MICROWAVE PYROLYSIS, A SUSTAINABLE TREATMENT FOR RECYCLING USED CAR ENGINE OIL

Su Shiung Lam *, Alan D. Russell and Howard A. Chase
Department of Chemical Engineering and Biotechnology, University of Cambridge,
New Museums Site, Pembroke Street, Cambridge CB2 3RA, United Kingdom

Summary

We demonstrate the applicability of microwave pyrolysis to recycle used car engine oil. Waste oil was thermally cracked in a microwave-heated bed of particulate carbon from which oxygen was excluded, and the relationship between temperature, the carbon number distribution, the chemical composition of the hydrocarbons and the metal fraction produced was determined. The recovered pyrolysis products contained light hydrocarbons that could be used as a valuable industrial feedstock and fuel. They also showed a significant reduction in the metal contaminants that are accumulated throughout the use cycle of the oil, showing the excellent potential of microwave pyrolysis as a means for disposing of problematic waste oil.
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Keywords

Sustainability, Green GRE, Alternate Energy

Introduction

The production of waste car engine oil (WO) is estimated at 24 million tons each year throughout the world, posing a significant treatment and disposal problem for modern society. The WO also represents a potential source of high-value fuel and chemical feedstock. The preferred disposal option in most countries is incineration and combustion for energy recovery, though vacuum distillation and hydro-treatment have been researched to recycle this waste.[1] However, these disposal routes are becoming increasingly impracticable as concerns over environmental pollution and additional sludge disposal are recognized due to contaminants in WO.[2]

As part of the growing interest in waste recycling, alternative treatments for WO have been investigated with the aim of recovering both the energetic and chemical value of the WO. Pyrolysis, the thermal decomposition of a substance without oxygen, has been considered as a recycling alternative to incineration of the waste oil, with the resulting pyrolysis products being able to be used as chemical feedstock, and the char produced being used as a substitute for activated carbon. Much literature has been reported on the pyrolysis of wastes of a hydrocarbon nature, such as used tyres[3] and plastic waste[4], demonstrating pyrolysis has much promise in treating these kinds of waste. Although several studies have revealed the potential of pyrolysis as a disposal method for waste oil,[5] the use of this technology is not widespread as yet.

Microwave-induced pyrolysis is a relatively new process that was initially developed by Tech-En Ltd in Hainault, UK.[6] In microwave pyrolysis, hydrocarbon wastes are mixed with a highly microwave-absorbent material such as particulate carbon. These waste materials are then thermally cracked by microwave heating in the absence of oxygen into shorter hydrocarbon chains. The resulting gaseous products are subsequently condensed into liquid oils of different composition depending on the characteristics of the input substances and reaction conditions. The use of microwave radiation as a heat source facilitates an efficient transfer of heat to the waste and allows exceptional control over the heating process. In addition, the use of a carbon reaction bed provides a highly reducing reaction environment that reduces the formation of undesirable oxidized species. These factors have the potential to increase yields of desirable pyrolysis products that can be further treated and used as valuable industrial feedstock while simultaneously recycling difficult to dispose of waste.

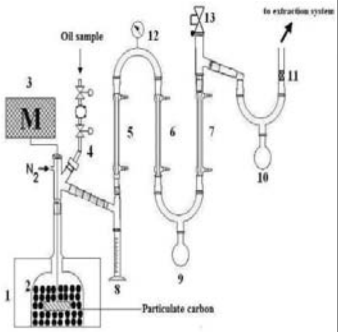
This study presents the development of a bench-scale semi-batch microwave-induced pyrolysis apparatus, which is tested with WO to compare the characteristics of this process with the results of previous work reported for WO pyrolysis. This work has been conducted to assess the technical feasibility of using microwave pyrolysis for the treatment of WO. While studies have been conducted using microwave pyrolysis to treat other wastes,[6] we

* To whom all correspondence should be addressed

believe this is the first application of this technology to WO.

Experimental Section

Apparatus.



1) Microwave oven
2) Reactor
3) Motor stirring system
4) Injecting vessel and valves
5,6,7) Condenser (60, 25, 0ºC)
8) Main collecting vessel
9) 2nd collecting vessel
10) Cold trap (about -70ºC)
11) Filter
12) Pressure gauge
13) Pressure relief valve.

Figure 1. Schematic layout of sembench-scale microwave-induced pyrolysis system.

