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Retraction

Retracted: Experimental Investigation to Utilize Adsorption and Absorption Technique to Reduce CO_2 Emissions in Diesel Engine Exhaust Using Amine Solutions

Adsorption Science and Technology

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope

(2) Discrepancies in the description of the research reported

(3) Discrepancies between the availability of data and the research described

(4) Inappropriate citations

(5) Incoherent, meaningless and/or irrelevant content included in the article

(6) Manipulated or compromised peer review

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

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[1] S. J. Muthiya, L. Natrayan, S. Kaliappan et al., "Experimental Investigation to Utilize Adsorption and Absorption Technique to Reduce CO_2 Emissions in Diesel Engine Exhaust Using Amine Solutions," *Adsorption Science & Technology*, vol. 2022, Article ID 9621423, 11 pages, 2022.

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Research Article

Experimental Investigation to Utilize Adsorption and Absorption Technique to Reduce CO_2 Emissions in Diesel Engine Exhaust Using Amine Solutions

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Due to the increased demand for global transportation needs, a long-range diesel engine is considered an important prime mover to fulfill the transportation demand. The major problem addressed by the diesel engines is it liberates harmful emissions and it also increases global warming. CO_2 is considered an important greenhouse gas and it has to be controlled by diesel engines. In this research, extensive experimental work is done to identify a suitable solution to control CO_2 emissions. For five different mole concentrations (0.1 to 0.5), three types of amino solutions (L-alanine, L-aspartic acid, and L-arginine) were prepared. By passing diesel exhaust through each solution, CO_2 absorption is investigated. For CO_2 absorption, an appropriate CO_2 control system is built and tested. The tests were carried out in a diesel engine which is a naturally aspirated single-cylinder engine with a water-cooled system. It was possible to obtain an effective CO_2 reduction of up to 90%, as well as a simultaneous reduction in HC and CO.

1. Introduction

It is not wrong to state that the advances in science and technology have caused uncontrollable changes in the atmosphere and an upsetting increase in pollution [1]. Automobiles, power industries, and other industrial processes majorly constitute to the air pollution [2]. Generally, the air we breathe in has a quantitative and qualitative equilibrium that upholds human well-being. However, imbalances, or pollution, of components in the air can endanger both human health and the Earth's ecosystems. Emissions of carbon dioxide are a major contributor to global climate change due to the greenhouse effect [3]. It is widely recognized that the world needs urgent reductions in emissions to avoid the worst effects of climate change. In the current scenario, emissions from automobiles are a serious environmental problem. As the density of vehicles on the road has increased, however, CO_2 emissions have amplified [4]. The gigantic automobile sector globally contributes around 25% of total CO_2 emissions, and its share of emissions is becoming more dominant than that of other sectors in the coming days [5]. However, to prevent global warming, reducing that share is a crucial issue, and many countries around the world have strengthened appropriate technological measures to mitigate CO_2 emissions. Europe has already made significant improvements to new vehicle CO_2 performance with an ongoing commitment to the efficient reduction of CO_2 emissions from passenger vehicles by 2030. To address this, improved vehicle technology needs to be integrated into connected and shared vehicles to advance road network efficiency. Promoting the use of public transport, cycling, and walking also play a vital role [6].

Regarding greenhouse gas emissions, the automobile industry has made great steps and remains committed to continuing in reducing CO_2 emissions from vehicles by adopting significant countermeasures such as improving the fuel economy of vehicles by reducing overall weights, applying optimum measures before the inlet into the combustion chamber and in the engine, and integrating pollutant capturing devices as post engine measures. Electrification/hybridization of vehicles and demand management measures, including intelligent transport systems, connected car technology, improved traffic flow and road infrastructure, ecodriving, alternative fuels, and modal shift policies, can help lower fuel consumption and CO_2 emissions [7].

Kii [7] from Japan has estimated that around 64-70% of passenger vehicle's CO_2 emissions would come down from the year of 2010 to 2050. They have stated that emerging technologies in automobile engineering and demand management play a major role to achieve the long-term target of CO_2 reductions. Jenoris Muthiya et al. [8] have successfully designed a carbon capturing unit using zeolite as an absorbent to reduce CO_2 emissions from exhaust gases. Further, the developed model was subjected to CFD analysis to check backpressure. It shows that backpressure is very less and the design is safe. A postcombustion CO_2 control system is not commercially available in any automobiles yet. This work focuses on the novelty to design and develop a CO_2 control system that can easily get connected to the tailpipe of the engine.

Balan et al. [9] also have made a dynamic effort to reduce carbon emissions through the physical adsorption technique from the exhaust gas. It is concluded that carbon emissions from 4 stroke SI engine was successfully decreased by means of molecular sieve 5A of 1.5 mm solid adsorbent. The previous work conducted by Muthiya et al. proved that the utilization of L-aspartic acid, L-arginine, and L-alanine is effective in reducing CO_2 emission. In this current experimentation, the investigation is carried out with various amine solution concentrations from 0.1, 0.2, 0.3, 0.4, and 0.5 for L-aspartic acid, L-arginine, and L-alanine. The results obtained in this work show that an increase in amine concentration in amino solution increases the CO2 reduction.

