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Co-pyrolysis characteristics of microalgae *Chlorella vulgaris* and coal through TGA

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HIGHLIGHTS

- ▶ Co-pyrolysis presented three stages.
- ▶ Interaction between solid phases inhibited the thermal decomposition.
- ▶ Kinetic triplets were obtained.

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ABSTRACT

To find out an alternative of coal saving, a kind of microalgae, *Chlorella vulgaris* (*C. vulgaris*) which is widespread in fresh water was introduced into coal pyrolysis process. In this work, the pyrolysis experiments of *C. vulgaris* and coal blend (CCB) were carried out by TGA, and those of *C. vulgaris* and coal were also taken respectively as control groups. It was found that: the TG and DTG profiles of CCB were similar to *C. vulgaris*, but different from coal under various blending ratios; DTG profiles of CCB were different at several heating rates; interaction was observed between the solid phases of CCB; kinetic triplets were determined by the Kissinger–Akahira–Sunose (KAS), Flynn–Wall–Ozawa (FWO), and master-plots method, respectively. The results provide a reference for further study on co-pyrolysis of microalgae and coal to a certain extent.

1. Introduction

Biomass is the third largest energy resource in the world while coal is the first one, and followed by oil. In view of the increasing energy demand, the great costs of fossil fuels, as well as the eco-friendly concerns in terms of the level of CO_2 release in the atmosphere, biomass utilization which provides a partial substitution of fossil fuels for power generation, has attracted increasingly interest over the world (Lou and Wu, 2011). Potential biomass fuels are in variety, which may include short-rotation woody crops and herbaceous species, forestry waste, municipal solid waste, as well as construction waste, etc. (Guo et al., 2010).

Microalgae, a type of prokaryotic or eukaryotic photosynthetic microorganism, growing rapidly and naturally in abundance over water areas such as ponds, lakes, and rivers, etc., is considered as one of the most promissory renewable feedstock for bio-fuels production. Many relative advantages of microalgae are brought into sight, comparing with other energy crops, in terms of faster growth, shorter rotation, higher oil content, higher photosynthetic efficiency, higher productivity, higher bio-chemical activity, as well as lower requirement of agricultural land (Amaro et al., 2011; Dragone et al., 2011; Huang et al., 2010; Lee et al., 2010a; Mata et al., 2010; Phukan et al., 2011). In addition, microalgae admits the direct generation of products desired such as bio-oil, hydrogen and by-products (e.g. starch) (Posten and Schaub, 2009). Although the huge cost of separating microalgae from water mixtures constrains their large-scale usage as an alternative fuels for energy supply, a research on valued and high quality fuels obtained from microalgae species is worthwhile for future achievements. *Chlorella*, a genus of unicellular green microalgae, with a spherical shape of 2.0–10.0 μm in diameter, living both in fresh and marine water, can generally be found in fresh water of ponds and ditches, moist soil or other damp situations such as the surface of tree trunks, water pots and damp walls (Phukan et al., 2011). *Chlorella* has eight species and *Chlorella vulgaris* (*C. vulgaris*) is one among them, growing in fresh water.

Pyrolysis is a promising thermochemical conversion method, playing a vital role in biomass conversion to green energy. A pyrolysis process can be considered not only as an independent process to produce various chemical compounds and fuels, but also as the initial stage of thermal conversion process of carbonaceous materials, including combustion and gasification. Biomass pyrolysis

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