



RESEARCH ARTICLE

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ASSESSMENT AND OPTIMIZATION OF ENGINE PERFORMANCE AND EMISSIONS USING ADDITIVE-INFUSED CORN OIL BIODIESEL

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ABSTRACT

Biodiesel was made in this experiment by transesterifying corn oil. By varying the proportions of fuel to air, the efficiency of the engine and the pollution caused by fossil fuels was measured. In the course of this study, there was an investigation of the impacts of hydrocarbons, carbon monoxide, thermal efficiency, mean effective pressure and braking power. A diesel engine powered the vehicle, producing 5.2 kilowatts. There is a possibility of producing biodiesel by using corn oil as a waste product. We combined 80% diesel and 20% corn oil to produce biodiesel. According to the ASTM criteria for fuel quality, the corn oil methyl ester was suitable. The experiment results were obtained by operating a diesel engine with a single cylinder and four strokes under a variety of load conditions. When compared to B20 alone, a mixture containing 100 parts per million of titanium oxide nanoparticles increased thermal efficiency, mean effective pressure, and braking power. The TiO₂ nanoparticles included in B20 reduce the engine's emissions of hydrocarbons and carbon monoxide. We determined the optimal values for brake power, brake mean effective pressure, brake thermal efficiency, carbon monoxide, and hydrocarbons through optimization using RSM (Response Surface Methodology). These values are as follows: The values are 11 463 kg and 56.242 parts per million of titanium dioxide. 4.223 kilowatts of brake power, 5.078 bars of mean effective pressure, 29.573 percent thermal efficiency, 0.257 percent carbon monoxide, and 52.246 percent hydrocarbons are the optimal numbers.



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I. INTRODUCTION

In response to rising concerns about pollution and its effects on human health, biodiesel has gained popularity as a viable fossil fuel substitute for ICEs, stoves, and other heating applications [1]. In many countries, policies encouraging the domestic production and use of first-generation biodiesel have fueled its growing popularity. Some regions specifically promote oil palm-based biodiesel production to meet energy demands for power generation [2]. The manufacture of first-generation biofuels requires a lot of water, which could jeopardize food security because it would divert water from crops grown for human consumption. This has sparked debate about the sustainability of using food crops for energy, highlighting the need for alternative strategies [3]. This necessitates careful consideration during the legislative process in different countries. Extensive research has been conducted globally to assess the efficiency of internal combustion engines [4]. There has been a plethora of research on the qualities and functionality of biodiesel, which is produced from vegetable oils that are not suitable for human consumption. Tobacco, flax, jatropha, cotton, jojoba, and rubber tree oils are among those that have been considered for use as raw ingredients. To satisfy fuel demands for power generation, several countries have prioritized oil palm development for biodiesel production [5]. Biodiesel made from corn oil meets international environmental criteria, even though it

has the same problems as first-generation biofuels [6]. In the best conditions, researchers used a combined method with sodium methoxide and a special membrane to get a transesterification conversion rate of 98.1%. Research into biodiesel's potential as a replacement fuel for internal combustion engines has been on the rise recently, with the hope of making transportation engines more efficient [7].

II. MATERIALS AND METHOD

II.1. PRODUCTION OF BIODIESEL

One of the first steps in making biodiesel is boiling corn, which usually results in about 10 liters of oil (FAO). The presence of free fatty acids is indicated by the acid number, which is assessed by analyzing a sample of the oil for acidity. If the acid number of the oil is 5 or below, it is considered appropriate for biodiesel manufacture when tested using potassium hydroxide in a titration procedure. Oils with pH levels higher than 5 are not suitable for use as biodiesel; however, they can have other applications. The acid number is found by heating 5 grams of oil with 50 milliliters of neutral ethyl alcohol to about 50 degrees Celsius, adding phenolphthalein, and then titrating with 0.1N potassium hydroxide. The transesterification mechanism is shown in Figure 1 [9].

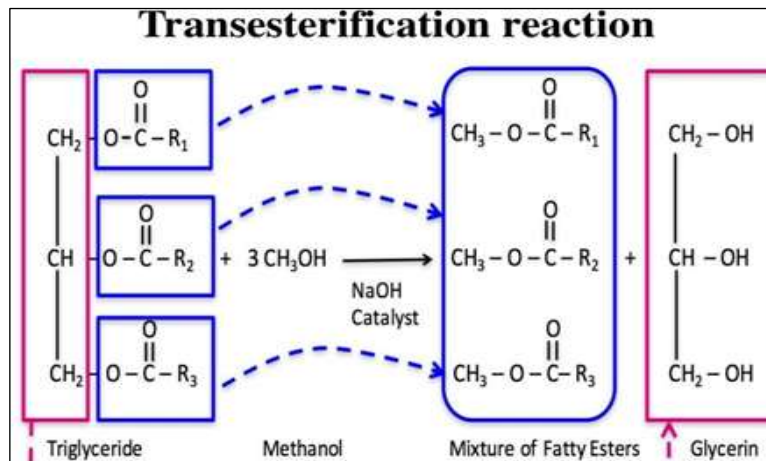


Figure 1: Process of Transesterification.

