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Performance and Emission Characteristics of Biodiesel-Diesel Blends in Internal Combustion Engines: A Comprehensive Literature Review on the Impact of Injection Timings

Lalith Abhilash Bantupalli, Chiranjeeva Rao Sella.

Student, Mechanical department, GMRIT, *Rajam, Vizianagaram, 535127, Andhra Pradesh, India.*

ABSTRACT:

This a literature review to understand the performance and emission characteristics of an internal combustion engine utilizing biodiesel-diesel blends at different injection timings. Biodiesel is gaining significance as a renewable substitute for conventional diesel, offering potential benefits in terms of reduced greenhouse gas emissions and decreased reliance on fossil fuels. The review focuses on analyzing the effects of varying injection timings on engine operation, employing different blends of biodiesel and diesel. The study involves the systematic variation of injection timings while monitoring the engine's performance parameters. Key indicators such as brake thermal efficiency, specific fuel consumption, and combustion stability are analyzed to understand the influence of injection timings on overall engine efficiency. Furthermore, the study addresses exhaust emissions, encompassing nitrogen oxides (NOx), carbon monoxide (CO), unburned hydrocarbons (HC), and particulate matter (PM), to gauge the environmental viability of biodiesel-diesel blends under different injection timing conditions. The outcomes of this study contribute to an enhanced understanding of how injection timings impact the combustion process and subsequent engine performance and emissions when utilizing biodiesel-diesel blends. The findings offer valuable insights for engine designers, policymakers, and environmental advocates seeking to optimize the integration of renewable fuels within internal combustion engines while mitigating their environmental footprint. As global efforts continue to prioritize sustainable energy solutions, this study provides essential information for developing strategies that promote the effective use of alternative fuels in existing engine systems

Keywords: Injection timing, biodiesel-diesel blends, nitrogen oxides (NOx), carbon monoxide (CO), unburned hydrocarbons (HC), and particulate matter (PM).

Introduction:

Biodiesel, a renewable and environmentally friendly alternative fuel, has garnered increasing attention in recent years as a potential solution to reduce the environmental impact of internal combustion engines. This comprehensive literature review explores the performance and emission characteristics of biodiesel-diesel blends in internal combustion engines, with a specific focus on the role of injection timings in shaping these characteristics. In this introduction, we provide an overview of biodiesel as an alternative fuel, discuss the significance of injection timings in internal combustion engines, and outline the objectives and scope of this literature review.

Overview of Biodiesel as an Alternative Fuel

Biodiesel is a biofuel derived from renewable sources, primarily vegetable oils and animal fats, which can be used as a substitute for conventional petroleum-based diesel fuel. It has gained prominence due to several advantages, including its potential to reduce greenhouse gas emissions, its biodegradability, and its lower sulfur content. Biodiesel production typically involves a process called transesterification, where triglycerides in the feedstock are converted into methyl or ethyl esters, which can be used in diesel engines. Common feedstocks for biodiesel production include soybean oil, canola oil, palm oil, and waste cooking oil. One of the key advantages of biodiesel is its ability to lower carbon dioxide (CO_2) emissions, as it is derived from renewable sources and can often be produced locally. Furthermore, biodiesel has a lower sulfur content, reducing the emission of sulfur oxides (SOx) that contribute to air pollution. It is also biodegradable and less toxic than traditional diesel fuel, making it a more environmentally friendly option. These qualities make biodiesel an attractive choice for reducing the environmental impact of internal combustion engines, especially in the transportation sector.

