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Experimental Investigations On The Behaviour Of A Diesel Engine Using Canola Methyl Ester As A Fuel At Different Injection Pressures

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ABSTRACT

This project investigates the performance and emission characteristics of a Single cylinder diesel engine fuelled with Canola Methyl Ester (CME) biodiesel at varying injection pressures, aiming to optimize pressure settings for enhanced efficiency and reduced emissions. A comparative analysis lwith conventional diesel was conducted under different load conditions, focusing on key parameters such as specific fuel consumption, specific energy consumption, brake thermal efficiency, and emissions including CO, HC, CO_2, and NOx. The engine demonstrated stable operation on CME across all test conditions. Among the tested pressures, 220 Bar is emerged as the most effective, delivering superior thermal efficiency, lower specific fuel consumption, and significantly reduced emissions, owing to better atomization and combustion characteristics of CME. Although NOx levels were slightly higher due to elevated flame temperatures, the overall results indicate that CME at 220 Bar is a promising and environmentally friendly alternative to conventional diesel fuel.

CHAPTER 1: INTRODUCTION

1.1 Diesel

Diesel fuel is obtained from crude oil through three main steps: separation, catalytic conversion, and purification. It is commonly used in engines for generators, trucks, buses, and boats. Apart from petroleum diesel, biodiesel can be produced from algae, vegetable oils, plants, and animal fats.

Diesel is made by refining crude oil, where hydrocarbons are separated based on boiling points in a fractional distillation column. Light components like propane and gasoline separate first, followed by diesel and lubricating oils. Heavy fractions are broken down using catalysts. Finally, purification reduces sulfur content, producing cleaner fuels like Ultra-Low Sulfur Diesel (ULSD).

1.2 Diesel Emissions

Diesel engines convert fuel into mechanical power, but the exhaust contains harmful pollutants. Incomplete combustion produces carbon monoxide (CO), hydrocarbons (HC), and aldehydes, which cause headaches, dizziness, and irritation, especially in enclosed spaces. Nitrogen oxides (NOx), formed at high temperature and pressure, contribute to smog and are highly toxic. Sulfur present in fuel forms sulfur dioxide, which further produces sulfuric acid responsible for acid rain. Diesel particulate matter (DPM) consists of soot, hydrocarbons, and sulfates. These particles are extremely fine and respirable, posing risks such as cancer, heart issues, and respiratory diseases. PAHs, present in both gas and particulate form, are also harmful carcinogens

1.3 Global Warming

Global warming occurs due to excess carbon dioxide (CO_2) trapped in Earth's lower atmosphere. While CO_2 is necessary to maintain habitable temperatures, excessive emissions from burning fossil fuels create a thick layer that retains heat. This intensifies the greenhouse effect and contributes to rising global temperatures.

1.4 Shortage of Fossil Fuels

Fossil fuels take millions of years to form and are non-renewable. Oil, which provides a major share of global energy, is depleting rapidly as wells produce less over time. With increasing technological needs, energy consumption is rising, accelerating the exhaustion of fossil reserves. Developing renewable energy sources and improving resource efficiency are essential to sustain energy needs for current and future generations.

CHAPTER – 2

LITERATURE REVIEW

The growing global energy crisis and environmental concerns related to fossil fuel usage have increased interest in renewable and cleaner alternatives. Biodiesel, especially from vegetable oils, is considered a promising substitute due to its biodegradable nature, reduced emissions, and compatibility with diesel engines. Among biodiesel feedstocks, canola oil has received significant attention because of its low saturated fat content, good oxidation stability, and high energy density. Engine performance and emission characteristics of canola methyl ester (CME) largely depend on fuel injection parameters, particularly injection pressure. This review summarizes studies on CME and the influence of injection pressure on diesel engine behaviour.

Arun Teja Doppalapudi et al. (2024)

The authors examined diesel engine performance using Tucuma and Ungurahui biodiesel blends. The fuels showed high yield (>99.4%), lower viscosity, and higher cetane numbers. Four blends were tested at full load, and results showed combustion behaviour similar to diesel. TB10 and UB10 blends demonstrated better brake thermal efficiency (BTE), lower brake-specific fuel consumption (BSFC), and higher peak pressures and heat release rates (HRR) than diesel [1].

Sharma and Dhar (2023)

This study explored the tribological performance of engine components using canola biodiesel. Results indicated improved lubricity, reduced friction, and lower wear due to biodiesel's higher viscosity and oxygen content. Even low blends like B20 improved wear resistance. Higher blends may require compatibility checks due to potential deposit formation. Overall findings highlight canola biodiesel as a durable and environmentally friendly alternative [2].

Nabi et al. (2022)

The authors optimized injection timing and pressure for biodiesel blends. Increasing injection pressure (200–250 bar) and advancing timing improved combustion efficiency, increased BTE, and reduced HC and CO emissions. However, NOx emissions increased due to higher combustion temperatures. Moderate blends (B20–B30) with optimized injection settings can balance performance and emissions [3].

