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PERFORMANCE AND COMBUSTION CHARACTERISTICS OF A DIESEL ENGINE USING FISH OIL BIODIESEL BLENDS WITH CETANE IMPROVER AND EGR

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ABSTRACT:
This study investigates the performance and combustion behavior of a single-cylinder, four-stroke diesel engine operating on fish oil biodiesel blends (B20, B30, B40), enhanced with 0.5% ethylhexyl nitrate (EHN) as a cetane improver. Exhaust gas recirculation (EGR) was applied at 0%, 10%, and 20% rates. Results show that brake thermal efficiency (BTE) improves with higher biodiesel blends, with B40E0.5 achieving 30.5% BTE at full load with 20% EGR—exceeding diesel's 28.9%. Brake specific fuel consumption (BSFC) increased due to biodiesel's lower calorific value. Combustion analysis revealed reduced cylinder pressure and heat release rates, indicating smoother combustion from EHN's ignition enhancement. A B40 blend with 15% EGR delivered the best balance of efficiency and combustion stability, highlighting fish oil biodiesel's promise as a sustainable diesel alternative.
Keywords: Fish oil biodiesel, cetane improver, exhaust gas recirculation, brake thermal efficiency, combustion characteristics

INTRODUCTION:
Rising environmental concerns and dwindling fossil fuel reserves have intensified the search for renewable fuels. Biodiesel produced from fish oil—a byproduct of fish processing—presents an eco-friendly fuel alternative. While biodiesel lowers carbon monoxide and hydrocarbon emissions, it typically raises nitrogen oxide (NOx) emissions and has lower energy content than diesel. To address these challenges, exhaust gas recirculation (EGR) reduces combustion temperatures, helping curb NOx emissions, while cetane improvers like ethylhexyl nitrate (EHN) enhance ignition quality, promoting efficient combustion. Given fish oil biodiesel's high oxygen content, its unique combustion behavior warrants focused study.This paper evaluates the performance (BTE, BSFC) and combustion characteristics (cylinder pressure, heat release rate) of diesel engines fueled with B20, B30, and B40 blends containing 0.5% EHN under varying EGR rates, with the goal of identifying conditions for optimal efficiency and stability.

METHODOLOGY:
A. Experimental Setup
The experimental study was conducted on a **single-cylinder, four-stroke, air-cooled, direct-injection diesel engine** operating at a constant speed of **1500 rpm**. Exhaust gas recirculation (EGR) was applied at three different levels: **0% (baseline), 10%, and 20%**. Engine performance and combustion parameters were recorded using a **dynamometer** for load measurement and a **cylinder pressure transducer** connected to a **data acquisition system** to capture real-time combustion data.
B. Fuels
Test fuels included diesel and biodiesel blends (B20, B30, B40) with 0.5% EHN.

Property	**Diesel**	**B20E0.5**	**B30E0.5**	**B40E0.5**
Flash Point (°C)	60	37	39	41
Density (g/cm³)	0.83	0.84	0.845	0.849
Viscosity (cSt)	3.15	5.14	5.43	5.72

C. Measured Parameters
BTE was derived from brake power and fuel consumption, and BSFC from fuel mass per unit power. Combustion data (cylinder pressure, heat release rate) were obtained using thermodynamic analysis of pressure data.

RESULTS & DISCUSSIONS :

A. Brake Thermal Efficiency

Thermal efficiency is a key indicator, without units, that reflects how effectively a system converts thermal energy into useful work. In the context of combustion engines, it represents how completely the fuel's energy is utilized to produce output power. More precisely, it is defined as the proportion between the work generated by the working medium inside the cylinder over a specific period and the total heat energy provided by the fuel during that interval. The relationship between brake thermal efficiency and engine load, under varying exhaust gas recirculation (EGR) levels, is illustrated through the following tables and graphs..

