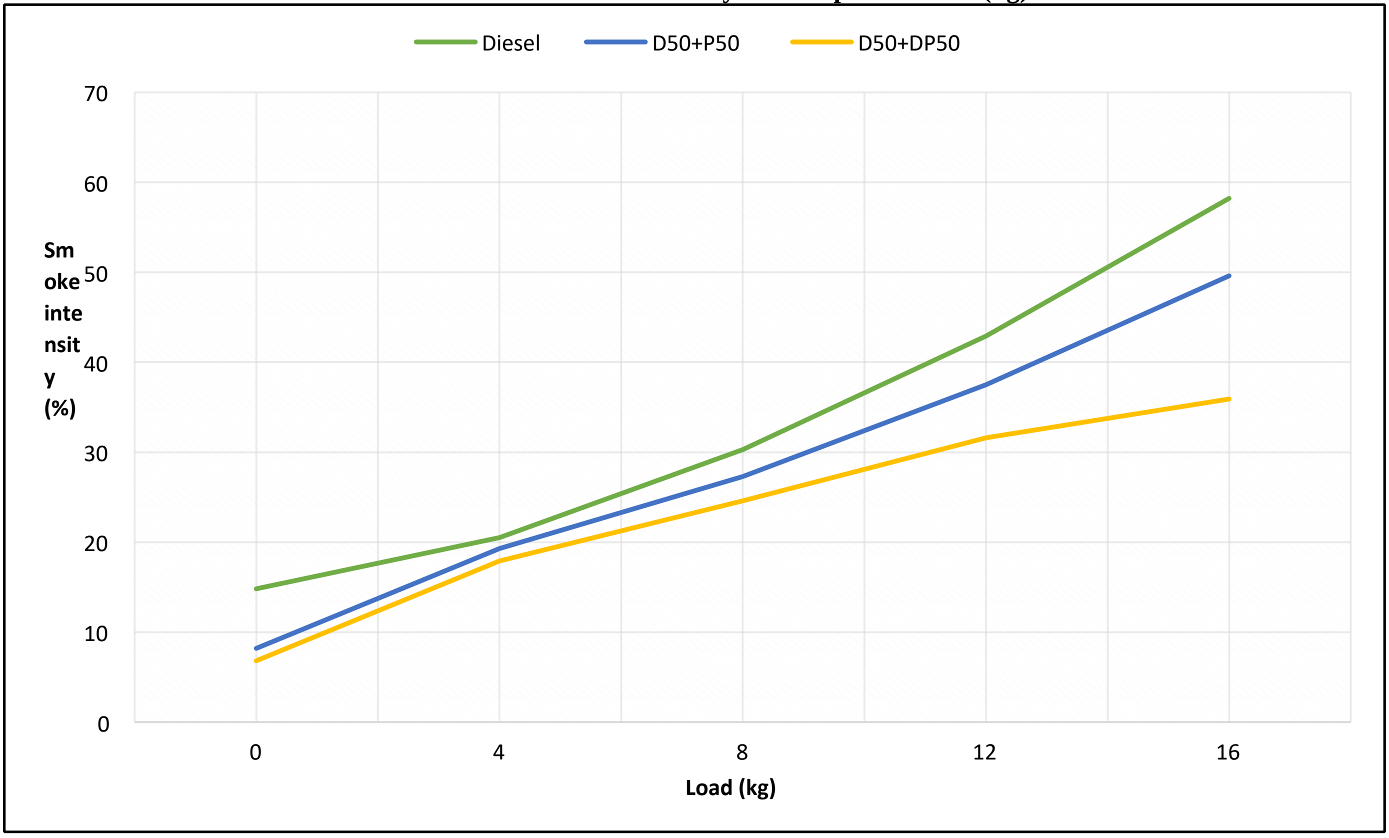

Fig 6.2.6 Variation of Smoke intensity with respect to Load (kg)

- The graph shows the plot between the emission of smoke and load.
- The emission of Smoke is lesser in the distilled plastic oil blend (D50+DP50) when compared to waste plastic oil blend (D50+P50) and diesel.

6.3 Results obtained

Table 6.3 Properties of fluids

SNO.	PARAMETER NAME	RAW WASTE PLASTIC OIL	DISTILLED WASTE PLASTIC OIL
1.	Ash content (%)	0.06	0.05
2.	Density at 15°C (gm/ml)	0.8755	0.8573
3.	Kinematic viscosity at 40°C (cst)	2.62	1.08
4.	Conradson Carbon Residue (%)	0.18	0.08
`	Flash point (°C)	30	30
6.	Fire point (°C)	37	37
7.	Gross calorific value (kcal/kg)	8832	9298

6.CONCLUSION

The distillate was found to be more refined than raw plastic oil as density and kinematic viscosity are less. It was light yellowish at 180˚C with more calorific value than raw plastic oil. The refined item of pyrolytic oil from plastic waste obtained by distillation can possibly be utilized as substitution fuel. Thus the distilled waste plastic oil (DWPO) is analogous with the pure diesel.

- Brake thermal efficiency found comparable with plastic oil blended with diesel, pure diesel and Distilled plastic oil blended with diesel.
- Brake thermal efficiency is equal for both distilled plastic oil blend and plastic oil blend and it is more than the pure diesel.
- Distilled plastic oil blend and waste plastic oil blend is 3.1% increased than pure diesel at maximum load.
- Specific fuel consumption is found to be the same in all the fuels used.

- NOx emitted is lesser in Distilled plastic oil by 31.6% with that of diesel which shows huge cut in the NOx emission in Distilled plastic oil at maximum load (16kg).
- Waste plastic oil is further less than Distilled plastic oil by 28.9%.
- CO_2 emission is identical for both Distilled plastic oil and Waste plastic oil till the load 12kg; at 16kg Distilled plastic oil has lesser CO_2 emission by 17.97% with Waste plastic oil and 29.93% with Diesel.
- Distilled plastic oil blend produces less CO and a decrease of 16.67% with waste plastic oil and a decrease of 37.5% with diesel.

Diesel is found to be producing medium HC emission as waste plastic oil blend is high and distilled plastic oil blend is low.

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