EVALUATION OF PERFORMANCE, EMISSION CHARACTERISTICS USING ARTIFICIAL NEURAL NETWORK IN an UNMODIFIED DIESEL ENGINE FUELED WITH ORANGE PEEL OIL & DIESEL BLENDS.

A Dissertation submitted to the Delhi Technological University, Delhi in fulfillment of the requirements for the award of the degree

MASTER OF TECHNOLOGY

In

Mechanical (Thermal) Engineering

by

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DECLARATION

I hereby declare that the dissertation entitled "**EVALUATION OF PERFORMANCE, EMISSION CHARACTERISTICS USING ARTIFICIAL NEURAL NETWORK IN an UNMODIFIED DIESEL ENGINE FUELED WITH ORANGE PEEL OIL & DIESEL BLENDS"** is an original work carried out by me under the supervision of Prof. Naveen Kumar, Professor Mechanical Engineering Department, Delhi Technological University, Delhi. This dissertation is prepared in conformity with the rules and regulations of Delhi Technological University, Delhi. The research work reported, and results presented in the dissertation have not been submitted either in part or full to any other university or institute for the award of any other degree or diploma.

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CERTIFICATE

This is certified that the work embodied in the dissertation **"EVALUATION OF PERFORMANCE, EMISSION CHARACTERISTICS USING ARTIFICIAL NEURAL NETWORK IN an UNMODIFIED DIESEL ENGINE FUELED WITH ORANGE PEEL OIL & DIESEL BLENDS"** by Sandeep Kumar Barnawal, (Roll No.- 2K19/THE/10) in partial fulfilment of requirements for the award of degree of **MASTER OF TECHNOLOGY in Mechanical (Thermal) Engineering,** is an authenticate record of student's own work carried by him under my supervision.

This is also certified that this work has not been submitted to any other university or institute for the award of any other diploma or degree.

27/X/21

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Sandeep Kr. Barnwal

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ABSTRACT

Energy is a fundamental necessity for economic growth. Every area of the Indian economy-agriculture, manufacturing, transportation, commercial, and domestic-requires energy input. Since independence, economic growth plans have necessitated a growing quantity of energy. As a result, consumption of all types of energy has been gradually increasing across the country. The 70% of energy demand is fulfilled by petroleum fuels. This also the exponential decay of crude oil and environmental degradation forced the researchers to investigate alternative sustainable fuels. One of the promising alternatives to petroleum oil is orange peel oil. Orange peel oil has characteristics that are similar to diesel, and it is also simple to blend. In this paper performance and emission, parameters are investigated, and using an artificial neural network (ANN) its prediction and validation have been done. The blend shows the best results for 30% orange peel oil by vol. and 70% diesel. At peak load, the brake thermal efficiency (BTE) of this blend is 17.5 % higher than diesel, and the brake specific energy consumption (BSEC) is 20 % lower. These experimental results were used to perform prediction and validation. Using time series analysis, the prediction of data is made by means of Quasi- newton method algorithm and it is found that it best fits the linear regression analysis. The value of R^2 for BTE and BSEC is 0.994 and 0.986 respectively. The suggested ANN model's performance and accuracy were totally satisfactory. There is a noticeable reduction in the emission parameters.

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CHAPTER 1

INTRODUCTION

1.1 GENERAL

The availability of energy resources is crucial to a country's growth. Almost all of humanity's energy demands are actually fulfilled by rapidly depleting fossil fuels with significant environmental implications. Over the past century, global energy demand has increased more than 20-fold, and all main sources, with the exception of hydropower and nuclear electricity, are limited and therefore expected to be depleted in the immediate future [1]. The exponential rise in the use of carbon fuels is causing climate change, which is regarded as the most serious environmental issue of the twenty-first century. According to recent estimates, the release of greenhouse gases into the atmosphere has led to an increase in global mean temperature of about 0.8 degrees Celsius over the past century[2]. The effect of climate change on ecosystems and human populations has allowed the development of environmentally sustainable and limitless renewable sources such as solar, wind, small hydro, biomass, and so on. Renewable energy sources in general, and biomass energy in particular, have the potential to reduce our reliance on foreign imports, thus rising energy supply security. The energy crisis that erupted as a result of the oil embargo of the 1970s compelled nations to take serious steps to reduce their energy usage habits. The dilemma is exacerbated further by the reality that the available fossil fuels are finite and deplete with each year of use. In comparison, renewable energy sources, especially limited hydropower, have an inexhaustible supply and, if used, could help to alleviate the pressure of fossil fuels while also bridging the yawning gap between demand and supply with economic benefit of country. Solar, wind, biomass, and tiny hydro are some of the clean energy options that are currently being used[3]. The centralized electric power generation system is without a doubt the most flexible in existence, but it is also well suited to meeting energy needs at the village level. With a population of over one billion people, India is the world's second most populous country after China. In terms of oil, India is a net importer and imports nearly 3% of overall global energy consumption[4]. The total installed capacity in India as on April 2019 is shown in fig (1) [4][5]

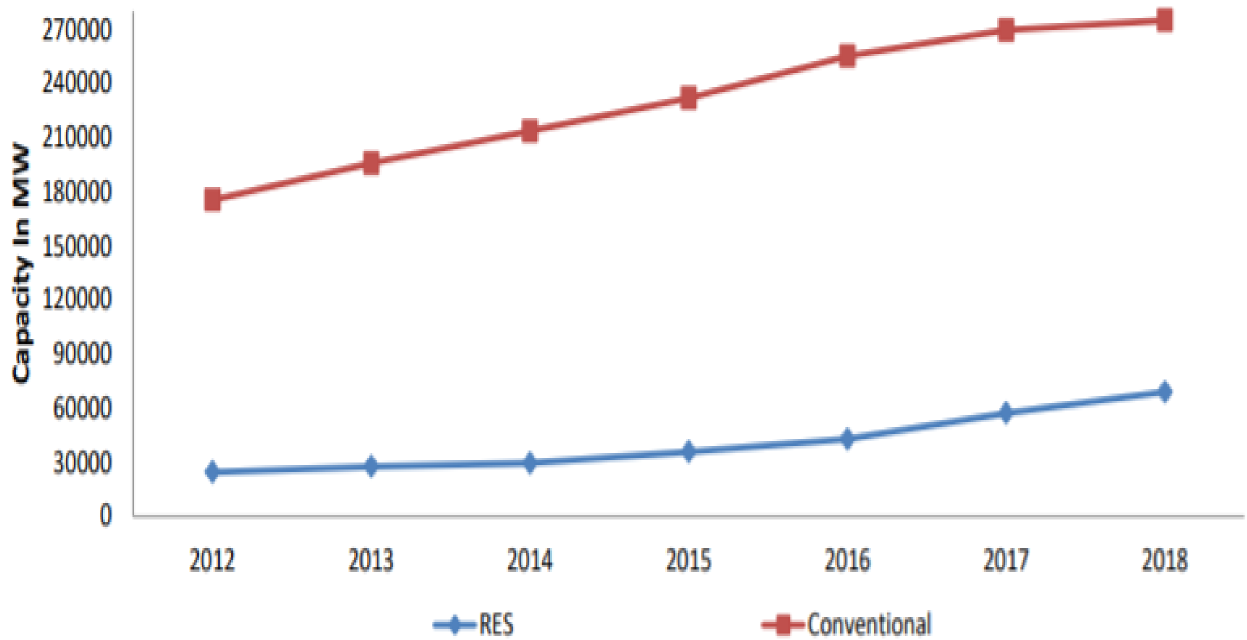

Fig.1 - installed capacity (MW) of power stations

In India, nearly 91% of the fuel used to generate electricity comes from hydrocarbon sources, and the top three consuming sectors are industry (56 %), transportation (17 %), and residential and industrial (13 %).

The total installed capacity in India as on December 2019 was 368785 MW, out of which 230701 MW (63%) is contributed bt thermal, 85905(23%) from renewable, 45399 MW (12%) from Hydro and 6780 MW (2%) from nuclear energy sources [6]. fig 2 shows the installed power generation capacity of India from different sources.

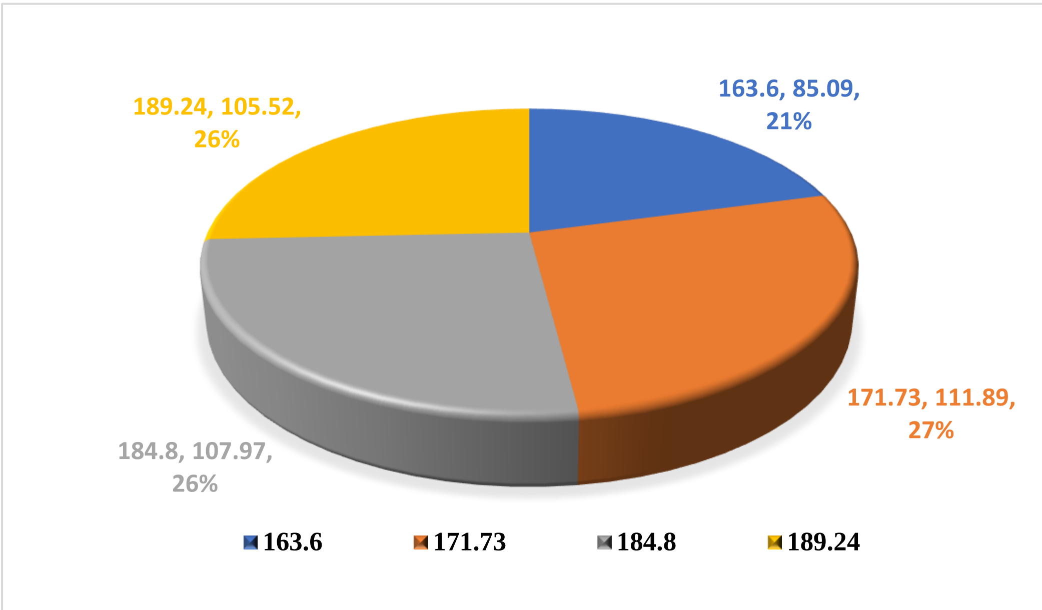

Fig.2- India Source Wise Installed Power Generation Capacity (MW) as on 31.12.2019 [6]

The table 1 shows the energy distribution of India's power capacity [6]

SECTOR	MODE WISE BREAKUP								
	THERMAL					Nuclear	Hydro	RES (MNRE)	Grand total
	Coal	Lignite	Gas	Diesel	Total				
State	65861.50	1290	7118.71	236.01	74506.21	0.00	26958.00	2350.43	103815.14
private	74173.00	1830	10580.60	273.70	86857.30	0.00	3394.00	81925.68	172176.98
central	58460.00	3640	7237.91	0.00	69337.91	6780.00	15046.72	1632.30	92796.93
total	198494.50	6760	24937.22	509.71	230701.42	6780.00	45399.22	85908.41	368789.05

According to the table above, the central sector's role in power generation is minor in comparison to other sectors. As a result, the central sector should play an important role in the generation of energy from both renewable and non-renewable sources in the coming years.

1.2 INDIAN ENERGY SECTOR

The bulk of India's electricity needs are met by coal-fired power plants[6]. The inadequacy of electricity supplies is compensated by energy imports from other nations. The Indian energy scenario indicates a shift in energy balance, owing primarily to the various energy sources. The Indian energy policy outlines the steps taken by the government of India to fulfil all of India's energy needs and cope with the potential energy crises that may occur if proper energy policy and energy conservation are not implemented. That include mass energy conservation and energy efficiency. Various energy sources have also been delineated for large-scale energy storage and optimal use by energy saving measures.

Energy is one of the main inputs for every country's economic growth. In the case of developing countries, the energy market is crucial because of the ever-increasing energy demands that necessitate massive investments to fulfil.

Based on the following parameters, energy can be divided into many categories

- Primary and secondary energy
- Commercial and Non-commercial energy
- Renewable and Non-Renewable energy

1.2.1 Primary and Secondary Energy

The primary energy sources are those contained or preserved in nature. Coal, oil, natural gas, and biomass are common primary energy sources (such as wood). Such main

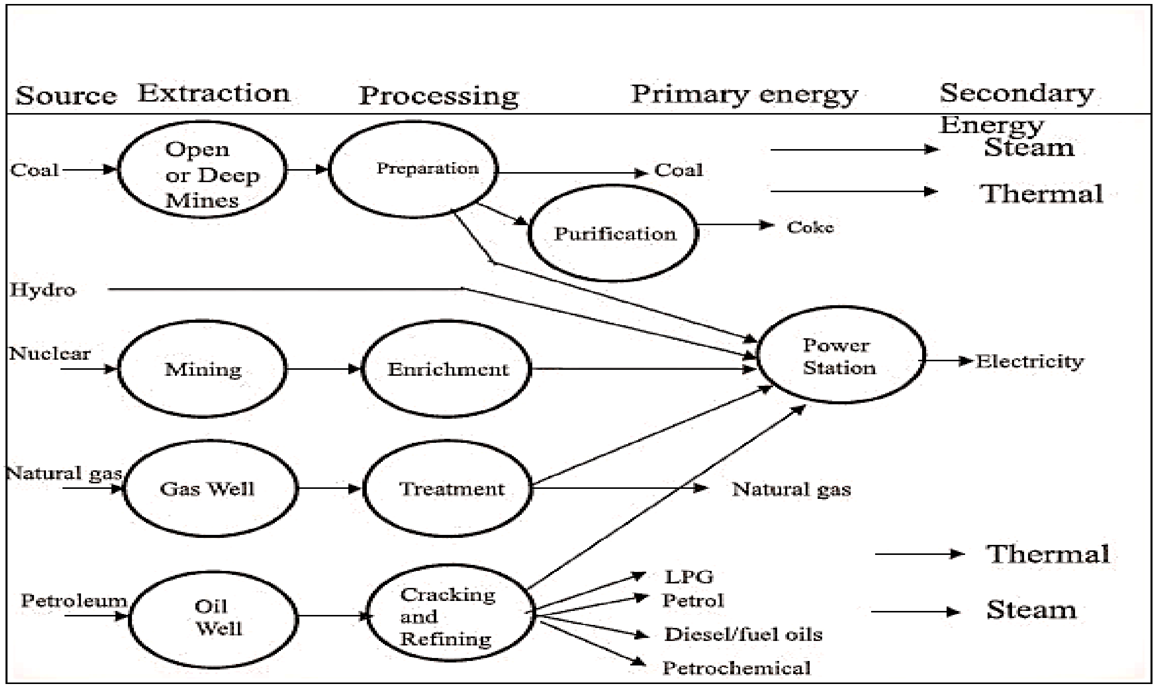

Fig.3- Major primary and secondary sources

energy reserves include nuclear energy derived from radioactive substances, thermal energy contained in the earth's interior, and potential energy derived from gravity. The major primary and secondary energy sources are shown in fig. 3. In electric utilities, primary energy sources are often transformed into secondary energy sources, such as oil or gas, or coal converted into steam.