Source: Authors, (2025).

One way to make biodiesel is by transesterifying renewable lipids, such as animal and plant oils, into long-chain monoalkyl esters of fatty acids. The researchers in this investigation mixed ten litres of discarded cooking oil with twenty percent v/v methanol. Eight grams of potassium hydroxide were dissolved in methanol and used as a catalyst to produce methoxide, according to the acid number of the oil. This mixture was stirred with the oil and heated to between 50 and 60 degrees Celsius for about two hours. Following the reaction, the glycerin was extracted by decantation. The biodiesel was then rinsed three to four times with water with a 20–30% (v/v) concentration, after which it was dried and filtered to get a clean, usable fuel.

II.2. FUEL SAMPLES

The B20 corn oil methyl ester mixture was prepared for further testing by completely mixing 20% biodiesel and 80% diesel by volume using a magnetic stirrer. The end product was created by the previously outlined procedure.

Table 1: Fuel blends properties.

	Diesel	BD20	BD20+50ppm TiO ₂	BD20+100ppm TiO ₂
Density(kg/m ³)	815	820	833	846
Viscosity (mm ² /s)	3.1	3.2	3.4	3.6
Calorific Value (MJ/kg)	44	43.4	44.8	46
Cetane Number	52	56.6	57.5	58.4
Flash Point °C	204	195.2	196.4	198.2
Fire Point °C	59	129.8	132.1	133.8

Source: Authors, (2025).

Following the aforementioned procedure, B20 fuel test samples were ultrasonically mixed with titanium oxide (TiO₂) nanoparticles. Fifty and one hundred parts per million (ppm) were the dose levels used. The fuels in testing were assessed utilizing the ASTM D 6751 evaluation procedure, an internationally recognized method for the analysis of fuel properties. Table 1 shows the fuel blend properties

III. EXPERIMENTAL SET-UP

The experiments used a Kirloskar TV1, a water-cooled CI engine with one cylinder, four strokes, and overhead valves driven by pushrods. The engine can produce up to 5.2 kW of power when revved to 1500 rpm. Following the manufacturer's instructions, the fuel injection pressure was set at 210 psi and the injection timing at 23° BTDC.

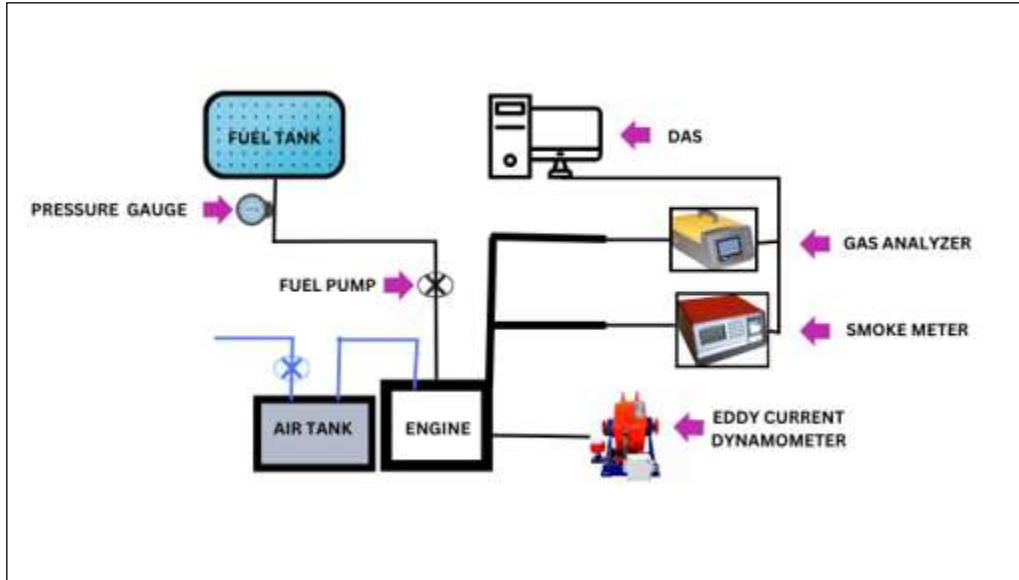


Figure 2: Experimental set-up.
Source: Authors, (2025).

To maintain a coolant temperature of 80 °C, an internal circulation system encircling the cylinder with water jackets was used. A piezoelectric sensor fitted flush-mounted to the engine block measured in-cylinder pressure, while an eddy current dynamometer recorded engine torque. Figure 2 shows a simplified schematic of the equipment used in the experiment.