Zahan and Kano (2018)

Their work reviewed canola oil biodiesel production and its engine performance. The study emphasized CME's renewable nature, reduced emissions, and suitability for existing diesel engines. It confirmed that CME is a viable alternative to fossil diesel and encouraged further technological developments to enhance biodiesel utilization [4].

Aydin and Bayindir (2018)

The researchers studied cottonseed oil methyl ester (CSOME) in diesel engines and found that performance was close to diesel, with a slight 2–5% drop in BTE. Emissions such as CO and PM were significantly lower (30–40% reduction). However, NOx emissions increased (8–12%) due to higher peak temperatures. They suggested using EGR or adjusting injection timing to counter NOx formation [5].

Damanik et al. (2017)

This comprehensive review concluded that biodiesel blends significantly reduce CO, HC, and PM emissions owing to their oxygen-rich structure. However, increased NOx emissions remained a challenge. Engine performance remained comparable to diesel, with small variations depending on blend percentage and feedstock. The study recommended optimized injection parameters and emission control strategies for practical biodiesel usage [6].

Aransiola et al. (2013)

The authors optimized CME production through transesterification. Key factors affecting yield were catalyst concentration, reaction temperature, and alcohol-to-oil ratio. Produced CME showed properties similar to diesel, with improved lubricity and reduced CO and HC emissions but increased NOx due to higher combustion temperatures. Fuel injection parameters were noted as crucial for engine performance with CME [7].

Sarin and Sharma (2010)

This study confirmed the feasibility of canola biodiesel as a sustainable diesel alternative. CME displayed a high cetane number, low sulfur content, and good oxidation stability, making it suitable for diesel engines and offering environmental benefits [8].

ESTERFICATION OF CANOLA OIL

Canola oil is a widely used vegetable oil extracted from the seeds of the canola plant (*Brassica napus* or *Brassica rapa*). It is known for its low saturated fat content and high levels of heart-healthy monounsaturated and polyunsaturated fats. With a high smoke point, it is commonly used in cooking, frying, and baking. Beyond culinary uses, canola oil plays a significant role in biodiesel production through transesterification. Its low viscosity and good oxidative stability make it suitable for fuel applications. Additionally, it is used in industrial products like lubricants, cosmetics, and bioplastics.

Canola Seed Oil

Transesterification Process

Biodiesel has recently received a lot of attention due to its many environmental benefits and the fact that it is produced from a renewable resource. Because of its lower viscosity, biodiesel produced by the transesterification of natural oils and fats is preferable to other techniques of biodiesel production. Transesterification and glycerol recovery are two approaches that may reduce production costs. Since the continuous transesterification process requires fewer steps and has a higher throughput, it has a lower production cost. A transesterification procedure may be used to convert canola oil into biodiesel. The following flowchart depicts the steps required to produce canola biodiesel (methyl ester

Esterification of Canola Oil

Properties of Pure Diesel and CME

PROPERTY	DIESEL	CME
DENSITY (Kg/m³)	827.5	860
SPECIFIC GRAVITY	0.8275	0.86
KINEMATIC VISCOSITY (m²/s)	2.0×10^5	3.4×10^5
CALORIFIC VALUE (KJ/Kg)	45380	41100
FLASH POINT (deg C)	53	160

EXPERIMENTATION

Description of the Diesel Engine Test Rig

The diesel engine is Kirloskar. The water-cooled single cylinder diesel engine is coupled to a rope pulley break arrangement to absorb the power produced. Necessary weights and spring balance are included to apply load on the brake drum. Suitable cooling water arrangements for the brake is provided. Separate cooling water lines fitted with temperature measuring thermocouple are provided for the engine cooling. A fuel measuring system consists of a fuel tank mounted on a stand, burette, three-way cock and is provided. Air intake is measured using an air tank fitted with an orifice and a water manometer.

Single Cylinder High Speed Diesel Engine.

Specifications of Engine

Make	Kirloskar
Bore	80mm
Stroke	110mm
R.P.M	1500
B. P	3.72KW
Compression ratio	16:01
Loading type	Mechanical
Brake Drum Diameter	0.315m
Fuel	High Speed Diesel Oil
Max. Load	15.335Kg

Theory

Load text is conducted to study the performance of single cylinder high speed diesel engines at various loads under constant speed maintained at 1500 rpm. The tangent to the curve drawn between brake power and the fuel consumed per hour is called WILAN'S line. An intercept made by this line on the negative side of the brake power axis will give frictional power to the engine at the particular speed of the engine. For the further study of performance of a cylinder high speed engine, the characteristics such as brake thermal efficiency, indicated thermal efficiency, Mechanical efficiency at different load factors are determined by calculating the brake power, fuel input power and indicated power of the engine at the respective loads. Specific fuel consumption and exhaust gas temperature are to be known in order to characterize the performance of the engine. The performance of the engine can be well defined by plotting these characteristics against brakes from the graphs. The optimum conditions of the engine can be standardized.

Procedure

1. The fuel and lubricating oil are fitted to the required level.
2. The three-way cock is opened so that oil flows to the engine.
3. Cooling water is supplied throughout the inlet pipe.
4. The engine is started and is allowed to run at different loads and at each load, time taken for 10 cc of fuel consumption readings are taken.
5. Simultaneously smoke analysis readings are noted.