1.2.2 Commercial and Non-Commercial Energy

1.2.2.1 Commercial Energy

Commercial energy refers to energy sources that are offered on the market at a fixed price. Electricity, coal, and refined petroleum products are by far the most important commercial energy sources. Commercial energy is the foundation of industrializing, transportation, agricultural, and commercial growth. In industrialized nations, marketed fuels constitute the primary source of not just economic output, but also numerous home duties performed by the general population. Examples include electricity, oil, coal, lignite, natural gas, and so on.

1.2.2.2 Non-Commercial Energy

Non-commercial energy refers to energy sources that are not available on the commercial market for a fee. Non-commercial energy sources include cattle dung, agricultural waste, and firewood, which are traditionally gathered and not purchased at a price that is affordable to rural households. These are also referred to as traditional fuels. Non-commercial energy is frequently overlooked in energy accounting in rural areas, for example, agro waste, firewood, solar energy for water heating and electricity generation, animal power for transportation, lifting water for irrigation, wind energy for lifting water and electricity generation.

1.2.3 Renewable and Non-Renewable Energy

Renewable energy is energy derived from practically limitless sources. Tidal power, wind power, geothermal energy, solar power, and hydroelectric power are examples of renewable resources. The most essential aspect of renewable energy is that it may be used without releasing hazardous pollutants. Non-renewable energy sources include traditional fossil fuels such as coal, gas and oil, which are likely to diminish with time.

1.3 MAJOR SOURCE OF ENERGY

- Fossil fuel
- Water power or stored energy in water
- Nuclear fission energy

1.3.1 Fossil Fuel

1.3.1.1 Coal and Lignite

India lacks huge primary energy supplies in proportion to its enormous geographical area, increasing final energy demand, and expanding population. The country's allocation of primary commercial energy resources is extremely uneven. Whereas coal is rich and primarily concentrated in the eastern area, which accounts for about 70% of total coal reserves, the western area possesses more than 70% of the country's hydrocarbon reserves. Coal is still the country's primary energy source. As of 1.4.2018, a total of 319.02 billion tons of geological resources of coal has been estimated in the nation as a result of exploration carried out up to a maximum depth of 1200m by the GSI, CMPDI, SCCL, and MECL, among others[5].

1.3.1.2 Petroleum

It is a viscous, dark-colored, and odorous crude oil. The term petroleum refers to rock oil. It is generally found trapped in rocks underneath the earth's crust. Crude oil is a complicated combination of solid liquid gaseous hydrocarbons, salt, earth particles and water. It is a naturally occurring substance derived from oil wells.

1.3.1.3 Natural Gas

It is composed of around 95% methane and the remainder ethane and propane. It occurs deep surface of the earth, either alone or in conjunction with oil above the petroleum reserves. It is a byproduct of petroleum extraction[3].

1.3.2 Hydro Power

India is deeply worried about climate change, and efforts are being made to encourage eco - friendly energy sources. One such source is hydropower, which should be prioritized in terms of energy security. Regardless of the scale and type of the hydro project, whether ROR or storage, it necessitates survey and investigation, DPR preparation, infrastructure construction, EIA, and other preliminary works, all of which are time demanding and take two to three years to complete. After the job is granted for construction, a hydro project would take roughly 5 years to complete. Thus, in order to finish the hydro project during the 13th plan, the project should either be under construction or should commence execution at the commencement of the plan.

1.3.3 Nuclear

Nuclear energy is an environmentally sound form of energy, and its share of total capacity should grow over time. Keeping fuel availability in mind, the nuclear power firm has planned a moderate capacity augmentation of 6780 MW nuclear facilities during the 13th plan. All of the projects are currently under development.

1.4 INDIA’S OIL ENERGY SCENARIO

According to 2019/20 projections, India's crude oil output remained at 32.17 MMT, a decrease from the previous year's 34.20 MMT (2018/19). Crude oil extraction in India decreased by 5.95 %in 2019-2020[3]. The country's crude oil requirement is fulfilled by both domestic and imported supply. The import of crude oil in 2019-20 was 226.95MMT valued at Rs 717001 crore, up from 226.50 MMT valued at Rs 783183 crore in 2018-19, representing a 0.2 % rise in quantity but an 8.4 % fall in value when compared to the import of crude oil in 2018-19 [3].

Figure 4 shows that crude oil demand has reached 226.95 MMT in 2019-20, which is 1.38 times more than the demand of 163.60 MMT in 2010-2011. The rapidly expanding need for crude oil, along with rising fuel consumption, has compelled governments to seek alternatives to traditional fuels. As previously said, non-edible vegetable oil is regarded as an indigenous source of oil for biodiesel production. Once oil resources become abundant in the nation, biodiesel/vegetable oil will be offered as a diesel replacement. It will minimize the country's reliance on oil imports and make it self-sufficient in fuel supply.

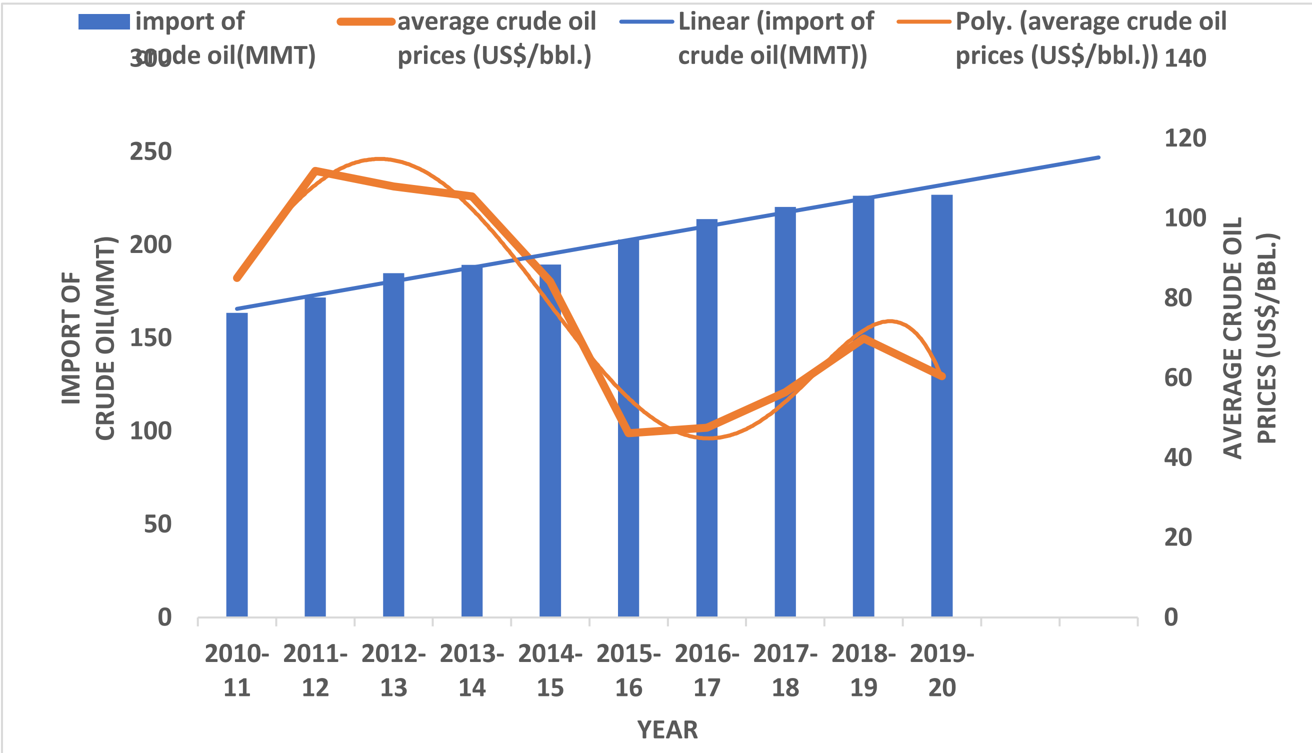

Fig.4- Annual import and average crude oil price [3]

1.5 WORLD EMISSION SCENARIO

Human-caused greenhouse gas (GHG) emissions disrupt the earth-atmosphere system's radiative energy balance. They amplify the natural greenhouse effect, causing temperature fluctuations and other disruptions to the Earth's climate. Changes in land use and forestry also have an impact on the quantity of greenhouse gases collected or released by carbon sinks. Carbon dioxide (CO_2) emissions from the burning of fossil fuels and deforestation are significant contributors to greenhouse gas emissions. CO_2 accounts for the largest share of greenhouse gases, making it a critical aspect in governments' ability to prevent climate change.

1.5.1 Emission Policy Challenges

The key difficulties are to reduce GHG emissions and stabilize GHG concentrations in the atmosphere at a level that would prevent harmful interference with the climate system, as well as to adapt to and manage climate change risks.

- This necessitates the implementation of national and international low-carbon strategies, as well as the further decoupling of GHG emissions from economic growth. This necessitates national and international low-carbon strategies, as well as further decoupling of GHG emissions from economic growth. increasing the share of renewable energy sources in the supply mix, as well as lowering energy intensity through the use of energy-efficient production methods and increasing the energy efficiency of consumer goods and services.
- Ensuring a proper mix of market-based instruments, such as promoting price on carbon, environment-related taxation, and eliminating government support and other forms of support for fossil fuels, is critical in this transition.

The United Nations Framework Convention on Climate Change (1992) is the primary international agreement, and it serves as the foundation for:

- The Kyoto Protocol (1997) established internationally binding and differentiated emission reduction targets for six greenhouse gases (GHGs) from 2008 to 2012. It has been in force since 2005 and has been ratified by 177 parties, including all but two OECD countries. 37 industrialized countries and the European Union committed to reducing GHG emissions by 5% below 1990 levels. The "Doha Amendment to the

Kyoto Protocol" (2012) includes new commitments for 2013-20, as well as a revised list of GHGs. Parties agreed to reduce GHG emissions by at least 18% below 1990 levels between 2013-20. The amendment has not yet taken effect.

- The Paris Agreement (2015) expands on the Convention and enhances the international solution to climate change. The goal is to keep the global mean temperature rise this century below 2 degrees Celsius and as near to 1.5 degrees Celsius over pre-industrial levels as feasible. Parties have stated their concerns. pledges to 2025 or 2030 by contributions decided at the national level (NDCs), consisting of a periodical report on their emission levels and implementation efforts

1.5.2 Green House Gas Emissions and CO_2 Emissions

Global CO2 emissions per year are estimated to be about 36 billion tones. Over the period 2004-2030, global energy-related carbon-dioxide (CO2) emissions are forecast to rise by 1.7 % each year. They will increase by 14.3 billion tones, or 55 percent, to 40.4 billion tones in 2030. From 2004 to 2030, power generation is expected to contribute slightly less than half of the increase in global emissions. Transportation accounts for one-fifth of the total, with the remainder accounted for by other uses. Transport remains the world's second-largest emitter, with its share of total emissions remaining stable at around 20% throughout the projection period.

Table 2. shows the increase in CO_2 by different sources

	1990	**2004**	**2010**	**2015**	**2030**	**2004-2030**
Power generation	6955	10587	12818	14209	17680	2.0%

Industry	4474	4742	5679	6213	7255	1.6%
Transport	3885	5289	5900	6543	8246	1.7%
Residential and services	3353	3297	3573	3815	4298	1.0%
Others	1796	2165	2396	2552	2942	1.2%
Total	**20463**	**26079**	**30367**	**33333**	**40420**	**1.7%**

- Global GHG emissions have grown by 1.5 times since 1990, owing to economic expansion and greater usage of fossil fuels.
- The rate of success in lowering emissions differs greatly amongst OECD nations. Overall progress has been insufficient, and GHG emissions are anticipated to grow again as a result of recent increases in energy demand and CO-related emissions.
- Presently, OECD nations account for around 35% of worldwide CO2 emissions from energy usage, compared to more than 50% in 1990.
- OECD countries tend to rely on fossil fuels for over 80% of their energy; renewable sources continue to play just a limited part in energy mix.

The above points and table 2 represent the greenhouse gas emission and its effects on climate changes and human life, so finding an alternative renewable and sustainable fuel and vegetable oils and biodiesel are being considered for alternative fuel. It will reduce dependency on diesel and also reduce import of crude oil.

1.6 NATIONAL BIODIESEL MISSION

The need for diesel in the country is five times that of gasoline. The ethanol sector is highly established, but the biodiesel/vegetable oil business is still in its preliminary phase.

