



Thermogravimetric and pyrolytic investigations on scrap tires



Mahmood M. Barbooti*

Applied Chemistry Division, Department of Applied Science, University of Technology, Sinaa Street, P.O. Box 18310, Baghdad, Iraq

ARTICLE INFO

Article history:

Received 24 January 2014

Accepted 20 October 2014

Available online 28 October 2014

Keywords:

Pyrolysis

Scrap tires

Thermogravimetry

Catalytic activity

Potassium carbonate

ABSTRACT

Thermogravimetric, TG, analysis of scrap tire (ST) powder indicated that it decomposes between 180 and 475 °C losing 60% of its weight in two step process. The material further decomposes to end up with only ~3.8% residual products at 680 °C. Potassium carbonate slightly affected the modes of scrap tires decomposition. On the basis of the TG results pyrolysis, experiments were carried out coupled with gas chromatographic analysis of the volatiles and trapping of the condensed liquids. The pyrolytic investigation was performed in a pyrex vertical reactor with sintered glass disc to hold the sample and aid fluidization with the nitrogen stream flowing upwards. Tar and char are collected and weighed. The effect of pyrolysis temperature and the presence of potassium carbonate on the tar, char and gas yields were studied. The C₁–C₃ content of the pyrolysis gases increased from 0.17% to 60.1% by increasing the pyrolysis temperature from 470 to 550 °C at the expense of the C₄ and C₅ components. Further, there was an increase in the hydrogen content of gaseous components with pyrolysis temperature increase.

© 2014 Elsevier B.V. All rights reserved.

1. Introduction

The search for energy alternative resources and raw materials stimulated studies for the conversion of the available by-products and wastes into useful materials and fuels. Pyrolytic routes have been employed to produce light hydrocarbons and liquids from local cellulosic materials using different systems [1,2]. Disposal of scrap tires (ST) is a serious environmental concern, occurring at an increasing rate every year. Disposal of large quantities of these materials in landfills, which is the current practice, is costly as well as a waste of a petroleum based resource. Pyrolytic treatment has been frequently evaluated for the conversion of ST into gases, liquids and carbon in several industrialized countries [1,3–6]. Juma et al. reported the characteristics of materials, methods, effect of various process parameters, kinetic modeling applied to the pyrolysis and combustion of tires, characteristics of the products and resulting emissions [7]. Some of the efforts in this context are in pilot plant stage, while others are still on the laboratory scale.

Benzene, toluene and xylenes present in the oils showed a significant increase in the presence of zeolite catalysts [8]. The benzene ring likely comes from the surface of the styrene-butadiene rubber, SBR. In addition, a Diels–Alder reaction can be a possible mechanism to create benzene rings in the gas phase [9]. Islam et al. [10], used a fixed-bed fire-tube heating pyrolysis reactor system for the recovery of liquid hydrocarbons from solid tire wastes. Pyrolytic

carbon black is one of the most important products of tire pyrolysis [11,12]. The resulting activated carbon displayed a specific surface area of 200 m² g⁻¹ [13]. The addition of NaOH facilitated the pyrolysis dramatically, as a maximum pyrolysis oil yield of about 48 wt% was achieved at 550 °C without the addition of basic additives, while a maximal pyrolysis oil yield of about 50 wt% was achieved at 480 °C by adding NaOH powder [14]. The pyrolysis kinetics of the scrap tire rubbers were well accounted for by the first-order irreversible independent reactions [15]. The reported activation energy of the pyrolysis was 147.95 kJ mol⁻¹ [16]. A pilot scalereactor was used by Kalitko (2009), with double-screw type with steam for the generation of steam as well as carbon (35% of the feed tires). Fluidized bed reactors were widely used of pyrolysis purposes as they offer short residence times and high heat and mass transfer [17].

In the present work a TG analytical investigation of ST is carried out to find the thermal decomposition paths and the catalytic activity of potassium carbonate on the decomposition. In addition, a batch-wise, bench-scale system was used to study the pyrolytic behavior of ST tires under various operating conditions. The catalytic effect of potassium carbonate on the thermal behavior of ST is also described.

2. Materials and method

2.1. Apparatus

The pyrolysis system is schematically shown in Fig. 1. A Pyrex tubular reactor (40 cm in length and 21 mm o.d.) with quickfit ends

* Tel.: +964 750 241 5259.

E-mail address: brbt2m@gmail.com

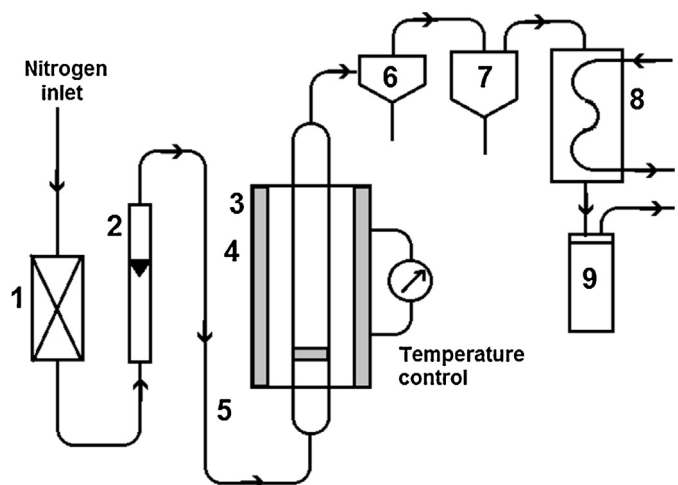


Fig. 1. Schematic diagram of the pyrolysis system: (1) dryer; (2) flow meter; (3) electrical furnace; (4) pyrex reactor; (5) sintered glass disc; (6) cyclone; (7) cooled trap; (8) condenser; and (9) distillate receiver.

was fixed vertically within a cylindrical furnace (250 mm in length) supplied from Analis Instruments Scientific, Belgium. The reactor was equipped with a sintered glass disc at one third of the reactor end 10 cm from the lower end of the furnace. The rest of the reactor extends upward and was thermally insulated with asbestos fiber. A gas inlet was applied to the lower end of the reactor, while a lab-scale glass cyclone was connected to the upper end for solid separation. The gases and vapors leaving the cyclone pass through traps and a condenser for liquid separation. Finally, the gases are stored and analyzed. Thermocouples were placed in various points along the internal wall of the furnace. The furnace temperature controller was then calibrated after running the furnace with empty reactors five times.

