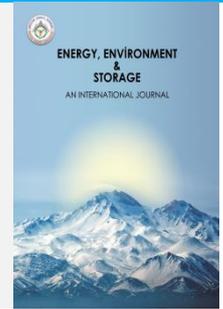




Energy, Environment and Storage

Journal Homepage: www.enenstrg.com



Overview on Acetylene as an Alternative Fuel in Engine Fuel Blends

Happy Sinkala^{1*}, Khelladi Mohammed², Athmane BEN RABAH²

¹Graduate School of Natural and Applied Sciences, Mechanical Engineering Dept. Erciyes University, Kayseri, Türkiye ORCID: 0009-0006-8871-6813

²Mechanical Engineering, Industrial Fluids, Measurements and Applications (FIMA), Khemis Miliana University, Algeria,

ABSTRACT. Acetylene, C_2H_2 , has been researched due to its high reactivity as a fuel in internal combustion engines because of its high flame speed, low ignition energy, and wide flammability limits. When added as a supplement fuel, acetylene can alter combustion characteristics, enabling improved thermal efficiency, extended lean operation, and substantial reductions of particulate emissions across SI, CI, and advanced combustion concepts. These advantages come at the cost of several significant challenges regarding abnormal combustion, elevated pressure rise rates, increased NO_x emissions, and very strict safety constraints. This work synthesizes experimental, numerical, and system-level research on acetylene-fueled engines based on a peer-review literature review with the aim of showing its future deployment in other alternative fuels, especially ammonia. Performance, combustion behavior, and emission characteristics are systematically compared for SI, CI, dual-fuel, HCCI, and RCCI arrangements. The study demonstrates that there is little overlap in operational time within which acetylene can be used effectively; it discusses differences between research and shows recurring tendencies. When the ultimate safety, storage, and life-cycle sustainability factors are assessed, it becomes evident that acetylene production, rather than just in-cylinder benefits, dominates its environmental feasibility. The use of acetylene can be preferred as an enhancer of combustion in strictly regulated multi-fuel systems, rather than a stand-alone alternative fuel. The research also identifies important research objectives needed for any future practical deployment.

Keywords: Acetylene; Dual-fuel engines; Spark-ignition engines; Compression-ignition engines; Combustion enhancement; Emissions; Alternative fuels

Article History: Received: 22.12.2025; Revised: 17.01.2026; Accepted: 27.01.2026; Available Online: 27.01.2026

Doi: <https://doi.org/10.52924/AQUN7716>

1. INTRODUCTION

Acetylene (C_2H_2) gas is well known for a long time for possible use as a fuel for engines because of its high flame speed, low ignition energy, and wide flammability limits [1,2,3]. The significance of these characteristics is sufficient to conclude that acetylene is not just another alternative fuel compared to other hydrocarbon fuels, even compared to hydrogen, considering the density of the energy they contain in a volume. The experience with early versions of acetylene engines indicated the possibility of stable, highly lean-burn combustion, but the problems of engine knock, backfiring, pre-ignition, and safety were also significant [3,6,7].

The current interest in Acetylene, a combustible gas, has been associated with the strict regulations on emission standards and the need to adopt more efficient combustion methods that promote increased efficiency while lowering particulate matter emissions [8, 9]. In contrast to Hydrogen, Acetylene can be blended with a low substitution rate to modify combustion, hence its beneficial application as a combustion promoter [4, 10, 11]. Notably, most current studies on Acetylene application are associated with its utilization in combined combustion methods rather than its application as a pure fuel [12, 3, 5].

*Corresponding author: happyysink@gmail.com

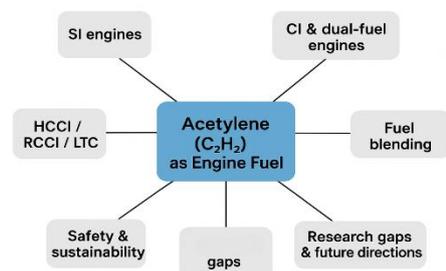


Fig. 1: Work Flow of Literature Review

This review provides a comprehensive synthesis of experimental, numerical, and system-level studies on acetylene-fueled internal combustion engines. Spark-ignition (SI), compression-ignition (CI), dual-fuel, and advanced combustion modes are discussed, with explicit attention to performance, combustion, emission behavior, safety constraints, and sustainability considerations as depicted in Figure 1. The main objective of the review is to

show how acetylene's properties could be leveraged in its use with ammonia in dual-fuel combustion systems.

2. FUNDAMENTAL COMBUSTION CHARACTERISTICS OF ACETYLENE

The fundamental combustion characteristics of acetylene (Table 1) underpin both its advantages and its limitations in engine applications. Acetylene exhibits one of the highest laminar flame speeds among practical fuels, typically exceeding 1.5–2.0 m/s under stoichiometric conditions, compared to approximately 0.37–0.43 m/s for gasoline–air mixtures [1,2,4,5]. Its minimum ignition energy is an order of magnitude lower than that of all the gaseous alternative fuels, enabling rapid flame initiation but also increasing susceptibility to unintended ignition events [3,4,6,13].

Chemical kinetic investigations identify acetylene as a key intermediate species in hydrocarbon oxidation and soot formation pathways [14,15]. Its strong tendency toward chain-branching reactions accelerates heat release, which is beneficial for efficiency but problematic for pressure rise rate control [16]. Experimental engine studies consistently report higher peak cylinder pressures and faster apparent heat release when acetylene is introduced, even at low energy fractions [16–18].

Another critical aspect is acetylene's chemical instability at elevated pressures and temperatures. Unlike saturated hydrocarbons, acetylene can undergo explosive decomposition under unfavorable conditions, which has direct implications on engine safety [19]. The understanding of these fundamental properties do not only provide insights on the nature of acetylene but also explain why acetylene is rarely used as a standalone fuel and instead appears predominantly as a supplementary or blended component in engine studies [3, 19].

3. FUEL BLENDING STRATEGIES

Fuel blending has emerged as the most practical and widely adopted strategy for exploiting acetylene's high reactivity while mitigating its inherent safety and controllability challenges. Rather than operating engines on pure acetylene, the literature strongly demonstrates that small acetylene fractions can be used to tailor ignition behavior, flame propagation, and heat release characteristics across SI, CI, and advanced combustion modes [19–23].

3.1 Acetylene Blending in Spark-Ignition Engines

Spark-ignition (SI) engines (Fig. 2) constitute one of the earliest investigated platforms for acetylene utilization, largely because acetylene can stabilize lean combustion and markedly accelerate flame propagation. Experimental studies consistently show that introducing small acetylene fractions into conventional SI fuel mixtures shortens combustion duration and reduces cycle-to-cycle variability, particularly under part-load and dilute operating conditions [22,24,25].

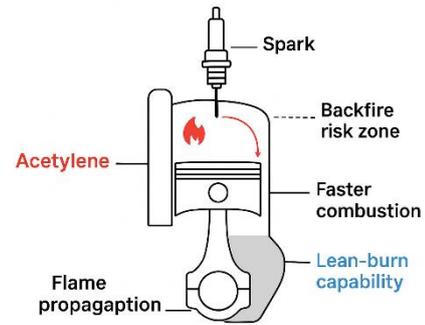


Fig.2: Spark Ignition Engine Operating on Acetylene

Acetylene blending modifies combustion phasing, heat-release behavior, and thermal efficiency in comparison to baseline gasoline operation, according to experimental studies on multi-cylinder, stationary, and modified SI engines. The results as shown to be highly dependent on operating conditions and control strategies. In a modified six-stroke SI engine, Gupta et al. [1] showed that replacing petrol with acetylene in conjunction with water injection allowed for stable operation with better brake power and brake thermal efficiency while lowering CO and HC emissions; the observed NO_x reduction was specifically attributed to water injection rather than acetylene itself. Sharma et al. [2] similarly reported that acetylene–gasoline mixtures in stationary four-stroke SI engines are feasible at optimized acetylene flow rates, identifying a specific operating point at which brake thermal efficiency was maximized than that of gasoline operation (Fig. 3 and Fig. 4).

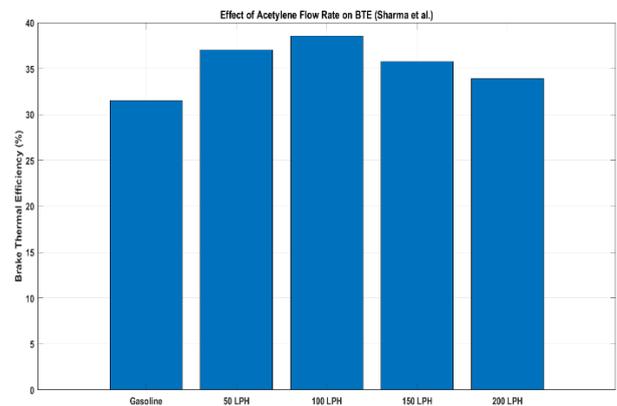


Fig.3: Brake thermal efficiency variation with acetylene flow rate in an SI engine [2].