Figure 1: Amine salts.

The performance and emission characteristics of the diesel engine with CO_2 control system are explained in detail in this work.

2. Materials and Methods

2.1. Absorbent Solution Preparation. In this research, an experimental analysis is carried out to identify the best amine concentration to absorb the CO_2 molecules. In this work, amine power used is L-aspartic acid, L-arginine, and L-alanine. The amine powder used in this work is shown in Figure 1. In this experiment, various trails of amine solution with various concentrations are prepared and tested for emission reduction. Initially, amine solution was prepared for 0.1 to 0.5 mole concentrations. This study focused on to find the effectiveness of the amine solution from 0.1 to 0.5. And with a maximum of 0.5 mole concentration, maximum emission reduction is achieved. Further increase of amine solution mole concentration from 0.5 to 0.6 and 0.7 results in similar emission reduction as 0.5 concentration. So the mole concentration is fixed to 0.1 to 0.5 mole concentration. Totally 15 different amino solutions are prepared, and it has been tested to identify the efficient CO_2 trapping with the amine solution concentration.

The amine salts were first combined with 4 liters of deionized water at a concentration of 0.1 ml based on their molecular weight. The molar concentration of amino salts also rose from 0.1 to 0.5. The concentration of amino acids rises as the molar concentration rises. To prepare a 0.1 mole concentration of amino acid, a molar mass of 174.2 and 4 liters of distilled water is required, which gives $(0.1 \times 174.2 \times 4) = (69.68)$ g of amino salt. So 69.68 g of amino salts is required to be dissolved in 4 liters of distilled water. Similarly, in 0.5 mole concentration, 438.4 g of amino salt is mixed to formulate the solvent solution.

For better and effective absorption, 1.6 g of sodium hydroxide (NaOH) has been added to the chemical solution based on the mole concentration in the amino solution [10].

Table 1: Properties of amines.

Properties	L-aspartic acid	L-alanine	L-arginine	Sodium hydroxide
Molecular formula	$C_4H_7NO_4$	$C_3H_7NO_2$	$C_6H_{14}N_4O_2$	NaOH
Appearance	Powder	Crystalline	Powder	Powder
Color	White	White	Colorless	White
pH at 25°C	2.7	5.6	11.24	12-13
pKa	1.88, 9.61	2.35,9.86	2.18, 9.08	13.7
Melting point (°C)	260	314	240	315
Boiling point (°C)	323	188	365	140
Density (g/cm^3)	1.662	1.422	1.662	2.11
Molecular weight (g/mol)	133.1	89.09	174.2	40.00

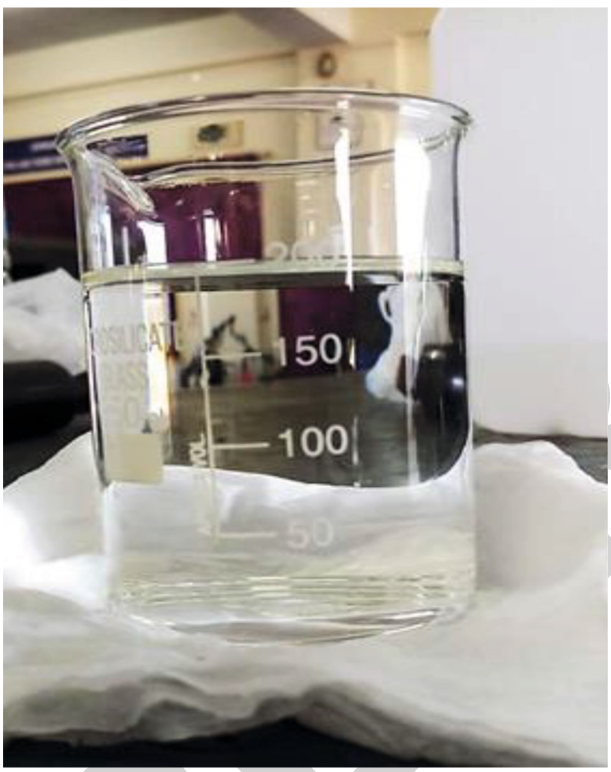

Figure 2: Amine solution used.

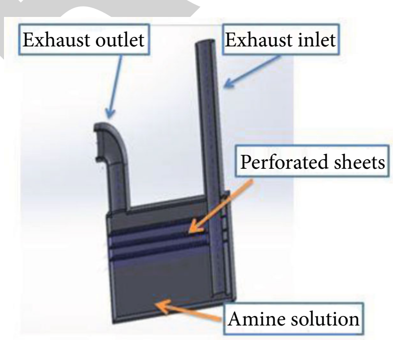

Figure 3: Design of CO_2 control system.

Figure 4: Fabricated photo of developed CO_2 control system.

In this work, 0.1 to 0.5 mole concentrations of L-arginine, .L-alanine, and L-aspartic acid amine solution are formed and tested for effective CO2 adsorption. Table 1 shows the properties of amines solution used. Figure 2 shows the prepared. mine solution.

