The Thermal Reactivity of Wood Waste Systems

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Abstract. The thermal decomposition of wood wastes obtained from jack pine has been studied in both oxidising and inert atmospheres using thermogravimetric techniques supported by gaseous and residue product analysis. The effects of selected sequences of chemical additives on the reaction rate parameters of both native and extracted bark samples have also been examined. The maximum rate of wood waste pyrolysis is believed to be related to the rapid decomposition of the cellulose constituent, which occurs at around 350 °C in nitrogen. In air, this value is shifted to around 300 °C and may be explained by the intervention of exothermic reactions involving other wood constituents present in the complex wood matrix. The trend shown in the analytical results for the various wood waste residues was similar to that established by previous workers for the pyrolysis of coalification products on the basis of H/C and O/C ratios which proceed towards the carbonisation and oxidation poles, respectively, for residues obtained from heating in inert and oxidising atmospheres. Isothermal weight-change data were found to fit model kinetic expressions which indicate that the pyrolysis process may be transport-controlled.

Introduction

Controlled pyrolysis of solid wood waste and similar materials presents a potentially important means of utilisation for either gaseous fuel production or as a source of raw materials for chemical synthesis. To maximise such pyrolytic conversions, a basic understanding of the mechanism of the low temperature pyrolysis of wood products has substantial significance. Thus, the present study has been undertaken in an effort to contribute to the elucidation of phenomena involved in the isothermal pyrolysis of wood products in both oxidising and inert atmospheres.

At the same time, the effects on pyrolysis of a wide range of inorganic salt additives have been observed by dynamic thermogravimetry (TG) in concentrations from 1.51 to 9.93 moles of additive per gram of wood waste. The additives were chosen to assess the possibility of the occurrence of systematic trends in pyrolysis patterns that might be related to the chemical nature and properties of the materials. For comparison, pyrolysis data were also obtained for waste samples in the presence of

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additives that are often regarded as “fire retardants” [Browne 1958; Browne, Tang 1963].

Previous investigations related to the present work include the few detailed kinetic studies of the isothermal pyrolysis of wood products [Akita 1959; Tang 1960; Eickner 1962] and more recent work on the pyrolysis of jack pine bark which also demonstrated that the range of kinetic parameters for wood pyrolysis in the literature fit a reaction rate compensation curve [Fairbridge, Ross, Spooner 1975].

In addition to pyrolysis data obtained by thermogravimetry, additional information has been obtained from gas chromatographic analysis of the gaseous products of pyrolysis, by surface area determinations of samples and residues using krypton adsorption at \(-196\,^\circ\text{C}\), and by elemental analysis.

**Experimental**

**Materials**

The sawdust and bark of jack pine, *Pinus banksiana*, Lamb., were chosen as the wood waste materials. Sawdust was collected from repeated cross cuts through a single log of jack pine, approximately 100 years old, and bark was obtained from the same source. All samples were shredded, sieved to \(<212\,\mu\text{m}\), and dried at \(10^{-2}\,\text{Torr}\) and \(60\,^\circ\text{C}\) for 1 h. Extracted bark samples were prepared as described previously [Fairbridge, Ross, Spooner 1975].

Certified nitrogen and helium, and the calibration gas for gas analysis (CO, 0.105%; CO\(_2\), 0.105%; CH\(_4\), 0.104%; H\(_2\), 0.10%; in helium) were used as supplied by Canadian Liquid Air, Ltd.

All additives were reagent grade and used as supplied in the impregnation procedure described previously [Fairbridge, Ross, Spooner 1975].

**Apparatus and method**

A Stanton Redcroft Thermobalance, model HT-5F, was used in the procedures reported previously [Fairbridge, Ross, Spooner 1975] with 40 mg samples in a flowing gas atmosphere, \(230\,\text{ml min}^{-1}\) (NTP). Isothermal weight-change determinations were conducted in a small platinum crucible while all dynamic TG studies were performed using an alumina crucible which gave a slight temperature lag compared to the platinum crucible.

Effluent gas analysis was obtained by gas chromatography using “Carbosieve B” columns in a Beckman GC-5 analyser linked directly to the high pressure quartz-spring apparatus recently described [Fairbridge, Ross, Sood 1977]. Pyrolysis was conducted in helium (6.5 atmos), after the sample had been dried in the apparatus at \(100\,^\circ\text{C}\) for 16 h, by raising the sample temperature in increments as shown in Table 4 and observing the gases produced after each increment.