The sensitivity of acetylene-blended SI combustion to engine control parameters is reinforced by variable compression ratio (VCR) studies. Sharma et al. [13] showed that advancing spark timing improves efficiency up to an optimum point, beyond which knock tendencies and abnormal combustion become evident as acetylene fraction increases. Comparative fuel studies by Ilhak et al. [24] indicated that acetylene exhibits higher thermal efficiency and lower unburned hydrocarbon and NO emissions than gasoline and ethanol under lean operating conditions. However, related investigations on gasoline–acetylene mixtures reported that while acetylene addition generally reduces hydrocarbon emissions, it can also lead to efficiency penalties and increased NO emissions at certain loads and operating regimes [22].

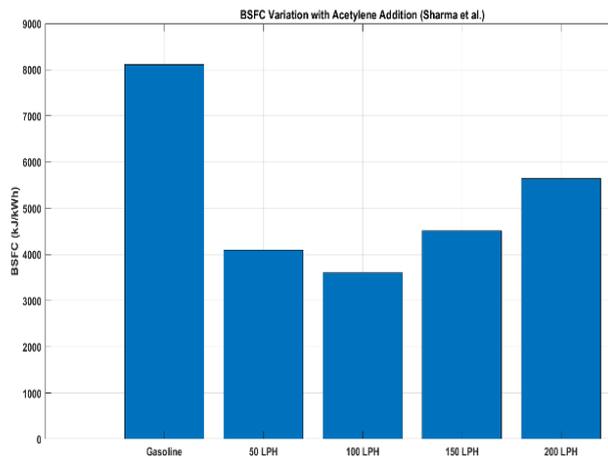


Fig. 4: Brake specific fuel consumption variation with acetylene flow rate in an SI engine [2].

Beyond liquid fuels, acetylene has also been examined in conjunction with other gaseous fuels in SI engines. Cinar et al. [25] reported that acetylene addition to LPG-fueled SI engines reduced CO and HC emissions while increasing NO emissions, with favorable outcomes confined to narrow excess-air-ratio and blend-proportion ranges. Tangöz et al. [26] further demonstrated that blending acetylene with hydrogen or methane substantially alters combustion phasing; hydrogen addition advanced combustion and reduced CO and HC emissions at fixed lambda, whereas methane addition retarded combustion and increased incomplete combustion products. Complementary emission-focused work by Özer et al. [27] examined acetylene addition at 5% and 10% by mass in a gasoline engine and reported increases in exhaust gas temperature, alongside air-fuel coefficient, highlighting the narrow operational window associated with acetylene use in SI engines.

Across the SI literature, the consensus is that acetylene is most effective when employed at low substitution levels [17,26,27]. When this range is exceeded, acetylene's quick heat release takes over combustion behavior, resulting in knock-limited operation and decreased controllability. Together, these results show that acetylene's main application in SI engines is as a small additive to improve flame formation and lean-burn capacity, not as a stand-alone or high-fraction fuel.

3.2 Acetylene Blending in CI and Dual-Fuel Engines

Compression-ignition (CI) and dual-fuel engines represent the most extensively studied configurations for acetylene utilization. In these systems, as shown in Figure 5, acetylene is typically inducted through the intake manifold or port, while a small quantity of diesel or biodiesel is injected as a pilot fuel to initiate combustion [19,28,29]. Acetylene is shown to influence the premixed combustion phase, producing significant particulate emission reductions and modest efficiency gains, but also introducing critical challenges related to pressure rise rate and combustion noise.

Dual-Fuel Operating Principle

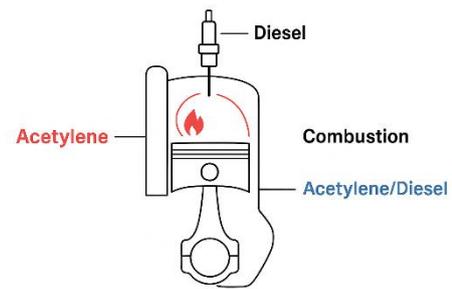


Fig. 5: Dual-Fuel Injection

Early investigations by Lakshmanan and Nagarajan [28-30] demonstrated that timed port or manifold induction of acetylene enables stable dual-fuel operation over a wide load range. These studies reported reductions in exhaust gas temperature and modest reductions in thermal efficiency under certain operating conditions. This early work highlighted the critical role of acetylene induction timing, duration, and flow rate in mitigating backfire, pre-ignition, and excessive pressure rise.

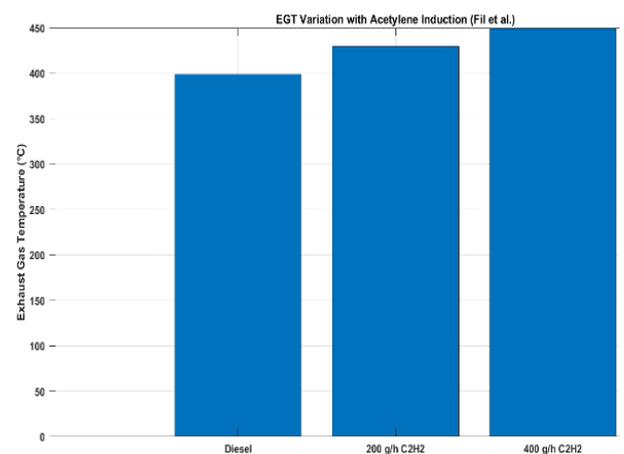


Fig. 6: Exhaust gas temperature for diesel and acetylene-fueled operation [19].

Subsequent experimental studies expanded the parametric understanding of acetylene dual-fueling. Raman and Kumar [4,31] showed that acetylene induction length and flow rate significantly influence combustion behavior, identifying optimal induction distances and substitution levels at which brake thermal efficiency approached or exceeded that of diesel operation. These conditions were associated with reduced diesel consumption and lower CO, HC, and smoke emissions, albeit often accompanied by increased NO_x at higher loads. Shaik et al. [18] further demonstrated that on-demand acetylene generation using a calcium carbide-water reaction can successfully support dual-fuel operation, yielding higher brake thermal efficiency and reduced CO, HC, and particulate matter emissions compared with conventional diesel operation.

The interaction between acetylene and liquid pilot fuels has been widely explored, particularly using biodiesel and multi-fuel blends. Behera et al. [32], Koli and Rao [33,34], and Fil et al. [19] reported that acetylene addition can either improve or reduce brake thermal efficiency depending on acetylene

flow rate, compression ratio, and engine load, while consistently modifying ignition delay and increasing the premixed combustion fraction. Fil et al. [19] observed increased temperatures at higher acetylene flow rates (Fig. 6), showing the strong sensitivity of both temperature and pressure rise outcomes to operating conditions. Extending this approach, Kumaran et al. [35] investigated a three-fuel mixture comprising diesel, turpentine blend, and acetylene, reporting a 1–3% improvement in brake thermal efficiency compared with diesel at an acetylene flow rate of 3 LPM. More recent studies have explored advanced pilot fuels and fuel additives to moderate acetylene reactivity [21].

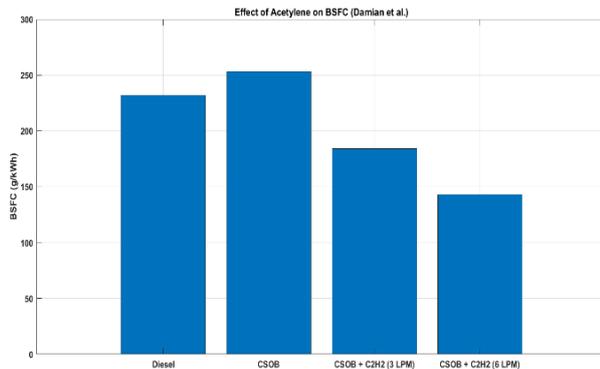


Fig. 7: Brake specific fuel consumption of diesel and CSOB blends with acetylene addition [21].

