Sustainable Conversion of Waste Lubricating Oil into Fuel-Grade Hydrocarbons through Catalytic Cracking

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***Abstract*—Lubricating oils are extensively used in automotive and industrial applications and are broadly classified as engine oils, gear oils, hydraulic oils, and turbine oils. Engine oils primarily reduce friction between moving components while also facilitating heat transfer, removal of wears debris and combustion by-products, and protection of metal surfaces against corrosion. These oils are formulated by blending base oils derived from crude oil with additives in specific proportions to achieve desired performance characteristics. The generation of large quantities of waste lubricating oil and its improper disposal pose significant environmental and public health risks. The conversion of used lubricating oil into high-value lighter gas oil fractions offers a resource-efficient and economically viable waste management strategy, particularly for developing economies such as India, by conserving petroleum resources and reducing foreign exchange expenditure. This study investigates a feasible process for converting waste lubricating oil into a high-value lighter gas oil fraction suitable for fuel applications. The hazardous nature of used lubricating oils and their environmental implications are also evaluated, highlighting the importance of effective recovery and reuse pathways.**

***Index Terms*—Catalytic cracking, Gas oil, Resource recovery, Recycling, Sustainability, Waste lubricating oil**

I. INTRODUCTION

The demand for lubricating oils in India is approximately 3.5 million tonnes annually, with engine oils accounting for nearly 55% of total consumption. Domestic production depends entirely on imported lube-bearing crude oils, making the sector resource-intensive and vulnerable to supply constraints. This highlights the importance of recycling and conversion pathways for waste lubricating oils.

During service, lubricating oils undergo physicochemical degradation due to thermal stress, oxidation, shear and contamination. These processes result in additive depletion, viscosity changes and accumulation of undesirable compounds, rendering the oil unfit for further use. Improper disposal of used lubricating oil poses serious environmental risks due to the presence of heavy metals and degraded additives. A single litre of used oil can contaminate up to one million litres of freshwater.

Waste engine oil is a complex mixture containing hydrocarbons, water, particulate matter and metallic contaminants. However, it can be effectively utilized as a feedstock for fuel production through appropriate processing techniques.

II. EXPERIMENTAL METHODOLOGY

A. Feedstock Preparation: Waste engine oil collected from petrol engines was filtered and dehydrated at 150^0C for 1 hour to remove moisture and impurities. The resulting filtered and dehydrated waste oil (FDWO) was used as feedstock.
B. Catalyst Selection: Cobalt oxalate (CoC_2O_4) was selected as the catalyst due to its effectiveness in hydrocarbon conversion reactions.
C. Reactor Setup and Operation: Experiments were conducted in a 3 L batch reactor.

- Feed: 1200 ml (1090.5 gm)
- Catalyst: 2 wt.%
- Temperature: 420^0C

Cracking initiated at approximately 395^0C, indicated by vapor formation.

III. RESULTS AND DISCUSSION

A. Feedstock Properties:

Table-1: Properties of filtered and dehydrated waste oil

SN	Property	Observations
1.	Redwood viscosity, (seconds)	at 40^0C- 424 at 100^0C- 61
2.	Specific Gravity at 29^0C	0.8885
3.	API Gravity at 29^0C, (^{0}API)	27.7589
4.	Pour Point, (^{0}C)	-24
5.	Flash Point (Clevland Open Cup method), (^{0}C)	193^0C
6.	Fire Point (Clevland Open Cup method), (^{0}C)	252
7.	Conradson Carbon Residue (wt. %)	0.9088

B. Material Balance:

Table-2: Material balance (Feed: 1090.5 gms)

SN	Products	Products obtained (gms)	Products obtained (wt.%)
1.	Liquid Product Obtained	928.8	85.17
2.	Residue Formed	50.10	4.60
3.	Amount of Feed Gasified	111.60	10.23
4.	Total Product Formed (Liquid+Gases), gms/% Total conversion	1040.4	95.40

C. Product Properties:

Table-3: Properties of products obtained

SN	Properties	
1	Redwood Viscosity (Sec.) at 40^0C	43.6
2	Specific Gravity, (at 29^0C)	83.58
3	API Gravity (at 29^0C), ^{0}API	37.7989
4	Aniline Point, (^{0}C)	75.5
5	Flash Point By Clevland Open Cup Method, (^{0}C)	37
6	Fire Point By Clevland Open Cup Method, (^{0}C)	56
7	Conradson Carbon Residue (wt.%)	0.0225
8	Pour Point, (^{0}C)	- 16
9	Bromine Number	3.66
10	Acid Value, mg KOH/gm	0.5619

D. Distillation Analysis

Table-4: ASTM distillation characteristics for liquid product obtained

SN	Temp.^{0}C	% Volume Distillate	Observations
1.	42	---	Heating started
2.	74	---	I.B.P.
3.	173	10 %	
4.	236	20 %	
5.	287	30 %	
6.	328	40 %	
7.	348	50 %	
8.	362	60 %	
9.	381	70 %	
10.	392	80 %	
11.	400	90 %	
12.	407	97.5 %	FBP

Total distillate collected: -- 97.50%, Residue: -- 0.9%, Losses: -- 1.6%

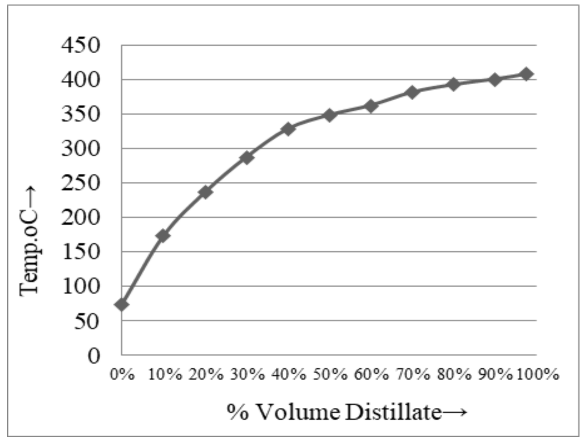

Figure-1: ASTM distillation characteristics of liquid product obtained

- Gasoline fraction (<200^0C): ~15.0%
- Gas oil fraction (200–390^0C): ~63.0%
- Heavy fraction (>390^0C): ~19.5%

The results indicate efficient conversion of waste oil into valuable fuel fractions. The high yield of diesel-range hydrocarbons demonstrates the effectiveness of catalytic cracking.

IV. CONCLUSION

Catalytic cracking of waste lubricating oil at 420^0C using cobalt oxalate yields high liquid recovery (85.17wt.%), with significant diesel-range fractions (~63%). The process effectively removes contaminants into the residue and produces cleaner fuel fractions. This method provides a sustainable solution for waste oil management by conserving resources, reducing environmental pollution, and supporting circular economy principles.

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