IV. RESULTS AND DISCUSSIONS:

IV.I. BRAKE POWER

Engine brake power grows roughly linearly with load, as shown in Figure 3, with very little variance across various fuel mixes. Brake power output appears to be unaffected by fuel type, according to the data [12]. At higher loads, the BD20 + 100 ppm TiO₂ combination produced the most effective brake power.

IV.II. BRAKE MEAN EFFECTIVE PRESSURE:

Figure 4 illustrates that the brake mean effective pressure (BMEP) increases almost linearly with rising load, regardless of the fuel blend used [13]. The data confirm that fuel type has minimal effect on BMEP [14]. The highest BMEP was recorded for the BD20 + 100 ppm TiO₂ blend at maximum load.

IV.III. BRAKE THERMAL EFFICIENCY:

Figure 5 shows that the brake thermal efficiency (BTE) increases almost linearly with rising load, remaining generally consistent across all fuel blends [15]. The results indicate no significant correlation between fuel type and brake power output [16]. The highest BTE was observed for the BD20 + 100 ppm TiO₂ blend at maximum load.

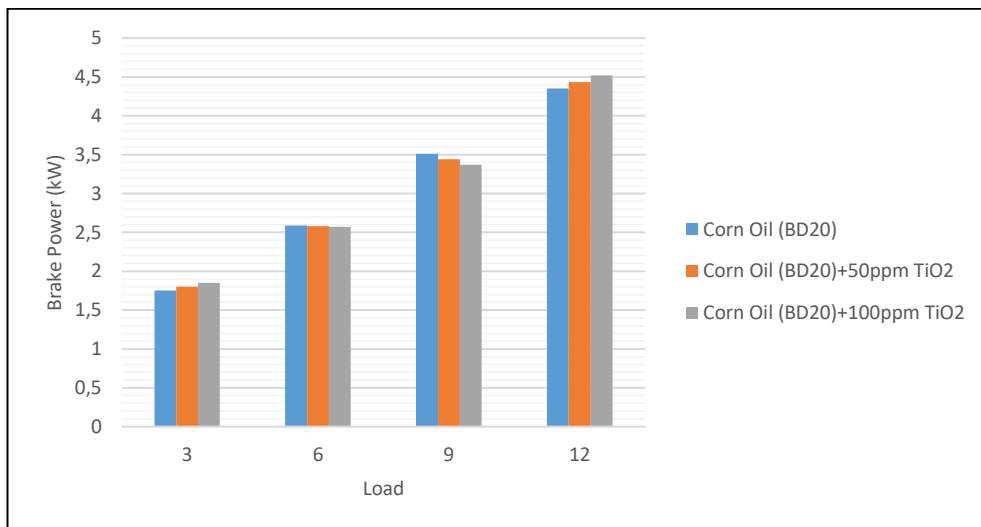


Figure 3: Brake power increases proportionally with increasing engine load.
Source: Authors, (2025).

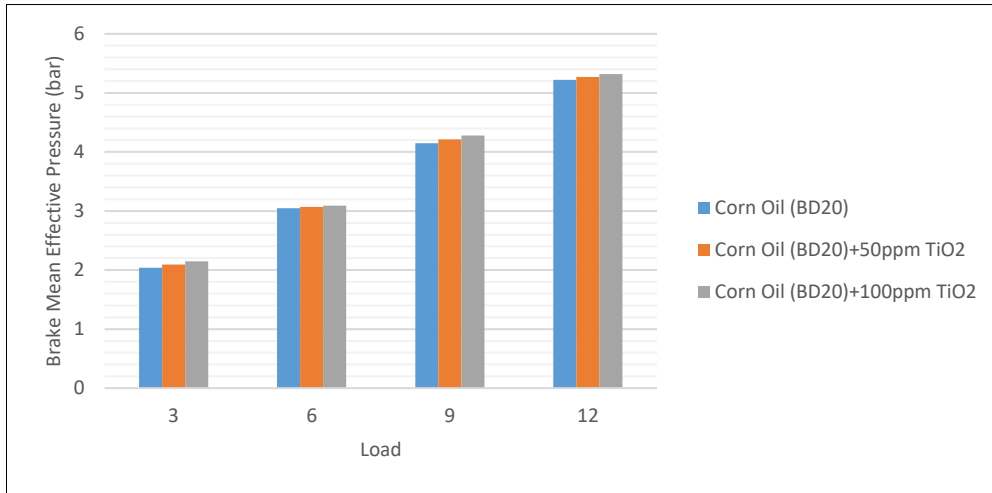


Figure 4: Brake Mean Effective Pressure increases proportionally with increasing engine load. Source: Authors, (2025).