Performance Parameters

Brake Power

The power developed by an engine at the output shaft is called Brake power (B.P)

$$B.P = \frac{\pi WDN \times 9.81}{60000} KW \qquad \text{Eq-2}$$

- W1-Applied load in Kg
- W2- Spring load in Kg
- W-Actual load applied in Kg (W1-W2=W)
- D-Brake drum diameter in meters
- N-Speed in rpm

Specific Fuel Consumption:

It is defined as the amount of fuel consumption per hour and density by break power.

$SFC = ((m_f \times 3600)/BP)$ Kg/KW-h

Where,

m_f= Mass Flow Rate- Kg/s

Brake Thermal Efficiency:

It is the ratio of brake power to energy supplied by the fuel.

$\eta_{Bth} = ((B.P) \div (m_f \times CV)) \times 100$

Specific Energy Consumption:

It is defined as an be defined in terms of mass flow rate ($\dot{m}_f$), calorific value (CV), and density by brake power (BP).

$SEC= ((m_f \times CV \times 3600)/ BP)$ KJ/KW-h

Mass of fuel:

It is the mass of fuel consumed per second during an engine test.

$$m_f = \frac{10}{t} \times \frac{density}{1000}$$

Description of Multi-Gas Analyzer

NETEL model NPM MGA-1 is a multi-gas analyzer meant for monitoring CO, CO_2, HC, O_2 and NOx in automotive exhaust. It is based on a principle of absorption/obstruction of light, which is indicative of the quality of smoke in an exhaust gas sample. A green LED, driven by a pulsating constant source, emits a light beam having peak spectral intensity between 550 to 570 nm wave length. This beam passes through a smoke cell and on to a silicon photo detector which is further processed by precise signal handling circuits.

Exhaust Emission Pipe

Specifications of Automotive exhaust monitor

Gasses Measured	CO, CO_2, O_2, HC, NO_2
Operating principle	Microcontroller Driven
Range	CO:0 – 9.99%, CO_2: 0-20.00% HC:20000 PPM(PROPANE), O2:0-25%. NO_2:5000PPM
Accuracy	CO:0.01%, HC:1 PPM, CO_2:0.1%, O_2:0.01% NO_2:1 PPM
Power supply	12VDC power consumption =35W ,230VAC
Measurement	Smoke density in K
Principle	Absorption of light beam
Type of smoke meter	Partial flow
Light source & detector	LED & Photocell

RESULTS AND DISCUSSIONS

Table 6.1 (a): Load Test on Pure Diesel at 200 Bar

S.NO	W1 (Kg)	W2 (Kg)	W (Kg)	N (RPM)	t (sec)	m_f (Kg/s)	BP (Kg)	SFC (Kg/KW-h)	SEC (KJ/KW-h)	η_{Bth} (%)
1	0	0	0	1500	102.15	0.000081	0	∞	∞	0
2	2	0.3	1.7	1500	78.21	0.000106	0.412	0.9231	41890	8.594
3	4	0.3	3.5	1500	75.33	0.000110	0.849	0.4655	21125	17.042
4	6	0.6	5.4	1500	56.79	0.000146	1.310	0.4002	18162	19.822
5	8	0.8	7.2	1500	50.41	0.000164	1.747	0.3382	15345	23.460
6	10	1	9	1500	45.91	0.000180	2.183	0.2970	13479	26.707
7	12	1.6	1.6	1500	40.57	0.000204	2.523	0.2909	13200	27.272

Table 6.2 (a): Load Test on CME at 200 Bar

S.NO	W1 (Kg)	W2 (Kg)	W (Kg)	N (RPM)	t (sec)	m_f (Kg/s)	BP (Kg)	SFC (Kg/KW-h)	SEC (KJ/KW-h)	η_{Bth} (%)
1	0	0	0	1500	72.12	0.000119	0.000	∞	∞	0.000
2	2	0.2	1.8	1500	64.15	0.000134	0.437	1.1053	45428	7.925
3	4	0.4	3.6	1500	57.22	0.000150	0.873	0.6196	25465	14.137
4	6	0.7	5.3	1500	49.16	0.000175	1.286	0.4899	20133	17.881
5	8	0.9	7.1	1500	43.36	0.000198	1.722	0.4146	17039	21.128
6	10	1.2	8.8	1500	38.76	0.000222	2.135	0.3742	15379	23.409
7	12	1.6	10.4	1500	34.51	0.000249	2.523	0.3556	14616	24.631