S.NO	LOAD (%)	DIESEL	B20E0.5	B30E0.5	B40E0.5
1	0	0	0	0	0
2	25	15.4	16.1	16.4	16.5
3	50	24.3	24.9	25.5	25.9
4	75	27.8	28.3	28.7	28.9
5	100	28.5	29.1	29.4	29.9

Table3(a): Brake thermal efficiency values with 0% EGR

S.NO	LOAD (%)	DIESEL	B20E0.5	B30E0.5	B40E0.5
1	0	0	0	0	0
2	25	15.9	16.4	16.7	16.8
3	50	24.35	25.1	25.7	25.9
4	75	27.9	28.5	28.9	29.2
5	100	28.7	29.3	29.7	29.9

Table 3(b): Brake thermal efficiency values with 10% EGR

S.NO	LOAD (%)	DIESEL	B20E0.5	B30E0.5	B40E0.5
1	0	0	0	0	0
2	25	16.2	16.7	16.8	16.9
3	50	24.6	25.3	26	26.4
4	75	28.2	28.8	29.4	29.8
5	100	28.9	29.5	29.9	30.5

Table 3(c): Brake thermal efficiency values with 20% EGR

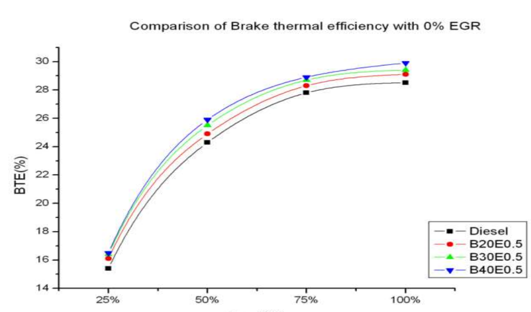

Fig 3(a): Comparison of BTE for 0% EGR with EHN (0.5%)

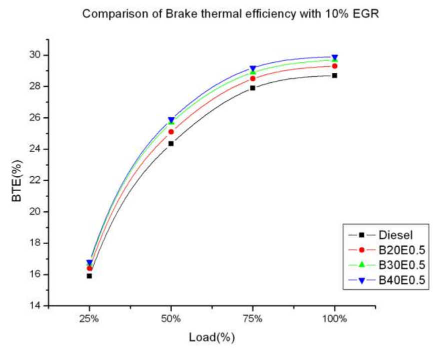

Fig 3(b): Comparison of BTE for 10% EGR with EHN (0.5%)

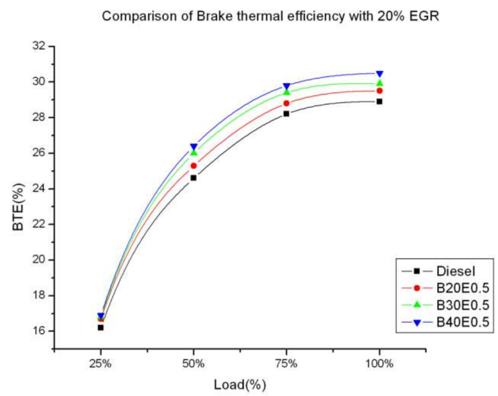

Fig 3(c): Comparison of BTE for 20% EGR with EHN (0.5%)

Figures 3(a), 3(b), and 3(c) illustrate how brake thermal efficiency (BTE) varies with engine load for biodiesel blends containing 0.5% EHN (ethylhexyl nitrate). The results indicate that BTE tends to increase noticeably as the proportion of the blend rises. Under no-load conditions, the improvement in BTE with biodiesel blends was minimal. However, at full load, a significant enhancement in BTE was observed when compared to conventional diesel fuel. It is also evident that the addition of 0.5% EHN led to a slight increase in BTE even at no load.

B. Brake Specific Fuel Consumption

Brake Specific Fuel Consumption (BSFC) is a key parameter used to assess the fuel efficiency of internal combustion engines. It represents the amount of fuel consumed per unit of power generated by the engine's shaft. In other words, it is the ratio of the fuel consumption rate to the engine's output power, and for this reason, it is sometimes referred to as power-specific fuel consumption. BSFC provides a useful basis for directly comparing the fuel efficiency of different engines. The following tables and graphs present how BSFC varies with engine load under different levels of exhaust gas recirculation (EGR).