In the year, the Indian government announced an ambitious National Biodiesel Mission to replace around 20% of total diesel with biodiesel by 2011-2012 [7]. At the present time the government allowed to use ethanol as a fuel and successfully demonstrated application of biodiesel. SpiceJet operated a civilian flight bombardier Q400 based on bio-jet fuel from Dehradun to Delhi on 27th August 2018 and military Flight Indian Airforce AN-32 operated on republic day parade on 26th January 2019[8]. These success shows the potential of bio-fuels and as a result HPCL is setting up a compressed biogas plant in Uttar Pradesh. Jharkhand government also show green flag to biodiesel with blending up to 20% with diesel [8]. Few researches are already worked on biofuels of jatropha, Karanja, waste cooking oil and some waste of orange peel and lemon seeds and results are in favor of biodiesel use[9][10][11]. India has ample capacity to produce the vegetable oil from jatropha curcas plant and from citrus fruit waste like orange peel. Orange is the 3rd largest fruit crop after banana and mango[12]. Sweet orange begins in the fifth year with 40-50 fruits per tree and reaches maturity in the eighth year. After stabilizing, the average fruit output per tree is 500-600 fruits [13]. Extraction of oil from the waste of orange peel and blending with the diesel will reduce dependency on diesel.

CHAPTER 2

LITERATURE REVIEW

The world's expanding industrialization and modernization must result in a sharp increase in demand for petroleum products. Economic expansion in emerging nations has resulted in a significant increase in energy consumption. India's energy consumption is shown in Table 3 for various sources

Table 3 Indian energy consumption for various source [3]

Year	**Coal (Million tonnes)**	**Lignite (Million tonnes)**	**Crude oil MMT**	**Natural Gas (Billion Cubic Meters)**	**Electricity (GWh)**
2010-11	593	37.69	196.99	64.16	694392
2011-12	638.73	41.88	204.12	64.45	785194
2012-13	713.39	46.31	219.21	57.36	824300.99
2013-14	739.34	43.90	222.50	52.37	874208.57
2014-15	822.13	46.95	223.24	51.30	948512.82
2015-16	836.73	42.21	232.86	52.51	1001190.68
2016-17	837.22	43.16	245.36	55.70	1061182.64
2017-18	898.50	46.32	251.93	59.17	1123426.86
2018-19	968.36	45.81	257.20	60.79	1209971.63
2019-20 (P)	942.63	42.27	254.39	64.14	1291493.75
Growth rate of 2019-20 over 2018-19 (%)	**-2.66**	**-7.73**	**-1.10**	**5.51**	**6.74**

- The overall use of natural resources of energy in 2019-20(P) has grown relative to 2018-19 for Natural Gas (5.51 %) and Electricity from Hydro, Nuclear, and other renewable sources from utilities (6.74 %)
- India is the largest producer and consumer of coal. Despite a 2.66 % decrease in 2019-20 over 2018-19, there has been an increased trend in coal demand in the region from 2010-11 to 2018-19. From 2010-11 to 2019-20, the CAGR is 5.28 % (P)

industrialization and transportation are improving in India and its results in rise of energy demand. The demand of crude oil in India is very high and importing 80% of crude oil. As a result, energy security has emerged as a critical concern for the nation as a whole, petroleum-based fuels are finite.

The world's limited reserves are highly concentrated in particular places. As a result, those nations who lack these reserves are suffering a foreign exchange crisis, owing mostly to crude oil imports. As a result, it is vital to explore for alternative fuels that may be created from feed supplies accessible in the country. Biodiesel/vegetable oil, an environment friendly and renewable fuel replacement for diesel, has attracted the attentions of researchers/scientists all over the world. Various researchers have determined performance and emission characteristics by using biodiesel as a fuel and it was found that there is slight change in efficiency while using B_{20} blends.

[14] investigated the performance and emissions parameters of a single cylinder, four stroke, naturally aspirated compression ignition engine which is fueled with blends of orange peel oil biodiesel and diesel. They found that, at peak load conditions, the brake thermal efficiency of the engine is improved, by decreasing the CO and HC emissions up to a greater extent.

However, there is an increment in the value of NOx emissions due to the presence of extra oxygen molecule in the orange peel oil biodiesel.

[15] investigates the sustainability of orange peel oil and butanol fuel blends, by conducting an experiment on single cylinder, four stroke, air cooled diesel engine. They found that, the brake thermal efficiency of the blended fuels is lowered than that of neat diesel operation. Moreover, on increasing the traces of butanol in the fuel blends, the CO and NOx emissions tends to reduce as that of neat diesel operation. Furthermore, the smoke opacity tends to increase for all engine loads.

On using the very promising optimization tool (ANN) [16] investigates the behavior of the CO, HC, NOx emissions and BTE of the single cylinder, air cooled diesel engine which is fueled with various blends of orange peel oil biodiesel and diesel respectively. They found that, using neat biodiesel of orange peel oil in an engine, the emissions (CO, HC, NOx, & Smoke opacity) are very much low as compared to neat diesel operation. On the other hand, fuel blends of biodiesel and diesel produces more NOx emissions as compared to diesel operation.

The sustainability of the orange peel oil is successfully studied by [17] by conducting an experiment on single cylinder, four stroke, VCR, air cooled diesel engine having common rail direct injection (CRDi) system, fulled with 20% of orange peel oil and mineral diesel. They observed that, at full loads, the brake thermal efficiency is higher and brake fuel consumption is lower than that of neat diesel operation. Moreover, UBHC, CO, are decreased by significant account as compared to neat diesel operation. On the other hand, oxides of nitrogen are enhanced by 15.46% than that of neat diesel operation.

[18]explore the sustainability of orange peel oil by using it with diesel in a single cylinder, four stokes, water cooled diesel engine in order to obtained the values of engine performance and emissions parameters. They observed that, at various loads, the BTE of the engine is improved as compared to neat diesel operation. Furthermore, the various engine emissions i.e. CO, HC, are tends to reduce as compared to neat diesel, while NOx emissions tends to increase.

[19]investigates the effect of engine performance and emissions parameters of a six-cylinder, four stroke, diesel engine equipped with common rail injection system (CRDi) fueled with blend of sweet orange peel oil and mineral diesel. They found that, the various fuel properties (density, viscosity & calorific value) of the blended fuel are improved as compared to mineral diesel. Moreover, the specific brake fuel consumption of the blended fuel is higher than that of mineral diesel, while BTE of the engine is improved. On the other hand, CO & HC emissions of the engine is tending to reduce for the blended fuel only. The NOx emissions tend to enhance as compared to neat diesel operation.

[20]The suitability of the orange peel oil and ethanol fuel blends for CI engine was investigated by in this study, they performed an experiment on single cylinder four stroke, unmodified water-cooled diesel engine fueled with fuels blends of ethanol and orange peel oil in different proportions. They observed that, both BTE and EGT of the engine are decreased with the increment in the concentration of orange peel oil. On the other hand, on increasing the dosages of ethanol in fuel blends, both CO2 and NOx emissions showed a decreasing trend.

[21]studied the effect of the orange peel oil on engine performance and emissions characteristics. The experimental engine trails are completed on single cylinder, four stroke, CRDi engine. They found that, BTE of the engine at peak loads is higher than neat diesel operation. With increasing the dosages of orange peel oil in the fuel blends, NOx, HC, CO2 emissions were decreasing.

Prediction of engine performance and emissions characteristics of a VCR engine fuelled with orange peel oil biodiesel was carried out by [22] using Artificial Neural Network (ANN) technique. They found that, on increasing the content of orange peel oil in the fuel blend, both BTE and NOx emissions of the engine were increases while BSFC and HC emissions were decreases.

[23] carried out an experiment on single cylinder, water cooled, four stroke VCR diesel engine fuelled with orange peel oil and cotton seed oil biodiesel. They found that, BTE of the engine is far better than neat diesel operation. Moreover, BSFC and other emissions were also decreases as compared to neat diesel.

The effect of orange peel oil biodiesel on the engine performance and emissions parameters were studied by [24]. They observed that, efficiency of the engine is increases with increasing the concentration of biodiesel of orange peel oil in the test fuel blend. HC and CO emissions were also decreasing with increasing the amount of biodiesel. But, with increasing the content of orange peel oil biodiesel, NOx emissions were risen because of the presence of extra oxygen molecules.

[25] observed the performance and emissions parameters of the CI engine fuelled with orange peel oil biodiesel blended with antioxidant additive. They found that, on adding the antioxidant in biodiesel, BTE of the engine decreases while BSEC increases. On the other hand, CO and HC emissions were increased because of the addition of antioxidant in neat biodiesel. NOx emissions were decreased on increasing the concentration of antioxidant in the biodiesel.

The effect of piston geometry on performance and emissions characteristics of the CI engine fuelled with orange peel oil and diesel was studied by [26] They observed that, on increasing the content of orange peel oil in the test fuel blends, BTE of the engine increases while emissions were decreases effectively at full load. Internal jet bowl in piston, and spiral grooved internal jet bowl-in piston showed better results in terms of engine performance and emissions parameters.

[27] performed a comparative study of engine performance and emissions characteristics of the CI engine fuelled with the blends of DEE and orange peel oil biodiesel. They found that, on increasing the amount of DEE in the fuel blends, there were a significant reduction in the emissions level and improves the performance of the engine.

[28]performed an experiment on single cylinder four stroke engine fuelled with nano-emulsion of waste orange peel oil biodiesel for finding out the performance and emissions characteristics. They reported that, on increasing the amount of TiO2 in the fuel blends, BTE of the engine is increased while BSFC decreased. Moreover, CO and HC emissions were also decreased significantly after the addition of TiO2 in the fuel blends. NOx emissions were increased with increasing the content of TiO2 in the fuel blend.

[29]enhanced the idling characteristics of light duty diesel engine fuelled with orange peel oil biodiesel using multi objective response surface methodology. They found that, on increasing the amount of orange peel oil biodiesel in the fuel blends, the BTE of the engine is decreased, while BSFC is increased. Moreover, the rate of pressure rise, heat release rate was also be increased. HC, NOx emissions were increased significantly while CO emissions were decreased because of the presence of extra oxygen molecule in the biodiesel which helps of facilitate the combustion process effectively.

Above literature review of various researchers work summarizes the opinions of many researchers on the engine performance when utilizing biodiesel from various sources. The key findings are also provided, providing a more comprehensive picture of the sort of work done on the current engine. The review demonstrates that utilizing various types of biodiesel boosts BSFC and engine efficiency when compared to diesel, whereas CO and HC emissions drop but NOx emissions rise.

The literature review illustrates that biodiesel is a feasible alternative to diesel owing to reduced gas emissions such as HC, NOx, and CO, as well as comparative thermal efficiency; there is also no engine modification when using B10 and B20. There has been a lot of study done on the influence of biodiesel on engine performance and emission.

2.1 PROBLEM FORMULATION AND OBJECTIVE OF STUDY

According to the material reviewed above, biodiesel production and consumption in India are in their infancy. According to the literature, extensive work on the kinetics of transesterification of edible vegetable oil and non-edible oil resources has been published, but very little work on straight vegetable oil, orange peel oil is regarded a potential option for diesel. The majority of studies on engine performance is dedicated on emission characteristics, with minimal study published on the performance of CI engines on orange peel oil blends. The current study is thus done to assess the performance of a diesel engine employing blends of orange peel oil and diesel under part/full load conditions and compare its performance to that of other existing works. The following are the aims of the proposed study:

1. To develop the methodology of oil extraction from the orange peel.
2. To compare the fuel characteristics of orange peel oil and its blend with biodiesel and neat diesel.
3. To assess the performance of an IC engine on various orange peel oil/diesel blends.
4. To investigate the emissions of various gases during engine operation under varied operating conditions.
5. prediction and validation of results using artificial neural network designing.

The dissertation is divided into five chapters

1. Chapter I deals with the introduction of an energy scenario in India, which includes renewable and non-renewable energy sources, as well as a global emission scenario.
2. Chapter II It discusses numerous edible and non-edible oils, as well as the applications and scope of orange peel oil. The usage of orange peel oil as an alternative fuel was also explained in the chapter.

3. Chapter III is concerned with the production of orange peel oil and preparation of its blends, as well as the measurement of different characteristics of orange peel oil and its blends.

4. Chapter IV includes the performance and emission assessment of an IC engine utilizing orange peel oil blends, as well as discussion, prediction, and validation of findings employing artificial neural network design.

5. Chapter V concludes, makes suggestions, and discusses the future scope

The present study has dealt with the production of orange peel oil from orange peel, measurement of properties and performance evaluation of diesel engine on blends of orange peel oil at various loads. The following conclusion can be drawn: The fuel properties like density, viscosity, calorific value and flash point value of OPO10, OPO20, OPO30 and OPO40. And they are very similar to the diesel and therefore diesel may be well replaced by OPO10, OPO20, OPO30 and OPO40.

CHAPTER 3

FUEL PREPARATION AND FUEL PROPERTIES

3.1 GENERAL

India ranks fifth in terms of energy consumption, accounting for 4.4 percent of total commercial energy consumption worldwide. Current consumption in India is around 72.72 MT, which declined by 12% in fiscal 2020-21. As of March 2018, the domestic crude oil reserve was 594.49 MT, while the natural gas reserve was 1339.57 BCM[4]. As a result, there would be a significant gap between demand and supply, which must be bridged by boosting fuel imports or boosting production of biodiesel as a diesel alternative by expanding oil seeds plants, particularly non-edible plantations, without compromising the country's food security. Biodiesel is a sustainable energy source that may be produced from waste and biodegradable soils. Biodiesel is a fuel made from mono-alkyl esters of long chain fatty acids found in vegetable oil or animal fats. It may be obtained from either plants or animals. When combined with diesel up to 20%, (B20) the use of biofuels needs very little or no engine change. The use of biofuels resulted in a 30% decrease in unburned HC, a 20% reduction in CO, and a 25% decrease in particulate matter. It has approximately 10% in-built oxygen, which aids in combustion and raises the cetane number[30].