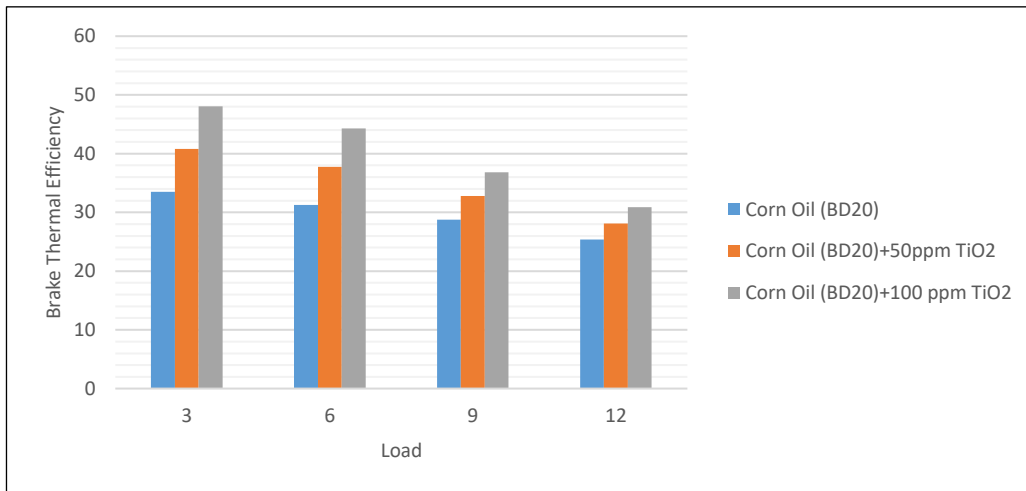


Figure 5: Brake Thermal Efficiency increases proportionally with increasing engine load. Source: Authors, (2025).

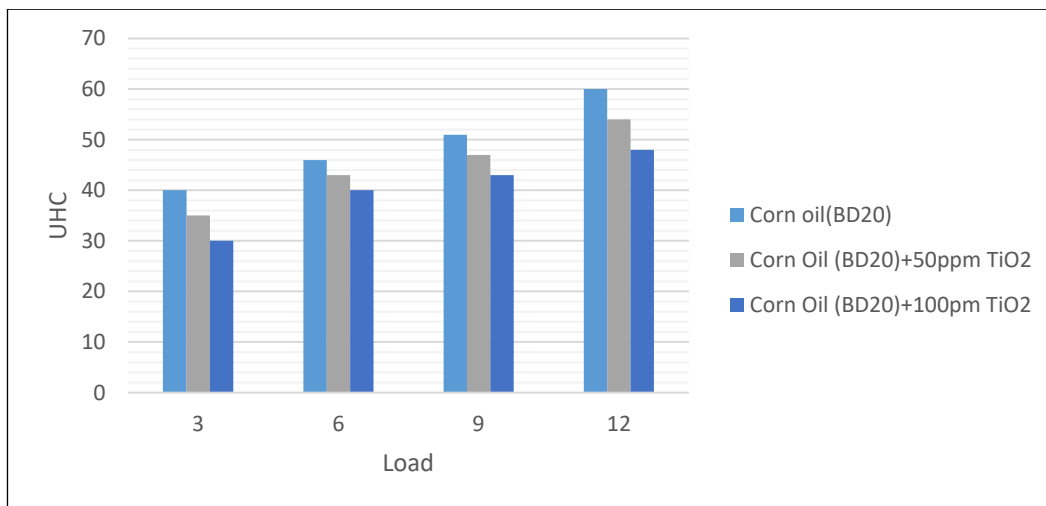


Figure 6: HC increases proportionally with increasing engine load. Source: Authors, (2025).

IV.4. HC EMISSION TEST

Hydrocarbon (HC) emission levels rise with increasing load, as seen in Figure 6, and they approach maximum power as shown in [17]. Based on the theoretical framework, when oxygen is scarce, the concentration of hydrocarbon (HC) emissions rises. According to the fuel-air mixture ratio, this means the fuel is richer. Figure 4 demonstrates that HC emissions are consistently lower across the operational range for all mixtures. The combination of B20 and 100 ppm TiO2 demonstrates lower emissions than the B20 mixture alone [18].

IV.5. CO EMISSION TEST

Figure 7 shows a positive correlation between engine load and CO emissions, with CO levels increasing as load rises. However, the use of corn biodiesel blends resulted in a notable 20–25% reduction in total CO emissions [19]. Among the tested fuels, B20 exhibited the highest CO emissions under ambient conditions [20]. The addition of 100 ppm TiO₂ to the B20 blend significantly reduced CO emissions, demonstrating its potential for lowering greenhouse gas output.