Gavaskar et al. [36] examined jackfruit seed biodiesel blended with nitrogen-doped carbon quantum dots and acetylene, reporting reductions in brake-specific fuel consumption, exhaust gas temperature, and cylinder pressure, and heat-release rate compared with diesel operation. Similar results were found in studies conducted on candlenut biodiesel (CSOB) by Damian et al [21] as shown in Figure 7. Raman and Kumar [37] demonstrated that blending *n*-butanol with diesel as a pilot fuel improved acetylene dual-fuel combustion, increasing brake thermal efficiency, and significantly lowering diesel consumption at high loads. Parametric investigations further highlight the sensitivity of acetylene dual-fuel operation to engine settings. Srivastava et al. [38] reported that increasing injection pressure to 200 bar maximized brake thermal efficiency. Thodda et al. [39] showed that higher acetylene flow rates, increased compression ratio, and optimized injection pressure and timing substantially improved brake thermal efficiency and reduced smoke emissions. Basha et al. [40] demonstrated that low-pressure acetylene generated on-board from calcium carbide can improve brake thermal efficiency at high loads, although NO_x increased across the load range, necessitating exhaust gas recirculation for mitigation.

Recent optimization and modelling studies have further refined these trends. Rabeti [41] applied artificial neural network (ANN) and response surface methodology (RSM) techniques to identify optimal acetylene flow rate, compression ratio, injection timing, and injection pressure, reporting high predictive accuracy for performance and emission parameters. Similar desirability-based optimisation and machine-learning models were used by Nguyen et al.

[42] to find operating parameters that increased efficiency and decreased CO and HC emissions while preserving acceptable NO_x levels.

3.3. Advanced Combustion Modes: HCCI, RCCI, and LTC

On the other hand, research has also been conducted on the use of acetylene, which has high reactivity as fuel in advanced combustion strategies such as reactivity-controlled compression ignition (RCCI) and homogeneous charge compression ignition (HCCI). These advanced modes of combustion rely on reactivity stratification to manage auto-ignition and heat release phases. In RCCI configurations, acetylene has been examined as either a low- or high-reactivity fuel depending on its pairing with biodiesel or other liquid fuels. Muthuswamy et al. [43] demonstrated that acetylene combined with B20 mahua biodiesel in RCCI mode improved brake thermal efficiency while simultaneously reducing smoke, NO_x, HC, and CO emissions when injector orientation and acetylene flow rate were optimized.

Further RCCI-oriented studies emphasize system-level optimization rather than fuel substitution alone. Deb and Paul [44,45] reported that premix ratio and injection strategy play a central role in shaping heat-release behavior and emission trends, with acetylene contributing to controlled autoignition only when appropriately phased and limited to moderate substitution levels. Sonachalam et al. [46] integrated injection timing optimization with machine-learning techniques to identify operating conditions that improved efficiency and reduced CO, HC, and smoke emissions, albeit with modest increases in NO_x.

Complementary numerical and chemical-kinetic studies provide mechanistic insight that supports interpretation of these experimental observations. Blanquart et al. [47] developed a detailed chemical kinetic mechanism identifying acetylene as a key intermediate species in polycyclic aromatic hydrocarbon and soot formation pathways under high-temperature combustion conditions. Zhao et al. [48] further demonstrated through CFD-based soot modeling that acetylene concentration strongly governs soot inception and surface growth dynamics in dual-fuel and low-temperature combustion engines. Although such modeling researches are not experiments on engines, they form a basic platform to grasp particulate and emission behaviors under advanced modes of combustion of acetylene fuel.

The results summary for both blends (Table 2 and Table 4) revealed that, at an advanced level of combustion, acetylene acts as an active reactivity control gas and not just an energy transfer gas.

3.4 Implications for Ammonia–Acetylene Blending

The acetylene blending literature provides critical guidance for the development of ammonia–acetylene dual-fuel strategies. For all engine platforms, it has been well documented that acetylene works well at low energy fractions, where it promotes ignition and combustion. This characteristic has a direct relation to those of ammonia engines, which are faced with problems such as slow combustion speed, high ignition energy, and lower combustion stability.

While not much direct experimental studies on ammonia–acetylene combustion were identified, several investigations

provide indirect conceptual support for acetylene and ammonia blending strategies. Brusca et al. [3] demonstrated that co-fueling approaches can be used to mitigate combustion instability and knock tendencies associated with highly reactive fuels, offering a general framework relevant to managing acetylene reactivity. Sharma et al. [5] further discussed blending philosophies, safety considerations, and operational constraints for acetylene across different engine platforms, which are directly applicable to the design of ammonia–acetylene fuel strategies.

Evidence from gaseous-fuel blending studies also supports the broader principle of reactivity balancing through mixture design. Tangöz et al. [26] showed that blending acetylene with other gaseous fuels, such as hydrogen or methane, significantly influences combustion behavior and reactivity, illustrating how fuel blending can be used as a control mechanism. In addition, RCCI investigations by Deb and Paul [44,45] reinforce the concept of reactivity stratification between fuels of differing ignition characteristics as an effective means of regulating combustion phasing and stability.

4. EMISSION CHARACTERISTICS AND CONTROL TECHNIQUES

The dual nature of acetylene combustion improved oxidation efficiency and increased thermal loading on the other. This is also reflected in the emission behavior of engines powered by acetylene (Table 3). The literature has revealed a similar pattern of carbon-based emissions in both spark ignition, compression ignition, and dual fuel engines, but higher sensitivity in the case of NO_x emissions, based on the operating requirements.

4.1 Carbon Monoxide and Unburned Hydrocarbons

Acetylene induction rate, combustion modes, and operational parameters influence the emission of carbon monoxide (CO) and unburned hydrocarbons (HC) in both Spark-Ignition (SI), Compression-Ignition (CI), and advanced modes of combustion. Gupta et al. [1], in Figure 9 and Figure 11 and Sharma et al. [2] observed lower CO and HC emissions in SI engines at optimized acetylene flow rates, suggesting better combustion completeness. In contrast, Özer et al. [27] observed increased CO emissions alongside reduced HC when acetylene was blended with gasoline by mass (Fig. 8 and Fig. 10).

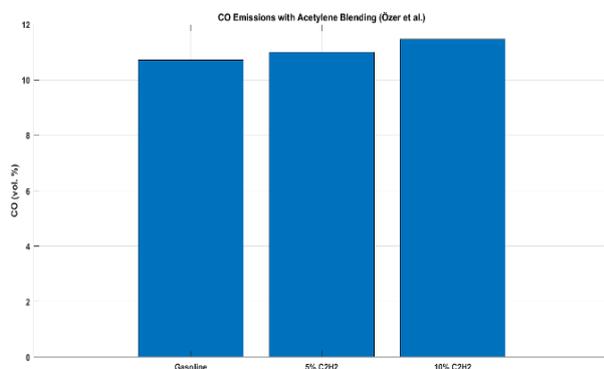


Fig. 8: Carbon monoxide emissions of gasoline–acetylene blends in an SI engine [27].

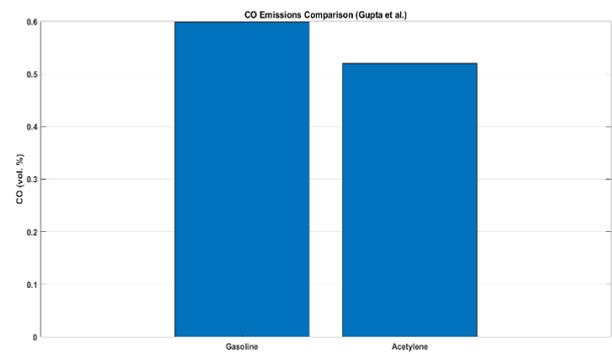


Fig. 9: Carbon monoxide emissions for gasoline and acetylene operation [1].

In CI and dual-fuel engines, multiple studies report reductions in CO and HC emissions at moderate acetylene induction rates due to improved premixed combustion and improved oxidation of fuel-rich regions [4,18,32,33,35]. However, these benefits diminish when acetylene induction becomes excessive or under low-load conditions, where incomplete utilization of the inducted gaseous fuel leads to increased partial oxidation products [19,34].

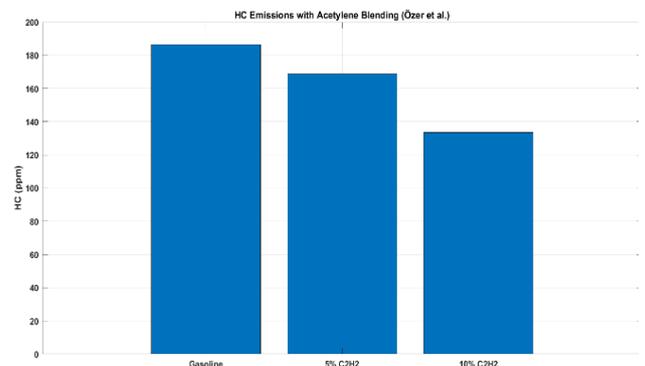


Fig. 10: Unburned hydrocarbon emissions of gasoline–acetylene blends in an SI engine [27].

