ISSN: 2985-4393

Performance Analysis of a Jet Burner Using Waste Oil and Gasoline Mixtures as Alternative Fuels

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Abstract. The increasing demand for fossil fuels and the depletion of non-renewable resources have encouraged the search for alternative energy sources. One potential solution is the utilization of waste oil as a substitute fuel. This study aims to analyze the performance of a jet burner operated with various mixtures of waste oil and gasoline. The experimental method was applied using mixture variations of 100% waste oil, 90%:10%, 80%:20%, 70%:30%, and 60%:40% (waste oil: gasoline). Several parameters were measured, including flame temperature, heating value, and combustion rate. The results showed that the 60% waste oil: 40% gasoline mixture produced the highest performance, with a maximum flame temperature of 517 °C, a heating value of 301,000 kJ, and the most efficient combustion rate of 36.732 g/min. The findings indicate that increasing the gasoline proportion improves combustion quality but also increases fuel consumption. Overall, the modified burner achieved better performance compared to using waste oil alone, demonstrating its potential as an alternative and more efficient energy source.

Keywords: Waste Oil, Gasoline Mixture, Jet Burner, Alternative Fuel, Combustion Performance.

1. INTRODUCTION

Growing energy demand and increasingly strict emissions regulations have accelerated the development of alternative fuels for combustion systems, including internal combustion engines, industrial burners, and gas turbine combustors. Evidence across combustion applications indicates that replacing conventional fossil fuels with bio-based, oxygenated, or waste-derived fuels can change combustion behavior and pollutant formation; however, such substitutions may introduce trade-offs in flame stability, efficiency, and regulated emissions depending on fuel physicochemical properties and operating conditions. A comprehensive review on gasoline engines emphasizes that density, viscosity, volatility, heating value, and oxygen content strongly influence performance and emissions, motivating systematic fuel screening and characterization when assessing alternative candidates [1]. A statistical, property-driven evaluation framework has also been proposed to connect physical properties to combustion and emission trends, supporting more structured selection of suitable alternative fuels [2].

In aviation and gas turbine contexts, Jet-A/Jet A-1 blending with bio-derived components and additives has been widely investigated to reduce environmental impacts while maintaining operability. Additives in Jet-A blends can significantly influence combustion, emissions, and exergetic performance in a micro-gas turbine engine, highlighting blend formulation as a key optimization lever [3]. Engine-level testing of soap-derived biokerosene blended with Jet A-1 demonstrated operational feasibility while revealing blend-dependent performance and emission variations [4]. In addition, lab-scale gas turbine combustor studies on drop-in aviation biofuels underline the need to assess stability and emissions under combustor-relevant conditions rather than relying solely on fuel property compliance [5].

Among waste-derived options, waste cooking oil (WCO) is attractive due to availability and circular-economy potential. Diagnostics such as flame spectroscopy have been used to evaluate WCO blends in industrial burner settings, illustrating measurable differences in flame behavior for alternative fuels [6]. For gas-turbine-relevant lean premixed/lean pre-vaporized premixed combustion, WCO methyl ester–Jet A-1 blends have been shown to affect combustion and emissions in swirl-stabilized configurations [7], and flame characteristics have also been reported for Jet A-1/WCO biodiesel blends stabilized by a radial swirler in lean pre-vaporized premixed combustors [8]. These findings motivate targeted studies linking blend ratio and stabilization aerodynamics to flame structure and emissions for safe and efficient high-substitution operation.

2. LITERATURE REVIEW

2.1 Fuel Properties As Drivers Of Combustion And Emissions

Fuel physicochemical properties are fundamental determinants of combustion behavior and emissions. Masuk et al. synthesized broad evidence that variations in fuel composition and key properties can shift performance and emission tendencies (e.g., CO/HC/NOx), reinforcing the need for systematic comparisons across candidate fuels [1]. Kumar et al. further provided a statistical approach linking combustion and emission outcomes to measurable physical properties, enabling more structured screening and ranking of alternative fuels [2]. This perspective is directly relevant for Jet A-1 blending, where viscosity, volatility, density, and oxygen content can change markedly with bio-components and waste-derived additions.

