



Fast pyrolysis of creosote treated wood ties in a fluidized bed reactor and analytical characterization of product fractions



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ABSTRACT

A fraction of creosote treated wood ties was pyrolyzed in a pyrolysis plant equipped with a fluidized bed reactor and char-separation system at different temperatures. Analyses of each pyrolysis product, especially the oil, were carried out using a variety of analytical tools. The maximum oil yield was obtained at 458 °C with a value of 69.3 wt%. Oils obtained were easily separated into two phases, a creosote-derived fraction (CDF) and a wood-derived fraction (WDF). Major compounds of the WDF were acetic acid, furfural and levoglucosan, while the CDF was mainly composed of polycyclic aromatic hydrocarbons (PAHs), such as 1-methylnaphthalene, biphenyl, acenaphthene, dibenzofuran, fluorene, phenanthrene, anthracene, fluoranthene and pyrene. HPLC analysis showed that the concentration of PAHs of the CDF obtained at 458 °C constituted about 22.5 wt% of the oil.

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1. Introduction

Creosote is widely used as a wood preservative for telephone poles, railroad ties and bridge timbers. To make railroad ties, the amount of creosote between 40 and 175 kg/m³ of wood is pressed by the vacuum-high-pressure method [1]. The lifetime of the creosote treated wood is more than 30 years, whereas, that of typical wood is only up to 3 years [2]. Despite its versatility, the use of creosote as a preservative has decreased due to its carcinogenic character [3–6]. This character is due to the fact that creosote is mainly composed of polycyclic aromatic hydrocarbons (PAHs), such as naphthalene, quinoline, acenaphthene, dibenzofuran, phenanthrene, fluorene, anthracene, fluoranthene and pyrene [2]. According to the European Directive 2001/90/CE, the concentration of benzo[a]pyrene in a creosote treated wood must be less than 50 ppm [7].

In South Korea, the distribution of creosote treated wood ties has been banned since 2008. Currently, most remaining creosote treated wood ties are stacked alongside railroad tracks or in train stations. Consequently, eco-friendly and efficient treatment of creosote treated wood ties is strongly needed for the benefit of society. Pyrolysis is a promising technology that can produce alternative fuel oil or chemical feedstock. In particular, fast pyrolysis, which offers a high heat and mass transfer rate and

consequently more constant reaction conditions, provides a uniform spectrum of product due to the shorter residence time of the pyrolysis vapor in the reactor. Research on the fast pyrolysis and product analysis of creosote treated wood ties is scarce. One study, in which a fraction of creosote treated wood was pyrolyzed in a bench-scale pyrolysis plant, reported that creosote did not affect the composition and amount of bio-oil components [8].

In this study, a fraction of creosote wood treated ties was pyrolyzed in a bench-scale plant equipped with a fluidized bed reactor and char separation system. One goal of this study was to find the optimum reaction temperature for high oil yield. The other was to characterize the pyrolysis product fractions, especially bio-oil, by various analytical techniques to give more reliable results. For that purpose, relative response factors (RRFs) for each component were calculated using the effective carbon number (ECN) and reference compounds were applied in the gas chromatography (GC) analysis. In addition, the quantification of PAHs in the pyrolysis oil was conducted using a high performance liquid chromatography (HPLC) with the external standard method.

2. Experimental design

2.1. Feed material

Creosote treated wood ties were ground using a crusher, and then sieved to obtain particle sizes of 1–2 mm. Proximate analysis was conducted following ASTM D3172. In proximate analysis,

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Table 1
Main characteristics of the feed material.

Proximate analysis ^a	wt%	Ultimate analysis	wt%	Metal analysis	ppm
Volatile matter	90.9 ± 0.65	C	61.3	Na	10.4 ± 0.00
Fixed carbon	8.7 ± 0.64	H	6.6	K	114 ± 0.02
Ash	0.4 ± 0.12	N	0.4	Mg	104 ± 0.01
		S	0.1	Ca	2510 ± 0.43
HHV (MJ/kg)	26	O	28.8		

^a Air dry basis.

moisture content could not be exactly determined due to the presence of light volatiles in the creosote, which were evaporated below 100 °C during drying. The moisture plus volatile matter content of the feed material was 90.9 wt%. TGA experiments presented in Section 2.3 illustrate this fact. Carbon content in the feed material was 61.3 wt%, which was much higher than other typical lignocellulosic biomasses, which would result from the presence of creosote in the feed material. In contrast, oxygen content was relatively low with a value of 28.8 wt%. Consequently, the higher heating value of the feed material was high compared to woody biomasses, with a value of 26 MJ/kg. The main characteristics of the feed material are shown in Table 1.

2.2. Pyrolysis plant

Experiments were conducted in a bench-scale pyrolysis plant comprised of a two-screw feeding system, fluidized-bed reactor, char separation system, quenching system and product gas circulating system. Fig. 1 shows a schematic diagram of the plant.

The feeding system was equipped with two screw feeders, with variable feed rates, which helped uniformly feed the feed materials.