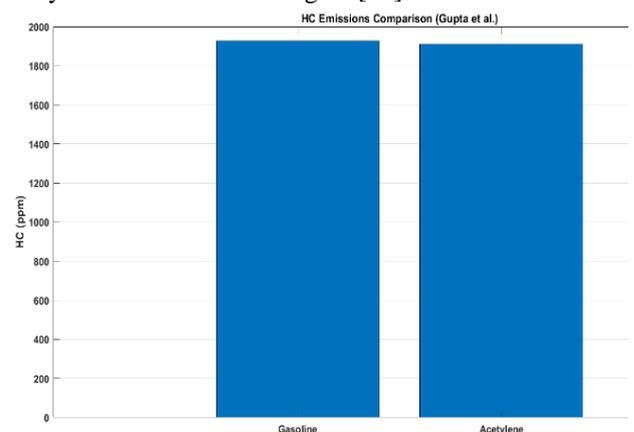


Fig. 11: Unburned hydrocarbon emissions for gasoline and acetylene operation [1].

In CI and dual-fuel engines, multiple studies report reductions in CO and HC emissions at moderate acetylene induction rates due to improved premixed combustion and improved oxidation of fuel-rich regions [4,18,32,33,35]. However, these benefits diminish when acetylene induction becomes excessive or under low-load conditions, where incomplete utilization of the inducted gaseous fuel leads to increased partial oxidation products [19,34].

Despite acetylene's high reactivity, poorly phased or excessively diluted mixtures can worsen incomplete combustion, as advanced combustion configurations, such as reactivity-controlled compression ignition (RCCI), further show that careful control of combustion phasing is essential to suppress CO and HC emissions [43,46]. It has been observed that adding acetylene can decrease CO and HC emissions, but this relies mostly upon fuel control.

4.2 Particulate Matter and Smoke Emissions

Particulate matter and smoke emissions in acetylene-fueled engines are primarily governed by changes in local equivalence ratio, mixing quality, and the balance between premixed and diffusion-controlled combustion. In compression-ignition and dual-fuel configurations, numerous experimental studies report substantial reductions in smoke opacity with acetylene induction (Fig. 12 and Fig. 13), which are commonly attributed to better premixed combustion and improved oxidation of soot precursors [4,16,19,30]. These smoke reduction trends are particularly pronounced when acetylene is combined with biodiesel or oxygenated fuels, which increase local oxygen availability and suppress soot formation under optimized operating conditions [16,21,32,33,36,37,49–52].

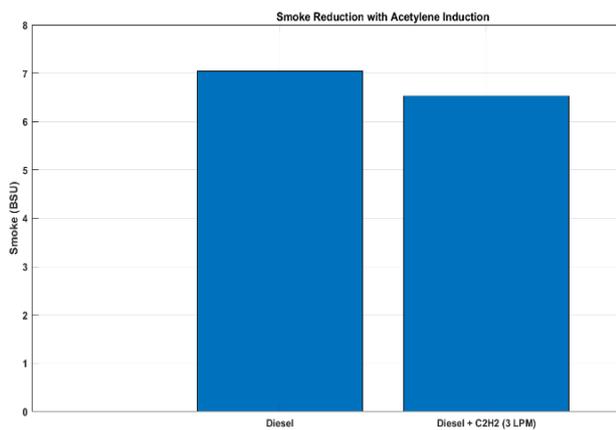


Fig.12: Smoke opacity variation with acetylene induction in a diesel engine [30].

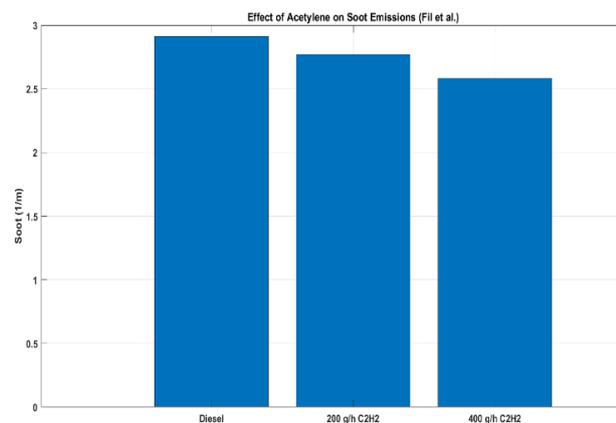


Fig. 13: Soot concentration for diesel and acetylene-fueled operation [19].

Despite these generally favorable trends, marginal increases in smoke emissions have been observed under certain operating regimes, such as very lean mixtures or poorly timed acetylene induction, where incomplete mixing can create locally rich zones and promote diffusion-limited combustion [28,29]. A finding that shows the sensitivity of

particulate formation to acetylene induction strategy and charge preparation rather than fuel chemistry alone. Numerical and experimental optimization studies further reinforce this interpretation, indicating that improvements in turbulence intensity, air–fuel mixing, and overall oxygen distribution play a dominant role in particulate mitigation [23,53]. Supporting this view, chemical kinetics modelling identifies acetylene as a key soot precursor species whose concentration influences soot growth dynamics, but whose impact on particulate emissions in engines is strongly mediated by combustion conditions and mixing processes [48].

4.3 Nitrogen Oxides: Divergent Trends and Underlying Causes

In contrast to carbon-based emissions, NO_x behavior shows significant variability across studies. The majority of investigations report an increase in NO_x emissions with increasing acetylene fraction, driven by elevated peak combustion temperatures and accelerated heat release rates [10].

These divergent trends across acetylene-fueled engine studies, reflect the competing influences of combustion temperature, heat release rate, and combustion phasing. In spark-ignition engines, Özer et al. [27], shown in Figure 14, reported increases in NO_x emissions and exhaust gas temperature with acetylene addition, indicating intensified combustion and elevated thermal conditions. However, studies incorporating charge-cooling or reactivity-management strategies demonstrate that this trend can be reversed. For example, Gupta et al. [1] showed that combining acetylene operation with water injection effectively reduced NO_x formation by moderating peak in-cylinder temperatures.

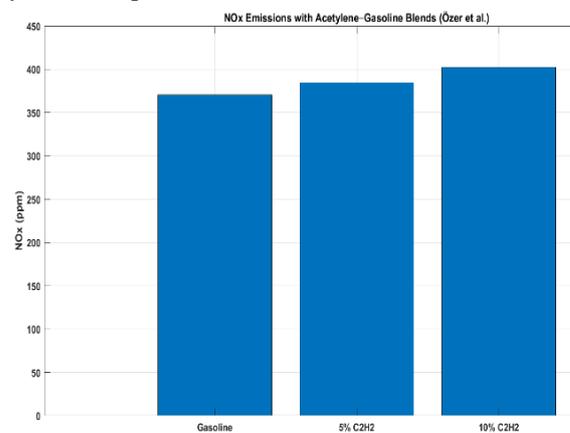


Fig. 14: NO_x emissions of gasoline–acetylene blends in an SI engine [27].

In conventional compression-ignition and acetylene dual-fuel engines, as shown Figure 15, many investigations report increased NO_x emissions at higher acetylene substitution levels due to improved rapid heat release, particularly under advanced injection or high-load conditions [4,30,38]. Similar NO_x increases have been observed when combustion phasing shifts toward earlier heat release, resulting in higher local flame temperatures [16,19,21,34].

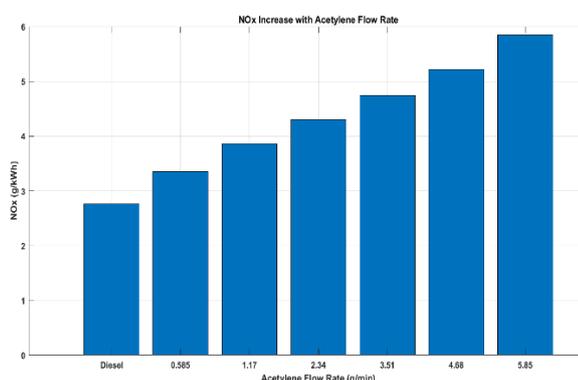


Fig. 15: NO_x emissions as a function of acetylene flow rate in a dual-fuel diesel engine [18].

In contrast, biodiesel-based dual-fuel configurations and reactivity-controlled combustion modes, such as RCCI, frequently report NO_x reductions despite acetylene addition [36,37,43,45,50]. These reductions are commonly attributed to altered combustion phasing, increased latent heat of vaporization, and more distributed heat release, which collectively suppress peak temperature formation.

4.4 Emission Control Strategies

A range of emission control strategies has been investigated in order to alleviate the trade-offs associated with acetylene-fueled combustion. Charge-cooling approaches, specifically water injection, are consistently reported to suppress NO_x formation by reducing peak in-cylinder temperatures while maintaining acceptable thermal efficiency [1,20]. Exhaust gas recirculation has also been shown to effectively lower NO_x emissions and moderate pressure rise rates, albeit with potential efficiency penalties at higher EGR levels [40].