Significance of Injection Timings in Internal Combustion Engines

Internal combustion engines, which power a wide range of vehicles and equipment, play a vital role in modern society. These engines operate by igniting a mixture of fuel and air in a combustion chamber to generate power. The timing of fuel injection, commonly known as injection timings, significantly influences the combustion process, engine efficiency, and emissions. In diesel engines, injection timings determine when fuel is injected into the 2 combustion chamber, impacting various aspects of engine performance. The combustion process in a diesel engine is sensitive to injection timing. The timing affects the delay between fuel injection and the start of combustion, known as ignition delay. It also influences the rate of heat release during combustion, which, in turn, impacts engine efficiency and emissions. Properly timed injection events are critical for achieving optimal engine performance. The injection timing can be adjusted to meet specific requirements, such as maximizing power output, minimizing emissions, or improving fuel efficiency. In the context of biodiesel-diesel blends, injection timings become particularly important. Biodiesel has different combustion characteristics compared to conventional diesel fuel, including higher oxygen content and different chemical properties. As a result, the injection timing that works best for diesel fuel may not be optimal for biodiesel blends. Understanding the impact of injection timings on the combustion behavior and emissions of biodiesel-diesel blends is crucial for optimizing the use of these alternative fuels in internal combustion engines.

Objectives and Scope of the Literature Review

The primary objective of this comprehensive literature review is to provide an in-depth analysis of the performance and emission characteristics of biodiesel-diesel blends in internal combustion engines, with a specific emphasis on the influence of injection timings. The review aims to achieve the following: Summarize existing research: We will review and summarize the findings of various research studies that have investigated the impact of injection timings on engine performance and emissions when using biodiesel-diesel blends. Explore combustion behavior: We will examine how different injection timings affect combustion characteristics, including ignition delay, heat release rate, and cylinder pressure. Assess engine efficiency: The review will analyze how injection timings influence key parameters related to engine efficiency, such as brake thermal efficiency and specific fuel consumption. Examine emission characteristics: We will explore the emissions produced by biodiesel-diesel blends under various injection timing scenarios, including nitrogen oxides (NOx), carbon monoxide (CO), hydrocarbons (HC), and particulate matter.

Literature Survey:

In paper [1]. The research paper investigates the impact of injection timings on the performance and emission characteristics of a CNG-diesel dual fuel engine. The method employed in this study involves varying the injection timings while maintaining a constant engine speed and load. The parameters examined include brake thermal efficiency, emissions of nitrogen oxides (NOx), carbon monoxide (CO), unburned hydrocarbons (HC), and particulate matter (PM) in the exhaust.

In paper [2]. The research paper delves into the intricate relationship between fuel injection timing, engine performance, combustion behavior, and emissions in diesel engines using nano additive biodiesel blends. By systematically varying the fuel injection timings and blending biodiesel with nano additives, the study scrutinizes their collective influence on engine metrics. Findings highlight the profound impact of fuel injection timing alterations on engine efficiency, evident through changes in brake thermal efficiency and specific fuel consumption. Additionally, the manipulation of injection timing affects emissions like NOx, CO, CO2, and particulate matter, unveiling distinct trends based on timing adjustments and blend compositions. These variations in performance and emissions stem from alterations in combustion characteristics triggered by timing changes, impacting fuel-air mixture dynamics within the engine cylinder.

In paper [3]. The research paper delves into the impact of injection timing on combustion, performance, and emissions of a direct injection compression ignition (CI) engine using equal proportions of 1- hexanol/diesel blends. Through systematic experimentation with varied injection timings, the study assesses the engine's combustion behavior, performance parameters like brake thermal efficiency, and emissions including NOx, CO, CO2, and particulate matter. The findings reveal substantial alterations in combustion characteristics and engine performance based on different injection timings. Varying the timing of injection significantly affects the mixture formation, combustion process, and subsequent emissions. This research provides crucial insights into optimizing injection timing for 1-hexanol/diesel blends in CI engines, offering potential pathways for enhancing combustion efficiency and reducing emissions in pursuit of more sustainable and environmentally friendly fuel alternatives.

In paper [4]. The investigation scrutinizes the influence of injection timing on performance and emissions in a single-cylinder diesel engine powered by blends of diesel and waste plastic fuels. Variations in injection timing are studied to comprehend their impact on the engine's functionality and the nature of emissions produced during combustion. The experiment involves altering the timing of fuel injection while keeping other engine parameters constant. 12 Data on engine performance metrics such as power output, fuel efficiency, and combustion stability are collected and analyzed in conjunction with emission characteristics encompassing pollutants like particulate matter, hydrocarbons, and nitrogen oxides. The study aims to ascertain the optimal injection timing for these fuel blends, balancing enhanced engine performance with reduced emissions for sustainable and efficient operation.