3.2 OIL SEED CROPS IN INDIA

The numerous oil sources are divided into edible and non-edible categories. Edible sources such as groundnuts, peanuts, and so on are primarily used to fulfil dietary requirements, with the remainder, if any, turned to biodiesel. Because the country currently imports 70% of its total edible oil, it is not practical to divert edible oil resources for biodiesel production. The remaining alternative is to produce non-edible seed crops for oil production and conversion to biodiesel. Non-edible oil resources include jatropha, Mahua, orange peel oil, Pongamia, Neem and so on. Depending on temperature and soil conditions, many countries are seeking for different vegetable oils as diesel fuel substitutes, such as sunflower and rapeseed oils in Europe, soyabean oil in the United States, coconut oil in the Philippines, and palm oil in Southeast Asia.

3.3 ORANGE PEEL AS A SOURCE OF BIOFUEL

Energy self-sufficiency is critical for the total economic growth of all countries, including India. To offer a sustainable energy supply, there is a need for renewable, safe, and non-polluting sources that will not only reduce reliance on fossil fuel resources but will also cut CO2 emissions and global warming. Uncertain supply and frequent inflationary pressures in the international market for fossil fuels pose severe economic concerns to emerging countries. Among the plant species that produce non-edible oil. Orange peel may be the most appropriate species in India, since it is widely farmed and generated non-edible oil. Sweet oranges accounted for nearly 70% of citrus production in 2012. In 2019, the globe produced 79 million tons of oranges, with Brazil providing 22% of the total, followed by China and India[13]. India produces around 10% of total world sweet orange production. Major quantity of orange is from Maharashtra, Madhya Pradesh and Assam. With 8.27 lakh tons (2009-10) accounting for 40% of overall output and a yield of 6 tons per hectare, Maharashtra is the leading orange (Mandarin) producing state. Madhya Pradesh comes in second with 6.78 lakh tonnes, followed by Assam (1.42 lakh tons)[13]. The physical property of sweet orange is listed in table 4

Table 4 Physical property of sweet orange

Characteristics	Value
Color	Yellow
Weight of fruit (gms)	200
Diameter (cms)	8.40
Weight of peel (gms)	47.10
Thickness of Peel (mm)	2.34
Weight of Flavedo (gms)	15.39
Weight of albedo (gms)	31.69
Weight of juice (gms)	77.65
Weight of fruit without peel (gms)	167.50
Weight of seeds (gms)	12.50
Weight of Pomace (gms)	65.00
Peel (%)	23.6
Oil from Peel (%)	0.5

3.4 OIL EXTRACTION FROM ORANGE PEEL

Extraction of oil from the peel of orange involves the drawing-out of 4-Isopropeny-1- methyl-cyclohexene, also known as D-limonene, by steam distillation. To start the distillation procedure combination of orange peel with distilled water is prepared. Then the blend was moved to the flask through the funnel and mixed properly. The distillation equipment was then mounted on top of the ring stand and also the ring in conjunction with the wire gauze. The heat was provided using a burner mounted below the equipment. The separating funnel was filled with distilled water. The still head and Claisen head were coated with aluminum foil. Depending on the orange peel blend's quality and flame strength, it takes around 18-22 min to attain its boiling point because as the mix achieves boiling point, the still pot's water volume reduces, a small quantity of water is applied through the separatory funnel. The distilled material was then extracted, and NaCl was applied to the distillation. A thin layer of limonene was determined over the distillation. This process's yield is 1.5 kilogram of peel ends up in 700 ml of peel oil.

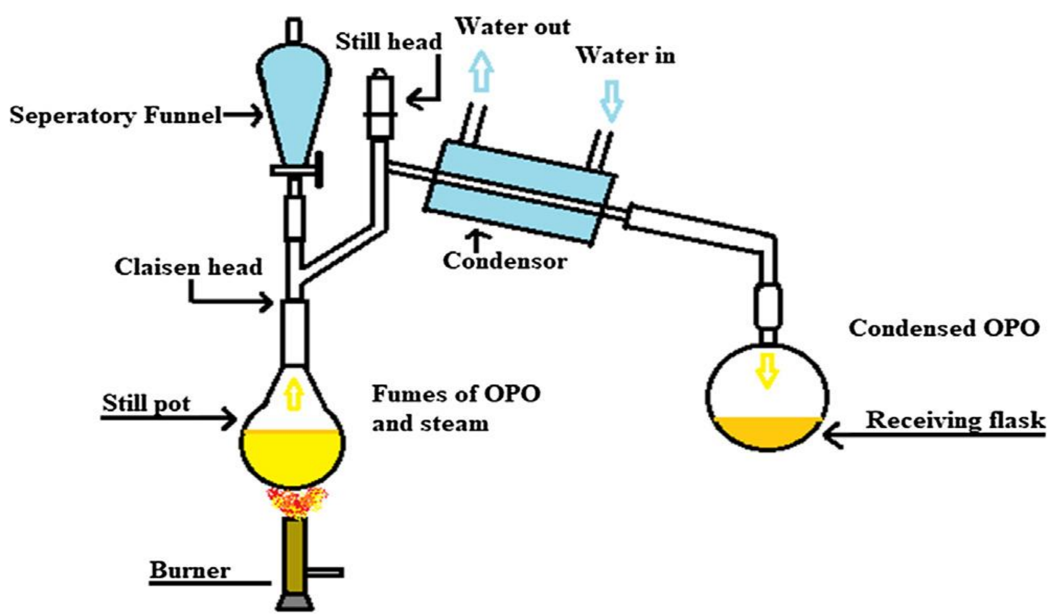

Fig.5- Schematic diagram of Steam distillation apparatus for OPO extraction

3.5 BLEND DEVELOPMENT OF ORANGE PEELS OIL AND DIESEL

Diesel and orange-peel oil's blending process is easy and can be blended easily without any phase separation and color change problem. The blends were prepared by volume/volume percentage. The orange peel oil is poured into a vessel and then diesel is mixed with the orange peel oil. The method used for blending orange peel oil and diesel is splash blending. It is more easy way to blend bio-fuels. In this process orange peel oil and diesel is mixed and with time it gets blended properly without any phase separation and color change. The nomenclature of different blends is shown in Table 5

Table 5 nomenclature of different blends

Blend name	Orange peel oil (%)	Diesel
OPO10	10	90
OPO20	20	80
OPO30	30	70
OPO40	40	60
D100	0	100

3.6 TESTING PROPERTIES AND PHYSIOCHEMICAL PROPERTIES OF FUEL SAMPLE

The chemical interaction between induced air and fuel in the combustion chamber, which allows the use of heat energy, has a significant impact on engine performance. As a result, a gasoline should have a variety of attributes to ensure dependable engine functioning. A thermo gravimetric analyzer was used for the proximate analysis. A CHNS Elementary Analyzer is used to determine the elemental determination (hydrogen, carbon, Sulphur, and nitrogen concentration). The chlorine content of PVC was measured using an enhanced oxygen bomb combustion – ion chromatography technique based on

ASTM D 4208-02. A bomb calorimeter was used to determine the heating value of each sample.

3.6.1 CALORIFIC VALUE

The amount of heat generated by a unit weight or unit volume of a substance during complete combustion and is measured by measuring the heat produced by the entire combustion of a defined quantity of it. Kilojoules per kilograms (kJ/kg) is currently the standard unit of measurement.

The calorific value of a fuel is the amount of heat generated by its burning under "normal" ("standard") circumstances (i.e., to 0^{0C} and under a pressure of 1,013 mbar).

The calorific values of any fuel that is to be utilized in any combustion process are first examined. The cost of gasoline is also influenced by the calorific value of the fuel. The fundamental information regarding calorific value and its kind may be found here. Calorific Value (CV) is a fuel characteristic; a fuel is chosen for a certain use based on this value, and the price is also determined based on CV.

If the water vapor produced by combustion is not condensed in water form, the net energy received by total combustion of a given quantity of fuel is referred to as lower calorific or net calorific value. In practice, LCV is taken into account.

$$\mathbf{CH_4 + O_2 \rightarrow CO_2 + 2H_2O + Energy}$$

The 6100 Calorimeter is a small, mobile instrument that employs a 1108-style oxygen bomb and an oval bucket. It also features the same automated oxygen filling mechanism and high accuracy electronic thermometer as the previous model. A microprocessor control system manages all phases of the test method, which is designed to run the calorimeter in either the usual equilibrium mode or a quicker dynamic mode. A dedicated microprocessor handles all data automatically. The best results are achieved when the instrument is used in an environment free of air draughts and temperature fluctuations. A temperature-controlled room (+/- 1 C) is the optimal operating environment. Any instrument calibration should be verified on a regular basis, according to a well-accepted concept of trustworthy analysis. The best frequency for calibrating the 6100 Calorimeter is determined by the temperature stability of the working environment.

The test was performed with 0.73940g of sample in accordance with ASTM D240. It is a thick-walled steel container used to determine the energy contained in a substance by

Fig. 6- Bomb Calorimeter Setup

measuring the heat generated during its combustion, and it is made up of a 1108P oxygen bomb with an oval bucket that fits into the jacket, as well as an automatic oxygen filling system and a high precision electronic thermometer.

3.6.2 DENSITY METER

Density (or "real density") is the relationship between mass and volume. Mass correlates to weight in vacuo since it is independent of external factors like as buoyancy in air or gravity. The Greek letter rho (ρ) represents density. The oscillating U-tube concept underpins modern digital density meters. The tube, which is typically a U-shaped glass tube, is activated and begins to oscillate at a certain frequency based on the filled-in sample. The density of the sample may be estimated by determining the associated frequency.

From 1967, when the first digital density meter was introduced, through 2018, all benchtop density meters used the “Forced Oscillating Method” of the U-tube concept. This technology, however, has reached its limits. The Pulsed Excitation Technique, an enhanced method of employing the U-tube concept, has been available since 2018.

Digital density meters based on the oscillating U-tube concept are extremely effective instruments for measuring fluid densities across a wide temperature and pressure range. They measure real density (density in vacuum), which is unaffected by air buoyancy or gravity.

Fig. 7- Density meter Setup

3.6.3 VISCO METER

Consider a capillary with specified specifications (inner diameter, length) and an equally accurate distance indicated by two markings. Allow a predetermined amount of liquid to flow through this capillary and time how long it takes the liquid level to go from one mark to the other. The measured time serves as a predictor of viscosity (due to the velocity of flow depending on this quantity). To calculate the kinematic viscosity, multiply the observed flow time (t_f) by the capillary constant (KC). This constant must be found for each capillary by calibrating the capillary, which is done by measuring a known viscosity reference liquid.

$$\mathbf{v = K_c * t_f}$$

Fig. 8 -Viscosity meter Setup

3.6.4 PHYSIOCHEMICAL PROPERTIES OF FUEL SAMPLE

Normal test expediencies were projected for orange peel oil and its blend with diesel (in different volumetric compositions). The calorific value for the straight OPO is low as compared to the diesel but has high density and viscosity. The diverse blends were OPO10, OPO20, OPO30, OPO40, and D100. As the percentage of OPO increases density and Kinematic viscosity also increases but the calorific value decreases. The physicochemical properties of OPO blends are listed in table (6)

Table 6 physicochemical properties of OPO blends

Properties	ASTM std.	D100	OPO10	OPO20	OPO30	OPO40	Measuring Instrument
Density@15°C (Kg/m^3)	ASTM D4052	0.853	0.821	0.824	0.838	0.832	Anton Par, DMA 4500
Kinematic viscosity at 40 °C (cST)	ASTM D445	2.48	2.62	2.95	3.12	3.04	Visco bath, Petrotest
Lower calorific value (MJ/Kg)	ASTM D240	43.12	42.75	42.02	41.64	41.03	Oxygen Bomb Calorimeter Parr

The density and calorific value of orange peel oil blends is lower than the neat diesel but the kinematic viscosity of blends is higher than diesel. Table 7 shows that the properties of orange peel oil blend are pretty equivalent to ASTM standards and other sources. As a result, it can be utilized as an alternate fuel source. The fuel characteristics of biodiesel were found to be nearly identical to those of diesel and ASTM standards.

So, in this chapter, the complete discussion regarding oil extraction methods from orange peel and evaluation of properties of orange peel oil blends has been discussed.

CHAPTER 4

PERFORMANCE AND EMISSION EVALUATION OF IC ENGINE USING ORANGE PEEL OIL AND DIESEL BLENDS

4.1 GENERAL

Thermal energy is released in an IC engine by burning the fuel in the engine cylinder. The burning of fuel in an IC engine is relatively quick, but the time required to get a correct air/fuel mixture is mostly determined by the composition of the fuel and the ways of introducing it into the combustion chamber. The fuel must meet the following performance requirements.

1. High energy density
2. High thermal stability
3. Low toxicity
4. Good combustion characteristics
5. Compatibility with engine hardware
6. Easy onboard vehicle storage
7. Good fire safety
8. Low deposit forming tendencies
9. Less pollution

The combustion process in the cylinder should be as quick as possible, with the highest amount of heat energy released during operation. Longer operation causes the accumulation of deposits, which, when combined with other combustion products, can cause excessive wear and corrosion of the piston, piston rings and cylinder. When the combustion product is released into the atmosphere, it should not be hazardous. These needs can be met by a variety of liquid and gaseous fuels. Biodiesel derived from non-edible sources such as jatropha, Mahua, Neem, orange peel oil, and so on satisfies the aforementioned engine performance requirements and may thus provide a perfect feasible alternative to diesel in India.