Fuel-based strategies play an important role in emission mitigation, especially in compression-ignition and dual-fuel configurations. The use of oxygenated fuels such as ethanol, diethyl ether, and butanol improves oxidation of CO and HC and contributes to smoke reduction by improving local oxygen availability during combustion [49,54]. In addition, recent studies incorporating nanoparticle additives, particularly cerium oxide, demonstrate further reductions in CO, HC, and smoke emissions without significant adverse effects on engine efficiency [23].

Operational control and optimization strategies are equally critical. Several studies emphasize the importance of optimizing acetylene induction rate to balance combustion enhancement against excessive heat release and NO_x formation [4,18,35]. Adjustments to injection pressure and timing of the pilot fuel have also been shown to influence combustion phasing and emission outcomes [38,39]. More recently, advanced optimization techniques, including response surface methodology and machine-learning-based approaches, have been applied to identify optimal operating windows that simultaneously improve efficiency and reduce emissions in acetylene-fueled engines [42,43].

5. SAFETY AND STORAGE

Storage and safety concerns represent the most significant barrier to the widespread deployment of acetylene in internal combustion engines [10]. As already alluded, acetylene is chemically unstable at elevated pressures and can undergo explosive decomposition. Furthermore, its wide flammability limits and extremely low ignition energy

substantially increase the risk of flashback, pre-ignition, and unintended ignition events [21,33,55]. Multiple studies emphasize that controlled induction, timed injection, and lean operation are essential to prevent backfire and preignition [3, 5, 20,28-30]. On-demand acetylene generation systems offer a practical solution to storage and handling challenges while supporting stable engine operation [18]. Basha et al. [40] and Kumaran et al. [35] demonstrated that on-board acetylene generation from calcium carbide can mitigate storage risks, although careful flow control remains essential.



Fig.16: Safety and Risks associated with the use of acetylene (Also refer to Table 5)

6. SUSTAINABILITY AND LIFE-CYCLE CONSIDERATIONS

The use of acetylene as an engine fuel will largely be influenced by the mode of its production. Conventional acetylene production routes based on fossil feedstocks are highly energy-intensive and associated with significant greenhouse gas emissions [56]. Life-cycle assessment (LCA) studies indicate that engine-level efficiency improvements achieved through acetylene addition are insufficient to offset these upstream emissions [39]. In contrast, acetylene produced via renewable electricity or low-carbon feedstocks could offer meaningful environmental benefits, particularly when used as a supplementary fuel in high-efficiency engine concepts.

Within literature, acetylene is predominantly framed as an enabling fuel that improved the utilization of renewable or waste-derived liquids [16,17,21,32,55, 57,58]. Studies involving turpentine oil [35], jackfruit seed biodiesel [36], n-butanol blends [37], microalgae biodiesel [59], cashew nut shell oil biodiesel with nanoparticles [50], waste cooking biodiesel [51], and cottonseed biodiesel in LHR engines [52] consistently report improvements in combustion behavior and reductions in smoke or incomplete-combustion emissions.

7. RESEARCH GAPS AND FUTURE DIRECTIONS

Although a substantial body of experimental work exists, some research gaps exist across the acetylene engine literature. Long-term durability and wear studies are notably absent, despite repeated reports of high pressure rise rates, combustion noise, and elevated peak pressures in acetylene-fueled SI and CI engines. Similarly, after treatment compatibility has received little attention, even though NO_x increases are consistently reported in both dual-fuel and advanced combustion configurations. The absence of standardized safety procedures for engine-scale acetylene use is another significant drawback. Today's experiments employ different research configurations, fueling techniques, and safety measures. Also, transient, load following, or cold

starting is largely overlooked in the experiments, as there is a focus on the steady state over a short term.

7.1 Acetylene–Ammonia Dual-Fuel Pathway: A Future Research Direction

Ammonia has gained increasing attention as a potential fuel for internal combustion engines due to its carbon-free molecular composition and compatibility with established fuel storage and distribution infrastructure [60,61]. However, the practical deployment of ammonia in engine applications is fundamentally constrained by its poor inherent combustion behavior. In particular, its low energy density, elevated autoignition temperature, slow flame propagation, restricted flammability limits, and high ignition energy requirement collectively result in delayed ignition, unstable combustion, and incomplete oxidation, especially under lean operation and low engine loads [62,63].

To mitigate these intrinsic drawbacks, a substantial body of research has focused on dual-fuel combustion approaches, most notably combining ammonia with diesel in compression-ignition engines [64–66]. Within these configurations, diesel is employed as a high-reactivity ignition source, while ammonia contributes a significant share of the total fuel energy.

Acetylene's combustion behavior contrasts sharply with ammonia's combustion difficulties, which include slow flame growth, great sensitivity to ignition timing, high ignition resistance, and restricted workable equivalency ratios. High laminar flame speed, low ignition energy, and quick heat-release kinetics are characteristics of acetylene that have been widely used in spark-ignition, compression-ignition, and advanced combustion modes to enhance early combustion development and promote flame stabilization even at very low energy fractions. From the perspective of combustion-reactivity, this basic difference indicates that ammonia and acetylene are conceptually complementary.

In light of acetylene's demonstrated effectiveness as a combustion-promoting additive across multiple engine platforms, its application as a low-fraction ignition enhancer for ammonia-fueled engines emerges as a technically sound extension of existing dual-fuel strategies. Equally important, prior acetylene studies emphasize the necessity of operating within narrow stability limits, carefully managing pressure rise rates, and applying appropriate NOx control measures. These provide a valuable design framework for ammonia–

acetylene systems that prioritize combustion stability and controllability rather than high levels of acetylene substitution. Consequently, targeted investigation of ammonia–acetylene co-fueling represents a well-justified and promising research direction for overcoming the fundamental combustion limitations that presently restrict ammonia engine implementation.

8. CONCLUSIONS

Based on data from the literature, this review has systematically examined the use of acetylene as a supplementary and alternative fuel for spark ignition, compression ignition, dual fuel, and advanced combustion cycles. Due to its narrow flammability limits, high burning speed, and low ignition energy, acetylene continuously elevates the levels of combustion intensity and thermal efficiency in conventional SI and CI engines. While NOx penalties have been observed at higher substitution levels and earlier compression ratios in advanced combustion cycles, acetylene merely acts as a reactivity modifier at dual fuel and RCCI modes by promoting the stability of ignitions and reducing the formation of incomplete combustion substances like CO, HC, Smoke, and Particulates.

The reviewed studies further demonstrate that emission trends associated with acetylene are strongly dependent on engine operating conditions, injection strategies, and synergistic fuel pairing. Techniques such as controlled manifold injection, optimized injection timing, oxygenated fuel blending, water injection, and combustion chamber design modifications are shown to mitigate safety concerns and manage NOx formation while preserving efficiency gains. Importantly, the literature confirms that acetylene should not be treated as a drop-in primary fuel, but rather as a carefully metered combustion enhancer within well-controlled dual-fuel or reactivity-controlled strategies.

Looking ahead, these findings offer a scientifically solid basis for expanding acetylene research to low-carbon fuels with weak auto-ignition properties, such as ammonia. The potential use of acetylene as a reactivity promoter in ammonia combustion cycles can be inferred by the fact that it has the potential to stabilize ignition, accelerate the development of the flame front, or improve the release of heat. However, such uses have not been experimentally validated. They include safe handling of the fuel, combustion phasing, and NOx reduction

A. 9. Summary Tables

1) Table 1. Properties of some main alternative and traditional fuels [2][67][68]

Properties	Diesel	CNG	*Aqueous Ammonia	Acetylene	Hydrogen	Gasoline	Biogas	LPG	Units
Higher Heating Value (HHV)	46.6	54.5	-	-	-	-	-	-	MJ/kg
Lower Heating Value (LHV)	42.98	49.2	4.65	48.22	120	44	17	45.7	MJ/kg
Cetane Number	52	-	-	-	-	-	-	-	-
Octane Number	-	120-125	-	-	> 120	92–98	130	-	-
Flash point	56	-188.5	-	-	-	-	-	-	°C
Auto-ignition Temperature	180-230	539-640	651	300–330	585	240–310	650	405–450	°C
Viscosity	2.2	-	-	-	-	-	-	-	-
Density	820	0.734	88	1.092	0.09	720–780	1.2	2.26	kg/m ³
Stoichiometric ratio	14.92	-	3.83	13.2	34.3	14.6	5.8	15.5	mm ² /s
Flammability limit	0.6–5.5	5–15	-	2.5-81	4–75	1.2–8	7.5–14	2.15–9.6	(Vol %)
Flame speed	-	0.38	-	1.5	1.85	0.37-0.43	0.25	0.44	m/s

* "WE CHEM Cas No: 1336–21–6, 25% Ammonia". Except aqueous ammonia, all other alternative fuels are gaseous fuels.