Brief Experimental Procedure. 1 kg of carbon was placed into the quartz reactor. The carbon was heated to temperatures ranging from 250 to 700ºC, and maintained within 1% of the target temperature by computer control. Once target temperature was attained, 100 g of waste oil sample was then injected into the reactor. During the experiment gas was sampled after the filter (

Figure 1) into 10 L bags for later analysis. When the accumulation of liquid product had stopped and the pyrolysis reactions were complete, the microwave generator was switched off. The yield of solid product was determined by measurement of the weight change in the reactor (no solid products were observed to have left the reactor). The yield of liquid product was determined by measuring the weight increase in the collecting vessels and filter. The gas yield was determined by mass balance and assumes that whatever mass of added sample that is not accounted for by the solid and liquid product measurements had left the system in gaseous form. The data recorded is the average of the results obtained from three valid repeated runs performed under identical conditions. The pyrolysis products were analyzed by GC-MS, AAS, and SEM/EDX to identify their chemical composition.

Results and Discussion

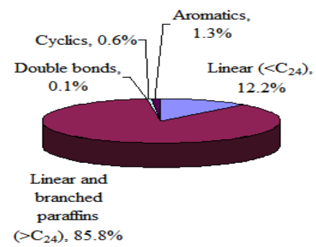


Figure 2. Main compounds identified by GC-MS for used car engine oil (peak area %).

Linear and branched paraffins with carbon chain lengths higher than C24 (i.e. 85.8%) are the predominant hydrocarbon structures in the composition of WO (Figure 2). The degradation rate increased rapidly with increase of temperature, showing the influence of process temperature on the reaction rate (Figure 3).

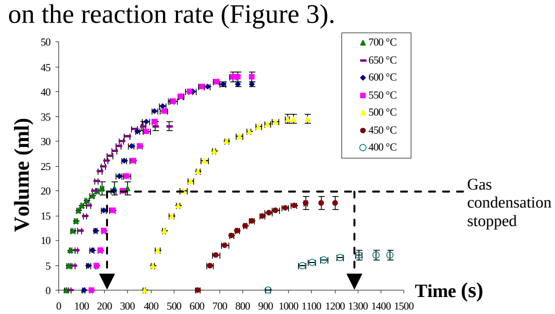


Figure 3. Cumulative yield (ml) of liquid products from WO pyrolysis.

Table 1 demonstrates the chemical compounds obtained in the pyrolysis products. Table 3 presents the concentrations of heavy metals in the waste oil and the liquid pyrolysis products obtained at different pyrolysis temperatures.

Table1. Prevalent compounds (TIC%) [1] obtained in microwave pyrolysis of WO

		500ºC	600ºC	700ºC
Liquid	Linear hydrocarbon	59.3	42.8	35.9
	Alkanes	28.4	9.2	1.1
	Alkenes	29.2	31.1	32.3
	Dialkenes	1.7	2.5	2.5
	Benzene	5.5	12.0	17.9
	Toluene	6.4	13.1	19.1
	Xylene	6.6	9.1	5.1
	Alkylbenzenes	18.1	17.9	6.4
Gas	Methane	10.0	16.6	24.1
	Ethane	3.1	7.5	6.7
	Ethene	25.4	33.7	37.3
	Propene	25.0	28.8	33.6
	Butenes	14.2	6.4	2.7
	1,3 Butadiene	8.5	5.4	1.9

[1] Total ion percentage.

Table 2. Concentrations (μg/g) [1] of each metal in the waste oil and liquid products

	Waste Oil	Liquid pyrolysis product 500ºC	600ºC	700ºC
Cd	0.26 ± 0.02	0.12 ± 0.01	0.14 ± 0.01	0.19 ± 0.03
Cr	2.0 ± 0.1	1.6 ± 0.1	1.6 ± 0.1	1.7 ± 0.1
Cu	11.0 ± 1.0	0.5 ± 0.01	1.1 ± 0.02	2.5 ± 0.01
Ni	55.0 ± 1.0	2.2 ± 0.1	2.5 ± 0.1	3.1 ± 0.1
Pb	74.0 ± 1.0	3.1 ± 0.2	3.9 ± 0.1	7.1 ± 0.2
Zn	760 ± 5	83 ± 6	127 ± 5	228 ± 2
Fe	86.0 ± 2.0	4.9 ± 0.1	6.2 ± 0.1	9.1 ± 0.4

[1] Values are means ± SD of three valid runs (N = 3).

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