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S.NO	LOAD (%)	DIESEL	B20E0.5	B30E0.5	B40E0.5
1	0	0	0	0	0
2	25	0.55	0.562	0.569	0.577
3	50	0.369	0.38	0.387	0.397
4	75	0.318	0.329	0.338	0.346
5	100	0.311	0.316	0.32	0.325

Table 3(f): Brake Specific Fuel Consumption values with 0% EGR

S.NO	LOAD (%)	DIESEL	B20E0.5	B30E0.5	B40E0.5
1	0	0	0	0	0
2	25	0.527	0.549	0.562	0.569
3	50	0.364	0.375	0.381	0.391
4	75	0.312	0.322	0.331	0.338
5	100	0.307	0.312	0.316	0.321

Table 3(g): Brake Specific Fuel Consumption values with 10% EGR

S.NO	LOAD (%)	DIESEL	B20E0.5	B30E0.5	B40E0.5
1	0	0	0	0	0
2	25	0.525	0.545	0.556	0.562
3	50	0.351	0.362	0.368	0.378
4	75	0.309	0.32	0.329	0.336
5	100	0.3	0.305	0.309	0.314

Table 3(h): Brake Specific Fuel Consumption values with 20% EGR

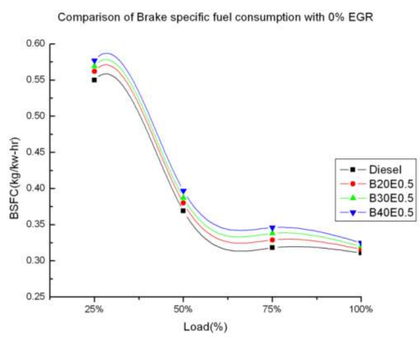

Fig 3(f): Comparison of BSFC for 0% EGR with EHN (0.5%)

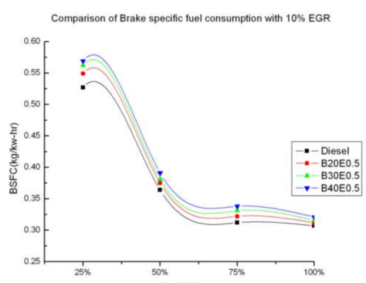

Fig 3(g): Comparison of BSFC for 10% EGR with EHN(0.5%)

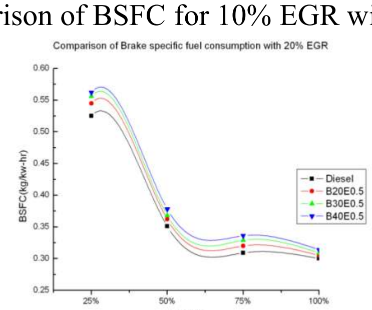

Fig 3(h): Comparison of BSFC for 20% EGR with EHN(0.5%)

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C. Combustion Analysis

Cylinder pressure is a vital parameter in internal combustion (IC) engines, as higher cylinder pressures generally lead to increased power output. However, this also tends to result in higher emission levels. The combustion characteristics, particularly the variation of cylinder pressure with crank angle, are illustrated in the following figures for different exhaust gas recirculation (EGR) percentages.

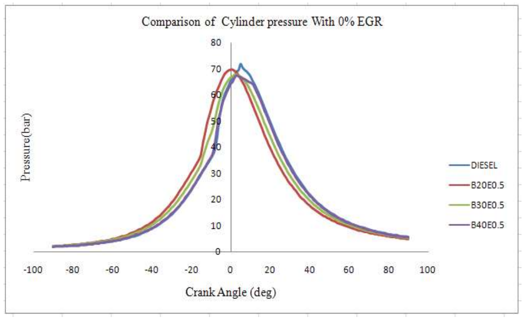


Fig 4(a): Comparison of cylinder pressure for 0%EGR with EHN (0.5%)

