EFFECT OF PYROLYSIS TEMPERATURE ON BIO-OIL PRODUCTION FROM VACUUM PYROLYSIS OF WASTE FROM WOOD INDUSTRY

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Abstract: In this study, wood industry waste (sawdust from pine wood) was used as model biomass to study the properties of bio-oil obtained by vacuum pyrolysis. The effect of temperature between the range of 300 and 700 °C on gas, liquid and solid products was investigated. The maximum bio-oil yield of 52.1 wt.% was obtained at the final pyrolysis temperature of 500 °C under vacuum atmosphere. Fourier Transform Infrared Spectroscopy (FT-IR) analysis was performed to characterize the organic functional groups in the bio-oil. The results of this study show that the bio-oil obtained from waste wood, such as pine wood sawdust was provided as an alternative fuels and chemical feedstocks.

Keywords: Bio-oil, Biomass, FT-IR analysis, Vacuum pyrolysis

I. INTRODUCTION

Over the last decade,researchers focus on renewable energy sources due to the concerns of greenhouse effect together with the decrease of fossil resources. Wood and other forms of biomass are some of the main renewableenergy resources available and provide the only source ofrenewable liquid, gaseous and solid fuels. Biomass can be converted to useful products by two main processes: thermo-chemical processes and bio-chemical processes. The thermochemical processes can convert biomass to fuel products via pyrolysis and gasification (Girods et al., 2009; Bridgewater et al., 1999; Goyal et al., 2008; Huynh and Kong, 2013).

Pyrolysis is thermal destruction of biomass in the absence of air/oxygen. Pyrolysis of biomass starts at 350–550 °C and goes up to 700 °C. This leads to theproduction of useful liquid oil, gases and solid products. Different condition leads toformation of products in different proportions (Goyal et al., 2008).Bio-oil is referred to by many names including pyrolysis oil, bio-crude-oil, bio-fuel-oil, wood liquids, wood oil, liquid smoke, wood distillates, pyroligneous tar, and pyroligneous acid. The bio-oil is usually dark brown and free flowing with a distinctive smoky smell. It can be used for the production of chemicals and substituted for fuel–oils in many stationary applications for heat or electricity generation (Bridgwater, 2004; Encinar et al., 2009).

In literature, lignocellulosic materials were investigated that different pyrolysis processes have been settled to maximize the formation of bio-oil that is used as fuels or chemicals (Yang et al., 2007; Ertaş and Alma, 2010; Heo et al., 2010; Gerçel, 2011; Kim et al., 2011; Heigenmoser et al., 2013; Özbay, 2015; Özbay et al., 2016), but there is still need for research on bio-oil production and its application.In this work, in this study, sawdust from pine woodwas used as afeedstock to study the properties of bio-oil obtained by vacuum pyrolysis. The effect of pyrolysis temperature between the range of 300 and 700 °C on gas, liquid and solid products was investigated. Fourier Transform Infrared Spectroscopy (FT-IR) analysis was carried out to characterize the organic functional groups in the bio-oil.

II. EXPERIMENTAL

2.1. Materials

Scotch pine (*Pinus sylvestris* L.)as the experiment feedstock was supplied by a commercial timber company in Karabuk, Turkey. Scotch pine is one of the major wooden material in European country. The samplewas ground and sieved to give fractions with particle diameters in the range of 0.8 – 1.5 mm. They were dried in an oven 24 h at 103 °C before the experiments were completed.

2.2. Experimental procedure

The pyrolysis experiments were performed on 2000 g of wood sample in a 316 stainless steel reactorwith a length of 360 mm and an internal diameter of240 mm under vacuum atmosphere.

The reactor is externally electrically heated. During the pyrolysis process, the heating rate and pyrolysis temperature were controlled with a Proportional–Integral–Derivative (PID) controller. The total pressure was fixed at about 10 kPa. The heating rate was 15 °C /min. The pyrolysis temperatures were 300, 400, 500, 600 and 700 °C and maintained for 60 min. A condenser was connected to the exit of the reactor and the liquid was condensed in a collector to be weighed. The bio-char yield collected in the reactor was weighed at the end of experiment. The gas yield was then calculated by the difference.

2.3. Bio-oil analysis

The liquid product obtained from experimental conditionsthat provided maximum oil yield was used for characterization. Liquid products were extracted

with an equal quantity of diethyl ether.Fourier transform infrared (FT-IR) spectroscopic analysis was carried out using a Shimadzu IR Prestige 21 series model instrument. Each spectrum was recorded over 10 scans, in the range from 4000 to 400 cm^{-1}.

III. RESULTS AND DISCUSSION

3.1. Effect of pyrolysis temperature on the productyields

Vacuum pyrolysis of pine wood sawdust was carried out in the pyrolysis temperature range of 300–700 °C., and each yield of pyrolytic productswas presented in Figure 1. Pyrolysis experiments showed that the distribution of the pyrolysis products were strongly affected by the pyrolysis temperatures. The yields of char decreased from 41.8 wt.% to 26.8 wt.% as the final pyrolysis temperature was increased from 300 to 700 °C. The yields of gaseous products rapidly increase with rising temperature. The liquid yield increased from 40.7wt.% at 300 °C to a maximum of 52.1 wt.% at 500 °C, and then decreased to 46.3wt.% at 600 °C. This could be explained thatthe secondary reactions of the heavy-molecular-weight compounds in the pyrolysis vapours, which is known to become active at temperatures over 500 °C. It can be claim that the pyrolysis temperature is one of the most important parameters affecting the pyrolysis products. These results of this study were accompanied to the literature(Park et al.,2009: Wang et al., 2009; Demiral and Ayan, 2011;Liaw et al., 2012; Amutioet al., 2012; Kim et al. 2014).