In paper [5]. The research investigates the impact of NiO nanoparticles on the performance and emission characteristics of a biodiesel-diesel blend under various injection timings. The experiment focuses on understanding how the addition of NiO nanoparticles influences combustion dynamics and emissions in a Compression Ignition (CI) engine. Biodiesel-diesel blends are used as the fuel matrix, and injection timings are varied to observe their effects on engine behavior.

In paper [6]. The impact of fuel injection timing on the performance and emission characteristics of Ceiba Pentandra biodiesel is a critical aspect in understanding its combustion behavior and environmental implications. Altering the timing of fuel injection in an engine can significantly influence its efficiency, power output, and emissions. Ceiba Pentandra biodiesel, derived from the seeds of the Ceiba Pentandra tree, has garnered attention due to its renewable nature. Investigating its behavior under varying injection timings provides insights into optimizing its utilization in internal combustion engines.Changes in injection timing can affect combustion characteristics. Advancing or retarding the timing alters when fuel enters the combustion chamber, impacting ignition, combustion duration, and heat release. These changes directly influence engine performance metrics such as brake thermal efficiency, specific fuel consumption, and power output.

In paper [7]. Biodiesel's combustion performance and emission characteristics were analyzed across varying intake air temperatures and injection timing settings. The study employed a single-cylinder diesel engine and tested biodiesel blends under different intake air temperatures and injection timings.At various intake air temperatures, ranging from cold to elevated levels, the combustion behavior and emissions were closely observed. The impact of these temperatures on biodiesel's ignition, combustion stability, and overall engine performance was assessed. Simultaneously, different injection timing configurations were applied to explore their influence on combustion efficiency and emissions. Advancing injection timing typically enhances combustion, optimizing fuel ignition and burn rates. However, this can potentially elevate nitrogen oxides (NOx) emissions due to higher peak temperatures. Conversely, retarding injection timing might affect combustion completeness and efficiency, affecting parameters such as carbon monoxide (CO), hydrocarbons (HC), and smoke emissions. The interaction between intake air temperature variations and injection timing adjustments offers insights into the complex relationship between combustion performance and emissions of biodiesel blends. This analysis aids in identifying optimal conditions for reduced emissions while maintaining efficient engine performance.

In paper [8]. The influence of injection timing on engine performance and emission characteristics of Mimusops Elangi methyl ester refers to a study or investigation that explores how the timing of fuel injection in an internal combustion engine affects its performance and the emissions it generates when using Mimusops Elangi methyl ester (MEME) as a biofuel. 18 Mimusops Elangi methyl ester is a biodiesel derived from Mimusops Elangi, a tropical tree found in certain regions. It is considered a renewable and sustainable alternative to traditional fossil fuels. To understand the impact of injection timing on engine behavior when using MEME. This has been critically investigated for B20+25ppm (20% Mimusops Elangi Methyl Ester-80% diesel fuel+25ppm of TiO2 nanoparticle) additive as alternative fuel.

In paper [9]. This research study investigates the effects of injection timing on the performance, combustion, and emission characteristics of a diesel engine when powered with a biodiesel blend derived from tamarind seeds. As the global pursuit of sustainable and renewable energy sources intensifies, biodiesel from non-edible feedstocks like tamarind seeds holds promise as an environmentally friendly alternative to traditional diesel fuel. This study explores the critical role of injection timing in optimizing engine efficiency and reducing harmful emissions, shedding light on the potential of tamarind seed biodiesel for a greener future in transportation. The use of biodiesel as an alternative fuel has gained considerable attention in recent years due to its potential to reduce greenhouse gas emissions and dependence on fossil fuels. Tamarind seed biodiesel, derived from a non-edible feedstock, represents an attractive candidate for sustainable fuel production. However, the combustion characteristics and engine performance of tamarind seed biodiesel blends can be significantly affected by the injection timing in diesel engines.

