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The kinetic analysis of the pyrolysis of agricultural residue under non-isothermal conditions

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HIGHLIGHTS

- ▶ Thermal decomposition characteristics of corn straw and rice husk.
- ▶ Characteristic parameters of TG–DTG curves of the samples are calculated.
- ▶ Variation of activation energy corresponding to different conversion fractions.
- ▶ Variation of reaction order corresponding to varied heating temperatures.

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ABSTRACT

The study concerns the pyrolysis kinetics of agricultural wastes, corn straw (CS) and rice husk (RH). Thermogravimetric experiments were carried out in a thermogravimetric analyzer under inert conditions, and operated at different heating rates ranging from 5 to 40 K/min. As the increment of heating rates, the variations of characteristic parameters from the TG–DTG curves were determined. Iso-conversional Starink approach and Avrami theory were used to evaluate the kinetic parameters, including apparent activation energy and reaction order. For the range of conversion fraction investigated (20–80%), the apparent activation energy of CS initially increased from 98.715 to 148.062 kJ/mol and then decreased to 144.387 kJ/mol afterwards, whilst the apparent activation energy of RH increased gradually from 50.492 to 88.994 kJ/mol. With varied temperatures (517–697 K), the corresponding value of reaction order was increased from 0.288 and 0.359 to 0.441 and 0.692, along with a decrease to 0.306 and 0.445, respectively.

1. Introduction

A large number of agricultural wastes have not been properly utilized in China every year. Corn and rice are the most widely cultivated crop in China, especially in the eastern area of the country. Consequently, as the agricultural waste of the two crops, corn straw and rice husk are abundantly available every year. The National Bureau of Statistics of China (NBSC) has reported in China Statistical Yearbook that the predicted availabilities of the two agricultural wastes are estimated to be approximately 220 Mt/year (dry basis) and 100 Mt/year (dry basis) respectively (National Bureau of Statics of China, 2009). However, a majority of the two kinds of agricultural wastes is burned in the farmland every year, which seriously pollutes the atmospheric environment and wastes the various biomass resources.

In order to address this common problem brought by direct burning, and promote the use of clean and highly efficient energy derived from agricultural wastes in rural areas, researchers have continuously paid special attention to convert agricultural wastes into solid, liquid or gaseous fuels using thermochemical conversion (TCC) technologies, which are summarized in Table 1. As for the biomass gasification, it is an important technology for converting wastes into combustible gas and subsequent use in power generation (Karmakar and Datta, 2011).

As a separate technology and the preliminary stage of combustion and gasification, pyrolysis not only involves complicated chemical processes, but also includes complex physical processes such as heat transfer, mass transfer and their interactions. It has a significant effect on the gasification process. According to White et al. (2011), a thorough understanding of pyrolysis kinetics is vital to supply guidance on the feasibility, design, and scaling of industrial gasification reactors, as well as pave the way for optimizing the operating conditions. In addition, as already discussed in a previous paper (Gai and Dong, 2012), during the gasification of agricultural wastes, apart from the pollutants of particulate dust and condensable tars, the detrimental element of sulphur and chlorine in the feedstock are also released in several chemical forms in

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