The following reaction depicts the CO2 absorption mechanism in an amine solution.

$$2-OOC-R-NH_2+CO_2 \xrightarrow{ABSORPTION} {}^{-}COO-R-NH-COO^{-}+{}^{-}OOC-R-NH_3{}^{+} \xrightarrow{O} {}^{-}OOC-R-NH_2{}^{+}HCO_3{}^{-}+{}^{-}OOC-R-NH_3 \xrightarrow{DESORPTION} 2-OOC-R-NH_2+CO_2 \quad (1)$$

2.2. CO_2 Control Device. The CO_2 control device is made such that exhaust gas can readily flow over the amine solution and CO_2 molecules get adsorbed over the solution. An inlet line from the CO_2 control device extends all the way to

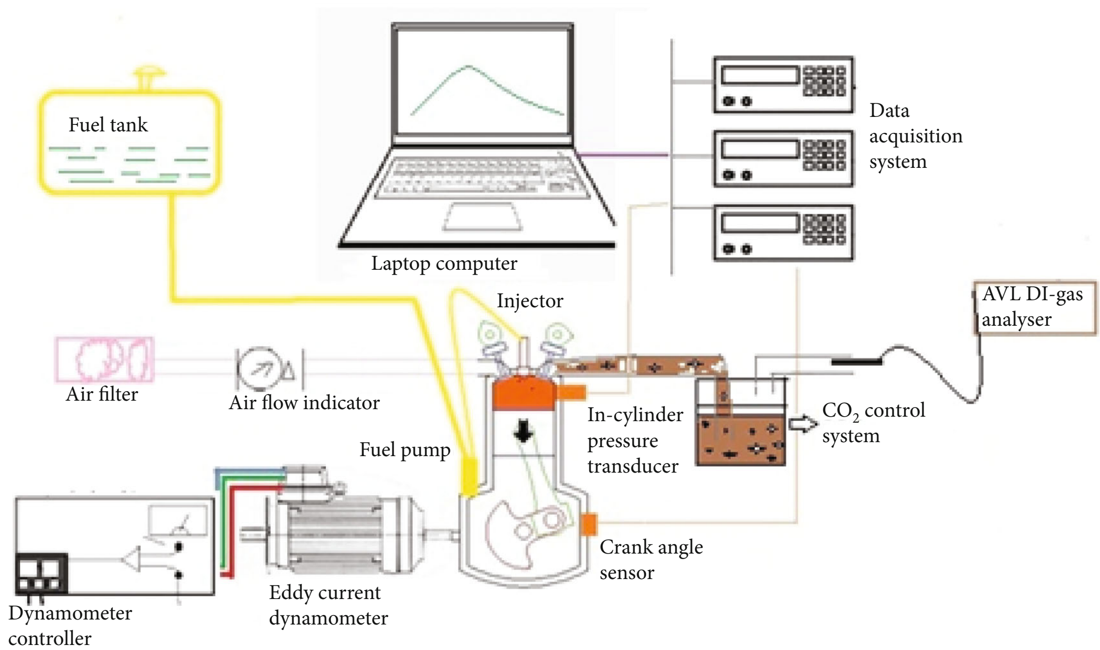

Figure 5: Layout of experimental test bench.

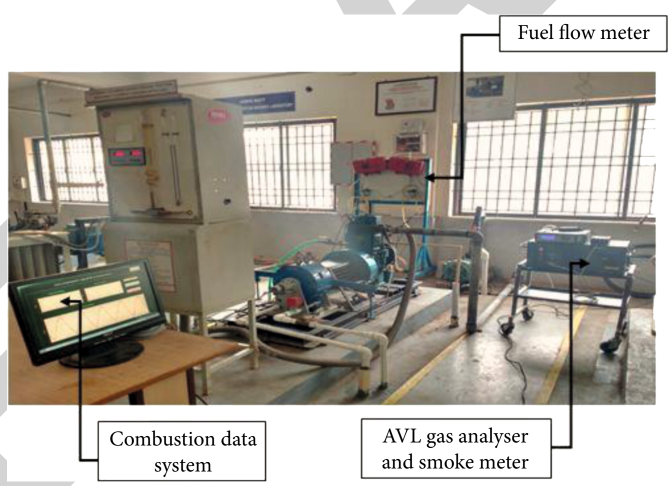

Figure 6: Photo of experimental test setup.

the reactor's bottom. The amine solution is mixed with the exhaust gas when it enters the reactor's inlet line finally, and exhaust gas rushes out of the solution through the exit pipe, which is fixed at the top of the reactor part. In the reactor, a stack of perforated sheets is used to stop the return flow solution from leaking into the pipe holes. The goal of the CO_2 control device design is to eliminate backpressure by removing impediments in the exhaust flow. Figure 3 shows the design model of the CO_2 control device. In the CO_2 control device, the design is crucial since the specific components, such as intake and outlet pipes, as well as the inbuilt perforated metal sheets, are all made and installed according to the design. Stainless steel is used to construct the CO_2 control device. It has a low weight and is corrosion-resistant. The overall height of the system is 1100 mm, and the width is 803 mm. The image of the manufactured CO_2 control device is shown in Figure 4.