2) Table 2. Performance Effects of Acetylene in Different Engine Types

Engine type	Operating conditions	Acetylene fraction	Typical BTE effect	Key limitation	References
SI engine	Part-load, lean / stoichiometric	Low mass or volumetric share ($\approx 5\text{--}10\%$)	Slight BTE improvement under lean conditions; reduction at higher fractions	Knock, backfire, NOx rise	[10,22,24,26,27]
CI engine (dual-fuel)	Medium–high load	Moderate energy share ($\approx 10\text{--}30\%$)	Increases or approaches diesel BTE; saturation at high flow	High PRR, NOx increase	[18,19,28,29,30,31,34,38–40,58]
RCCI / reactivity-controlled	Variable load	Low gaseous fraction	Improved combustion phasing and efficiency	Narrow operating window, ringing	[43,46,69,70]
LHR / modified engines	High load	High induction possible	Noticeable BTE improvement	Thermal stress, durability	[23,52]

3) Table 3. Emission Trends Associated with Acetylene Utilization

Emission	Typical trend	Dominant cause	Sensitive parameters	Key references
CO	Decrease (most CI dual-fuel cases)	Faster oxidation, improved premixed burn	Load, oxygenated fuels	[16,18,23,28,29,31,36,37,43,49,54,58]
HC	Decrease especially in CI	Improved ignition vs flame instability	Acetylene flow, AFR	[18,22,24,27,28,29,31,37,43]
NOx	Often increases	Higher peak temperature, advanced phasing	Injection timing, additives	EGR, [16,19,21,34,38,39,40,51,59]
PM/Smoke	Consistent decrease (CI)	Reduced diffusion combustion, better oxidation	Pilot fuel, load	[18,23,28,29,30,31,43,50,58]

4) Table 4. Acetylene-Based Fuel Blends and Their Implications

Blend	Engine type	Primary benefit	Key limitation	References
Acetylene–gasoline	SI	Lean operation, HC reduction	NOx rise, knock	[10,22,24,27]
Acetylene–LPG	SI	Lean limit extension	Backfire risk	[25]
Acetylene–hydrogen methane	/ SI	Reactivity tuning	Efficiency loss (CH_4), (H_2)	NOx [26]
Acetylene–diesel	CI (dual-fuel)	PM and CO reduction	NOx, PRR	[18,19,28,29,30,31,34,38,39,40]
Acetylene–biodiesel blends	CI / RCCI	Efficiency and emission synergy	Thermal NOx	[43,21,16,21,23,36,46,49–54,58,69,70]

5) Table 5. Key Safety and Practical Challenges

Challenge	Affected systems	Impact	Mitigation strategy	References
Backfire / pre-ignition	SI, gaseous induction	Engine damage	Low fraction, controlled injection	[10,22,28,29,40]
High pressure rise rate	CI, RCCI	Noise, wear	Injection timing, EGR, dilution	[19,34,38,39,40]
Storage and handling	All	Safety risk	On-board generation, low pressure	[18,30,40]
Thermal / material stress	High-load, LHR	Durability concerns	Additives, cooling strategies	[16,50,56]

REFERENCES

- [1] Gupta, Keshav & Suthar, Kishanlal & Jain, Sheetal & Agarwal, Ghanshyam & Nayyar, Ashish. (2018). Design and experimental investigations on six-stroke SI engine using acetylene with water injection. *Environmental Science and Pollution Research*. 25. 1-12. 10.1007/s11356-018-2407-2.
- [2] Sharma, Sumit & Sharma, Dilip & Soni, Shyam & Singh, Digambar. (2020). Effect of acetylene fuelling on performance, emission and combustion characteristics of stationary spark-ignition engine. *Environmental Progress & Sustainable Energy*. 39. 10.1002/ep.13451.
- [3] Brusca, S. & Lanzafame, R. & Garrano, A. & Messina, Michele. (2014). On the Possibility to Run an Internal Combustion Engine on Acetylene and Alcohol. *Energy Procedia*. 45. 889-898. 10.1016/j.egypro.2014.01.094.
- [4] Raman, Roshan & Kumar, Naveen. (2020). Experimental Studies to Evaluate the Combustion, Performance and Emission characteristics of Acetylene fuelled CI Engine. *International Journal of Ambient Energy*. 43. 1-28. 10.1080/01430750.2019.1709896.
- [5] Sharma, Sumit & Sharma, Dilip & Soni, Shyam & Singh, Digambar. (2019). Performance, combustion and emission analysis of internal combustion engines fuelled with acetylene – a review. *International Journal of Ambient Energy*. 43. 10.1080/01430750.2019.1663369.
- [6] Wulff, Joseph W., Maynard Hulett, and Sunggyu Lee. 2001. "Dual Fuel Composition Including Acetylene for Use with Diesel and Other Internal Combustion Engines." United States Patent.
- [7] Lakshmanan, T. & Govindan, Nagarajan. (2010). Experimental investigation on dual fuel operation of acetylene in a DI diesel engine. *Fuel Processing Technology - FUEL PROCESS TECHNOL*. 91. 496-503. 10.1016/j.fuproc.2009.12.010.
- [8] Salvi, Dr. B.L. & Subramanian, Kizhaeral & Panwar, N.L.. (2013). Alternative fuels for transportation vehicles: A technical review. *Renewable and Sustainable Energy Reviews*. 25. 404–419. 10.1016/j.rser.2013.04.017.
- [9] Sharma, Pushpendra & Sharma, Dilip & Soni, Shyam & Jhalani, Amit. (2019). Characterization of the Nonroad Modified Diesel Engine Using a Novel Entropy-VIKOR Approach: Experimental Investigation and Numerical Simulation. *Journal of Energy Resources Technology*. 10.1115/1.4042717].
- [10] Sharma, Sumit, Dilip Sharma, Shyam Lal Soni, and Digambar Singh. 2022. "Experimental Investigation on Spark-Ignition (SI) Engine Fuelled with Acetylene in Dual-Fuel Mode." *International Journal of Ambient Energy* 43 (1): 2369–75. doi:10.1080/01430750.2020.1735519.
- [11] Meda, V.S. Optimization of Induction Length and Flow Rates of Acetylene in Diesel Engine, Ms Thesis, National Institute of Technology, Orissa, India, 2011.
- [12] Raman, Roshan. (2023). Acetylene as a Sustainable Fuel for Diesel Engine. 10.1201/9781003272717-2.
- [13] Sharma, Sumit & Sharma, Dilip & Singh, Digambar & Sharma, Pushpendra. (2021). Impact assessment of acetylene fueling on the performance, emissions, and combustion of a spark-ignition engine. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*. 47. 1-19. 10.1080/15567036.2021.1991051.
- [14] Wang, Qian-Peng & Yang, Jing & Xu, Yu-Feng & Zhu, Zi-Qiang & Wu, Ling-Nan & Kuang, Jiu-Jie & Du, Wang & Braun-Unkhoff, Marina & Tian, Zhen-Yu. (2025). Elucidating high-pressure chemistry in acetylene oxidation: Jet-stirred reactor experiments, pressure effects, and kinetic interpretation. *Combustion and Flame*. 272. 113835. 10.1016/j.combustflame.2024.113835.
- [15] Slavinskaya, Nadezhda & Mirzayeva, Aziza & Whitside, Ryan & Starcke, Jan Hendrik & Abbasi, Mehdi & Auyelkhankyzy, Moldir & Chernov, Victor. (2019). A modelling study of acetylene oxidation and pyrolysis. *Combustion and Flame*. 210. 10.1016/j.combustflame.2019.08.024.
- [16] Jayabal, Ravikumar. (2024). Environmental and energy impacts of lychee seed biodiesel blends with acetylene fumigation in a dual-fuel diesel engine. *Results in Engineering*. 25. 103659. 10.1016/j.rineng.2024.103659.
- [17] Aisosa Oni, B., Eshorame Sanni, S., Daramola, M., and Victoria Olawepo, A., "Effects of oxy-acetylation on performance, combustion and emission characteristics of Botryococcus braunii microalgae biodiesel-fuelled CI engines", *Fuel*, vol. 296, Art. no. 120675, Elsevier, 2021. doi:10.1016/j.fuel.2021.120675.
- [18] Basha, Khader. "Experimental Analysis of Diesel Engine with Variable Flow of Acetylene Gas in Dual Fuel Mode." *International Journal of Ambient Energy*, 2020. doi:10.1080/01430750.2020.1797873.
- [19] Fil, Enes & Akansu, Selahaddin & Ilhak, Mehmet. (2022). Experimental assessment on performance, emission and combustion characteristics of the use of diesel-acetylene mixtures at different loads in a ci