Table 6.3 (a): Load Test on CME at 210 Bar

S.NO	W1 (Kg)	W2 (Kg)	W (Kg)	N (RPM)	t (sec)	m_f (Kg/s)	BP (Kg)	SFC (Kg/KW-h)	SEC (KJ/KW-h)	η_{Bth} (%)
1	0	0	0	1500	82.42	0.000104	0.000	∞	∞	0.000
2	2	0.2	1.8	1500	67.24	0.000128	0.437	1.0545	43340	8.306
3	4	0.4	3.6	1500	59.29	0.000145	0.873	0.5980	24576	14.648
4	6	0.7	5.3	1500	50.35	0.000171	1.286	0.4783	19657	18.314
5	8	0.9	7.1	1500	44.25	0.000194	1.722	0.4062	16696	21.562
6	10	1.1	8.9	1500	39.17	0.000220	2.159	0.3661	15047	23.925
7	12	1.6	10.4	1500	35.39	0.000243	2.523	0.3468	14252	25.259

Table 6.4 (a): Load Test on CME at 220 Bar

S.NO	W1 (Kg)	W2 (Kg)	W (Kg)	N (RPM)	t (sec)	m_f (Kg/s)	BP (Kg)	SFC (Kg/KW-h)	SEC (KJ/KW-h)	η_{Bth} (%)
1	0	0	0	1500	99.15	0.000087	0.000	∞	∞	0.000
2	2	0.2	1.8	1500	71.16	0.000121	0.437	0.9964	40953	8.791
3	4	0.4	3.6	1500	61.32	0.000140	0.873	0.5782	23762	15.150
4	6	0.7	5.3	1500	52.11	0.000165	1.286	0.4621	18993	18.954
5	8	0.9	7.1	1500	45.24	0.000190	1.722	0.3973	16331	22.044
6	10	1.1	8.9	1500	40.08	0.000215	2.159	0.3578	14705	24.481
7	12	1.8	10.4	1500	36.61	0.000235	2.523	0.3352	13777	26.130

Table 6.5 (a): Load Test on CME at 230 Bar

S.NO	W1 (Kg)	W2 (Kg)	W (Kg)	N (RPM)	t3 (sec)	m_f (kg/s)	BP (Kg)	SFC (Kg/KW-h)	SEC (KJ/KW-h)	η_{Bth} (%)
1	0	0	0	1500	99.38	0.000087	0.000	∞	∞	0.000
2	2	0.2	1.8	1500	73.34	0.000117	0.437	0.9668	39736	9.060
3	4	0.3	3.7	1500	55.64	0.000155	0.898	0.6200	25480	14.129
4	6	0.4	5.6	1500	47.08	0.000183	1.358	0.4841	19896	18.094
5	8	0.6	7.4	1500	42.23	0.000204	1.795	0.4084	16786	21.447
6	10	1.2	8.8	1500	38.82	0.000222	2.135	0.3736	15355	23.445
7	12	1.6	10.8	1500	33.49	0.000257	2.620	0.3529	14503	24.823

Table 6.1 (b): Emissions of Exhaust Gases on Pure Diesel at 200 Bar.

S.NO	W1 (KG)	CO (%)	HC (PPM)	CO_2 (%)	O_2 (%)	NO_X (%VOL)
1	0	0.061	59	1.64	18.46	2
2	2	0.053	53	1.82	18.14	4
3	4	0.045	45	1.81	18.52	2
4	6	0.036	37	2.12	18.08	3
5	8	0.031	35	2.19	18.46	3
6	10	0.035	31	2.4	19.02	5
7	12	0.029	28	2.76	17.39	6

Table 6.2 (b): Emissions of Exhaust Gases on CME at 200 Bar

S.NO	W1 (KG)	CO (%)	HC (PPM)	CO_2 (%)	O_2 (%)	NO_X (%VOL)
1	0	0.058	64	1.64	18.16	3
2	2	0.051	60	1.9	18.15	6
3	4	0.042	53	1.69	18.29	2
4	6	0.034	46	2.17	18.08	5
5	8	0.029	47	2.22	18.46	4
6	10	0.027	39	2.34	19.09	5
7	12	0.028	37	2.68	18.41	7

Table 6.3 (b): Emissions of Exhaust Gases on CME at 210 Bar

S.NO	W1 (KG)	CO (%)	HC (PPM)	CO_2 (%)	O_2 (%)	NO_X (%VOL)
1	0	0.057	62	1.76	18.14	3
2	2	0.051	58	1.82	18.11	5
3	4	0.039	51	1.54	18.28	4
4	6	0.032	44	2.09	18.01	6
5	8	0.028	39	2.22	17.45	4
6	10	0.026	34	2.42	17.22	6
7	12	0.025	32	2.72	17.14	7