3. Experimental Methods

In this present study as mentioned earlier, the experiments were conducted in a single-cylinder direct injection diesel engine. Before starting the engine, the dynamometer calibrations, lubrication, and coolant level checking were done. Initially, the engine was made to run at ideal load conditions until it reaches its steady state. Once the engine

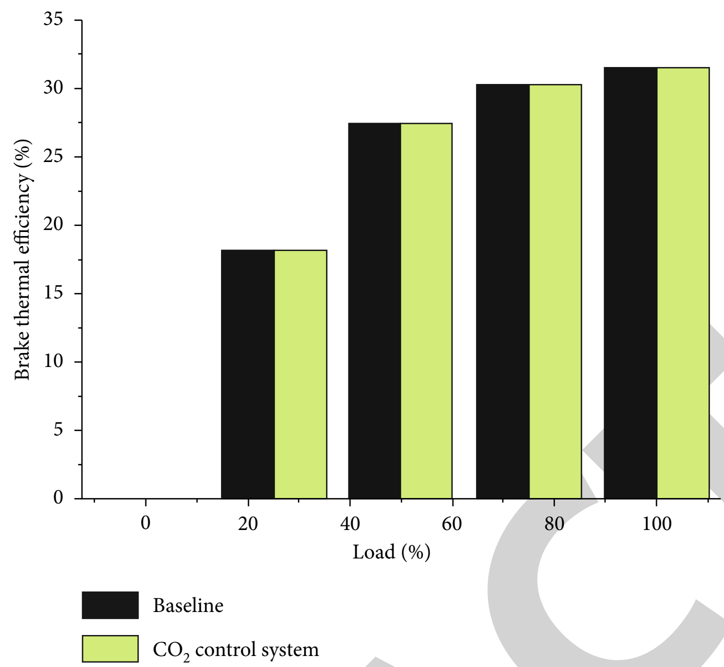

Figure. 7: Variation of brake thermal efficiency with respect to engine load.

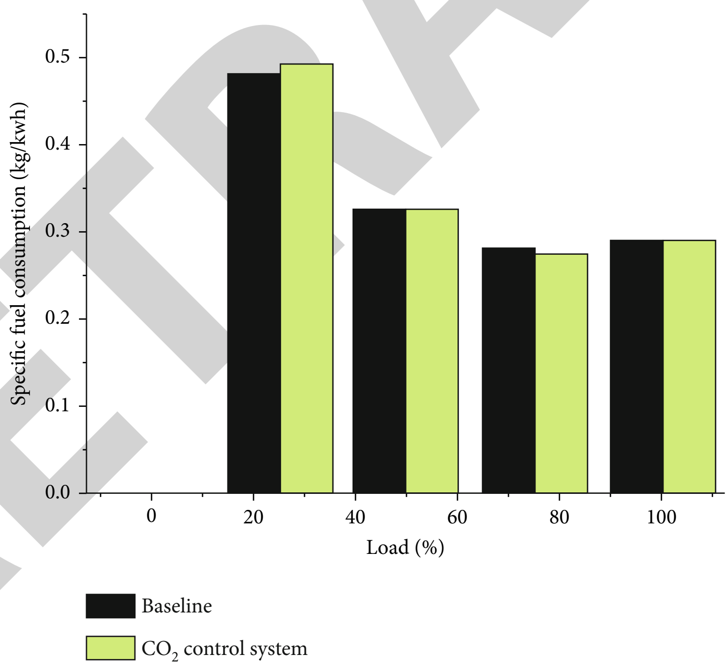

Figure. 8: Effect of CO_2 reduction trap on specific fuel consumption.

reaches the steady-state conditions, emission measuring devices are connected to the tailpipe. Before placing the adsorbent chamber, carbon dioxide emissions at various load conditions (indicate load conditions) were noted down. To evaluate the adsorption efficiency of the CO_2 control system, the engine readings were taken once again after placing the adsorption chamber in the tailpipe. Finally, the difference between the two readings indicates the adsorption efficiency of the designed trap. Figure 5 shows the layout of the experimental setup. Figure 6 shows the photos of the experimental test setup.

4. Results and Discussion

The main objective of this work is to identify the suitable mole concentration of amino acid to trap the CO_2 molecules