4.2 PERFORMANCE AND EMISSION OF DIESEL ENGINE WITH ORANGE PEEL OIL BLENDS

According to a literature review, vegetable oils function satisfactorily during diesel engine running, and B_{20} blends give fuel economy that is nearly identical to diesel[31]. It produces less wear and tear on engine parts because to its high lubricity. Numerous researches have been published on the performance and emissions of CI engines powered by B_{100} biodiesel and its diesel mixes. Because of its oxygenated nature, it burns more completely, resulting in lesser emissions owing to a greater combustion temperature. Because the fuel characteristics of blends and diesel are almost same, the performance of vegetable oil blends with diesel is comparable to diesel. The criteria listed below are used to assess the performance of a diesel engine utilizing vegetable oil blends.

4.2.1 BRAKE MEAN EFFECTIVE PRESSURE

The mean effective pressure is a quantity related to the functioning of a reciprocating engine that is a useful measure of an engine's capacity to accomplish work irrespective of engine displacement

4.2.2 BRAKE SPECIFIC ENERGY CONSUMPTION

The amount of energy consumed for the development of unit power is represented by Brake specific energy consumption (BSEC). As it considers both heating value and mass flow rate of fuel, so it is an essential parameter of engine performance. The output power is not measured at the engine's shaft. The efficiency of the generator is assumed to be 90% for the purpose of calculating output power at the shaft. The following equation may be used to compute BSEC:

BSFC (Mj/kWh) = (W_f/P_b)* (NCV)

Where, W_f = fuel consumed (kg/h)

P_b = brake power (kW) is calculated as:

$P_b = P_g / ŋ_g$

Where, P_g = load (kW) at generator end

$ŋ_g$ = efficiency of generator

Several authors [[32],[33],[34],[35]] have conducted experiments on diesel engines to enhance BSFC using various blends of biodiesel/vegetable oil from diverse supplies, including diesel. The results show that when utilizing vegetable oil instead of diesel for the same power output, the BSFC increases. This is due to the fact that biodiesel has a lower heating value than diesel.

4.2.3 BRAKE THERMAL EFFICIENCY

The ratio of output energy available at the engine shaft to input energy provided to the engine is described as brake thermal efficiency. The mathematical formula for calculating brake thermal efficiency is as follows:

$\eta_b = P_b/(m_f \times NCV)$

P_b = brake power (kW)

m_f = Fuel Consumption (Kg/Sec)

NCV= net calorific value (KJ/kg)

Various workers [[36],[37] measured BTE using vegetable oil/ biodiesel as a fuel and discovered that there is no significant difference in thermal efficiency when using biodiesel up to B20, but there is a minor drop in thermal efficiency when using B100, which is due to the reduced energy content.

4.2.4 EXHAUST GAS EMISSION

According to the literature, engines running on biodiesel/vegetable oil mixes with diesel generate fewer gaseous emissions than diesel fuel, with the exception of NOx, which increases to 2% with B20 and 10% with B100 use. The use of biodiesel or a mix of biodiesel and diesel increases NOx emissions while lowering HC and CO emissions [[38],[39]].

4.3 EXPERIMENTAL SETUP

For conducting the engine trails, a 4-stroke single cylinder direct injection was chosen. It has a constant rpm of 1500 with a rated power output of 3.5Kw. The comprehensive specification of the engine is listed in table 7. The engine and generator are attached and further connected to the electrical loading unit. To monitor and measure the fuel flow rate, engine load, and temperature at different conditions an electronic information acquisition system is employed on the test rig engine. To measure the current, voltage, and speed of the engine the ammeter, voltmeter, and rpm indicator is mounted on the electrical loading unit. The setup of the engine is represented in fig 9. To measure the exhaust gas temperature, a thermocouple is fitted on the exhaust pipe. To measure the exhaust gas emissions an AVL-made smoke meter and gas analyzer is installed at the exhaust pipe.

Table 7 Technical Specification of engine

Parameters	**Specifications**
Type	The single-cylinder, four-stroke, direct-injection engine
Model	KSA-2057-P-1170 (Kirloskar)
Cubic capacity	0.78 ltr
Bore diameter	95mm
Orifice diameter	13.4mm
Rated speed	1500 rpm
Rated power	3.5 kW
Fuel injection pressure	200 bar
Fuel injection timing	23° bTDC (before top dead center)
Compression ratio	17.5:1
Lubrication System	Forced feed
Cooling system	Air-cooled (Radial Cooled)

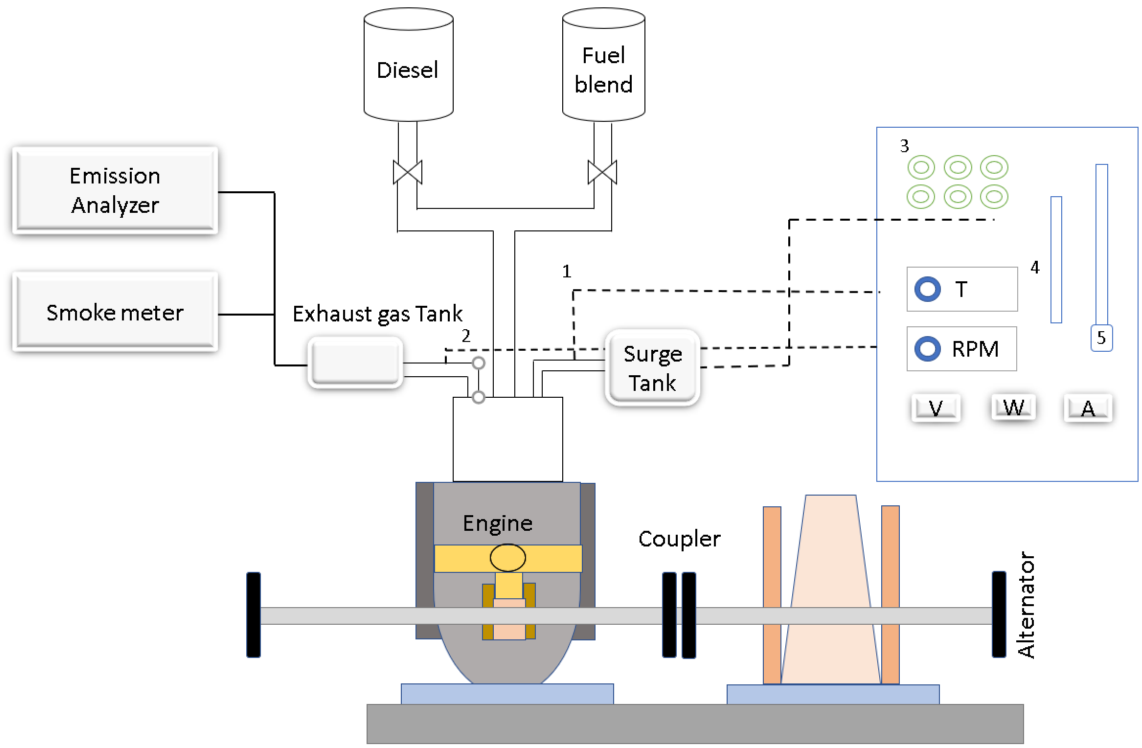

Fig. 9-Schematic diagram of engine setup

4.4 OPERATING PROCEDURE

Electrical resistance was used to load the engine, which was directly connected to the alternator. The engine was linked to a separate fuel measuring device. The generator's output was connected to a resistive load panel. Initially, the engine generator set used diesel for 10 minutes at 25, 50, 75, and 100% load. A timer was used to track the fuel usage. At the same time as the voltmeter measurement, the ammeter reading was taken. Orange peel oil was blended into four different blends: OPO10, OPO20, OPO30, and OPO40. Each mixture was properly blended before being used. The diesel engine's filter was opened, and the whole combination of biodiesel and diesel was emptied, preventing it from mixing with the next blend. For each blend, the experiment was repeated.

4.5 PERFORMANCE AND EXHAUST EMISSION ERROR AND UNCERTAINTY ANALYSIS

It is not unusual for errors to arise throughout an experimental research. The comprehensive study of the uncertainties during the physical measurement is known as error analysis. During the experiment, human intervention, erroneous data input, out-of-date instrument calibration, and adverse climatic conditions were all prevalent mistakes. The accuracy and ambiguity of the different instruments employed are addressed in depth in table 8

Table 8. Measuring principle, range, accuracy and percentage uncertainty of different measurements.

Measurements	Measurement Principle	Range	Accuracy	Uncertainty (%)
Engine speed	Magnetic pick-up type	0-2000 rpm	±10 rpm	±0.3
Engine load	Strain gauge type load cell	0-25 kg	±0.1 kg	±0.1
Time	Digital stop watch	-	±0.2 s	±0.1
Temperature	K-type thermocouple	0–1000 ^{o}C	±0.5 ^{o}C	±0.4
Fuel flow	Differential pressure transmitter	0-500 mm	±0.05 mm	±0.02
NO	Chemi-luminescence principle, electrochemical sensor	0-5000 ppm	±50 ppm	±0.5
CO	Non-dispersive infra-red sensor	0-10% vol.	±0.01%	±0.1
HC	Flame ionization detector-FID	0-20000 ppm	±10 ppm	±0.2
Smoke density	Hatridge principle	0-100%	±1%	±0.5
Fuel consumption	Level sensor	-		±0.2
Air consumption	Turbine flow type	-		±0.1

The overall uncertainty of the present experimental study:

=Square root of [(uncertainty of Brake Power)^2+(uncertainty of BTE)^2+(uncertainty of BSEC)^2 (uncertainty of NO)^2+(uncertainty of CO)^2+(uncertainty of HC)^2+(uncertainty of smoke)^2]

$= \text{Square root of } [(0.05)^2+(0.25)^2+(0.3)^2+(0.5)^2+(0.1)^2+(0.2)^2+(0.5)^2]$

$=0.8396$

4.6 RESULTS AND DISCUSSIONS

4.6.1 BSEC OF ORANGE PEEL OIL BLENDS

The amount of energy consumed for the development of unit power is represented by Brake specific energy consumption (BSEC). As it considers both heating value and mass flow rate of fuel, so it is an essential parameter of engine performance. The effect of the fuel sample on BSEC is shown in fig 10 respectively. BSEC at lower load is high, and as the load increases, the BSEC starts decreasing; this can be seen for all the fuel samples. This can be due to improper mixing of fuel at lower load, which leads to incomplete burning of and increases the BSEC. Because of the mutual effect of high calorific value and oxygen content, OPO30 has the lowest BSEC. Several researchers have noticed a similar trend[14].The viscosity of OPO30 is higher and cannot be neglected, but its oxygen content and heating value overcome it. At peak load conditions, the BSEC of OPO10, OPO20, OPO30, and OPO40 is lower than diesel by the percentage of 8.81, 15.55, 20, and 3.81respectively.

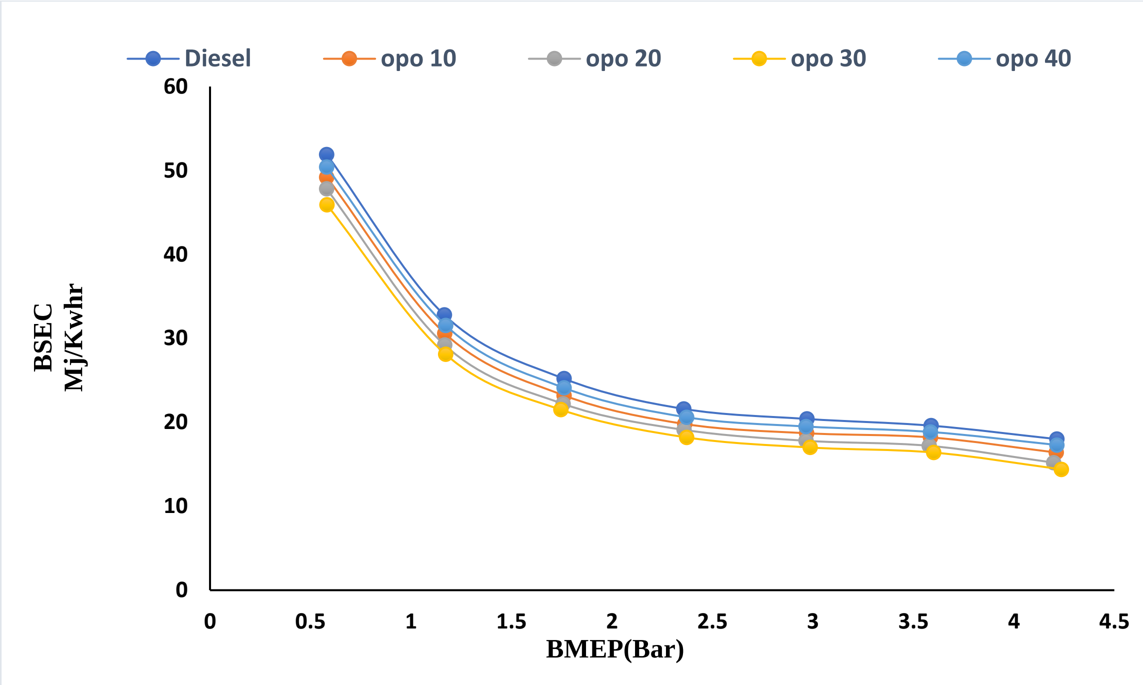

Fig. 10 -variation of BSEC with respect to BMEP

4.6.2 BRAKE THERMAL EFFICIENCY (BTE) OF ORANGE PEEL OIL BLENDS

Fig (11) shows the deviation of thermal brake efficiency (BTE) with Brake mean effective pressure (BMEP) of the various fuel samples. BTE is the amount of chemical energy of fuel that gets converted into valuable energy, i.e., shaft work. All fuel samples show an increasing trend in BTE with the rise in engine load. This can be due to the richer fuel supply at the higher load. Richer fuel has more chemical energy, which releases high power, but at the peak load, the BTE decreases for all the fuel samples; this can be because of an insufficient amount of oxygen inside the cylinder. A similar kind of trend is mentioned by various researchers[40]. Moreover, with the increase of OPO percentage, the BTE increases significantly. At peak load conditions, the BTE of OPO10, OPO20, OPO30, and OPO40 is higher than diesel by the percentage of 3.51, 9.9, 17.5, and 13.06. Due to the higher Calorific value and higher oxygen content in the fuel OPO30, it has better BTE than other fuel samples.