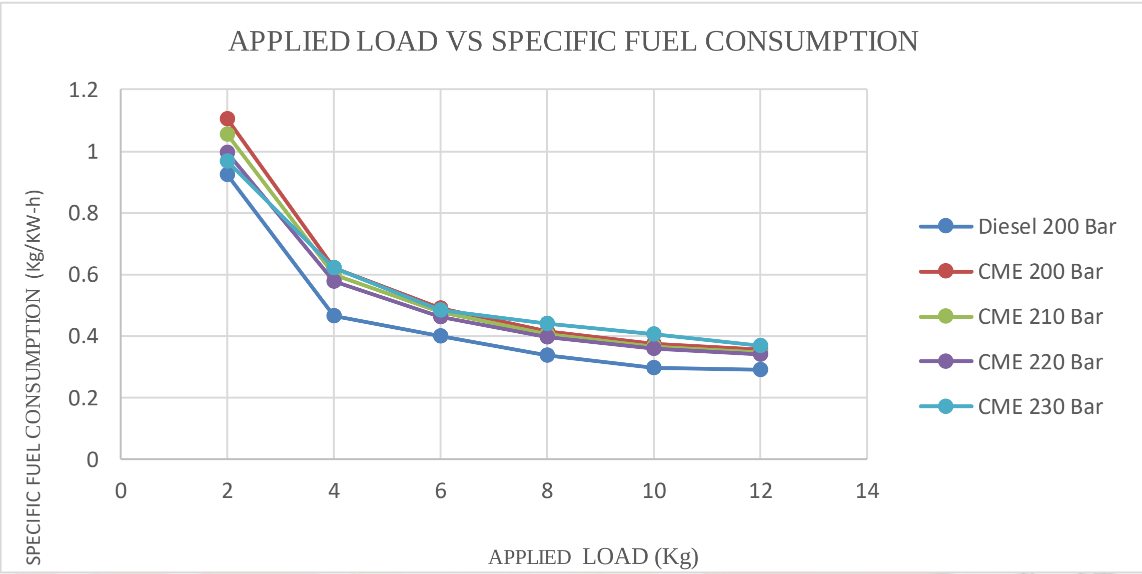
Table 6.4 (b): Emissions of Exhaust Gases on CME at 220 Bar

S.NO	W1 (KG)	CO (%)	HC (PPM)	CO_2 (%)	O_2 (%)	NO_X (%VOL)
1	0	0.056	55	1.89	17.56	4
2	2	0.049	49	1.99	17.15	5
3	4	0.039	39	2.42	17.21	4
4	6	0.031	33	2.42	17.56	6
5	8	0.027	30	2.34	17.46	5
6	10	0.024	26	2.58	18.09	7
7	12	0.021	24	2.88	18.49	8

Table 6.5 (b): Emissions of Exhaust Gases on CME at 230 Bar

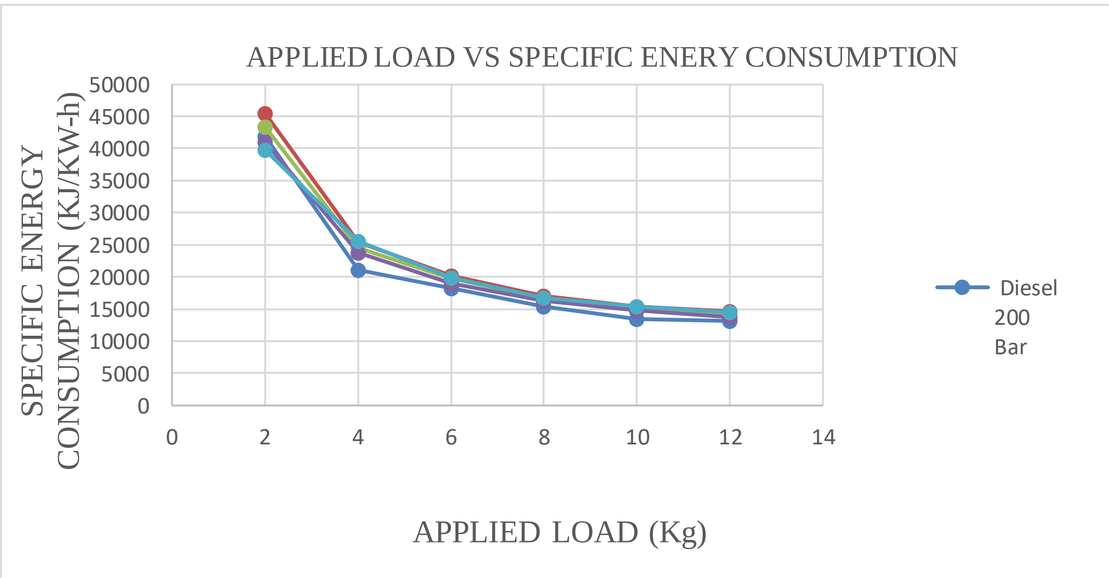
S.NO	W1 (KG)	CO (%)	HC (PPM)	CO_2 (%)	O_2 (%)	NO_X (%VOL)
1	0	0.056	59	1.78	18.35	3
2	2	0.05	55	1.99	18.15	3
3	4	0.041	48	1.98	18.29	2
4	6	0.031	42	1.99	18.09	4
5	8	0.029	34	2.01	18.15	4
6	10	0.029	30	2.36	18.06	5
7	12	0.024	32	2.74	18.87	7