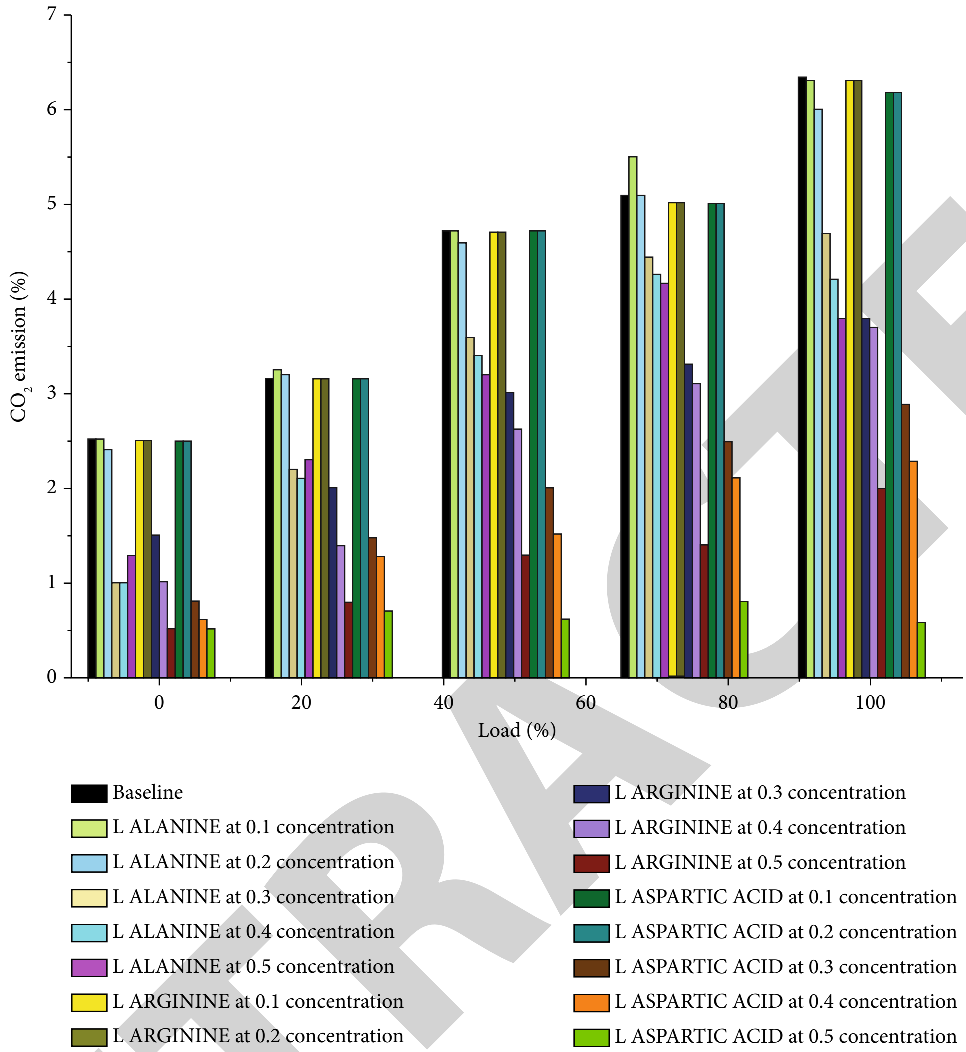

FIGURE 9: The difference in carbon dioxide with respect to engine load.

from the diesel exhaust. In this experimentation, three amino acid solutions L-aspartic acid, L-arginine, and L-alanine are prepared with five different mole concentrations from 0.1 to 0.5 moles. Each solution is filled in a CO_2 control system and tested for its CO_2 control efficiency in the diesel engine.

4.1. Performance Characteristics. The brake thermal efficiency and brake-specific fuel consumption can be used to assess the engine's performance after the CO_2 control system has been fixed. Without the CO_2 control device connected in the engine exhaust, the baseline reading was collected, and after connecting the CO_2 control system in the engine tailpipe, the readings were taken. Figure 7 depicts the relationship between brake thermal efficiency and engine load. The engine's brake thermal efficiency was not significantly affected once the CO_2 control device was connected. This is because after attaching the trap, the backpressure does not increase, and the design is safe.

The variance of specific fuel consumption with regard to engine load is shown in Figure 8. The graph shows that particular fuel usage for the baseline does not change once the CO2 control system is connected. This is because the CO_2 control system does not affect the engine's load, and the fuel consumption range remains the same. The readings are taken before and after connecting CO_2 control system with the diesel engine. Backpressure does not affect engine performance while using the CO_2 control system.

4.2. Emission Characteristics. In this investigation, the prepared amine solutions are tested one by one in the diesel engine exhaust for identifying the efficient emission reduction. The emission testing is performed for the prepared amine solution of 0.1 to 0.5 mole.

Amine solution is poured into the CO_2 control system, and the maximum level of filling is determined. In CO_2 control system, exhaust gas passes over the amine solution, and it gets scrubbed. The diesel exhaust goes continually through