The TG, and derivative thermogravimetric, DTG, curves were recorded on a Stanton Redcroft model TG 760 Thermobalance under nitrogen atmosphere at a heating rate of $20\text{ }^{\circ}\text{C min}^{-1}$ and sample size of 3–6 mg.

The chromatographic analyses of the gaseous products were carried out on a Pye–Unicam GC-204 gas chromatograph equipped with Spectra Physics Autolab Minigrator. The conditions for the separation-determination of the various gases and volatiles are given in Table 1. A splitter was fitted into the outlet of the analytical column (Poropak Q or Squalane) to aid the parallel detection of hydrocarbons on a flame ionization detector (FID) and CO and water on thermal conductivity detector (TCD). The molecular sieve column was directly connected to the TCD. The signals from the two detector amplifiers were fed into the Minigrator via a selector switch to facilitate the integration recording of the output from either of them. For the identification and quantitative determination of individual gases, calibration standards supplied from Supelco were used.

2.2. Materials

The ST sample was supplied in powdered by the State Company for Rubber Industries, Diwaniya, Iraq and represented that piece of the tire which is in direct contact with the ground. The company has a separate factory for the production of reclaimed rubber to be included as 5% of the recipe of new tire production. The grinding facility is efficient to produce scrap tire particle with diameters of 0.5–10 mm. The material was a mixture of

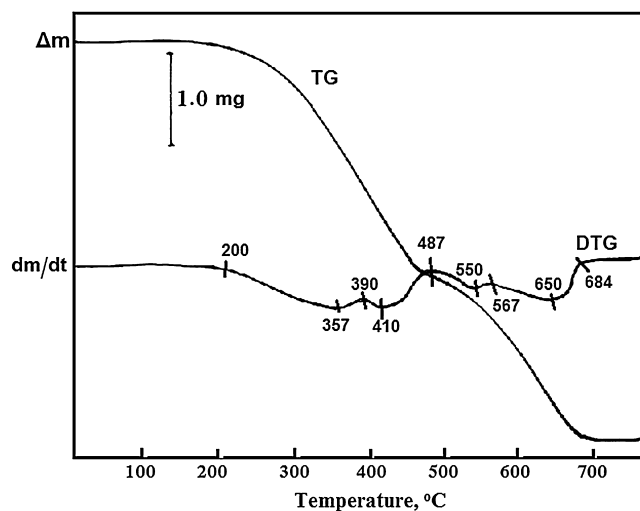


Fig. 2. TG and DTG curves of scrap tire sample.

various brands with the following average elemental analysis was:

Carbon%	H%	N%	S%
84.5	7.8	0.5	1.8

Potassium carbonate was obtained from BDH.

2.3. Procedure

The ST (0.5 mm particle size)- K_2CO_3 mixtures for the TG measurements were prepared by adding increasing volumes of K_2CO_3 solution to one gram samples of ST in a small beaker to incipient wetting. The samples were treated with the necessary amount of water to end up with equal volume aliquots. Another lot mixture of 100 g of SC was treated with an aliquot of K_2CO_3 solution to give a final salt concentration of 5% to be used for catalytic pyrolysis experiments. The beaker contents were thoroughly mixed and left for few days for natural drying.

The pyrex reactor loaded with the ST (1 mm particle size) or the ST- K_2CO_3 samples (2.5–4.0 g) was located and introduced into the furnace preheated to the required pyrolysis temperatures for the various experiments 450, 500, and 550 $^{\circ}\text{C}$. A nitrogen gas stream (250 ml min^{-1}) was maintained throughout the experiments. The experimental set up was made to ensure the quick (within 10–15 seconds) connection to other components. The pyrex reactor holding the sample is inserted into the hot furnace, to ensure the immediate heating at the set temperature. Preliminary runs indicated that appreciable pyrolysis occurs 35–50 s after the reactor's introduction into the furnace. Two gas samples were taken from each run: the first after 5 min of the reactor's introduction into the furnace and the second after 10 min.

3. Results and discussion

3.1. Thermogravimetric analysis

The TG and DTG curves of the ST samples are shown in Fig. 2. The ST started decomposition above 150 $^{\circ}\text{C}$ became appreciable at 180 $^{\circ}\text{C}$ and then proceeded at increasing rate. The process was terminated at 475 $^{\circ}\text{C}$ after the loss of 60% of the weight. It can be inferred from the DTG curve, which comprised two peaks, which the process occurs in two steps with a borderline at 400 $^{\circ}\text{C}$. At 400 $^{\circ}\text{C}$, the extent of weight loss was 45%. The product undergoes thermal decomposition in two overlapping steps at 480–550 $^{\circ}\text{C}$ and

Download English Version:

<https://daneshyari.com/en/article/1197334>

Download Persian Version:

<https://daneshyari.com/article/1197334>

[Daneshyari.com](https://daneshyari.com)