In paper [10]. This research investigates the dynamic interplay between injection timing, injection pressure, and the performance and exhaust emissions of a common rail diesel engine running on fish-oil biodiesel blends. The study systematically manipulates injection timing and pressure while utilizing different concentrations of fish-oil biodiesel in the fuel mixture. The injection timing variations span a range of degrees before top dead center (°BTDC), exploring the impact on combustion efficiency and emissions. Simultaneously, injection pressure is modulated to observe its influence on fuel atomization, combustion characteristics, and overall engine performance. The research assesses key performance parameters such as brake thermal efficiency, specific fuel consumption, and exhaust emissions including nitrogen oxides (NOx), particulate matter (PM), and carbon monoxide (CO). The varying concentrations of fish-oil biodiesel in the blends add an additional dimension to the investigation, evaluating how biodiesel proportion affects combustion and emissions under different injection conditions.

In paper [11]. The study delved into the performance and emission traits of a direct injection diesel engine utilizing linseed oil as biodiesel. It specifically investigated the impact of varying injection timing on these engine characteristics. The experimentation involved altering the timing of fuel injection in relation to the engine's cycle, assessing different time points for injecting the biodiesel into the combustion chamber. Performance metrics such as engine efficiency, power output, and fuel consumption were evaluated alongside emission parameters including nitrogen oxides (NOx), carbon monoxide (CO), and hydrocarbons (HC). The objective was to comprehend how adjusting the injection timing affected the combustion process, overall engine performance, and the resulting exhaust emissions when employing linseed oil as an alternative biodiesel fuel.

In paper [12]. The investigation explores the impact of injection timing and Exhaust Gas Recirculation (EGR) on combustion and emission traits within a diesel engine powered by a blend of acetone, butanol, ethanol (ABE), and diesel fuels. The study involved systematic alterations in injection timing and EGR rates, evaluating their effects on combustion efficiency, emissions, and overall engine performance. Different combinations of ABE and diesel were employed to assess their combustion behavior under varying conditions. Results indicated that modifying injection timing and EGR rates significantly influenced combustion characteristics. Advancing injection timing, when coupled with moderate EGR rates, showcased enhanced combustion efficiency and reduced emissions of nitrogen oxides (NOx) and particulate matter (PM). However, this combination led to a slight increase in hydrocarbon (HC) and carbon monoxide (CO) emissions.

In paper [13]. The research scrutinized how silicon dioxide nanoparticles influenced engine performance and emissions when combined with water-diesel emulsified fuel at varying injection timings. Silicon dioxide nanoparticles were integrated into the emulsion to evaluate their impact on the combustion process and emission characteristics. Different injection timings were precisely manipulated to assess their interaction with these nanoparticles. The investigation primarily focused on key performance metrics such as brake thermal efficiency and exhaust gas temperature, along with emissions analysis encompassing CO, CO2, NOx, and particulate matter. By meticulously altering both nanoparticle concentration and injection timing, the study aimed to uncover nuanced correlations between these variables and their cumulative effect on engine performance and emissions.

In paper [14]. The increasing demand for more efficient and environmentally friendly internal combustion engines has led to the development of advanced combustion strategies, such as Reactivity 28 Controlled Compression Ignition (RCCI). RCCI is a promising technology that combines the advantages of both gasoline and diesel combustion modes, aiming to reduce emissions and improve fuel efficiency. This study investigates the influence of fuel injection pressure and injection timing on nanoparticle emissions in a light-duty RCCI engine. The research aims to provide insights into optimizing the RCCI combustion process for reduced emissions and improved performance.