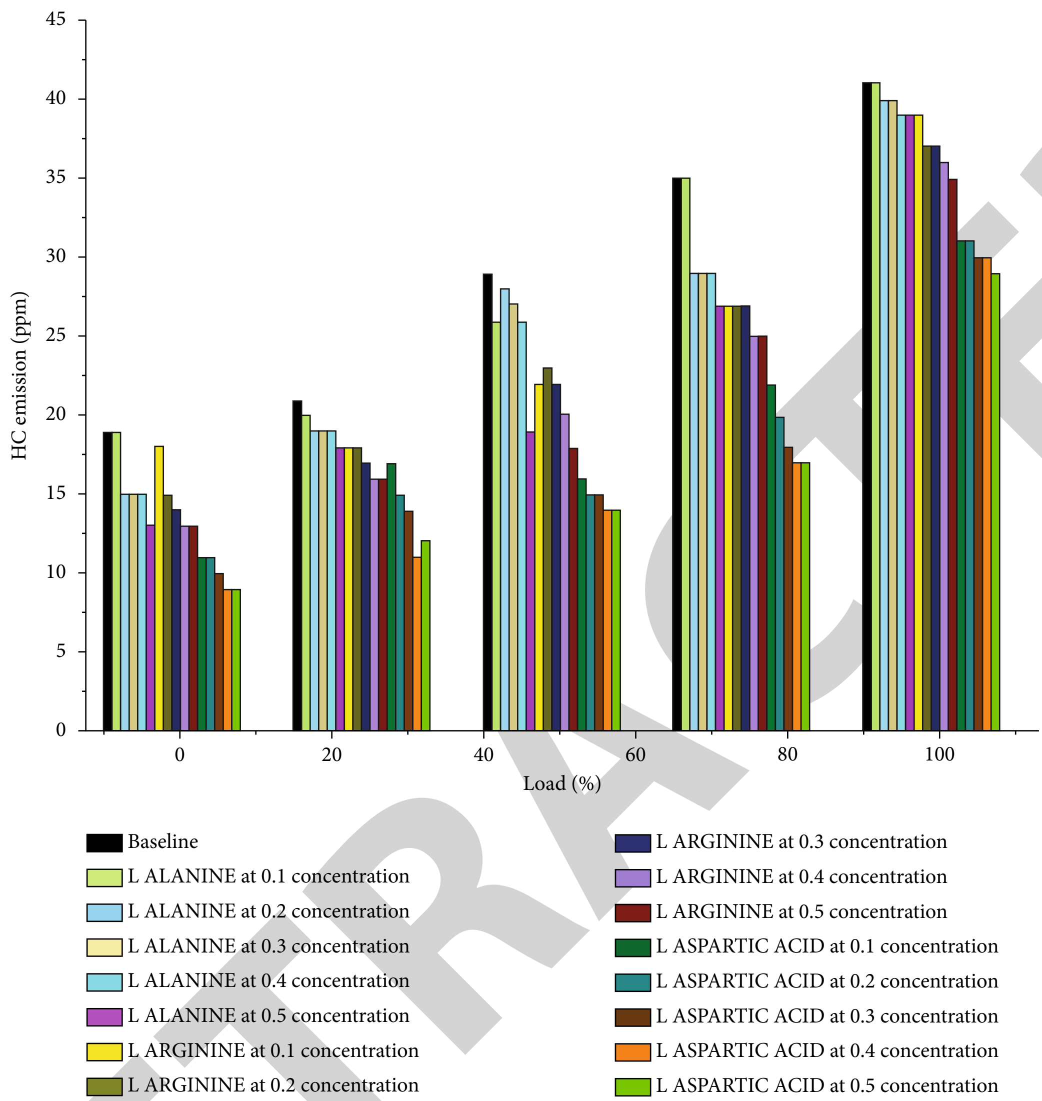

FIGURE 10: The difference in hydrocarbon with respect to engine load.

the CO_2 control system, where it reacts with the amine solution to reduce emissions. By varying the engine load from 0 to 100%, the experiment is conducted. Switching the engine load also changes the exhaust concentration. The graphs for various. emissions for the specified engine load are plotted and explained below.

The complete burning of fuel increases CO_2 emissions [11]. Figure 9 depicts the relationship between CO_2 emissions and engine load. The CO_2 emission concentration fluctuates with the given engine load, as can be seen in the graph. The highest CO_2 emission from the exhaust was 6.5 percent, which was liberated when the engine was fully loaded. The CO_2 level was drastically lowered after being connected to the CO_2 control system. It is because of the amine solution's efficient wet scrubbing of exhaust gas [12].

It is observed from the graph that with L-alanine, there is a moderate reduction in CO_2 observed. But by the increase of mole concentration from 0.1 to 0.5, the CO_2 emissions were progressively reduced. A maximum 25% CO2 reduction was observed with L-alanine. With L-arginine, the CO_2 emission was further reduced; it is due to the good tendency of L-arginine amino solution to trap the CO_2 molecule [13]. Up to 60% reduction of CO_2 is observed with L-arginine 0.5 mole concentration amino. With L-aspartic acid, there was observed a drastic reduction in CO_2 emission [14]. L-Aspartic acid indicates a maximum reduction of 90 percent in CO_2 output when compared to the baseline value. It is because L-aspartic acid's amine characteristics are ideal for absorbing CO_2 molecules [15].

Figure 10 depicts the relationship between HC emission and engine load. The incomplete combustion of fuel in a diesel engine causes HC emissions to grow [16]. The diesel engine released a maximum concentration of 45 PPM when it was fully loaded. HC emissions tend to be reduced after being connected to the CO_2 control system It is owing to the amine solution's absorbent reaction with the HC molecules [17].