2.2 Alternative Fuels And Blends For Gas Turbines and Jet A/Jet A-1 Combustors

A large body of work focuses on Jet-fuel-compatible alternatives for turbines. Manigandan et al. demonstrated that additives in Jet-A blends affect combustion, emissions, and exergetic metrics in a micro-gas turbine engine [3]. Reksowardojo et al. experimentally evaluated soap-derived biokerosene/Jet A-1 blends in a gas turbine engine, showing blend-dependent performance and emissions while confirming feasibility [4]. Feser and Gupta assessed drop-in aviation biofuels in a lab-scale gas turbine combustor and highlighted the importance of combustor-based stability and emission evaluation [5].

Other candidates include bio-derived jet blends and waste-derived liquids. Wang et al. investigated camelina-oil-derived jet fuel blends under distributed combustion and reported changes in performance and emissions tied to the combustion regime and blend composition [9]. Suchocki et al. tested kerosene blended with waste tyre pyrolysis oil in a miniature gas turbine and observed measurable impacts on performance and emissions, underscoring integration challenges for waste-based liquids in turbine hardware [10]. In swirl-stabilized combustors, comparative and parametric studies have shown that fuel chemistry and inlet conditions jointly control flame behavior—e.g., limonene/Jet A-1 blends under pre-heated swirling air [11], butyl butyrate/Jet A-1 blends across inlet-air temperatures [12], and acetone–butanol–ethanol (ABE)/Jet A-1 mixtures for turbine potential [13].

2.3 Waste Cooking Oil (WCO) Biodiesel and Waste-Derived Fuels In Burners/Combustors

WCO-based fuels have been studied using both diagnostics and performance-emission approaches. Mahfouz et al. applied flame spectroscopy to assess WCO blends in an industrial burner, indicating that optical diagnostics can help distinguish combustion behavior among alternative fuels [6]. For gas-turbine-relevant premixed combustion, Attia et al. examined WCO methyl ester–Jet A-1 blends in a swirl-stabilized lean pre-vaporized premixed flame and reported changes in combustion and emissions with blending [7]. Masoud et al. investigated Jet A-1/WCO biodiesel blends stabilized by a radial swirler in a lean pre-vaporized premixed combustor, demonstrating that both swirler configuration and blend ratio affect flame characteristics [8].

Broader waste-fuel studies also provide useful context. Comparative work on burner aerodynamics shows that configuration (e.g., swirl vs cross-jet) influences efficiency and environmental performance through mixing and stabilization mechanisms [14]. In industrial deployment, modern kiln burner technology has been discussed as enabling higher alternative-fuel substitution under current energy constraints [15]. Investigations of oil-burner flames using biodiesel blends further highlight changes in thermal, radiative, and pollutant emission characteristics relative to conventional fuels [16]. Waste automotive oil has also been compared against light diesel oil to evaluate combustion property differences relevant to alternative utilization [17], while low-NOx combustion of diesel and waste oil has been demonstrated in a steam burner concept, emphasizing the role of burner design in controlling emissions even with challenging fuels [18]. Finally, blending studies beyond turbine applications—such as jatropha oil with kerosene for lighting and cooking—provide additional evidence that kerosene blending behavior depends strongly on fuel properties and blend ratio [19].

2.4 Research Gap

Overall, prior studies confirm that (i) fuel properties govern combustion and emissions [1], [2], (ii) Jet A/Jet A-1 blends with additives and bio-components can be feasible but show blend- and condition-dependent stability/emissions [3]–[5], [9]–[13], and (iii) WCO biodiesel–Jet A-1 blends can significantly affect flame characteristics and emissions in swirl-stabilized lean premixed configurations [6]–[8]. However, a structured linkage is still needed between blend ratio and swirl-based stabilization parameters and their combined effects on flame structure (e.g., flame length/shape, heat-release distribution, radiative behavior) and regulated emissions (NOx, CO). Establishing such relationships would strengthen practical guidance for combustor/burner design and safe high-substitution operation with WCO-derived and other waste-based jet-fuel blends.