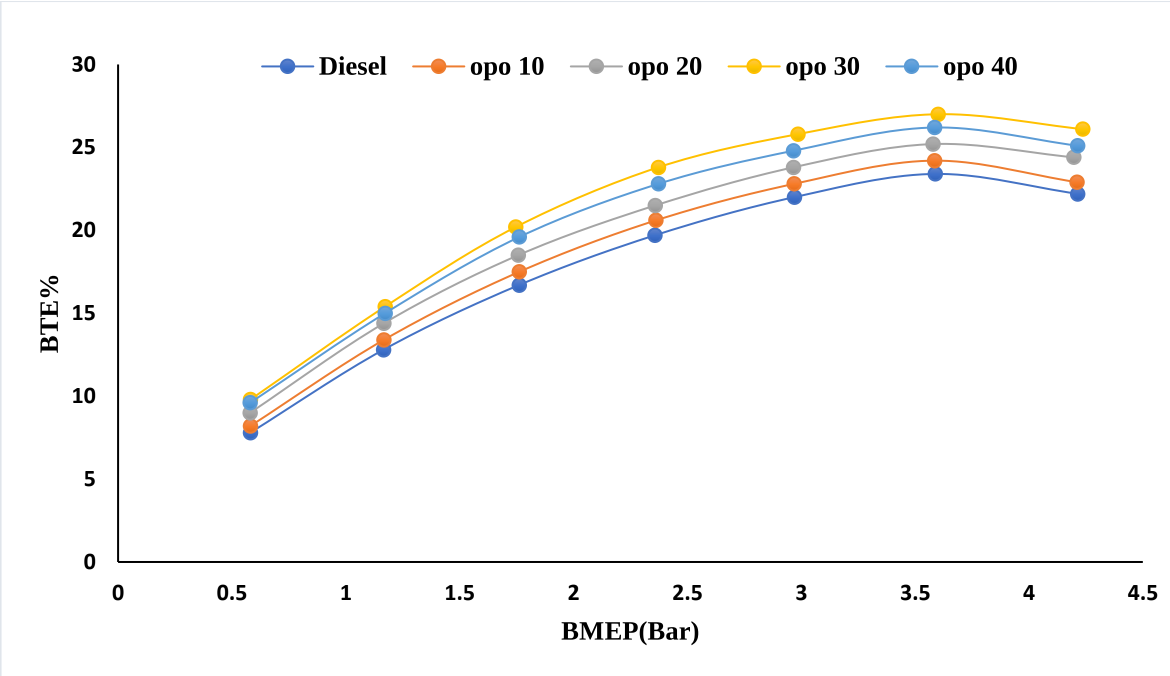

Fig. 11-variation of BTE with respect to BMEP

4.6.3 EXHAUST GAS TEMPERATURE (EGT) OF ORANGE PEEL OIL BLENDS

Deviation of Exhaust gas temperature (EGT) with BMEP is highlighted in fig (12) for different fuel samples. The graph shows that the increase of load EGT also increases for all the blend samples. The reason for the increase in EGT is heat released during the diffusion combustion. As this heat cannot be utilized for helpful power production termed as waste heat. All the engine loads diesel shows the least EGT, and OPO30 shows the highest EGT for all loading conditions. Because of high density and oxygen content OPO30 shows the maximum exhaust gas temperature than the other blended fuel sample[31]. OPO30 has the highest EGT; this may be because of the high density and oxygen content value. At the peak load, the EGT of OPO30 is 7.5 % higher than diesel.

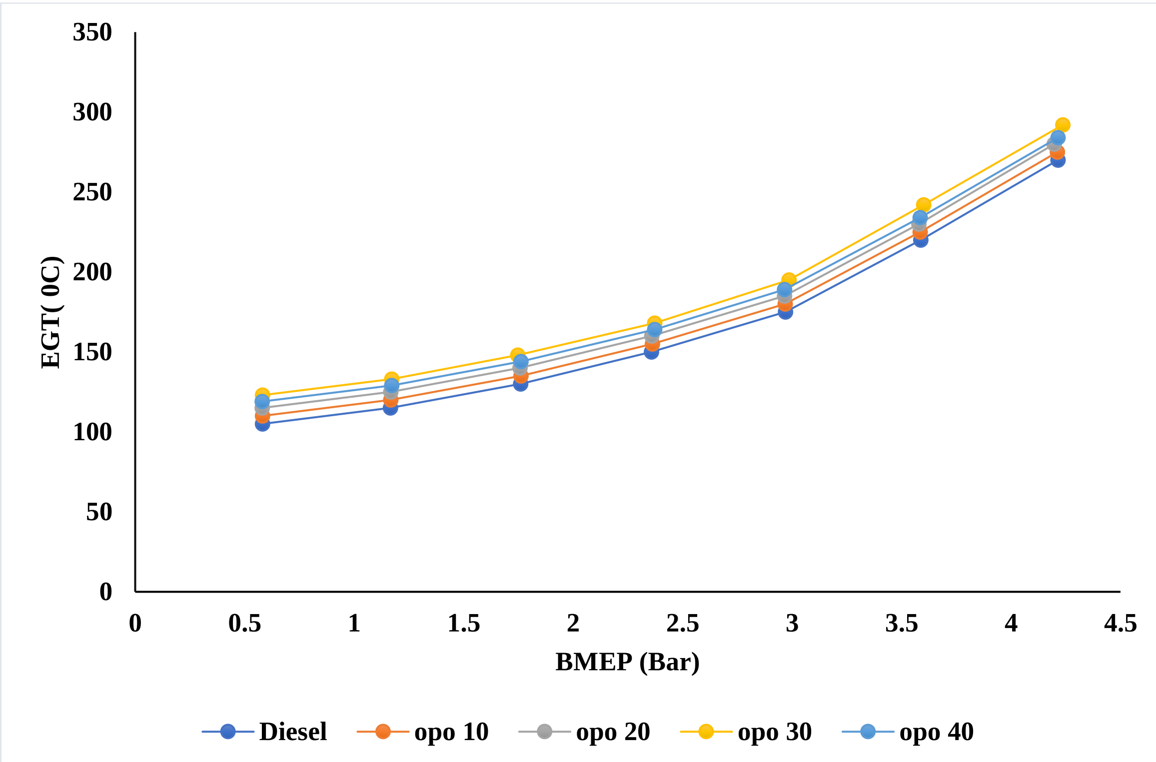

Fig 12-variation of EGT with respect to BMEP

4.6.4 NITROGEN OXIDE EMISSION OF ORANGE PEEL OIL BLENDS

Fig (13) shows the deviation of NOx emission with BMEP for various blend samples. The NOx for all samples shows an increasing trend with the load. NOx emission depends on the ignition temperature, reaction time, and oxygen availability. As combustion temperature increases, the NOx emission also increases. The NOx emission for diesel is lower than the other OPO fuel samples; this may be due to the lower EGT of Diesel, and since OPO fuel samples have higher oxygen content than diesel, better combustion takes place in OPO samples, and it increases its NOx emission. Several studies have suggested a similar type of tendency[41]. OPO30 has the highest NOx emission; this may be because of the high EGT and high oxygen content. At the peak load, the NOx of OPO30 is 5.07 % higher than diesel.

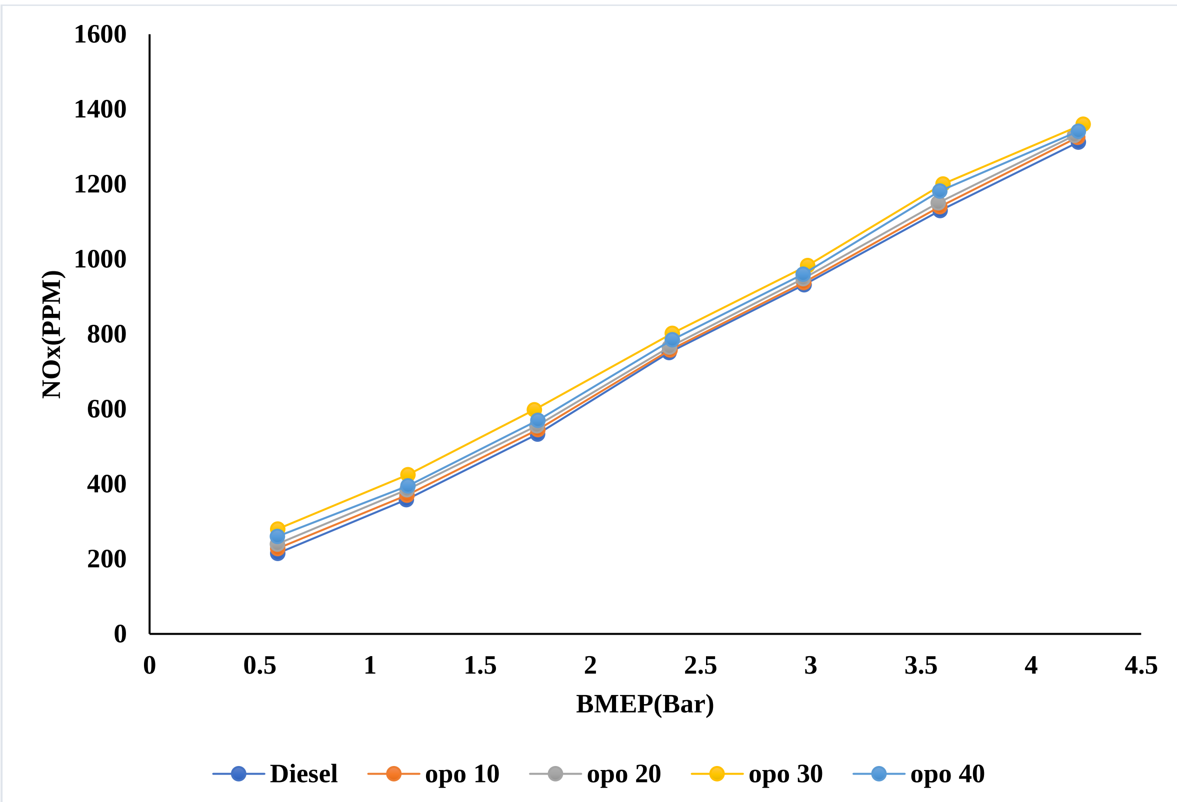

Fig 13-variation of NOx with respect to BMEP

4.6.5 OPACITY EMISSON OF ORANGE PEEL OIL BLENDS

Indirect measurement of the soot particles in emission is smoke opacity. The formation of smoke mainly depends upon the air-fuel ratio and fuel consumption. Fig (14) shows the deviation of smoke with BMEP for different blend samples. The graph is of increasing in nature for all samples and all load conditions. Among the fuel sample for D100, the smoke is maximum. This is because of the low oxygen content and poor detonation characteristics of pure diesel. On the other side, because of the higher oxygen content in biofuels, the burning is efficient, and it leads to low smoke opacity [28]. In a complete load condition, the Opacity of OPO10, OPO20, OPO30, and OPO40 drops by the percent of 2.7, 6.9, 9.7, and 8.3, respectively.

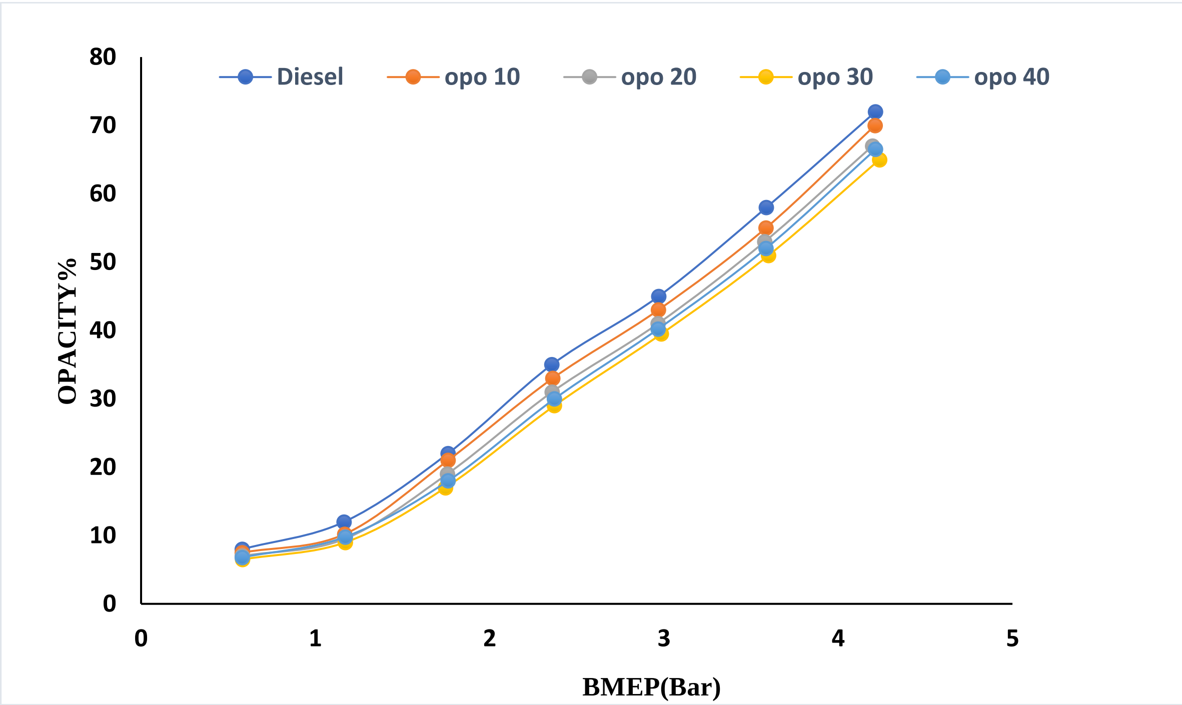

Fig 14-variation of Opacity with respect to BMEP

4.6.6 CARBON MONOXIDE EMISSON OF ORANGE PEEL OIL BLENDS

Fig (15) shows the deviation of the CO emission for various blend samples with BMEP. The emission is more petite at a lower load, and as the load increases, the emission level also increases. The formation of CO is the result of incomplete combustion of fuel. At the peak load, the CO emission is higher; it may be due to improper fuel and air mixing. CO emission is found significantly higher at the peak load. This may be due to the deficiency of oxygen at peak load. The value of CO emission at the peak load for D100, OPO10, OPO20, OPO30, and OPO40 is 8.8, 8.5, 8.2, 8.1, and 8.2, Percent respectively. Various researchers mention a similar kind of trend. [14]. Among the various samples for OPO30 emission is minimum; this may be because of higher oxygen content and proper combustion.

