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Reaction decoupling in thermochemical fuel conversion and technical progress based on decoupling using fluidized bed

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ABSTRACT

Thermochemical conversion of fuels via pyrolysis/carbonization, cracking, gasification and combustion has to involve a number of individual reactions called attribution reactions to form an intercorrelated reaction network for any conversion process. By separating one or some attribution reactions from the others to decouple their interactions existing in the reaction network, the so-called reaction decoupling enables a better understanding of the complex thermal conversion process and further the optimization of the conditions for attribution reactions as well as the entire conversion process to realize advanced performances. The dual bed conversion and two-stage conversion are the two representative types of fuel conversion technologies developed in recent years based on reaction decoupling. Many technical advantages have been proven for such decoupling fuel conversion technologies, such as poly-generation of products, low-cost production of high-grade products, elimination of undesirable products or pollutants, easy operation and control, and so on. The treated fuels with decoupling conversion technologies mainly include solid biomass and coal, as well as liquid petroleum oil. This paper is devoted to reiteration of the reaction decoupling concept and further to reviewing the research, developments and successful applications of several decoupling fuel conversion technologies of two such types by using fluidized bed as their major reactors.

Contents

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1. Concept of reaction decoupling

1.1. Reaction interactions and network

The macro processes of thermochemical fuel conversion such as pyrolysis, gasification, combustion and cracking involve essentially many individual reactions called attribution reactions [1,2], which are inter-connected or interactive. In each of these conversion processes, not a single but a series of reactions occur to constitute a complex network of chemical reactions that bring about the observed explicit chemical changes. In such a chemical reaction network, some reactions and their interactions can facilitate the conversion for high efficiency, low pollutant emission, high product quality and wide fuel adaptability, whereas the others are of no such superior effects and even have certain opposite effects.

Fig. 1 shows a simplified reaction interaction and network in fuel conversion. As well known, pyrolysis (with drying) is the first step of fuel thermochemical conversion and then the generated char and volatiles are conducted to the downstream gasification and combustion reactions. On the other hand, char and volatiles can also be separated out without further conversion to have products char, tar and pyrolysis gas as fuel or chemicals. Apart from the above basic reactions, a series of interactions between/among intermediates or products, even with external reagents occur simultaneously, which greatly impact the quality or composition of products generated from basic reactions (combustion, gasification, etc.). In fact, a fuel conversion process has to contain several basic reactions and large amount of interactions, which are collectively interconnected to form a reaction network. The network is so extensive and complex that just major interactions are highlighted as follows.

For pyrolysis process, the generated char and its inherent metals can catalyze the reforming or cracking of gaseous pyrolysis products including condensable tar, and char also adsorbs (heavy) tar on its surface to facilitate the char-catalyzed tar reforming as well as cracking (①⑦). This in turn reduces tar yield and meanwhile enhances its quality with increased pyrolysis gas yield. The presence of volatiles during fuel pyrolysis can change reaction atmosphere to promote or inhibit pyrolysis reactions (②). For gasification process, the metals in ash, such as Ca, K and Ni, can catalyze char gasification, methanation and C_mH_n reforming (⑤). And the volatiles generated from pyrolysis will greatly inhibit the char gasification reaction (③). For combustion process, the volatiles can reduce the NOx generated from combustion (of char) and inhibit NOx generation with combustion process (④). The metals in ash can adsorb (abate) certain pollutants in flue gas, such as SO_2, Hg and so on (⑥). There are many other interactions, as summarized in our monograph "Fundamentals and Technologies of Decoupling Thermochemical Conversion of Fuels" [1]. The essence of such reaction interactions represents the fact that the products from a part of attribution reactions have to impact the other attribution reactions and affect consequently the final processing products including emissions by providing special atmosphere, surface, catalysis, reactants and so on.

It is clear that some of the preceding interactions can facilitate conversion reactions to lead to low pollutant emission, high reaction efficiency and high product quality, whereas the others are possibly not. For manipulating individual reactions to strengthen

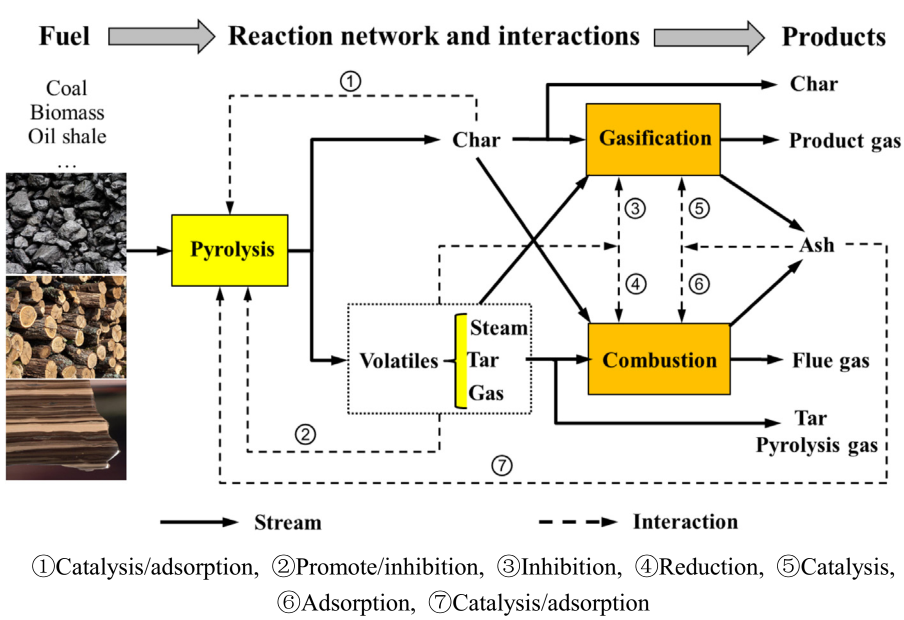

Fig. 1. Reaction interaction and network in fuel conversion.