- engine. *Fuel*. 324. 124469. 10.1016/j.fuel.2022.124469.
- [20] Lakshmanan, T. & Ahmed, A. & Govindan, Nagarajan. (2012). Effect of Water Injection in Acetylene-Diesel Dual Fuel DI Diesel Engine. ASME 2012 Internal Combustion Engine Division Fall Technical Conference, ICEF 2012. 10.1115/ICEF2012-92145.
- [21] Damian, Christopher & Devarajan, Yuvarajan & Jayabal, Ravikumar. (2025). Enhancing diesel engine thermal efficiency with candlenut biodiesel and acetylene fumigation: A dual-fuel approach to performance improvement and emission reduction. *Environmental Progress & Sustainable Energy*. 10.1002/ep.70168.
- [22] Ilhak, Mehmet & Akansu, Selahaddin & Ünal, Sebahattin. (2018). Experimental study on an SI engine fuelled by gasoline/acetylene mixtures. *Energy*. 151. 10.1016/j.energy.2018.03.108.
- [23] Thodda, Gavaskar & Saravanamuthu, Murugapoopathi & Vasudevan, D. & Baligheid, Sagar & Amesho, Kassian. (2024). Sustainable emission reduction in CI engines using cerium nanoparticles and acetylene-cedar wood oil biofuel. *Clean Technologies and Environmental Policy*. 26. 1-17. 10.1007/s10098-024-02768-4.
- [24] Ilhak, Mehmet & Doğan, Reyhane & Akansu, Selahaddin. (2020). Experimental study on an SI engine fueled by gasoline, ethanol and acetylene at partial loads. *Fuel*. 261. 116148. 10.1016/j.fuel.2019.116148.
- [25] Cinar, Gursel & Eldamanhory, Abdelrahman & Akansu, Selahaddin & Fil, Huseyin & Ilhak, Mehmet. (2020). Experimental Study on an Si Engine Fuelled by LPG/Acetylene Mixtures. *International Journal of Automotive Technology*. 21. 1323-1331. 10.1007/s12239-020-0125-5.
- [26] Tangöz, Selim & Ilhak, Mehmet & Akansu, Selahaddin. (2018). Experimental Investigation of Performance and Emissions of an Si Engine Fueled by Acetylene-Methane, and Acetylene-Hydrogen Blends. *Fresenius Environmental Bulletin*. 27.
- [27] Özer, Salih & Akçay, Mehmet & Yilmaz, Ilker. (2020). The effects of the use of acetylene gas as an alternative fuel in a gasoline engine. *International Advanced Researches and Engineering Journal*. Early. 10.35860/iarej.680463.
- [28] Lakshmanan, T. & Govindan, Nagarajan. (2011). Experimental investigation of port injection of acetylene in DI diesel engine in dual fuel mode. *Fuel*. 90. 2571-2577. 10.1016/j.fuel.2011.03.039.
- [29] Lakshmanan, T. and Nagarajan, G., "Experimental investigation of timed manifold injection of acetylene in direct injection diesel engine in dual fuel mode". *Energy*. vol. 35, no. 8, Elsevier, pp. 3172–3178, 2010. doi:10.1016/j.energy.2010.03.055.
- [30] Lakshmanan, T. & Govindan, Nagarajan. (2009). Performance and Emission of Acetylene-Aspirated Diesel Engine. *Jordan J Mech Indust Eng*. 3.
- [31] Raman, Roshan. "Experimental Investigation to Analyze the Effect of Induction Length of Diesel Acetylene Dual Fuel Engine," 2019. doi:10.1080/15567036.2019.1663314.
- [32] Behera, Pritinika & Murugan, Santhosh & Govindan, Nagarajan. (2014). Dual fuel operation of used transformer oil with acetylene in a DI diesel engine. *Energy Conversion and Management*. 87. 840–847. 10.1016/j.enconman.2014.07.034.
- [33] Koli, Somnath & Rao, Y.V.H.. (2021). Combustion analysis of single cylinder diesel engine operated on dual fuel mode. *Materials Today: Proceedings*. 47. 10.1016/j.matpr.2021.03.389.
- [34] Koli, Somnath & Rao, Y.V.H.. (2021). Study of low compression ratio on the performance of diesel engine in dual fuel operation with different flow rates of acetylene. *Fuel*. 284. 118969. 10.1016/j.fuel.2020.118969.
- [35] Kumaran, Dhandayuthapani & Rajendran, Mahadevan & Kumaravelan, R. & Sathish Gandhi, V. C.. (2013). Testing of three-fuel mixture in a four-stroke single cylinder direct injection diesel engine. *Transactions of FAMENA*. 37. 75 - 86.
- [36] Gavaskar, T. & M, Venkata & Arun, K. & Arivazhagan, S.. (2023). The combined effect of green synthesized nitrogen-doped carbon quantum dots blended jackfruit seed biodiesel and acetylene gas tested on the dual fuel engine. *Energy*. 275. 127296. 10.1016/j.energy.2023.127296.
- [37] Raman, Roshan & Kumar, Naveen. (2019). The utilization of n-butanol/diesel blends in Acetylene Dual Fuel Engine. *Energy Reports*. 5. 1030-1040. 10.1016/j.egy.2019.08.005.
- [38] Srivastava, Anmesh & Soni, Shyam & Sharma, Dilip & Jain, Narayan. (2018). Effect of injection pressure on performance, emission, and combustion characteristics of diesel-acetylene-fuelled single cylinder stationary CI engine. *Environmental Science and Pollution Research*. 25. 10.1007/s11356-017-1070-3.
- [39] Thodda, Gavaskar & Kathapillai, Arun & Madhavan, Venkata & Saravanamuthu, Murugapoopathi. (2022). Experimental analysis on the influence of compression ratio, flow rate, injection pressure, and injection timing on the acetylene — diesel aspirated dual fuel engine. *Environmental*