GRAPHS

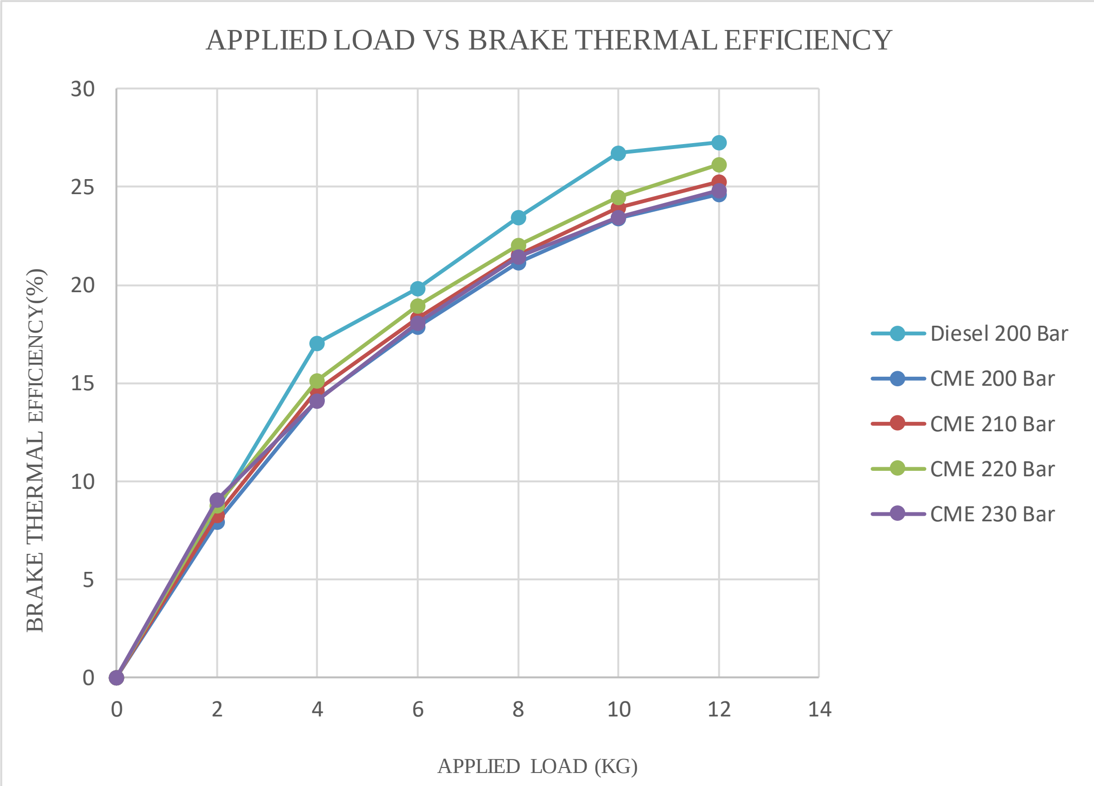


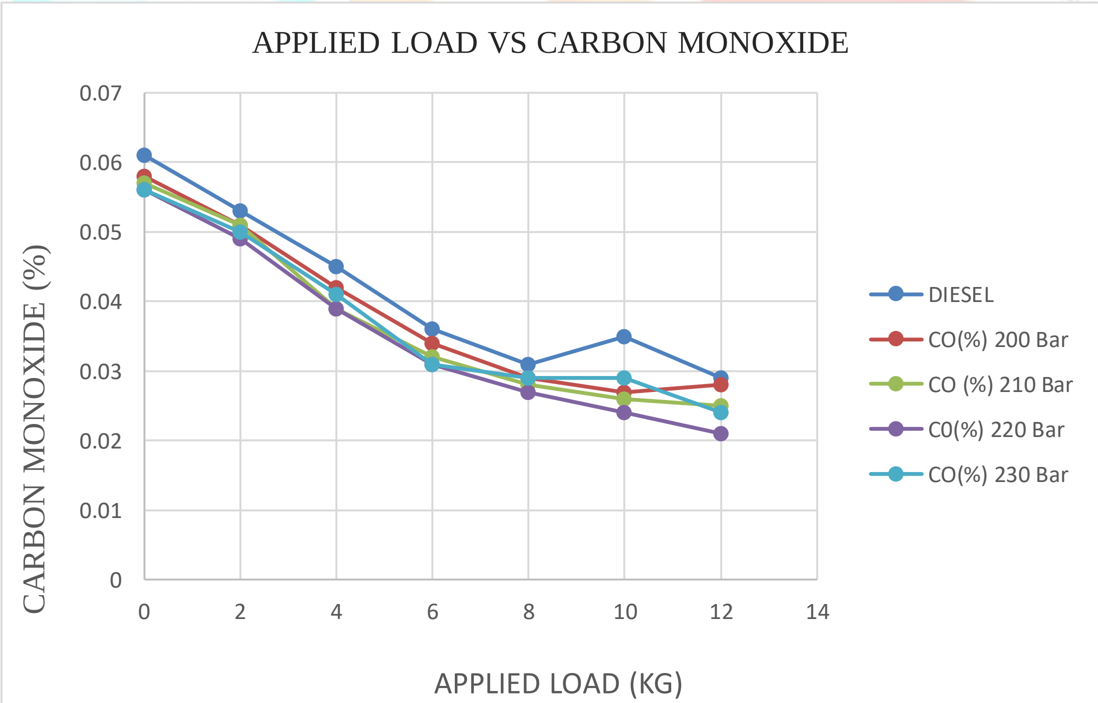
Applied Load Vs Specific Fuel Consumption

- Specific fuel consumption is decreased with increase in load.
- Specific fuel consumption is decreased with increase in injection pressure for CME due to complete combustion at elevated injection pressure.

