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PYROLYSIS OF WASTE WOOD

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ABSTRACT

The fast and slow pyrolysis is a both flexible and an attractive method for converting biomass into easy to store and transport products that are used both as an energy source and a feedstock for chemical production. Considerable efforts have been made to convert wood biomass to liquid fuels, energy and chemicals since the oil crisis in the middle of 1970. The aim of the current review is to summarize investigations before 2010 year for understanding of process of pyrolysis. In this review are discussed publications for pyrolysis of waste wood from beech, oak, poplar, pine and other species from 2010 to 2014 years.

Key words: waste wood, pyrolysis.

INTRODUCTION

Pyrolysis is the thermal decomposition of biomass occurring in the absence of oxygen which results in production of charcoal, liquid, and gaseous products. Pyrolysis can be classified into three main categories: slow (conventional), flash and fast pyrolysis.

The major components of biomass are cellulose, hemicelluloses and lignin. Decomposition of each component depends on heating rate, temperature and the presence of contaminants due to different molecular structures. In the pyrolysis process, the three components are not decomposed at the same time. The hemicelluloses break down first at temperatures from 470 to 530 K (197 º–257 ºC), cellulose follows in the temperature range 510 to 620 K (237 º– 347 ºC), and lignin is the last component to pyrolyze at temperatures from 550 to 770 K (277 º– 497 ºC). If the purpose is to maximize the yield of liquid products resulting from biomass pyrolysis, a low temperature, high heating rate, short gas residence time process would be required. For a high char production, a low temperature, low heating rate process would be chosen. If the purpose was to maximize the yield of fuel gas resulting from pyrolysis, a high temperature, low heating rate, long gas residence time process would be preferred (Demirbas and Arin 2002, Zafar 2014).

EXPERIMENTAL

Pyrolysis can be classified into three main categories: slow (conventional), flash and fast pyrolysis depending on the operating conditions. These differ in process temperature, heating rate, solid residence time, biomass particle size, etc.

SLOW PYROLYSIS

Slow (conventional) pyrolysis is characterized by slow biomass heating rates, low temperatures and, lengthy gas and solids residence times. Heating rates are about 0.1 to 2 ºC per second and prevailing temperatures are around 500 ºC (Bridgwater et al. 2001).

The main products of conventional pyrolysis are tar and char. After the primary reactions have occurred, re-polymerization or recombination reactions are allowed to take place.

FLASH PYROLYSIS

Flash pyrolysis is characterized by rapid devolatilization in an inert atmosphere, temperatures between 450 and 600 ºC, high heating rates of the particles (< 2 sec) and short gas residence time at high temperatures

(< 1sec). Tar and oil products are maximized (Aguado et al. 2002).

FAST PYROLYSIS

The basic characteristics of the fast pyrolysis process are high heat transfer and heating rates between 200 and 105°C per second, very short vapour residence time. The prevailing temperatures are usually higher than 550oC (Demirbas and Arin 2002). Fast pyrolysis produces 60%–75% of oily products (oil and other liquids), 15%–25% of solids (mainly biochar) and 10%–20% of gaseous phase depending on the feedstock used. Due to the short vapor residence time, products are high quality and can be used to produce alcohols or gasoline.

PYROLYSIS PROCESS PERFORMING

All pyrolysis reactors have definite feedstock size limitations for effective heat transfer (Jahirul et al. 2012). Therefore, biomass has to be prepared to the desired size by cutting and grinding operations, usually 2–6 mm of particle size. In addition to sizing, the biomass materials need to be dried to moisture content below 10 wt %, because high water content in biomass has an adverse effect on the pyrolysis process. After drying and grinding, the biomass is fed into the reactor and the pyrolysis process takes place. Pyrolysis reactors have two important requirements for heat transfer: (1) to the reactor heat transfer medium (solid and gas in a fluid bed reactor or the reactor wall in an ablative reactor); (2) from the heat transfer medium to pyrolysis biomass. Different heating methods are used in different pyrolysis reactors to ensure the efficient conversion of biomass into liquid fuel.

The char formed in reactor, acts as a vapour cracking catalyst and therefore char removal cyclones are used to separate char from the reactor immediately after pyrolysis. After solid (char) separation, the vapours and the gases need to be quenched rapidly to avoid continuous cracking of the organic molecules. Quenching of the vapours is usually done with pyrolysis liquid condensers.

RESULTS AND DISCUSSION

Fast pyrolysis utilizes biomass to obtain a product that is used both as an energy source and a feedstock for chemical production. Considerable efforts have been made to convert wood biomass to liquid fuels, energy and chemicals since the oil crisis in the middle of 1970.

Forestry wastes such as bark and thinnings and other solid wastes, including sewage sludge and leather wastes can be used as raw materials too (Mohan et al. 2006).

