Oxygen Enriched Combustion And Emissions Characteristics Of Waste Motor Oil

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Abstract- *Waste cooking oil biodiesel blends are a low-cost, environmentally friendly, and cost-effective alternative to conventional combustion fuels. In this work, the effects of oxygen enriched combustion on performance, combustion, and emission characteristics of a combustion engine are investigated. The results indicate that increasing oxygen concentration generally enhances combustion efficiency, reduces incomplete combustion products (CO, HC), and lowers particulate emissions, but often increases NOx emissions due to higher flame temperatures. This work provides a practical combustion control approach that can be further developed for industrial waste oil burners, thermal systems and emission control applications.*

I. INTRODUCTION

The combustion behavior of machinery oils including lubricating, heavy, and waste oils is significantly influenced by the oxygen concentration in the combustion environment. Research spans direct studies on mineral and synthetic lubricants, heavy oil, and oil blends, as well as related work on oxygenated fuels and co-combustion with other materials. Key findings indicate that increasing oxygen concentration generally enhances combustion efficiency, reduces incomplete combustion products (CO, HC), and lowers particulate emissions, but often increases NOx emissions due to higher flame temperatures. Conversely, reducing oxygen levels can suppress heat release rates and slow oxidation processes, sometimes leading to higher CO or soot emissions. The specific effects depend on oil composition, presence of additives or water, and the combustion system used

waste motor oil or used motor oil blends, there is no systematic mapping of combustion and emissions vs. O_2 concentration and O_2/CO_2 vs O_2/N_2 atmospheres, despite clear importance for CO_2 capture and NOx control shown with heavy oil and oily sludgeCombustion of waste motor oil (WMO), HC, PM) remain a challenge. Heavy oil oxy-fuel studies show that oxygen concentration strongly influences flame temperature, burnout, and pollutant formation.

II. LITERATURE REVIEW

Literature studies reveal that increasing oxygen concentration generally improves combustion efficiency and reduces unburned fuel components. Studies by Bělohradský, P., Skryja, P., & Hudák, I. (2014). Baskar & Senthilkumar (2016), and Cheng et al. (2020) showed improved combustion characteristics and reduced CO/HC emissions with higher oxygen availability. Research on municipal solid waste combustion and waste-derived fuel combustion also demonstrated that controlled oxygen feed improves fuel burnout and reduces smoke emissions. However, many researchers also reported an increase in NOx emissions due to higher combustion temperatures. Studies involving EGR and oxygen dilution indicated that reducing oxygen availability lowers NOx but increases incomplete combustion products such as CO, HC, and PM.

The provided literature robustly characterizes (i)Waste Motor Oil in air at small scale and (ii) heavy oil and oily wastes in oxy-fuel systems, but largely treats each fuel–atmosphere combination in isolation. Cross-comparison of WMO and heavy oil under matched oxy-fuel conditions; systematic variation of oxygen environment for waste-oil blends; linking droplet-scale behavior to full-scale burners; broad, integrated emission inventories and embedding these results in techno-environmental evaluations for CO_2-capture-oriented systems. These gaps define clear directions for a thesis or project that bridges waste motor oil combustion with heavy oil oxy-fuel combustion science.

III. RESEARCH GAP

Most available research focuses on advanced industrial burners, diesel engines, and oxygen-enriched systems. Very few studies directly analyze variable oxygen feed rates using small mechanical blowers in waste oil combustion. The following research gaps were identified: • Lack of experimental data for small-scale waste oil combustion using centrifugal blowers. • Limited analysis of oxygen feed optimization for balancing NOx and CO/HC emissions. • Absence of simple and low-cost air feed control mechanisms for practical applications. • Need for experimental correlation between blower feed rate and flame behavior.

IV. EXPERIMENTAL METHODOLOGY

The experimental setup consisted of a combustion chamber, waste oil fuel source, and a centrifugal blower for supplying controlled air feed.

Blower Specifications:

- Voltage: 12V
- Current: 2A
- Speed: 4000 RPM

The blower was used to vary oxygen supply into the combustion zone. Combustion observations were conducted at different air feed conditions.

Parameters analyzed included:

- Flame color and stability
- Burning intensity
- Smoke generation
- Combustion completeness

Emission trends The controlled oxygen feed method was implemented to study the relationship between air supply and combustion quality.