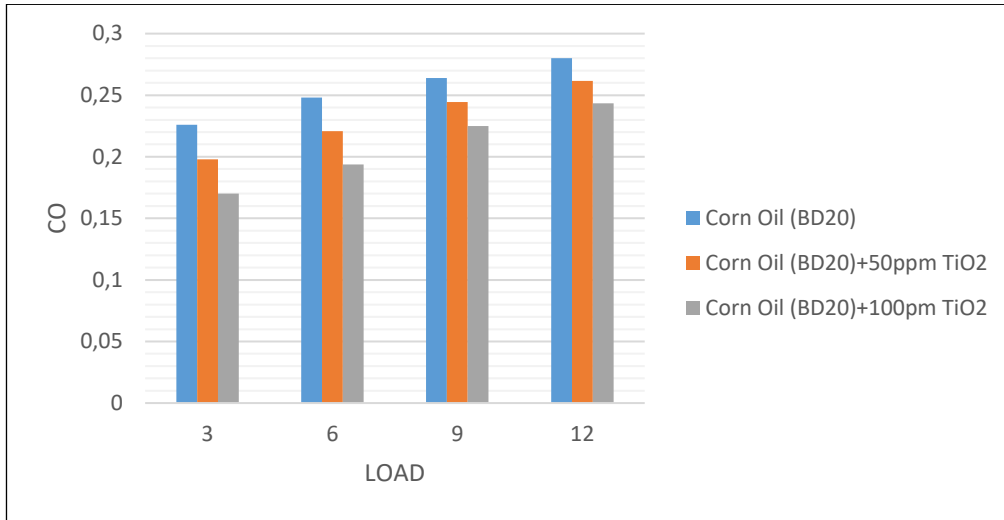


Figure 7: CO increases proportionally with increasing engine load. Source: Authors, (2025).

IV.6. OPTIMIZATION OF DATA USING RSM:

IV.7. I. RSM:

Response Surface Methodology (RSM) employs statistical and mathematical techniques to develop empirical models, where a limited number of input factors are used to evaluate and optimize the response variable. This research assessed the effectiveness of various models using RSM. We selected and analyzed the optimal model to achieve the highest possible values.

IV. VI. II. OPTIMUM VALUES OF TORQUE, UHC, AND CO₂:

The optimum values were found to be at a load of 11.463 kgs and 56.242 ppm concentration of TiO₂ the optimum values of Brake Power, Brake mean effective pressure, Brake thermal Efficiency, Carbon Monoxide, and Hydrocarbons are found to be 4.223 kW, 5.078 bar, 29.573%, 0.257 and 52.246 respectively [21].

As the engine load goes up, more TiO₂ nanopowder leads to better braking power, higher mean effective pressure, improved thermal efficiency, and reduced emissions of CO and HC. Figure 8 (a-e) uses 3D surface plots to illustrate the change in these parameters concerning load and TiO₂ concentration [22] The optimal input parameters, including engine load and TiO₂ concentration, resulted in the best response values for brake power, BMEP, thermal efficiency, and reduced CO and HC emissions are shown in figure 9. The suggested deal has a satisfaction rating of close to 100%. The situation is dependable, as the solution is acceptable and desirable [23].

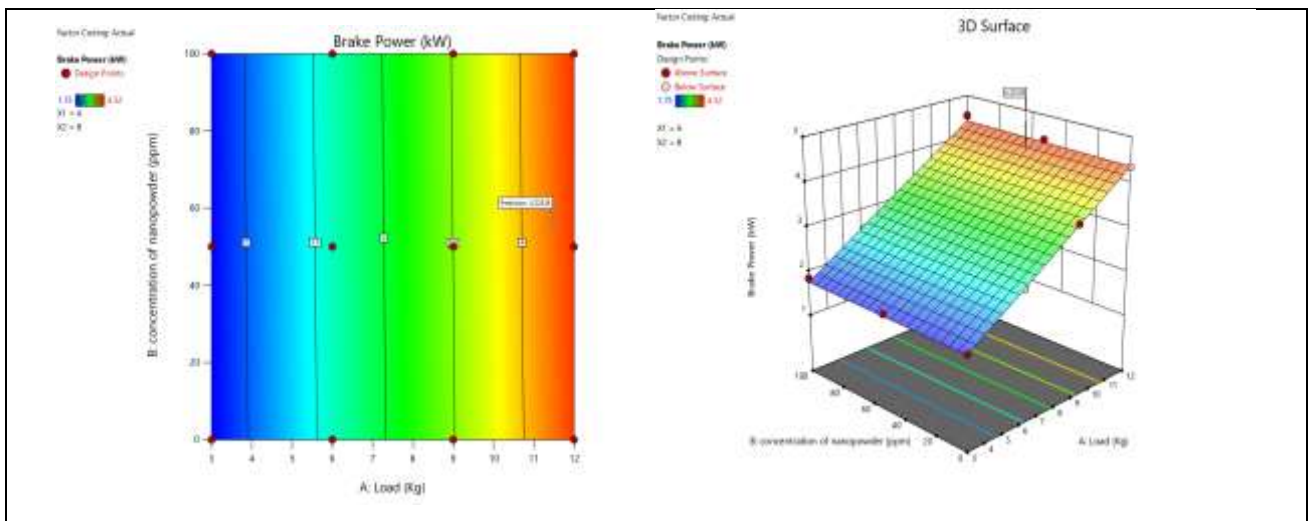


Figure 8a: Surface plot and 3D plot for the chosen model’s brake power is based on the load and concentration of nanoparticles. Source: Authors, (2025).