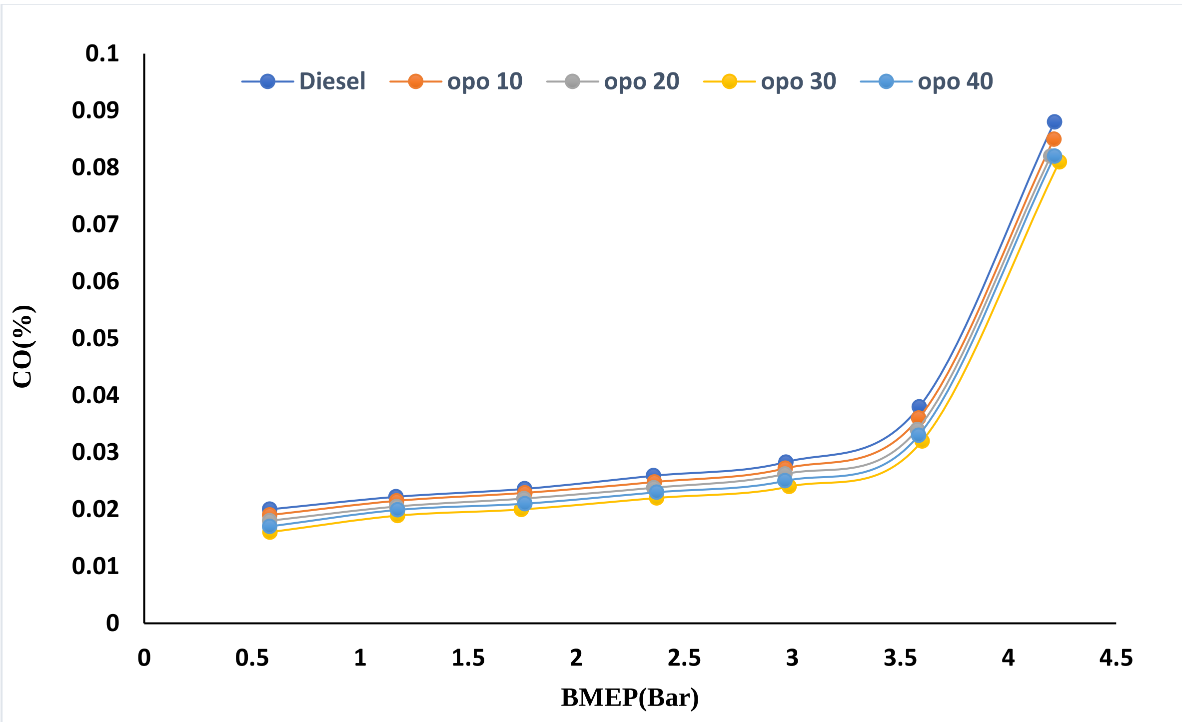

Fig 15-variation of CO with respect to BMEP

4.6.7 HYDROCARBON EMISSON OF ORANGE PEEL OIL BLENDS

Emission of hydrocarbon is the consequence of partial combustion of fuel samples. Fig (16) shows the deviation of the hydrocarbon with the brake mean effective pressure. As the load increases, the emission of hydrocarbon also increases. At a lower load, the hydrocarbon emission is low; this may be due to the proper mixing of fuel and air. At low load, the combustion timing is more and more oxygen is present. At higher load, combustion timing is less, and oxygen content is also low, resulting in higher hydrocarbon emission.

Among the various fuel samples, diesel has higher HC emissions compare to other fuel samples. Several studies have suggested a similar type of tendency[18]. The OPO30 has minor HC emissions; this may be due to high oxygen content, high calorific value, and high density. At the peak load condition, the OPO30 has 5.8 % less emission than the diesel.

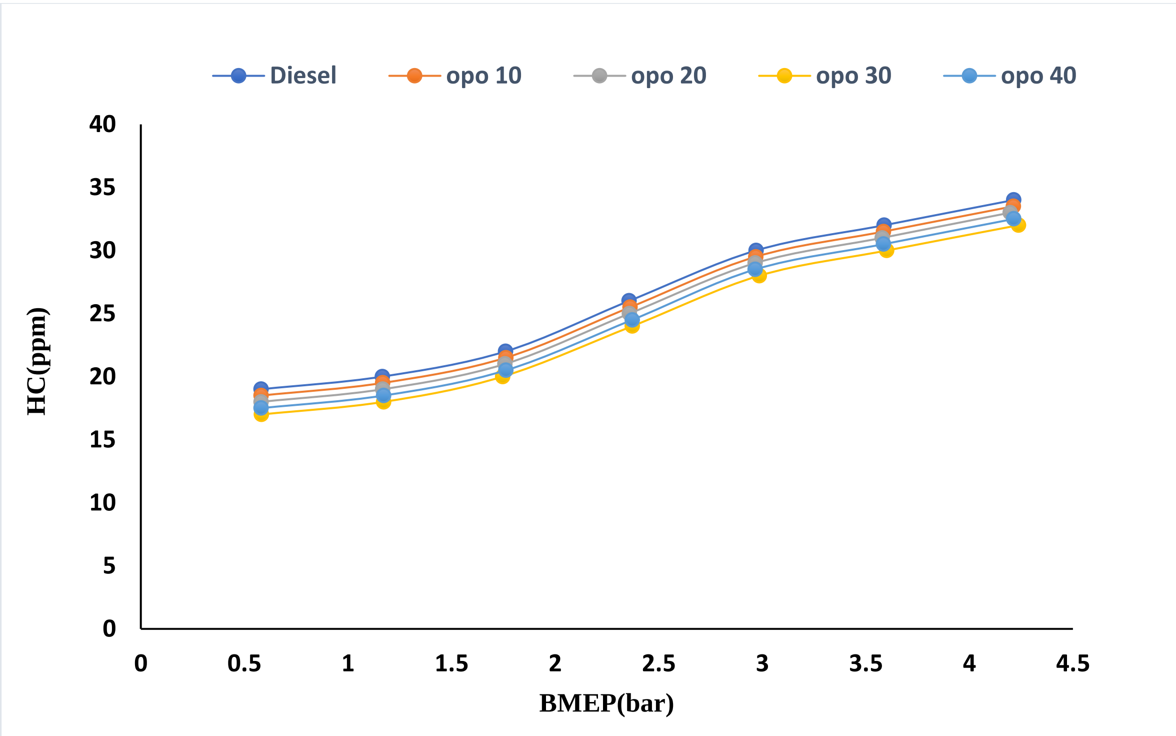

Fig. 16-variation of HC with respect to BMEP

On the basis of above results the performance of orange peel oil blends, BTE is higher than diesel and BSEC is lower for Orange peel oil blends. In case of emission the gases CO and HC is minimum for orange peel oil blends compare to diesel but emission rate of NO_x is higher for orange peel oil blends compared to diesel.

It seems that vegetable oil/ biodiesel is good substitute for diesel fuel. The BSEC for all type of blends of orange peel oil is lower than diesel while opposite trend in BTE and shown similar efficiency to that of diesel and emissions are also less and comparable.

4.7 Artificial Neural Network (ANN) application

ANN is the piece of the computing system that is designed in such a way that it can simulate information and data that exhibit human-like intelligence. It is the basis of artificial intelligence (AI) and resolves glitches that would prove impossible or challenging by human or statistical standards. Artificial Neural Network (ANN) uses the brain's processing as a foundation to grow algorithms that can be used to model multifaceted outlines and forecast glitches. It mainly comprises of three layers; input layers, hidden layers, and output layers [42]. All three layers have a specific number of trivial entities, called neurons and approximately attentive processing components. The neurons are fortified to each other through communication joins, which are related to the association weights [43].

There are two stages in all machine learning algorithms and ANN life cycle. One is the training stage, and the other is the prediction stage [40]. in the training stage, weight and bias of data are provided. In the training stage, the network is trained for output according to input data.

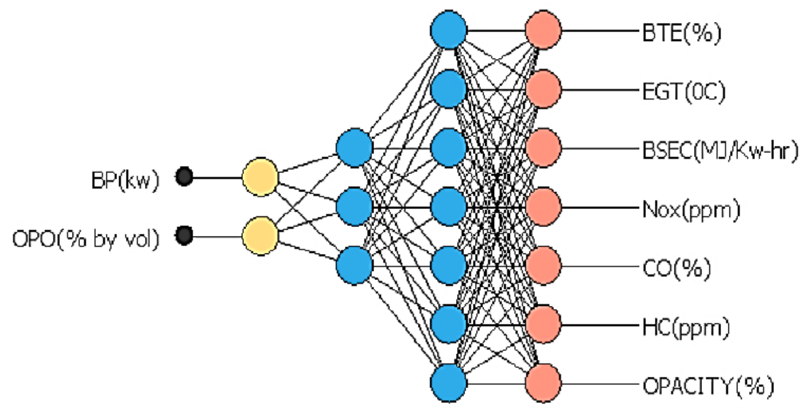

Fig.17-ANN Model Structure

The ideal algorithm is the "Quasi-Newton method" in ANN model development and optimization. Quasi-Newton methods are used to find either zeros or local maxima and minima of the functions. In this employed algorithm, ANN is cast-off to evaluate the output parameters (BTE, BSEC, EGT, NOx, HC, CO, and Opacity) based upon the input parameters (OPO% and engine load). In the designed model, 60% data is used for training instance, 20% data is used for selection instance, and the rest 20% data is used for testing instance. Using data, linear regression is performed, and the relation between experimental output parameters and predicted output parameters is established.

4.8 EXPERIMENTAL AND PREDICTED DATA VALIDATION

To test the loss of a model linear regression analysis is performed between the scaled neural network outputs and the corresponding targets. This analysis mainly consists of three parameters for each of the output variables. a and b are the two-parameter links to the y-intercept and the slope of the finest linear regression relating to targets and scaled outputs. R^2

is the third parameter known as correlation co-efficient. It gives a relation between targets and scaled outputs. If the slope is one then we had a perfect fit i.e., outputs and targets are the same and for this y-intercept would be zero. If the correlation coefficient (R^2) is equivalent to one, then it is a perfect correlation between the outputs from the Neural Network and targets in the testing subset.

4.8.1 REALTION BETWEEN VARIOUS PARAMETER OF ENGINE WITH REAL AND PREDICTED VALUES

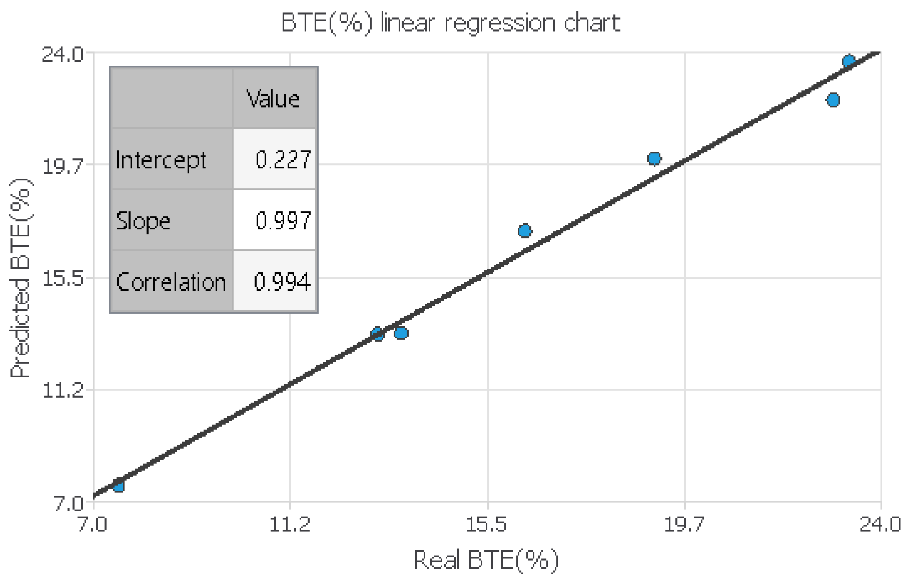

Fig.18- Real BTE(%) vs. Predicted BTE(%)