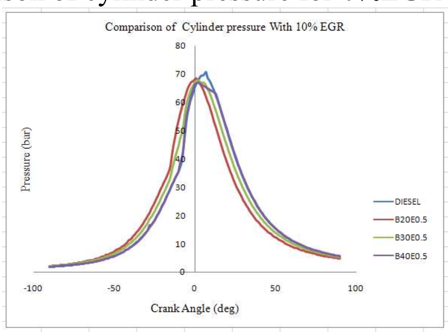


Fig4(b): Comparison of cylinder pressure for 10%EGR with EHN (0.5%)

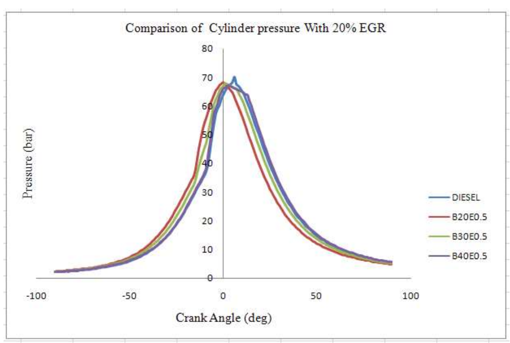


Fig 4(c): Comparison of cylinder pressure for 20%EGR with EHN (0.5%)

The **combustion characteristics**, specifically the relationship between cylinder pressure and crank angle, are presented in **Figures 4(a), 4(b), and 4(c)**. The results show that the maximum cylinder pressure is lower for the biodiesel blends compared to pure diesel. Additionally, it is observed that the blends tend to ignite earlier and complete the combustion process sooner than diesel. This behavior can be attributed to the presence of EHN (ethylhexyl nitrate), which reduces the ignition delay and minimizes the accumulation of unburned fuel during the premixed phase of combustion. As a result, both cylinder pressure and the delay period are reduced.

2) Heat release rate

The **energy released** during the combustion of materials, often referred to as fire intensity, is typically measured in kW/m² or MW/m². In compartment fires, a certain minimum heat release rate (HRR) is generally required for flashover to occur. This threshold can rise due to factors such as (1) a larger ventilation opening area or (2) an increase in compartment volume. The **combustion characteristics**, including the variation of heat release rate with crank angle, are illustrated in the following figures.

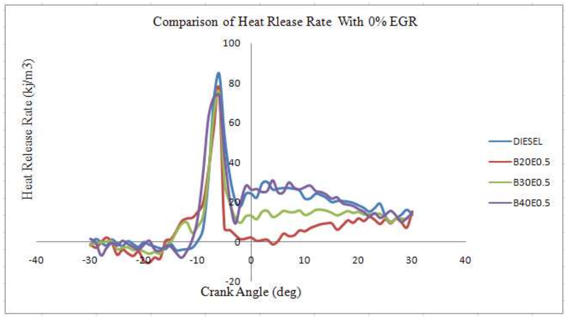


Fig 4(d): Comparison of Heat Release Rate for 0% EGR with EHN (0.5%)

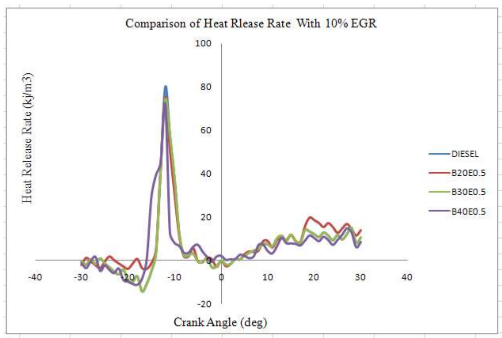
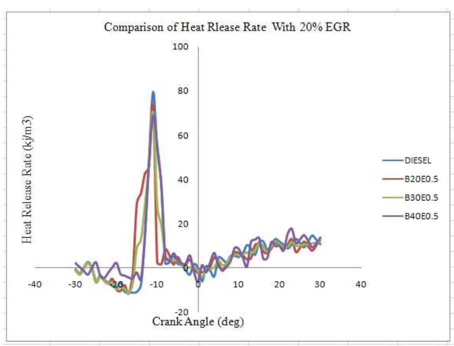


Fig 4(e): Comparison of Heat Release Rate for 10% EGR with EHN (0.5%)



Figures 4(d), 4(e), and 4(f) present the variation of **heat release rate (HRR)** with crank angle under different conditions. The results indicate that the maximum HRR is lower for biodiesel blends compared to conventional diesel fuel.