3. RESEARCH METHODOLOGY

3.1. Research Design

This study applied an experimental method with direct testing of a jet burner fueled by waste lubricating oil and gasoline mixtures. The purpose of the experiment was to analyze the effect of different blending ratios on combustion performance, heating rate, burning rate, and exhaust emissions. The research was conducted in a laboratory environment with controlled conditions to ensure reliable data collection.

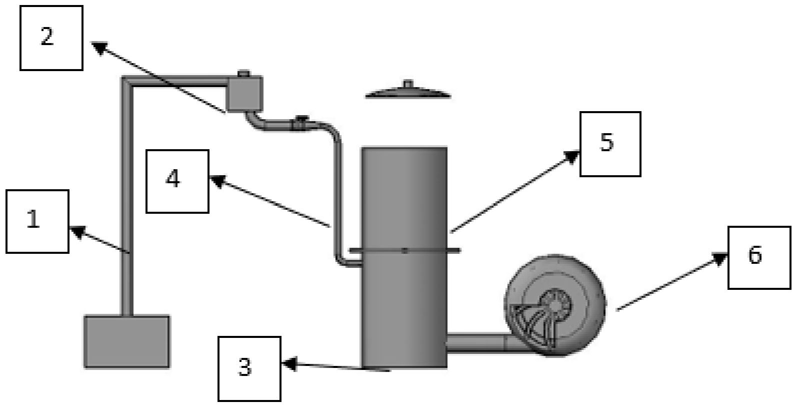

Figure 1. Burner Assembly

Description:
1. Fuel tank support
2. Fuel tank
3. Burner
4. Fuel hose
5. Water boiling pot
6. Blower

3.2. Tools and Materials

Tools
1. Burner – The burner used in this research was constructed from a 5.5 kg gas cylinder coated with refractory cement made of clay. The cement layer functions as heat insulation to prevent heat loss to the burner's surface. The burner dimensions are 35 cm in height and 25 cm in diameter, with an inner refractory coating of 5 cm and an outer aluminum insulation layer.
2. Capillary Tube – A copper tube with a diameter of 5 mm and a length of 3 m was used as the fuel inlet. The tube was shaped into a spiral to preheat the fuel before entering the burner, enhancing pressure and atomization. Copper was selected due to its high melting point (1085 °C).
3. Blower – A 2.5-inch blower with specifications of 220 V/50 Hz, 150 W power, 2-inch output diameter, and 3000 RPM no-load speed was employed to supply combustion air at pressures up to 2.5 atm.
4. Fuel Tank – Served as a container for fuel before it was supplied to the burner.
5. Infrared Thermometer – Used to measure flame temperature during combustion with high accuracy and practicality.
6. Measuring Glass – Used to measure the volume of water for heating tests.

Materials
1. Waste Lubricating Oil – Used as the primary fuel in different volume ratios (60%, 70%, 80%, and 90%).
2. Gasoline – Blended with waste oil at complementary ratios (40%, 30%, 20%, and 10%).
3. Water – One liter of water was used as the heating medium for calorific value measurements.

3.3. Research Procedure

The experimental procedure consisted of the following steps:
1. Problem Identification – Defining the research objectives and parameters to be analyzed.
2. Literature Review – Collecting and analyzing previous research related to waste-oil-based fuels and combustion systems.
3. Burner Testing – Conducting operational tests using different waste oil–gasoline ratios.

4. Data Collection – Measuring flame temperature, heating rate, burning rate, and exhaust emissions using appropriate instruments.
5. Data Processing – Analyzing results using quantitative methods with Microsoft Excel 2013 to generate tables and graphs.
6. Conclusion Drawing – Summarizing the findings based on experimental data.