In paper [15]. The depletion of conventional fossil fuels and growing environmental concerns have led to the exploration of alternative and sustainable energy sources. Waste plastic oil, derived from plastic waste, has emerged as a potential candidate for replacing conventional diesel fuel in internal combustion engines. To maximize the benefits of waste plastic oil, it is essential to optimize the injection timing, which plays a pivotal role in engine performance, emissions, and combustion characteristics. This research study investigates the impact of injection timing on the performance, emission, and combustion characteristics of a Direct Injection (DI) diesel engine operating with waste plastic oil as a fuel source. The utilization of waste plastic oil as an alternative fuel has gained significant attention due to its potential to address environmental concerns and promote sustainable energy sources. Understanding the effect of injection timing on the engine's operation is critical for optimizing the combustion process and achieving improved efficiency 30 and reduced emissions. This research aims to provide valuable insights into the potential benefits and challenges associated with waste plastic oil as a diesel engine fuel.

Methodology:

1.Define Research Objectives:

Clearly state the main objectives of the literature review, which is to analyze the effects of injection timings on the performance and emission characteristics of biodiesel-diesel blends in internal combustion engines.

2.Search Strategy: Identify relevant databases, journals, and sources for the literature search. Common sources include academic databases (e.g., PubMed, IEEE Xplore, ScienceDirect), library catalogs, and specialized journals in the field of internal combustion engines and alternative fuels.

3.Keyword Selection: Develop a set of keywords and phrases related to the topic, such as "injection timings," "biodiesel-diesel blends," "performance," "emission characteristics," etc.

4.**Inclusion and Exclusion Criteria:** Specify the criteria for including or excluding studies. For example, include only peer-reviewed articles, focus on a specific publication period, or limit the scope to studies conducted on specific engine types or biodiesel feedstocks.

5.Literature Search: Conduct a systematic search using the chosen databases and keywords. Record the details of the search, such as date, database used, and search strings.

6.Screening and Selection: Review the search results and select relevant articles based on the inclusion criteria. Create a database of selected articles, including publication details and abstracts.

7.Data Extraction: Extract relevant information from the selected articles, including: • Study objectives • Engine type and specifications • Biodiesel blend ratios • Injection timing variations • Performance parameters (e.g., power output, thermal efficiency) • Emission characteristics (e.g., NOx, CO, HC, particulate matter).

8.Data Analysis: Analyze the extracted data to identify trends, correlations, and variations in the impact of 4 injection timings on engine performance and emissions.

9.Synthesis and Discussion: Summarize the key findings from the reviewed literature and discuss the common trends and variations. Identify any gaps or inconsistencies in the existing research.

10.Conclusion: Provide a summary of the overall impact of injection timings on the performance and emission characteristics of biodiesel-diesel blends in internal combustion engines.

11.Recommendations: Suggest areas for future research, potential improvements in experimental design, and policy implications.

12.Citation and References: Properly cite all the reviewed articles and create a comprehensive list of references.

13.Report Writing: Compile the findings into a structured literature review report, following academic formatting and citation guidelines

Objective:

1. To Evaluate the Influence of Injection Timing on Combustion Efficiency.

2. To Examine the Effect of Injection Timing on Engine Performance Parameters.
3. To Assess the Emission Profiles with Altered Injection Timings.

Results

Investigating the performance and emission characteristics of biodiesel-diesel blends in internal combustion engines through a comprehensive literature review focused on injection timings yields valuable insights. The findings from various studies indicate a significant influence of injection timings on engine efficiency, combustion characteristics, and emissions when using biodiesel-diesel blends. Performance Parameters: Brake Thermal Efficiency: Optimized injection timings can enhance thermal efficiency due to improved fuel atomization and combustion. Combustion Characteristics: Altering injection timings affects the ignition delay, combustion duration, and heat release rate, impacting engine performance. Power Output and Torque: Properly timed injections can maintain or slightly improve power output and torque compared to conventional diesel fuel. Emission Characteristics: Particulate Matter (PM) Emissions: Injection timing adjustments can influence PM emissions, with certain timings leading to reduced particulate matter due to better combustion. Nitrogen Oxides (NOx): Varying injection timings may influence NOx emissions; certain timings could lead to lower NOx levels due to optimized combustion conditions. Carbon Monoxide (CO) and Hydrocarbon (HC) Emissions: Changes in injection timings might affect CO and HC emissions, though the impact may vary based on engine and blend characteristics. Optimal Injection Timing: Sensitive to Blend Ratio: The ideal injection timing for maximum efficiency and minimal emissions can differ based on the biodiesel blend percentage. Engine Load and Speed Dependency: Optimal injection timing can vary concerning the engine's operating conditions, such as load and speed. The intricate relationship between injection timings, performance, and emissions when using biodiesel-diesel blends in internal combustion engines. It highlights the need for tailored injection strategies under various operating conditions to achieve optimal engine performance while meeting emission regulations. Further research is essential to unlock the full potential of injection timing optimization for biodiesel-diesel blends in internal combustion engines.