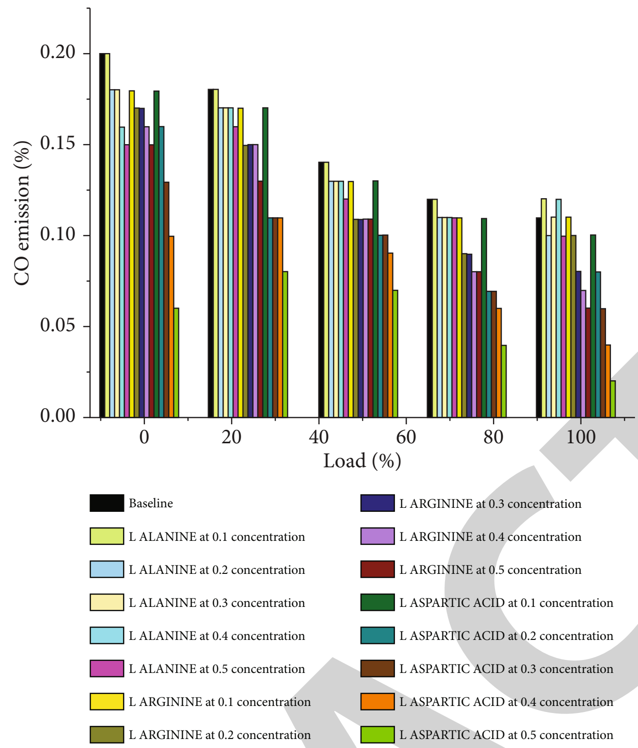

Figure 11: The difference in carbon monoxide with respect to engine load.

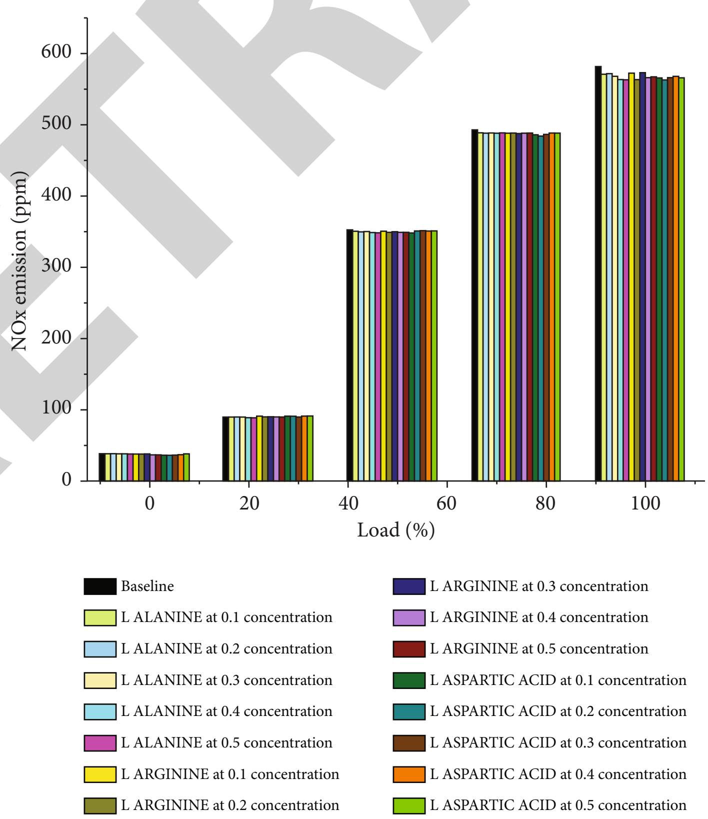

Figure 12: The difference in NOx concentration with respect to engine load.