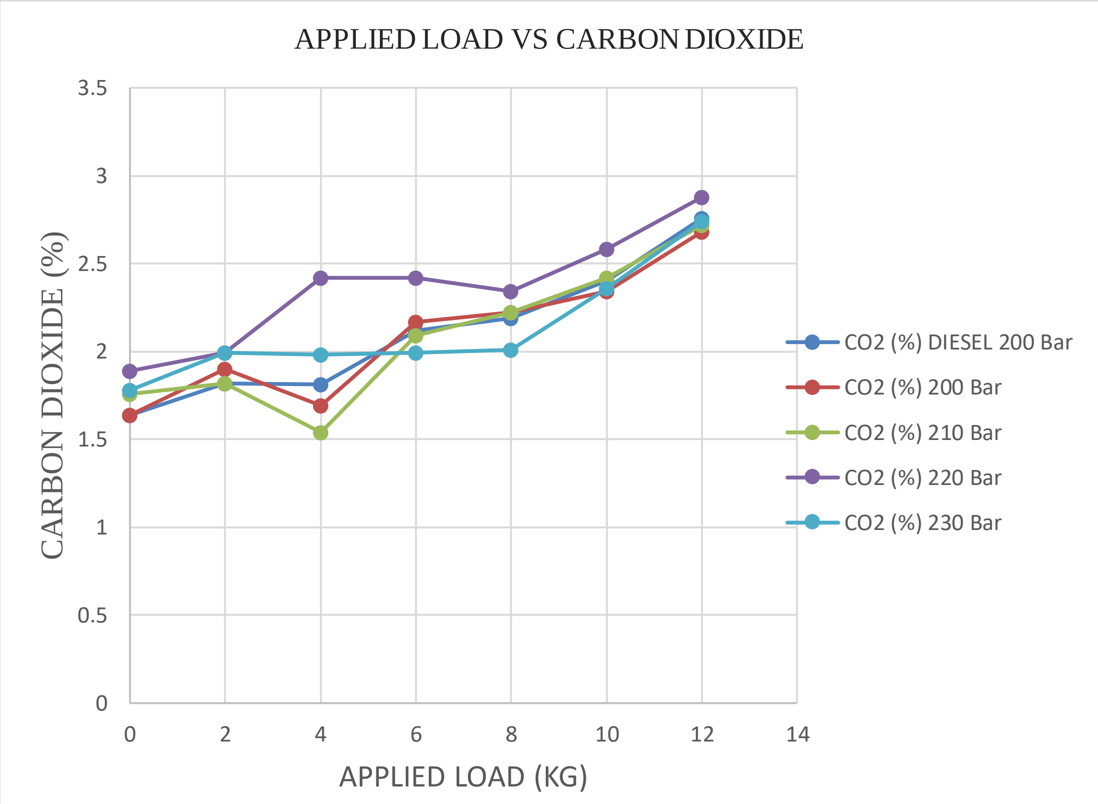


Applied Load Vs Specific Energy Consumption

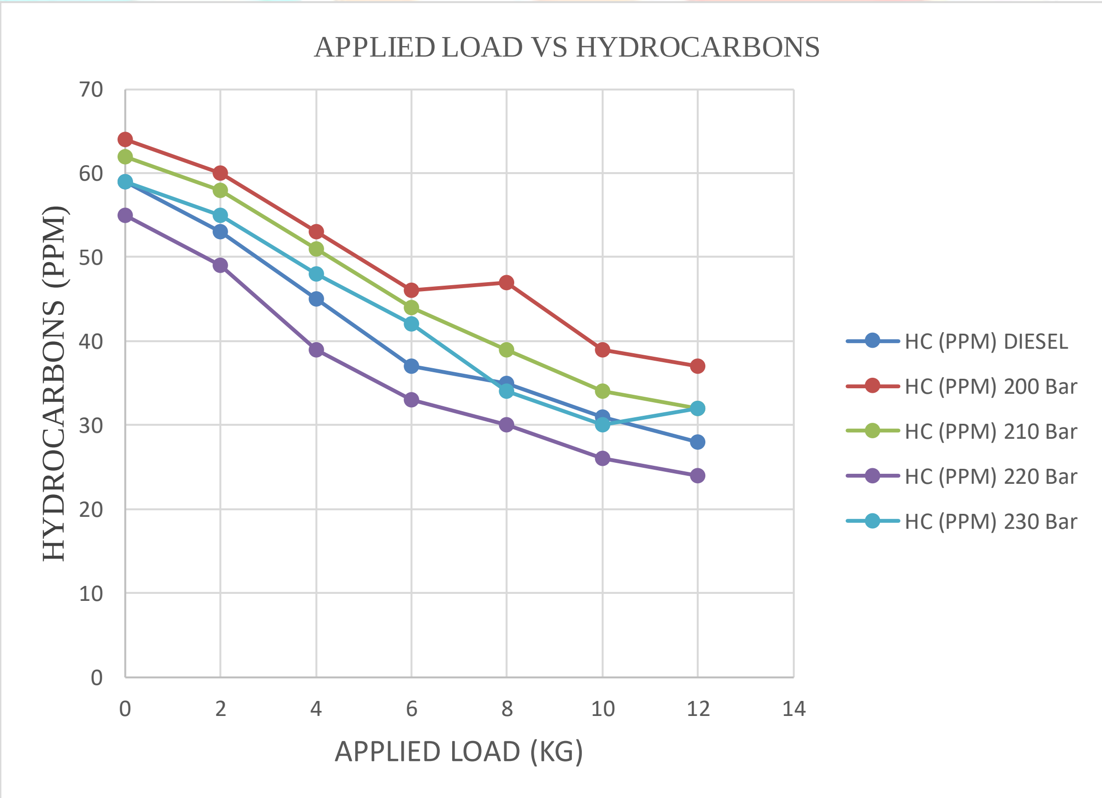




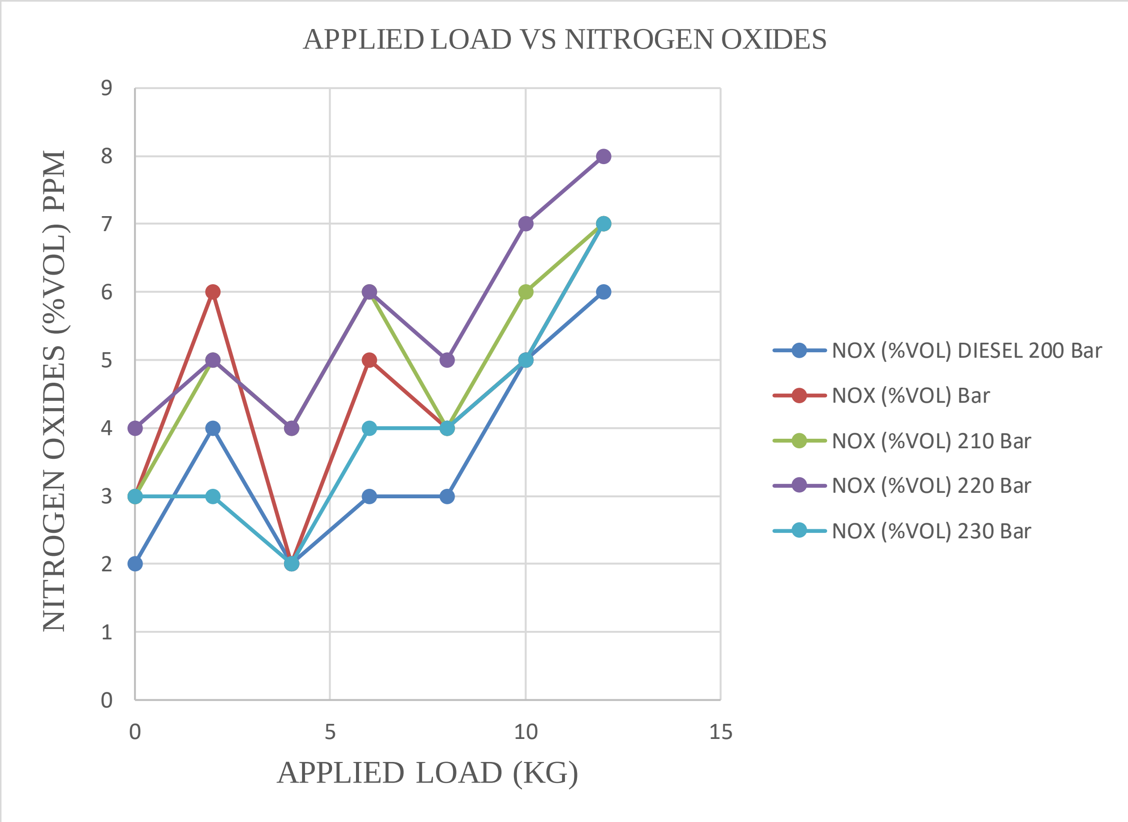
Applied Load Vs Carbon Monoxide



Applied Load Vs Carbon Dioxide



Applied Load Vs Hydro Carbons



Applied load Vs Nitrogen oxide

CONCLUSIONS

1.The existing single cylinder diesel engine is successfully run by the canola methyl ester at different injection pressures and loads.

2.CME at 220 bar injection pressure exhibited better thermal efficiency when compared with other injection pressures. This is due to improved combustion with better atomization and vaporization at elevated injection pressures as CME is having higher viscosity.

3.Nitrogen oxides are slightly higher for CME because of high flame temperature of combustion due to better atomization of the fuel.

4.As a whole, CME at 220 bar injection pressure is the best substitute for pure diesel at 200 bar injection pressure in view of better performance and lower emissions.

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