The feed material was put directly into a quartz sand bed with a mean diameter of 0.4 mm. To avert the deformation of feed material from heat, the entrance of the reactor was equipped with a water jacket. The fluidized-bed reactor, which was indirectly heated by electricity, was made of a 316 SS tube with an inner diameter of 110 mm and a height of 390 mm. The pyrolysis reaction temperature was determined by the average value of the three thermocouples in the reactor. To prevent a reflux of pyrolysis vapor into the feed system, part of the product gas was introduced into the silo and screw feeder during the pyrolysis experiments. The char separation system consisted of a cyclone and a ceramic hot filter designed to capture chars bigger than 10 and 2 μm, respectively. The quenching system, where pyrolysis oil was condensed, consisted of one water-cooled steel condenser and two ethanol-cooled glass condensers, which operated at 20 and −25 °C, respectively. To capture the aerosols, an electrostatic precipitator was installed after the condensers. For fluidization, the product gas was circulated into the fluidized bed reactor through a pre-heater using a compressor (N0150ATE, KNF). To analyze product gas composition, the gas was sampled using Tedlar gas bags (2 L) at intervals of 10 min after stabilizing the reaction temperature. To maintain a constant pressure in the reactor during experiments, the surplus gas was burned via a flare stack.

2.3. TGA experiments

To observe the thermal degradation behavior of the creosote treated wood ties, experiments were conducted using a thermogravimetric analyzer (TGA Q50, TA Instruments). The sample amount used in the experiment was 10–20 mg. In experiments, each sample was heated in a platinum pan within the temperature range 30–

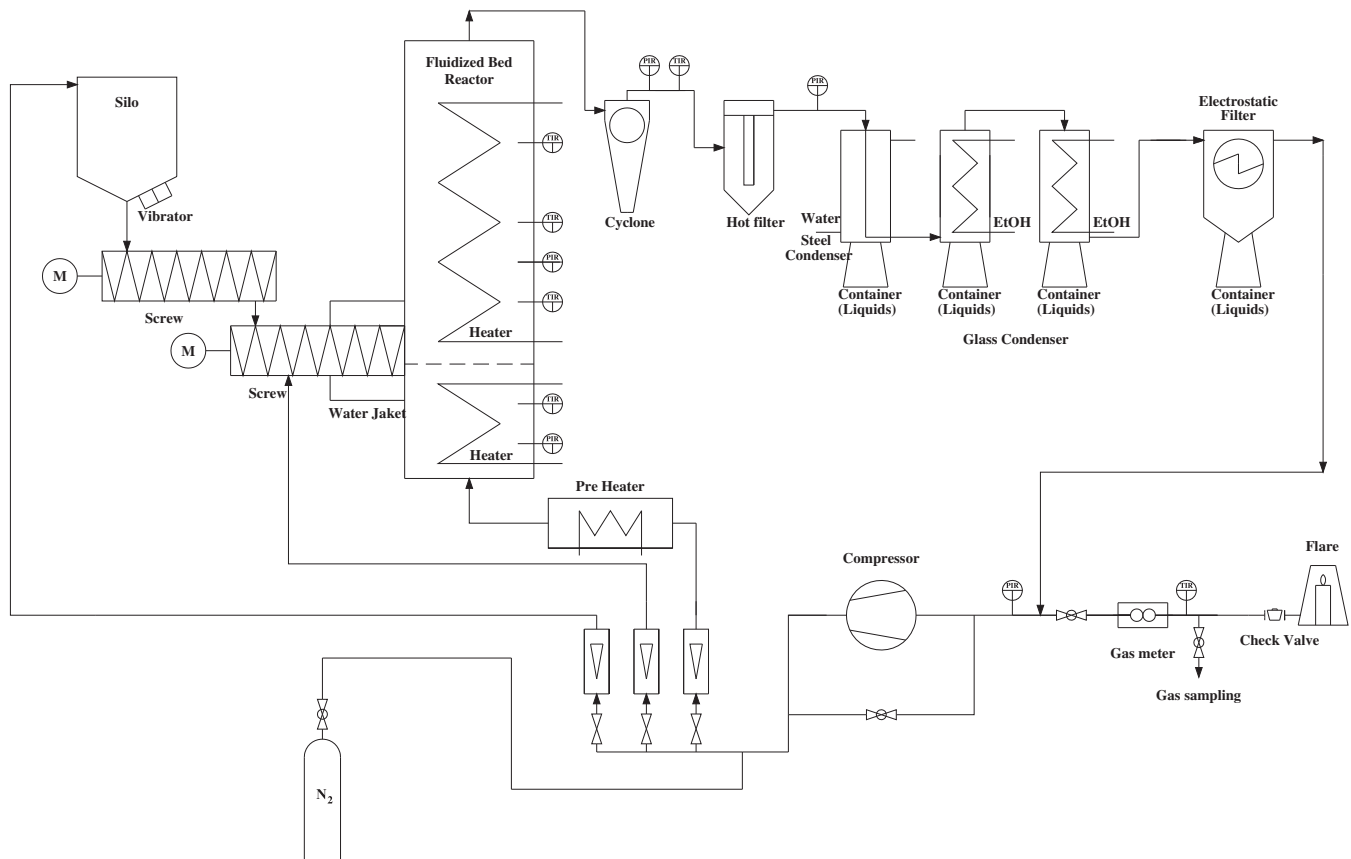


Fig. 1. Schematic diagram of the pyrolysis plant.

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