3.4. Data Collection and Analysis

(1) Flame Temperature Measurement

- The burner was ignited and allowed to reach stable combustion.
- Flame temperature was measured using an infrared thermometer.
- Each blending ratio was tested three times, and the results were tabulated

(2) Heating Rate Measurement

- One liter of water was used as the heating medium.
- Initial water temperature was recorded.
- The burner was operated for 10 minutes, after which the final temperature was measured.
- Heat released was calculated using the formula:

$$Q=m \cdot c \cdot \Delta T$$

where:

- Q = heat energy (J)
- m = mass of water (kg)
- c = specific heat capacity of water (J/kg·°C)
- ΔT = change in water temperature (°C)
- Each blending ratio was repeated three times, and the results were tabulated (Table 3.3).
  (3) Burning Rate Measurement
- One liter of water was heated until completely evaporated.
- The burning rate was calculated using the formula:

$$V=M/T$$

where:

- V = burning rate (liter/minute)
- M = fuel mass consumed (liter)
- T = combustion time (minute)
- Each fuel blend was tested three times, and results were recorded in tabular form.

4. RESULTS

The pineapple jam mixer machine was tested three times, with data collected three times, each with different results and different time intervals. The complete data can be seen in the table 1. Measurements were conducted on the jet burner using an infrared thermometer.

Table 1. Flame Temperature Test Results (°C)

No	Fuel Variation	Test 1	Test 2	Test 3	Average
1	Waste oil	393	405	395	397
2	90% : 10%	455	452	446	451
3	80% : 20%	459	463	466	462
4	70% : 30%	480	475	478	477
5	60% : 40%	515	510	528	517

Table 2. Heating Rate Test Results (Kilojoules)

No	Fuel Variation	Test 1	Test 2	Test 3	Average
1	Waste oil	294,000	289,800	298,200	292,600
2	90% : 10%	294,000	294,000	298,200	295,400
3	80% : 20%	294,000	298,200	294,000	295,400
4	70% : 30%	302,400	294,000	298,200	298,066
5	60% : 40%	302,400	294,000	302,400	301,000

Table 3. Combustion Rate Test Results (g/min)

No	Fuel Variation	Test 1	Test 2	Test 3	Average
1	Waste oil	27.027	28.571	26.315	27.304
2	90% : 10%	30.303	31.250	28.571	30.041
3	80% : 20%	31.250	35.741	32.258	33.083
4	70% : 30%	32.258	28.571	38.461	33.096
5	60% : 40%	34.482	40.000	35.714	36.732

5. DISCUSSION

Figure 1. The performance testing of the burner focused on three main parameters: flame temperature, heating rate, and combustion rate. These parameters were measured to evaluate the influence of different fuel variations (waste oil and its mixtures with gasoline) on burner efficiency.

Figure 1 summarizes burner performance testing using three key indicators—flame temperature, heating rate, and combustion rate—to evaluate how fuel composition affects overall burner efficiency. These indicators are commonly used to represent combustion intensity, useful heat transfer to the load (water), and fuel consumption behavior during operation. In general, the results show that blending waste oil with a more volatile fuel improves atomization and mixing, which can enhance flame stability and increase the effective heat release, consistent with broader findings that combustion and emission behavior are strongly driven by fuel physical properties such as viscosity and volatility and by the quality of air–fuel mixing in the burner/combustor [1], [14], [20].

Flame temperature. Based on Table 1, the highest average flame temperature was achieved by the 60% waste oil : 40% gasoline blend, reaching 517 °C, whereas pure waste oil yielded the lowest average at 397 °C. This trend is consistent with the underlying fuel-property mechanisms: waste oils typically have higher viscosity and lower volatility than light fuels such as gasoline, which can worsen atomization and delay evaporation, leading to weaker mixing and a greater likelihood of locally fuel-rich zones and incomplete combustion. Conversely, adding a more volatile component promotes finer spray breakup and faster vapor formation, improving air–fuel mixing and increasing the effective reaction rate and temperature [1], [14]. Similar conclusions have been reported in waste-oil combustion studies, where combustion behavior and pollutant formation are tightly linked to evaporation/mixing constraints and burner design strategies for stabilizing the flame [20]. Comparative assessments of waste-derived oils against conventional diesel-type fuels also show that waste oils can exhibit less favorable combustion properties without blending or burner modifications, reinforcing the need for improved atomization and mixing when using such fuels [17].