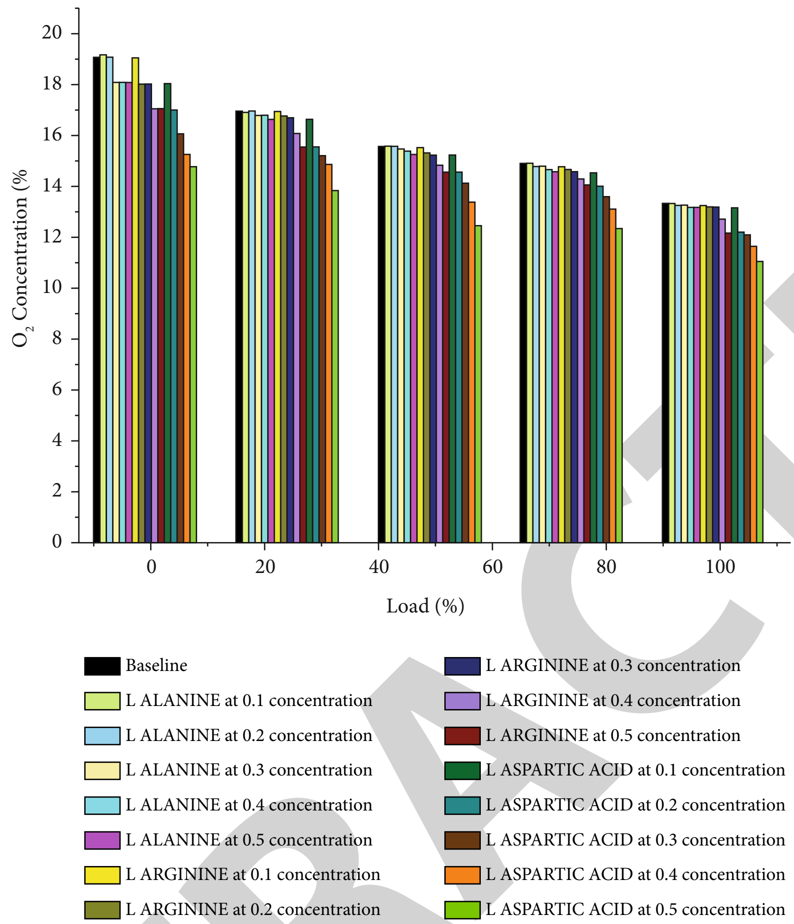

Figure 13: The difference in O_2 concentration with respect to engine load.

It is observed from the graph that with L-alanine, there is not much reduction in HC observed. But by the increase of mole concentration from 0.1 to 0.5, a slight variation in HC emissions was observed [18]. A maximum of 15-20% HC reduction was observed with L-alanine. With L-arginine, the HC emission was not much reduced. It is almost similar to L-alanine with a 20% reduction in HC when compared with baseline HC. With L-aspartic acid amino solution, a good reduction in HC emission was observed [19]. L-Aspartic acid indicates a maximum reduction of 30-40% percent in HC output when compared to the baseline value. It is because L-aspartic acid's amine characteristics are ideal for absorbing CO_2 molecules. It is because L-aspartic acid has the right amine characteristics for absorbing HC molecules.

Figure 11 depicts the fluctuation in CO emissions as a function of engine load. CO emissions rise in diesel engines due to lower oxygen concentrations during combustion [20]. A rich mixture also increases CO emissions [21]. CO emissions reduce after being connected to the CO2 control system. It is caused by the amine solution reacting with the CO molecules [22].

It is observed from the graph that with L-alanine and L-arginine, there is a moderate reduction in CO emission observed. With L-aspartic acid amino solution, a good reduction in CO emission was observed [23]. L-Aspartic acid indicates an extreme reduction of 70% percent in CO output when compared to the baseline value. It is because L-aspartic acid's amine characteristics has a good tendency in absorbing CO_2 molecules.

Because of the high peak cycle temperature in diesel engines, NOx emissions increase [24]. NO and O_2 conduct endothermic reactions to generate NOx at high combustion temperatures [25]. Figure 12 depicts the NOx emission variance as a function of engine load for three distinct amine solutions.

It is observed from the graph that, with L-aspartic acid, L-arginine, and L-alanine amines solution with variable mole concentration, small reductions in NOx of 5-10% have been observed [26]. It is because the amine solution has a tendency to capture double-bond carbon molecules, whereas the double-bond nitrogen molecules unable to interlock in the molecular site of the amine solution [27].

Figure 13 depicts the relationship between O_2 concentration and load. The concentration of oxygen in diesel engine exhaust varies with load [28]. The CO_2 control system makes little difference in terms of O_2 concentration. From the graph, it is observed that O_2 concentrations varied little when L-aspartic acid was used [29]. It is because of the effective oxidation and reduction of HC and CO molecules in the exhaust.

5. Conclusion

The engine emission investigation test was conducted with and without the CO_2 control system connected in this experimental testing. The amino solution was made according to molar solubility and molar concentration. L-arginine and sodium hydroxide were mixed with deionized water, and the amino solution was made according to concentration and solubility quantity. L-Alanine and L-aspartic acid are used in the same way to generate an amine solution. The CO_2 control system has been intended, and fabrication has been completed in accordance with the design and dimensions. By attaching a CO_2 control system to the diesel exhaust, emission testing is carried out in the experimental setup. For emission reduction, the difference in HC, CO, CO_2, and O_2 emission percentage levels from the diesel engine is examined. AVL Di-gas analyzer is used to measure the HC, CO, CO_2, and O_2 concentrations. The results obtained are the following:

(i) According to the findings, L-aspartic acid has a high rate of CO_2 reduction of 90 percent

(ii) As a result of the findings, it is concluded that L-alanine has 25% and L-arginine has 60% CO_2 reduction at 0.5 mole concentration

(iii) In this study, L-aspartic acid reduced HC by 40%, CO by 70%, and NOx by 5-10%

L-Aspartic acid is beneficial in reducing CO_2 emissions, according to the findings of this study. This research successfully demonstrated CO_2 management through a post-combustion approach. Wet scrubbing as a method of CO_2 reduction over amine solutions was found to be successful. In the next phase of research, amine solution modification with nanoadditives to reduce the evaporation rate of amine will be carried out, and more investigation will be carried out on the CO_2 control system design.

Data Availability

The data used to support the findings of this study are included in the article. Should further data or information be required, these are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Acknowledgments

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