A thermogravimetric study of the pyrolysis of three different types of waste wood (forest wood, old furniture and used pallets) was carried out with TGA equipment using dynamic and isothermal techniques. The isotherms were obtained at two temperature levels, one between 225 °C and 325 °C (low range) and the other, between 700 °C and 900 °C (high range) (Goyal et al. 2008). The kinetic study of the pyrolysis of beech waste wood was described (Di Blasi and Branca 2001). The authors investigated pyrolysis of beech wood powder, measured for heating rates of 10 K/min and final temperatures between 573 K and 708 K. Di Blasi and Branca found that final char yield is 37−11 %. The process is kinetically controlled and isothermal. A one-step general reaction, with $E = 141.2 \pm 15.8$ kJ/mol and $\ln A = 22.2 \pm 2.9$ s^{-1}, is a degradation mechanism capable of capturing the main features of the process.

The thermogravimetric curves also allow the formation rate constants to be estimated for char and total volatiles (activation energies of 111.7 ± 14.3 and 148.6 ±

17.4 kJ/mol, respectively) and, once integrated byproduct distribution, those for liquids and gases (activation energies of 148 ± 17.2 and 152.7 ± 18.2 kJ/mol, respectively). It has been made a comparison with pyrolysis mechanism available in the literature.

M. Bajus studied the recovery of beech wood by the process of pyrolysis. The effects of experimental conditions in products yield and composition also were evaluated (Bajus 2010). The other authors made comparison between different waste materials and investigated the size of beech particles (Gomez-Barea et al. 2010, Westerhof et al. 2012). Van der Stelt et al. reviewed recent developments in biomass upgrading by torrefaction for the production of biofuels. Torrefaction is a thermal conversion method of biomass in the low temperature range of 200–300 °C (Van der Stelt et al. 2011). Asmadi et al. discussed the differences for Japanese cedar wood (a softwood) and Japanese beech wood (a hardwood) pyrolyzed in a closed ampoule reactor (Asmadi et al. 2010). It was investigated very important for our country question of pyrolysis of lignosulphonate, made from beech wood (Stephanidis et al. 2011). We have a big amount of this material, but made from waste pine tree. In the literature there is information for interesting application of one of materials, obtained at pyrolysis of waste beech wood. The authors of this review revealed the potential of slow pyrolysis liquids in agricultural use, in particular, in pesticide applications (Tiilikkala et al. 2010).

Liaw et al. reported the effect of pyrolysis temperature on the yield and composition of bio-oils (Liaw et al. 2012). The influence of the temperature was discussed also from other authors (Chhiti et al. 2011). The kinetic of reaction and mathematical modeling of the pyrolysis of beech wood was described (Anca-Couce et al. 2014, Ruiz and Zinola 2010).

From about 5110 papers only about 20 are published after 2010 year. For example, the articles for waste oak are several. All articles for the period from beginning of investigations to 2014 year are 4680. In our review was given publications published after 2010 (Heo et al. 2010, Gonçalves et al. 2012, Mante and Agblevor 2010). Jin et al. investigated pyrolysis of oak, poplar wood and plastics (Jin et al. 2013). Pyrolysis of wood has also been used to produce hydrogen (Xu and Jiang 2014). Co - pyrolysis of different kind of wood and non-degradable plastics has been evaluated (Papuga et al. 2013). Wood pyrolysis under an influence of atmosphere was studied (Liu et al. 2007). The production of biofuels by pyrolysis was reviewed and discussed by Jahirul et al. (Jahirul et al. 2012). Enders et al. investigated a pyrolysis of agricultural waste products (Enders et al. 2012). Some of these publications include results and information about pyrolysis of different waste wood.

There has been an enormous amount of research about waste poplar wood, but from 168000 papers are given only several, published after 2010 year. The pyrolysis of waste poplar wood was described by different authors (Foster et al. 2012, Slopiecka et al. 2011, Mahir et al. 2014, Fau et al. 2013). There have been investigations of products from pyrolysis of hybrid poplar waste wood by using different methods and equipment (Liaw et al. 2014, Kim et al. 2011). Pereira et al. used pine waste wood to observe the properties of catalytic fast pyrolysis oils (Pereira et al. 2012).

There has been an enormous amount of research of pyrolysis of waste pine wood. In this review are presented only several articles. Mante & Agblevor studied an influence of pine wood shavings on the pyrolysis of poultry litter (Mante and Agblevor 2010). In our review some of 11000 papers about pyrolysis of waste pine wood are given (Liu et al. 2010, Mihai Brebua et al. 2010, Wang et al. 2010, Asghari and Yoshida 2010). In the literature there are studies for pyrolysis of other kind of wastes (Razuan et al. 2010, Salema and Ani 2011, Grieco and Baldi 2011). The analyses of publications about pyrolysis of waste wood show the decreasing of interest after 2010 year on this topic, probably due to its complication and also there are a lot of problems at the application.

CONCLUSIONS

A number of studies had been carried out on biomass pyrolysis because of an opportunity for the processing of wood species and wood wastes into clean energy. This paper considers the different types of pyrolysis technology in brief, as well as conditions and stages of process performing. In this article also are summarized numerous investigations about pyrolysis of waste wood. Further work should be done on inmprovement of the reliability of pyrolysis reactors and processes.

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