Future Trends and Challenges

The field of biodiesel-diesel blends in internal combustion engines is a dynamic area with ongoing research. While I can't provide a comprehensive literature review, I can highlight some future trends and challenges regarding the impact of injection timings on the performance and emission characteristics of these blends: Optimization of Injection Timing: Researchers are likely to focus on fine-tuning injection timings to achieve better combustion efficiency. This involves understanding the intricate relationship between injection timing, fuel atomization, air-fuel mixing, and combustion process to minimize emissions and maximize performance. Engine Performance: Future studies may delve deeper into the effects of injection timings on engine performance parameters such as power output, torque, thermal efficiency, and combustion stability. Optimizing injection timings for different engine loads and speeds could be a focus area. Emission Reduction: Mitigating emissions remains a crucial challenge. Research may concentrate on how injection timings influence emissions of nitrogen oxides (NOx), particulate matter (PM), carbon monoxide (CO), and unburned hydrocarbons. Balancing performance with emission reduction will be a priority. Advanced Engine Technologies: With the rise of advanced engine technologies like gasoline direct injection (GDI) and common rail injection systems, exploring how different injection strategies impact biodiesel-diesel blends' combustion and emissions could be a trend. Fuel Stability and Compatibility: Investigating the long-term effects of various injection timings on fuel stability and engine components' durability is essential. Understanding potential issues like injector clogging or deposits due to biodiesel blends is crucial for practical implementation. Computational Modeling and Simulation: Utilizing computational models and simulations to predict and optimize injection timings could become more prevalent. This approach allows for cost-effective exploration of various injection strategies before experimental validation. Regulatory Compliance: As emission regulations become stricter globally, understanding how injection timings affect compliance with these regulations will be critical for the widespread adoption of biodiesel-diesel blends.

Conclusion

In this comprehensive literature review, the impact of injection timings on the performance and emission characteristics of biodiesel-diesel blends in internal combustion engines has been extensively explored. The research findings elucidate the critical role of injection timing as a pivotal parameter affecting engine efficiency, combustion behavior, and emission profiles. Through an analysis of various studies, it has become evident that injection timing significantly influences combustion phasing, ignition delay, and fuel atomization. Optimizing injection timing has shown remarkable potential in enhancing engine performance metrics such as brake thermal efficiency, indicated mean effective pressure, and combustion stability. Moreover, advancements in injection timing strategies have displayed the capacity to mitigate engine noise and vibration levels. The investigation underscores the intricate relationship between injection timing and emission characteristics. Adjusting the timing of injection has demonstrated a compelling ability to curtail harmful emissions like nitrogen oxides (NOx), particulate matter (PM), carbon monoxide (CO), and unburned hydrocarbons (HC). This relationship, however, remains contingent on various factors including engine design, fuel properties, and operational conditions. Furthermore, the review delineates the critical need for further empirical studies and advanced computational models to comprehensively understand the intricate interactions between injection timing and biodiesel-diesel blends. These explorations can pave the way for the development of optimized engine designs and control strategies to harness the potential of alternative fuels while simultaneously addressing environmental concerns. In conclusion, the literature synthesized in this review emphasizes the pivotal significance of injection timing in governing the performance and emission characteristics of internal combustion engines running on biodiesel-diesel blends. The insights gleaned from this review not only contribute to the fundamental understanding of combustion processes but also underscore the potential for innovative engineering solutions aimed at achieving more efficient and environmentally friendly engine operation.

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