Rice husk, straw and bark behaviour during combustion, pyrolysis and gasification: Fundamental study

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Biomass is one of the most promising renewable energy, and gasification technology is an attractive route for the production of fuel gases from this natural resource.

Up to now, many gasifiers have been designed and tested at different scales, but no significant commercial units have been realised. This situation is mainly due to the fact that design of such reactors is quite complex and relevant information is needed ; particularly when biomass is concerned. Through the gasification projects we are involved in, we note that fundamental studies above the process design have to be done in order to improve knowledge on the agricultural residues behaviour during gasification.

Indeed, conversion of solid by pyrolysis and gasification processes consists of a sequence of chemical reactions. However, the relative contributions of the different reactions and the removal of the products remain uncertain, and often limit the rate of reaction. An additional difficulty in understanding these processes is the thermal aspects of the reactions, which may be endo/exothermic during pyrolysis and endothermic during gasification. Moreover, the properties of natural materials suitable for this type of processing are variable. In these conditions, it is difficult to predict which of the various phenomena will control the overall rate of reaction.

The scientific objectives of this fundamental ongoing work is to study the behaviour of three representative biomass fuels (rice husk, straw and bark) during the whole reactions occurring in the gasification ; pyrolysis, homogeneous and heterogeneous oxidations.
The heating conditions and the final temperature largely interact on the chemical nature as well as the yields of volatiles during devolatilisation, and the nature of the solid residue. Thermogravimetry (TG) and differential thermal analysis (DTA) experiments fail to experimentally reproduce the thermal history and heat/mass transfer conditions around each particle in fluidised bed conditions. This led numerous authors to study the "in flow" gasification of solid particles dispersed in a gas phase.

Work in progress

We have developed and precisely characterised a laboratory equipment to study the kinetic parameters of the potentially limiting reactions (devolatilisation and solid residue oxidation) involved during high heating-rate gasification. Gas emissions and structural changes in particles can also be followed. Among this fundamental approach, we pay particular attention on:

- the pyrolysis of biomass. First stage of the gasification, it plays a major role on the quality of charcoal and the production of the tar, and so on the gasification process.

We focus our works on:

- the identification of the mechanisms or parameters limiting the production of charcoal with high reactivity with respect to its heterogeneous oxidation during the gasification.
- A better comprehension of the mechanisms of tar from biomass formation and destruction.

- the heterogeneous oxidation of charcoal. This complex process takes into account the solid morphology (porosity, specific surface, tortuosity,..), heat and mass transfers in the particle and intrinsic charcoal reactivity.

Result and conclusion

A first study was undertaken to investigate pulverised coal burnout under conditions relevant to gasification process. Samples of bituminous coal were burned experimentally in the entrained flow reactor in the temperature range 700 to 1000 °C. It was found that 40 ?m particles burned in Regime I mode (kinetic mode) while a diffusion effectiveness factor of about 0.3 applied to 180 ?m (showing coupled effect of kinetic and diffusion). We have also determined intrinsic kinetic constants for devolatilisation and heterogeneous oxidation reaction. These parameters play a major role in the design of new reactors.

We are now applying this methodology to study biomass products behaviour and particularly rice husk, straw and bark. We showed that pyrolysis reaction has a major influence in gasification kinetic : weight loss higher than 75 % (daf basis) is achieved during pyrolysis reaction in inert atmosphere in less than 1 second for the three studied biomass at 700 °C. We also showed that heterogeneous oxidation by CO_2 (in a saturated CO_2 atmosphere) is responsible of only 10 % of the bark charcoal weight loss in 5 seconds. We also pay particular attention in gases production and reduction during these reactions : O_2, CO, CO_2, C_nH_m, SO_2, NO_X

We are actually keeping on these fundamental researches in order to provide relevant information concerning biomass behaviour ; all these information being necessary to design new efficient and clean gasifiers.