- Science and Pollution Research. 30. 1-17. 10.1007/s11356-022-21483-5.
- [40] Basha, Shaik & Rao, N.V.Narasimha & Shaik, Meeravali & Balasubramaniam, Stalin. (2020). Performance analysis and control of NOx emissions in diesel engine using on-board acetylene gas from calcium carbide. *Materials today: proceedings*. 33. 10.1016/j.matpr.2020.08.439.
- [41] Rabeti, Masoud. "Predictive Modelling and Optimization of Performance and Emissions of Acetylene Fuelled CI Engine Using ANN and RSM." *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, 2020. doi:10.1080/15567036.2020.1829191.
- [42] Van Giao Nguyen, Brijesh Dager, Ajay Chhillar, Prabhakar Sharma, Sameh M. Osman, Duc Trong Nguyen Le, Jerzy Kowalski, Thanh Hai Truong, Prem Shanker Yadav, Dao Nam Cao & Viet Dung Tran. (2024) Desirability-based optimization of dual-fuel diesel engine using acetylene as an alternative fuel. *Case Studies in Thermal Engineering* 59, pages 104488
- [43] Muthuswamy, Sonachalam & Paul Pandian, P. & V, Manienyan. (2020). Emission reduction in diesel engine with acetylene gas and biodiesel using inlet manifold injection. *Clean Technologies and Environmental Policy*. 22. 1-15. 10.1007/s10098-020-01968-y.
- [44] Deb P, Paul A. Advancing RCCI engine performance via optimal acetylene premix ratios and advanced diesel injection timing: An experimental investigation. *Environ Prog Sustainable Energy*. 2024; 43(4):e14375. doi:10.1002/ep.14375
- [45] Deb, Parthasarathi. (2023). Effect of acetylene as a low reactivity fuel on performance, combustion, exergy and emissions of an acetylene/diesel RCCI engine with variable premix ratios. *Sustainable Energy & Fuels*. 7. 10.1039/D3SE00440F.
- [46] Muthuswamy, Sonachalam & Jayaprakash, R. & V, Manienyan & Rao, P.S. & Vinodhini, G. & Sharma, Manish & Kalyani, Teku & Warimani, Mahammadsalman & Majdi, Hasan & T.M., Yunus Khan & Shaik, Abdul & Shetty, Keerthi. (2024). Performance Analysis of Dual-Fuel Engines Using Acetylene and Microalgae Biodiesel: The Role of Fuel Injection Timing. *Case Studies in Thermal Engineering*. 64. 105370. 10.1016/j.csite.2024.105370.
- [47] Blanquart, Guillaume & Pepiot, Perrine & Pitsch, H.. (2009). Chemical mechanism for high temperature combustion of engine relevant fuels with emphasis on soot precursors. *Combustion and Flame*. 156. 588-607. 10.1016/j.combustflame.2008.12.007.
- [48] Zhao, Feiyang & Yang, W.M. & Zhou, Dezhi & Wenbin, Yu & Li, Jing & Tay, Kun. (2017). Numerical modelling of soot formation and oxidation using phenomenological soot modelling approach in a dual-fueled compression ignition engine. *Fuel*. 188. 10.1016/j.fuel.2016.10.054.
- [49] Said, Zafar & Raman, Roshan & Garg, Aman & Caliskan, Hakan & Khan, Yunis & Rashidi, Mohammad. (2025). Oxygenated Fuels in Acetylene-Diesel Dual Fuel Engine: Enhancing Performance and Emission Control. *Energy*. 317. 134710. 10.1016/j.energy.2025.134710.
- [50] Leo, G & Saravanamuthu, Murugapopathi & Thodda, Gavaskar & Baligheid, Sagar & Jayabal, Ravikumar & Nedunchezhiyan, Mukilarasan & Devarajan, Yuvarajan. (2023). Optimisation and environmental analysis of waste cashew nut shell oil biodiesel/cerium oxide nanoparticles blends and acetylene fumigation in agricultural diesel engine. *Sustainable Energy Technologies and Assessments*. 58. 103375. 10.1016/j.seta.2023.103375.
- [51] Bhan, Suraj & Yadav, Prem & Gautam, Girish & Gautam, Ragvendra & Kumar, Saket & Kumar, Manish. (2025). Optimization of performance and emissions of a diesel engine using acetylene-enriched waste cooking biodiesel. *Clean Technologies and Environmental Policy*. 27. 6365-6386. 10.1007/s10098-025-03267-w.
- [52] Sree, G. & Sree, P. & Reddy, Chandra. (2024). Performance evaluation of low heat loss piston engine fuelled with acetylene and cottonseed biodiesel. *Multiscale and Multidisciplinary Modeling, Experiments and Design*. 7. 10.1007/s41939-024-00478-4.
- [53] Babusankar, G. & V, Manienyan & Shanmugam, Sivaprakasam. (2022). Numerical Investigation of a Dual Fuel Engine Fueled by Diesel-Acetylene and Biodiesel-Acetylene with Modified Piston Bowl Geometry. *Arabian Journal for Science and Engineering*. 48. 10.1007/s13369-022-07254-x.
- [54] Singh, Gursharan & Sharma, Shubham & Singh, Jujhar & Kumar, Som & Singh, Yadvinder & Ahmadi, Mohammad & Issakhov, Alibek. (2021). Optimization of performance, combustion and emission characteristics of acetylene aspirated diesel engine with oxygenated fuels: An Experimental approach. *Energy Reports*. 7. 1857-1874. 10.1016/j.egyr.2021.03.022.
- [55] Pandey, Krishna Kumar, 2024. "Application of acetylene in multi-cylinder low heat rejection diesel engine fueled with ternary blend," *Energy*, Elsevier, vol. 311(C).
- [56] Smirnov, N. & Betelin, V.B. & Nikitin, V. & Phylippov, Yu.G. & Koo, Jaye. (2014). Detonation
-

- engine fed by acetylene–oxygen mixture. *Acta Astronautica*. 104. 134–146. 10.1016/j.actaastro.2014.07.019.
- [57] Karuppaiya, Muthukumar & Kasiraman, Ganapathy. (2024). Downcycled neat LDPE plastic wastes fuelled CI engine's Carbon and Soot Emission reduction with an elevated performance by Acetylene (HC CH) Premixed combustion. *Process Safety and Environmental Protection*. 191. 10.1016/j.psep.2024.08.070.
- [58] R L, Dr & Anchupogu, Praveen & Reddy, R. Meenakshi & Gangula, Vidyasagar & Balasubramanian, Dhinesh & Veerasamy, Saravanan. (2023). Optimization of biodiesel yield and performance investigations on diesel engine powered with hydrogen and acetylene gas injected with enriched Jojoba biodiesel blend. *International Journal of Hydrogen Energy*. 50. 10.1016/j.ijhydene.2023.09.166.
- [59] Muthuswamy, Sonachalam & Jayaprakash, R. & V, Manieniyam & M, Srinivasa & MGM, Johar & Shanmugam, Sivaprakasam & Warimani, Mahammadsalman & Kumar, Nithin & Majdi, Ali & Alsubih, Majed & Islam, Saiful & Abdullah, Muhammad Irsyad. (2024). Impact of injection pressure on a dual-fuel engine using acetylene gas and microalgae blends of *Chlorella protothecoides*. *Case Studies in Thermal Engineering*. 60. 104653. 10.1016/j.csite.2024.104653.
- [60] MacFarlane, D. R., P. Cherepanov, J. Choi, B. Suryanto, R. Y. Hodgetts, J. Bakker, F. Ferrero Vallana, and A. Simonov. 2020. A Roadmap to the Ammonia Economy. *Joule*, 4, 1186-1205. <https://doi.org/10.1016/j.joule.2020.04.004>.
- [61] Gubbi, S., C. Renee, E. Benjamin, N. David, S. Robert, S. Wenting, and T. Lieuwen. 2023. Air Quality Implications of Using Ammonia as a Renewable Fuel: How Low Can NO_x Emissions. *ACS Energy Letters* 8 2023: 4421- 4426. <https://doi.org/10.1021/acsenerylett.3c01256>.
- [62] Estevez, R., J. Francisco, López-Tenllado, L. Aguado-Deblas, F. M. Bautista, A. A. Romero, and D. Luna. 2023. Current Research on Green Ammonia NH₃ as a Potential Vector Energy for Power Storage and Engine Fuels: A Review. *Energies* 16, no. 14 2023: 5451. <https://doi.org/10.3390/en16145451>.
- [63] Rocha, A. S., Br. Morales, H. M. El Mashad, Y. Pan, Y. Zhao, and F. M. Mitloehner. 2024. Effect of Eminex® on Greenhouse Gas and Ammonia Emissions from Dairy Slurry and Lagoon Wastewater. *Sustainability* 16, no. 13 2024: 5778. <https://doi.org/10.3390/su16135778>.
- [64] Manigandan, S., J.I. Ryu, T.R. Praveen Kumar, and M. Elgendi. 2023. Hydrogen and Ammonia as a Primary Fuel – A Critical Review of Production Technologies, Diesel Engine Applications, and Challenges. *Fuel* 352 2023: 129100. <https://doi.org/10.1016/j.fuel.2023.129100>.
- [65] Qian, F., S. Zhang, J. Wang, N. Zhu, X. Bao, H. Yang, X. Xu, W.A. Alshahrani, M.H Helal and Z. Guo. 2024. Ammonia Energy Fraction Effect on the Combustion and Reduced NO_x Emission of Ammonia/Diesel Dual Fuel. *Environmental Research* 261 2024: 119530. <https://doi.org/10.1016/j.envres.2024.119530>.
- [66] Al-Dawody, M.F., W. Al-Obaidi, E.D. Aboud, M.A. Abdulwahid, K. Al-Farhany, W. Jamshed, A. Iqbal. 2023. Mechanical engineering advantages of a dual fuel diesel engine powered by diesel and aqueous ammonia mixtures. *Fuel* 346, 128398.
- [67] Kül, V. S., and S. O. Akansu . 2023. Experimental Investigation into the Impact of Natural Gas-Diesel Mixture on Exhaust Emissions and Engine Performance in a Heavy-Duty Diesel Engine with Six Cylinders. *International Journal of Automotive Science and Technology* 7, no. 4 December 2023: 360–71. <https://doi.org/10.30939/ijastech>.
- [68] Kül, V. S., and S. O. Akansu , and G. Çınar. 2024. Experimental Investigation of the Effects of Aqueous Ammonia and Water Mixtures on the Efficiency and Emissions of a Compression Ignition Engine. *Process Safety and Environmental Protection* 191. <https://doi.org/10.1016/j.psep.2024.09.051>.
- [69] Samir, Ahmed & Devarajan, Yuvarajan & Al-Ridah, Zaid & Sandeep, H. & Nagarajan, A.. (2020). Ignition study of neat biodiesel in dual fueled research engine. *Fuel*. 281. 118673. 10.1016/j.fuel.2020.118673.
- [70] Oni, Babalola & Sanni, Samuel & Alaba, Peter & Hessien, Mahmoud & El-Bahy, Zeinhom. (2021). Investigating the performance of acetylated diethyl ether–Camelina sativa biodiesel as fuel in compression ignition engine. *Energy Ecology and Environment*. 2021. 1-15. 10.1007/s40974-021-00230-5