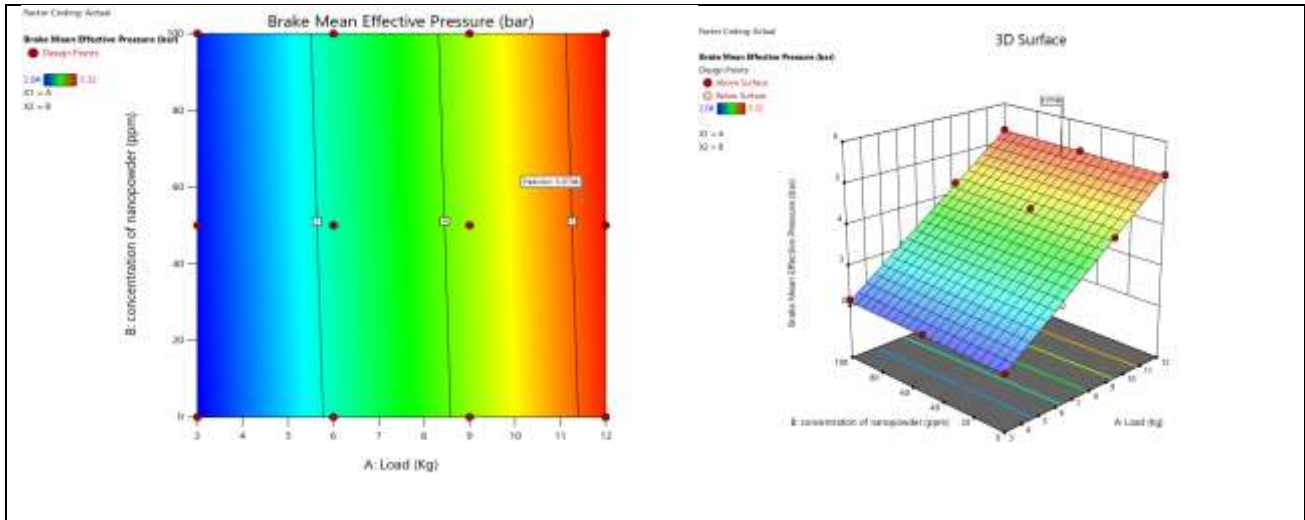


Figure 8b: Surface plot and 3D plot for the chosen model's Brake Mean Effective Pressure is based on the load and concentration of nanoparticles.

Source: Authors, (2025).

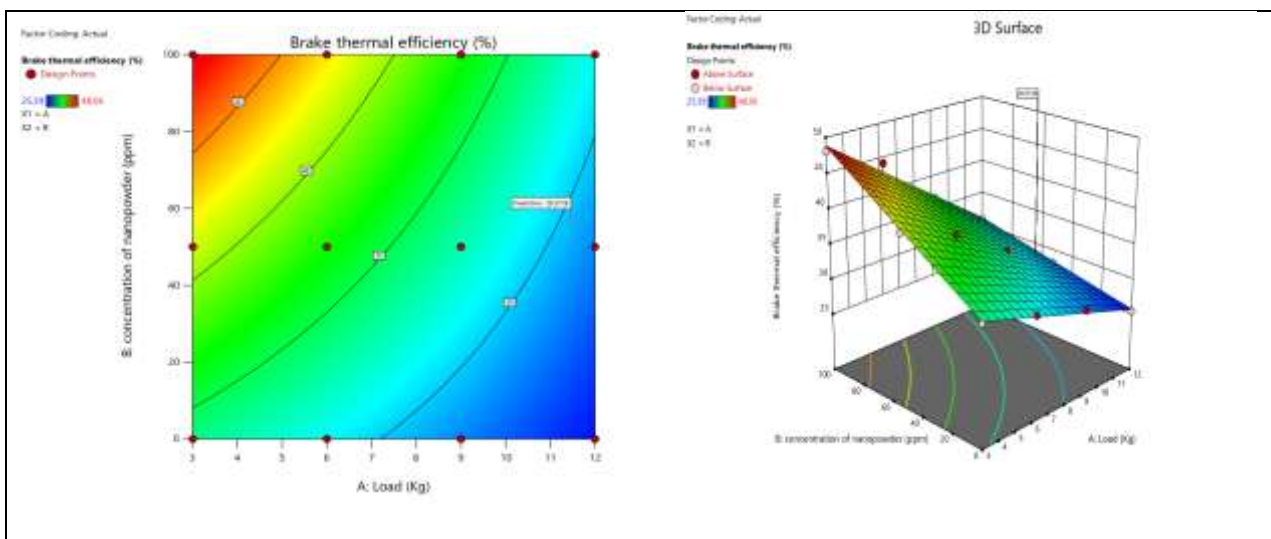


Figure 8c: Surface plot and 3D plot for the chosen model's Brake Thermal Efficiency is based on the load and concentration of nanoparticles.