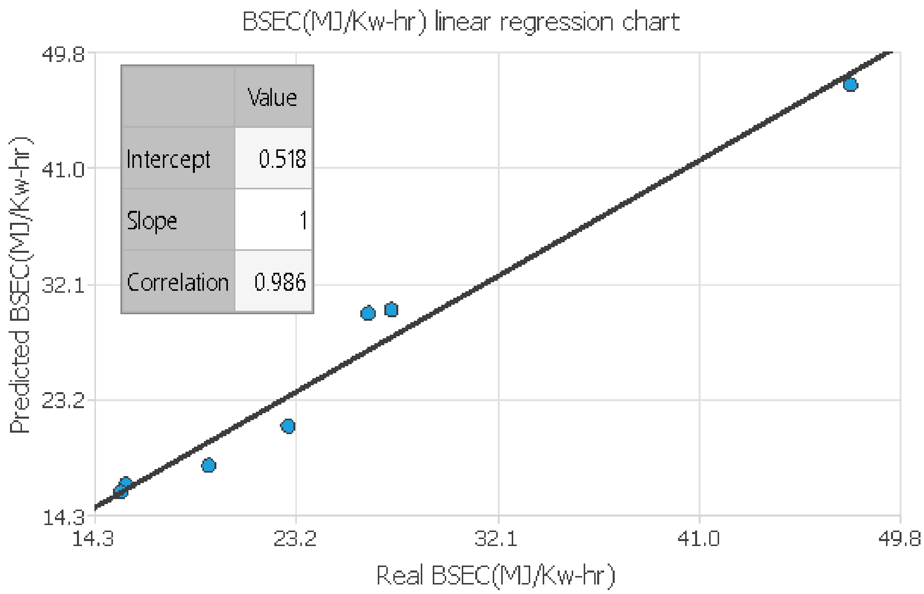

Fig.19- Real BSEC(MJ/Kw-hr) vs. Predicted BSEC (MJ/Kw-hr)

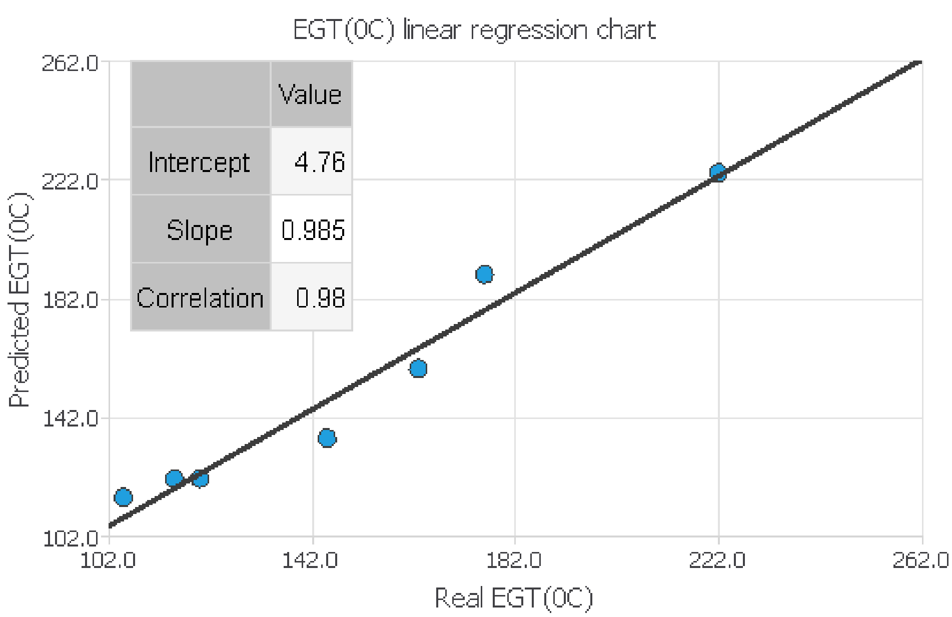

Fig.20-Real EGT(^{0}C) vs. Predicted EGT(^{0}C)

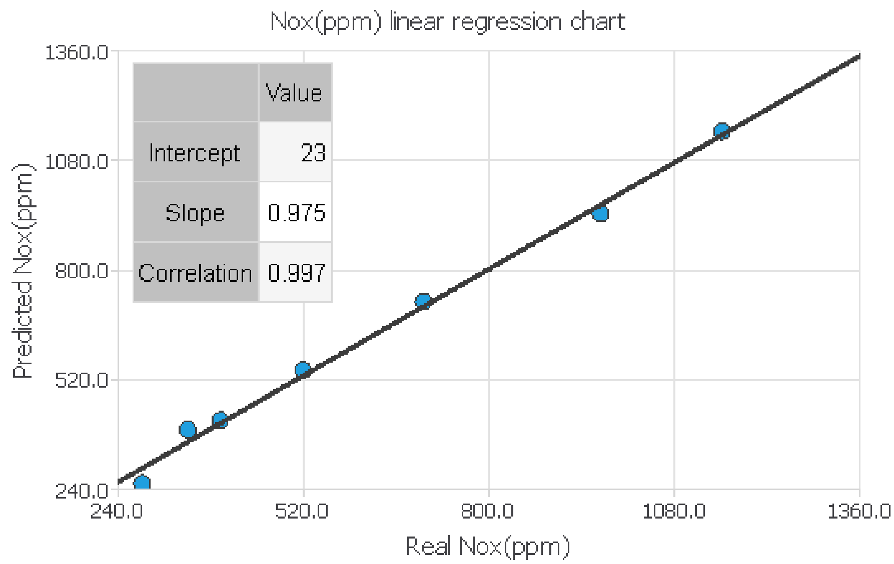

Fig.21-Real NOx (ppm) vs. Predicted NOx (ppm)

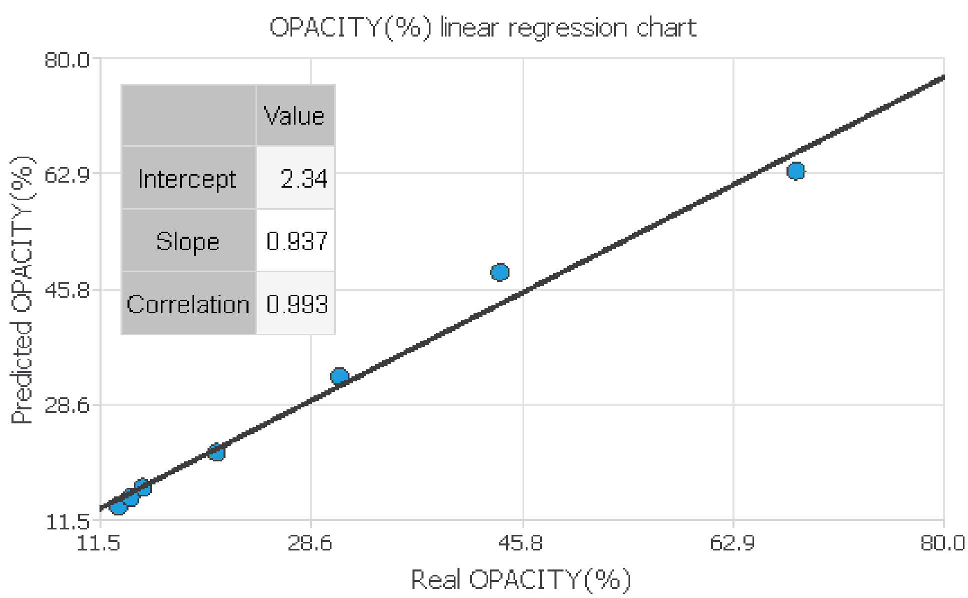

Fig.22-Real Opacity (%) vs. Predicted Opacity (%)

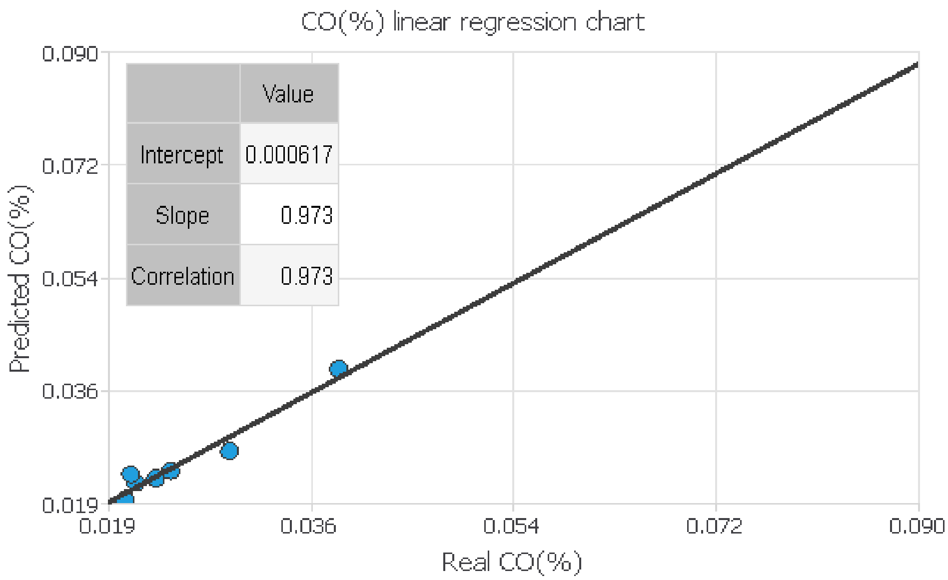

Fig.23-Real CO (%) vs. Predicted CO (%)

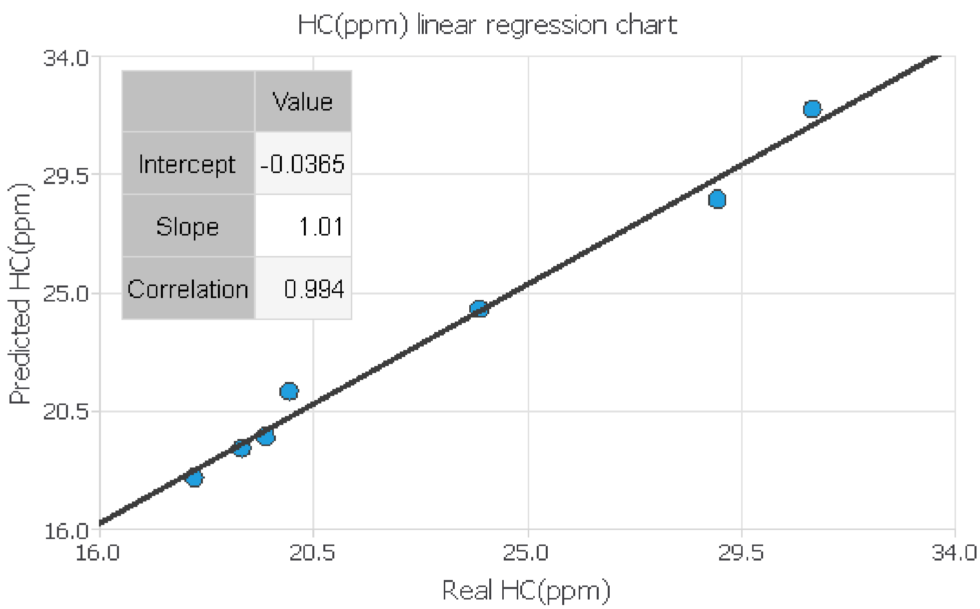

Fig.24-Real HC (ppm) vs. Predicted HC (ppm)

Guesstimates by using ANN aiming the performance and emission of the CI engine confirmed respectable statical performance. The chart obtained by linking the results from investigational and ANN guesstimates shows that ANN can simulate a single cylinder CI engine with OPO-diesel fuel blends. The assessment of ANN guesstimates results and experimental results for NOx in fig (21), opacity in fig (22), CO in fig (23), and HC in fig (24). According to obtained data, R^2 values were 0.997, 0.993,0.973, and 0.994 respectively. The mean relative error is also calculated for NOx, opacity, CO, and HC and it is 4.01%, 4.5%, 4.112%, and 3.42% respectively.

The assessment of ANN guesstimates results and experimental results for BTE in fig (18), BSEC in fig (19), and EGT in fig (20). According to obtained data, R^2 values were 0.994, 0.986, and 0.98 respectively. The mean relative error is also calculated for BTE, BSEC, and EGT and it is 0.864%, 0.568%, and 2.035% respectively.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

In the present experimental study, homogeneous blends of diesel and orange peel oil are prepared, and these blends were tested on a conventional single-cylinder diesel engine. The physicochemical properties suggest that it is a homogeneous and stable blend. Density and calorific value decreases but the kinematic viscosity increases by blending diesel and orange peel oil. ANN modeling on performance and emission validates the experimental results.

1. OPO blends have similar fuel characteristics to diesel, such as calorific value, viscosity, and density, and so may be used to replace diesel.
2. The BTE of OPO30 is 17.5% greater than diesel at peak load, according to the engine performance test. This increase in BTE and 20% reduction in BSEC is due to increased oxygen content and calorific value and also ANN results are close to each other. R^2 and mean relative error for BTE, BSEC is 0.994 and 0.864%, 0.986 and 0.568% respectively.
3. When compared to diesel, OPO30 had the greatest EGT of all the fuel samples tested. In comparison to OPO blends, NOx emissions in diesel are minimal due to low viscosity and low oxygen concentration. When compared to diesel, the increase in NOx emissions for OPO30 is 3.6 %. The EGT and NOx, ANN findings are promising. For EGT and NOx, the R2 and mean relative error are 0.98 and 2.035 %, 0.997 and 4.01 %, respectively.
4. In contrast with diesel, a decrease in emission of 5.8% in HC and a 9.7% decrease in CO emissions were observed for OPO30, and from ANN modeling, the value of

R^2 and mean relative error for HC, CO is 0.994 and 3.42%, 0.973, and 4.112% respectively. The above result demonstrates how this blend is cleaner and more environmentally friendly.

5. Outstanding oxygen content in OPO30, combustion improved, and it results reduction in smoke. The smoke is reduced by 9.7% compared to neat diesel. Moreover, from the ANN modelling for smoke, the value of R^2 and mean relative error is 0.993 and 4.5%, respectively.

Experiments show that OPO blends can completely replace diesel as a fuel for IC engines. Even if a greater quantity of OPO fuel must be examined. Since OPO40, there has never been an engine failure experienced during the trial.

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