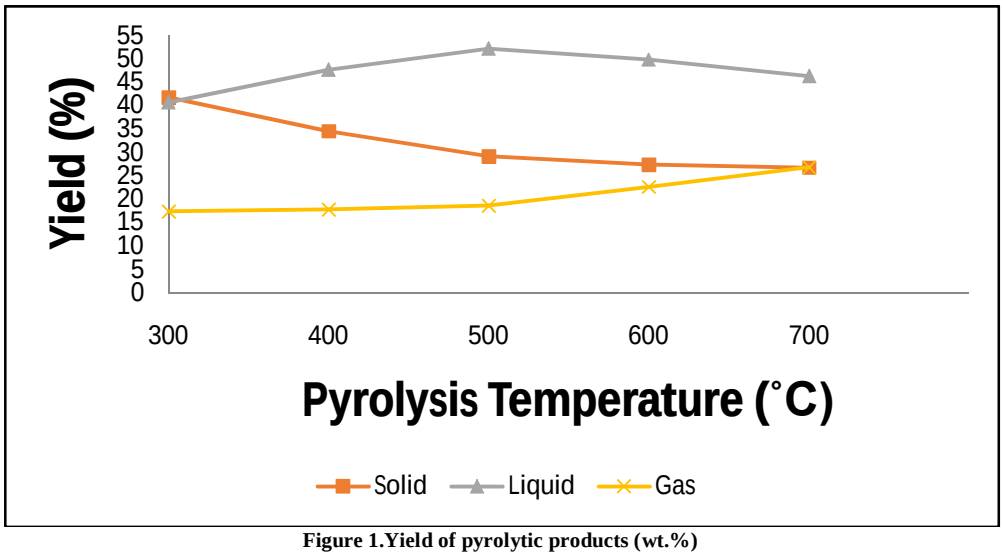


Figure 1.Yield of pyrolytic products (wt.%)

3.2. Analysis of the bio-oil

The FTIR spectrum of thebio-oil was givenin Figure2. The O–Hstretching vibrations between 3600 and 3200 cm^{-1} indicate the presenceof phenols and alcohols. The absorbance peak of C-H stretching vibrations of aliphatic CH_3 and CH_2 groups (2900-2800 cm-1).The peak at around 1600 cm^{-1} was responsible to the aromatic ring vibrations, indicating the existence of the phenols in the bio-oil. Also apeak at around 1650 cm^{-1}, which attributed to C=O stretching, indicating that carbonyl compounds in the bio-oil. Şensöz and co-workers reported that the spectral data showed that alcohol, ketone,ester and carboxylic acid groups are also major oxygenfunctions present in the polar fractions of the bio-oil (Şensöz et al., 2003).

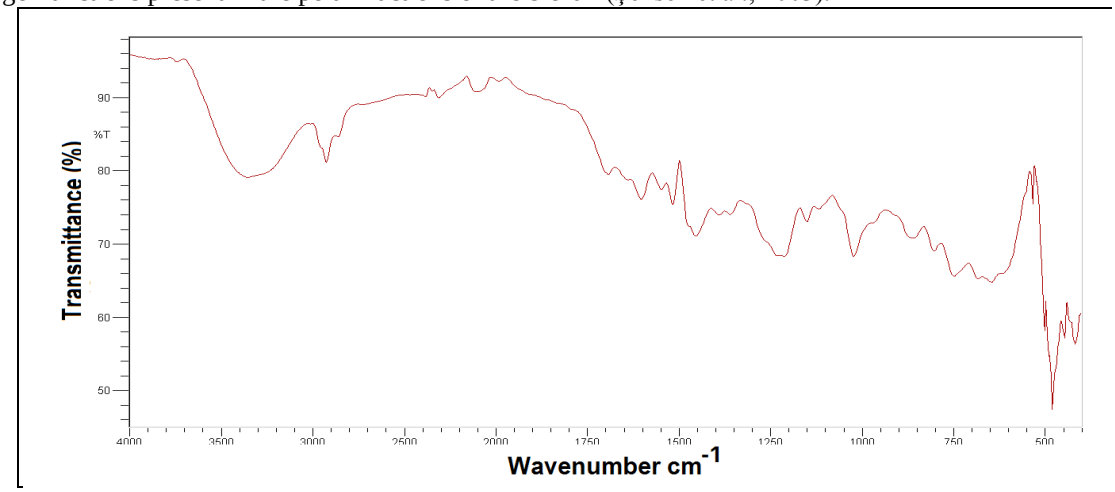


Figure 2. FT-IR spectrum of the bio-oil

CONCLUSIONS

In this work, in this study, sawdust from pine wood was used as a feedstock to study the properties of bio-oil obtained by vacuum pyrolysis. The effect of pyrolysis temperature between the range of 300 and 700 °C on gas, liquid and solid products was investigated. Fourier Transform Infrared Spectroscopy (FT-IR) was performed to characterize the organic functional groups in the bio-oil. The yields of pyrolytic products distribution, bio-oil, bio-char and gases, was significantly influenced by reaction temperature. The maximum bio-oil yield of 52.1 wt% was obtained at the final pyrolysis temperature of 500 °C under vacuum atmosphere.The FT-IR spectrum showed that alcohols and phenols were major oxygenfunctions present in the bio-oil. The bio-oil obtained from waste wood, such as pine wood sawdust was provided as an alternative fuels and chemical feedstocks

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