Heating rate. The heating rate (Table 2) followed the same overall pattern. The 60% waste oil : 40% gasoline blend produced the highest average heating value (reported as 301,000 kJ), while pure waste oil gave 292,600 kJ. The improvement suggests that the blend not only increased flame temperature but also enhanced useful heat transfer to the water load. In burner applications, better atomization and more complete combustion increase the fraction of released chemical energy converted into sensible heat in the flame and hot gases, which can improve convective/radiative heat transfer to the heated medium [15], [20]. The relatively small differences among the 70:30 and 80:20 cases indicate diminishing returns beyond a certain gasoline fraction, meaning that once atomization and evaporation improve sufficiently, additional volatility enhancement yields only limited extra gains because other constraints (airflow, mixing time, heat losses, and burner geometry) begin to dominate performance [14], [20].

Combustion rate. The combustion-rate results (Table 4.3) confirm that fuel composition strongly affects the speed of burning and overall fuel consumption. Pure waste oil showed the lowest average combustion rate (27.304 g/min), while the 60% waste oil : 40% gasoline blend showed the highest (36.732 g/min). A higher combustion rate for the blend is expected because improved volatility and reduced viscosity typically shorten ignition delay and increase the burning rate through faster evaporation and more intense mixing-controlled combustion [1], [14]. However, it also implies that fuel consumption increases as gasoline fraction rises, which must be interpreted carefully: higher consumption may indicate higher heat release and stronger combustion, but it can also reduce overall fuel economy depending on whether the additional burning translates proportionally into useful heat delivered to the load [14]. In practical burner systems, the observed increase in combustion rate often accompanies reduced visible smoke and more stable flames when transitioning from heavy/waste oils to blended fuels, as more complete oxidation reduces soot-forming conditions [20].

Overall performance interpretation. Considering all three indicators together, the results consistently identify 60% waste oil : 40% gasoline as the best-performing blend among the tested conditions because it produced the highest flame temperature, highest heating rate, and fastest combustion rate. Meanwhile, pure waste oil exhibited limitations consistent with its physical characteristics—high viscosity and lower volatility—which reduce atomization quality, slow evaporation, and increase the risk of incomplete combustion and smoke formation [1], [14], [17], [20]. These outcomes align with broader burner/combustor literature showing that combustion efficiency and environmental performance depend not only on fuel chemistry but also on mixing and stabilization mechanisms; improved mixing generally increases efficiency and can reduce incomplete-combustion products [6], [20]. Therefore, the experiment demonstrates that blending waste oil with gasoline is an effective approach to enhance burner performance and flame stability in the tested setup, primarily by improving atomization and air–fuel mixing and thus increasing the intensity and completeness of combustion [1], [14], [20].

6. CONCLUSION

Based on the experimental results and analysis, the following conclusions are drawn:

1) Fuel blending significantly improved burner operation. The 60% waste oil : 40% gasoline mixture produced the highest average flame temperature (517 °C), highest heating result (301,000 kJ), and highest combustion rate (36.732 g/min) compared with other tested variations.
2) Among all tested fuels, the 60% waste oil: 40% gasoline blend delivered the most optimal overall performance, indicating that introducing a sufficiently volatile component can overcome the atomization and evaporation limitations of pure waste oil and lead to more complete combustion.
3) Increasing the gasoline fraction tended to increase the combustion rate (fuel consumption). This reflects faster burning associated with improved volatility and mixing, and it should be considered in future work when optimizing both performance and fuel economy.
4) Overall, the burner system achieved the intended goal of improving performance relative to operating with pure waste oil, demonstrating that blending is a practical and effective method to enhance combustion stability and heat delivery in this configuration.

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