Source: Authors, (2025).

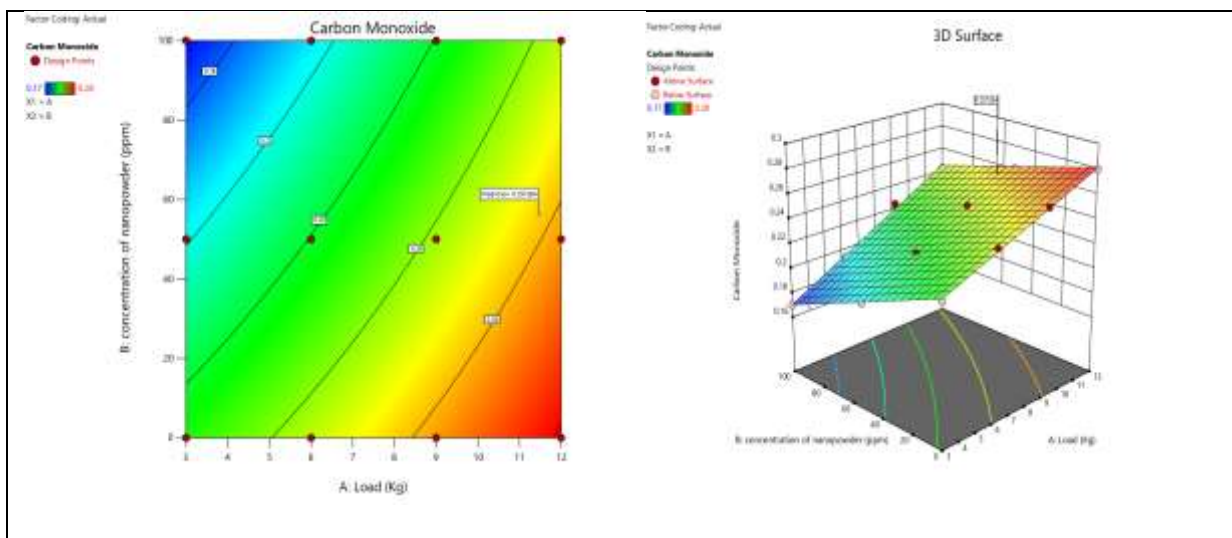


Figure 8d. Surface plot and 3D plot for the chosen model's Carbon Monoxide is based on the load and concentration of nanoparticles.

Source: Authors, (2025).

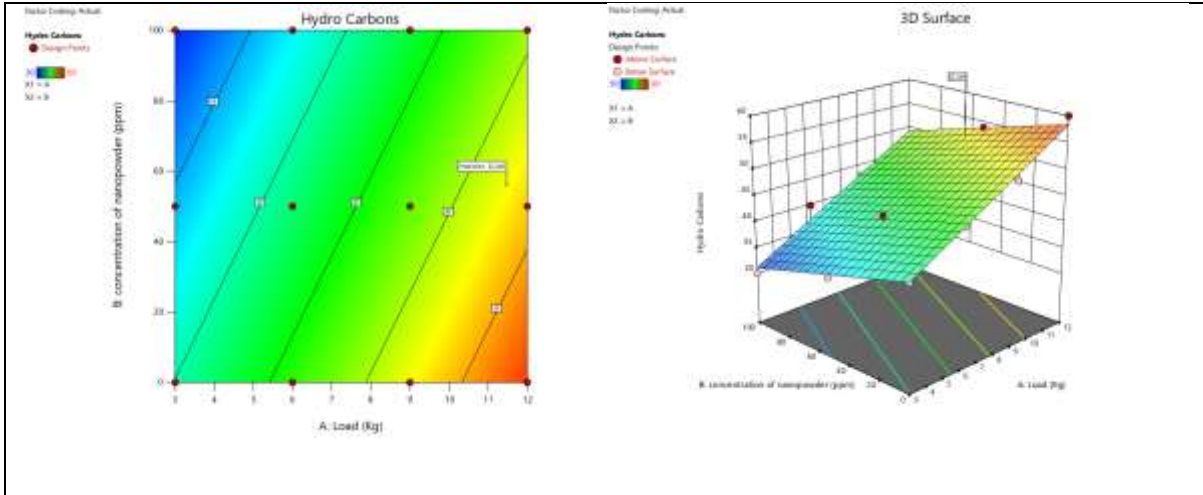


Figure 8e. Surface plot and 3D plot for the chosen model’s Hydrocarbons are based on the load and concentration of nanoparticles. Source: Authors, (2025).