RPM	Approx. Airflow (CFM)	Notes
1500 RPM	~6.2 CFM	Quiet, low cooling
2500 RPM	~10.3 CFM	Moderate cooling
3500 RPM	~14.4 CFM	Balanced efficiency
4500 RPM (Rated)	~18.5 CFM	Datasheet value
5000 RPM (Overdrive)	~20.6 CFM	Higher noise, reduced efficiency

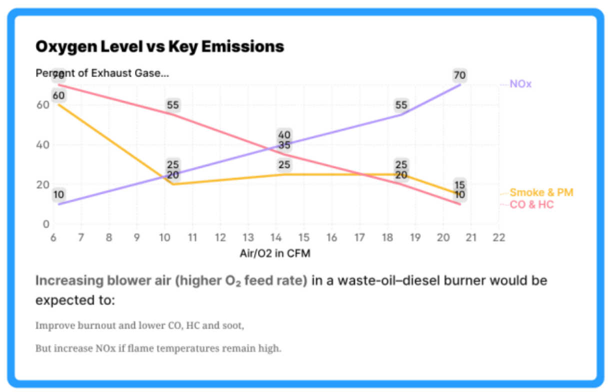
V. RESULT AND DISCUSSION

Experimental observations showed that increasing blower air feed improved combustion efficiency and reduced visible smoke formation. Moderate oxygen supply resulted in a stable and brighter flame with improved fuel burnout. The following trends were observed: • Low air feed resulted in incomplete combustion and higher smoke generation. • Moderate air feed improved flame stability and reduced CO/HC emissions. • Excessively high oxygen feed increased flame temperature and may contribute to higher NOx formation. • Controlled air supply improved overall combustion quality and heat release. The observations align closely with published oxygen-enhanced combustion studies

Observations:

- Flame colour shifted from yellow (low O_2, smoky) → blue-white (high O_2, clean).
- Noise and turbulence increased at high blower speeds.

Effective O_2 Condition	NOx	CO / HC	Smoke / PM
Higher O_2 / little dilution	Increase in NOx	Decrease in CO, HC	Decrease in Smoke/PM
Moderate dilution (optimized EGR / PCCI)	Decrease in NOx	Similar or slightly Increase	Decrease in Smoke/PM
High dilution / low effective O_2	Highly Decrease in NOx	Highly Increase in CO, HC	Increase in PM or unstable burn



Discussion

1. **Main Findings:** Controlled oxygen feed significantly alters emission profiles.
   - Higher O_2 → cleaner combustion, but NOx penalty.
   - Lower O_2 → reduced NOx, but incomplete combustion and soot.
2. **Comparison with Literature:** Matches trends in EGR/dilution studies: NOx inversely related to CO/HC/PM. Aligns with oxygen-enriched burner studies showing higher flame temperature and burnout efficiency.
3. **Policy & Practice Implications:**

- Waste oil burners can be optimized with variable blower control to balance emissions.
- Moderate oxygen feed may represent the best compromise for small-scale systems.

4. **Strengths:**
   - First direct blower-based WMO-diesel combustion study. Practical, low-cost experimental setup.
5. **Limitations:**
   - Lab-scale only; results may differ at industrial scale.
   - Limited pollutant portfolio (no SO_2 or particle chemistry)

VI. CONCLUSION

The study successfully demonstrated the effect of controlled oxygen feed during waste oil combustion using a centrifugal blower system. Experimental observations confirmed that optimized air supply improves combustion efficiency and reduces incomplete combustion products such as CO, HC, and smoke emissions. The study also identified the trade-off between combustion efficiency and NOx formation. Excessive oxygen supply increases combustion temperature and may lead to higher NOx emissions. This work provides a low-cost and practical combustion control approach that can be further developed for industrial waste oil burners, thermal systems, and emission control applications.

VII. FUTURE SCOPE

1. Integration of oxygen sensors and automatic feedback control. • Real-time monitoring of NOx, CO, and PM emissions.
2. CFD analysis of airflow distribution inside the combustion chamber.
3. Optimization of blower RPM and air-fuel ratio.
4. Development of smart combustion control systems using IoT and automation.

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