The incorporation of **ethylhexyl nitrate (EHN)** led to earlier ignition, shortening the ignition delay and enhancing combustion efficiency. Meanwhile, the use of **exhaust gas recirculation (EGR)** helped lower combustion temperatures, thereby reducing **NOx emissions**. Among the tested conditions, the **B40E0.5 blend with 15% EGR** was found to offer the best compromise between efficiency, fuel economy, and stable combustion.

The increased density and viscosity of the biodiesel blends influenced spray characteristics and air-fuel mixing, which contributed to improved combustion behavior. The addition of EHN also played a role in suppressing knocking tendencies, while EGR helped maintain stable combustion, particularly under higher load conditions.

CONCLUSION :

The use of **fish oil biodiesel blends** combined with **0.5% ethylhexyl nitrate (EHN)** and **moderate exhaust gas recirculation (EGR) at 15%** has demonstrated a clear improvement in diesel engine performance. Notably, the **B40E0.5 blend** (40% fish oil biodiesel with 0.5% EHN) achieved a **brake thermal efficiency (BTE)** of **30.5% at full load**, surpassing that of standard diesel fuel under the same conditions. This increase in BTE can be attributed to the synergistic effect of EHN and EGR—EHN promotes earlier and more efficient combustion by reducing ignition delay, while EGR helps moderate peak combustion temperatures and lower **NOx emissions**.

Although the **brake specific fuel consumption (BSFC)** was slightly higher for the blends, largely due to the lower calorific value of biodiesel compared to diesel, the engine exhibited smoother and more stable combustion. This was a result of improved ignition characteristics and better control of combustion phasing, which together contributed to enhanced overall performance and reduced knocking tendency.

These findings suggest that fish oil biodiesel blends with EHN and EGR offer a promising pathway for cleaner and more efficient diesel engine operation. However, to further optimize engine performance and emissions, future studies should investigate the effects of **cold EGR** systems and examine engine behavior across a range of **engine speeds and load conditions**. Such investigations could provide deeper insights into achieving optimal fuel-air mixing, combustion stability, and emission control under real-world operating scenarios.

REFERENCES:

[1] S. Oberweis and T. T. Al-Shemmeri, “Impact of biodiesel blending on diesel engine emissions and efficiency,” Proc. Int. Conf. Renewable Energies Power Quality, 2010.

[2] Y. X. Li et al., “Fuel efficiency and emissions of biodiesel blends in agricultural tractors,” Canadian Biosyst. Eng., vol. 48, 2006.

[3] R. M. Alagu and E. G. Sundaram, “NOx emissions in biodiesel-fueled CI engines: A review,” Frontiers Autom. Mech. Eng., 2010.

[4] V. K. Belagur and V. R. Chitimini, “Injector opening pressure effects on performance of honne oil-diesel blends,” Thermal Sci., vol. 14, 2010.

[5] M. M. Roy, “Diesel engine performance with biodiesel blends: Exhaust odor,” Can. J. Mech. Sci. Eng., vol. 2, 2011.

[6] N. Ladommatos et al., “CO2 in EGR on diesel emissions,” Proc. Inst. Mech. Eng., Part D, vol. 212, 1998.

[7] H. Yokomura et al., “Venturi EGR in turbo diesel engines,” Tech. Rev., no. 15, 2003.

[8] M. Gomaa et al., “EGR effects on NOx and smoke in Jatropha biodiesel IDI engines,” Int. J. Energy Environ., vol. 2, 2011.