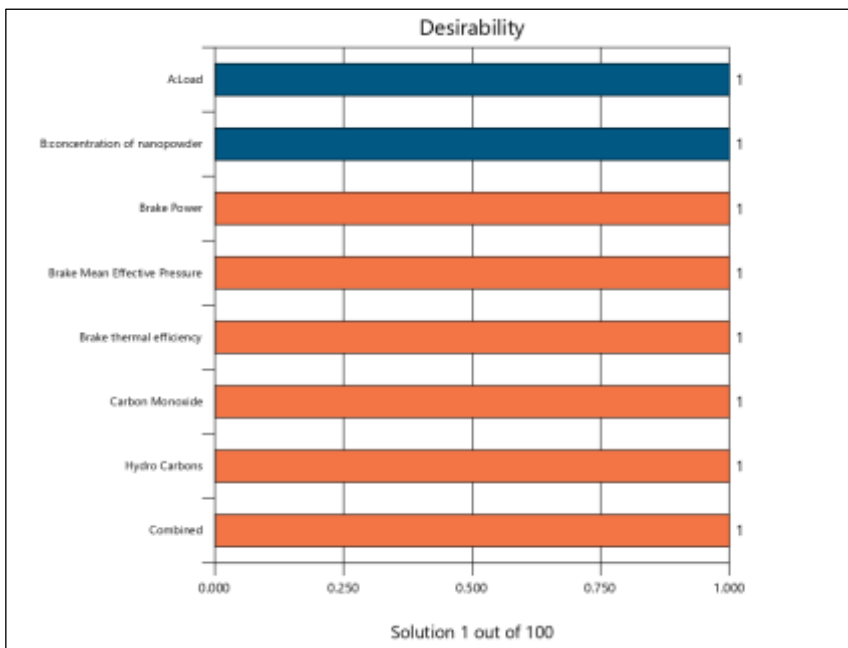


Figure 9: The optimal values for both input and response parameters were identified through the analysis. Source: Authors, (2025).

V. CONCLUSION

The TiO₂ nanoparticle-blended biodiesel demonstrated improved performance over the base B20 fuel, particularly in terms of torque and emissions. The brake power of B20 remained relatively constant, showing no significant variation, while power output increased proportionally with load, indicating a consistent trend. The results indicate that with each increase in engine load, there is a corresponding rise in brake thermal efficiency (particularly for B20 + 100 ppm TiO₂), brake mean effective pressure (BMEP), and brake power. Across all tested fuels, carbon monoxide (CO) and hydrocarbon (HC) emissions decreased with increasing load, with the lowest emission levels observed for the B20 + 100 ppm TiO₂ blend.

Using Response Surface Methodology (RSM) for optimization, the ideal operating conditions were determined to be a load of 11.46 kg and a TiO₂ concentration of 56.242 ppm. Under these conditions, the optimal performance metrics were:

- Brake Power: 4.223 kW
- Brake Mean Effective Pressure: 5.078 bar
- Brake Thermal Efficiency: 29.573%
- Carbon Monoxide (CO): 0.257%
- Hydrocarbons (HC): 52.246 ppm

VI. AUTHOR’S CONTRIBUTION

Conceptualization: Raviteja Surakasi, Makka Jayakrishna, Yenda Srinivasa Rao, Iván Leandro Rodríguez Rico.

Methodology: Raviteja Surakasi, Makka Jayakrishna, Yenda Srinivasa Rao, Iván Leandro Rodríguez Rico.

Investigation: Raviteja Surakasi, Makka Jayakrishna, Yenda Srinivasa Rao, Iván Leandro Rodríguez Rico.

Discussion of results: Raviteja Surakasi, Makka Jayakrishna, Yenda Srinivasa Rao, Iván Leandro Rodríguez Rico.

Writing – Original Draft: Raviteja Surakasi, Makka Jayakrishna, Yenda Srinivasa Rao, Iván Leandro Rodríguez Rico.

Writing – Review and Editing: Raviteja Surakasi, Makka Jayakrishna, Yenda Srinivasa Rao, Iván Leandro Rodríguez Rico.

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Supervision: Raviteja Surakasi, Makka Jayakrishna, Yenda Srinivasa Rao, Iván Leandro Rodríguez Rico.

Approval of the final text: Raviteja Surakasi, Makka Jayakrishna, Yenda Srinivasa Rao, Iván Leandro Rodríguez Rico.

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