A novel technique to characterize inhomogeneous fuels for use in fluidized bed combustors and gasifiers

Arij I van Berkel* , Gerrit Brem
TNO Institute for Energy, Environment and Process Innovation, PO Box 342, NL-7300 AH Apeldoorn, The Netherlands
Fax: +31-55-5493290; a.i.vanberkel@mep.tno.nl

Introduction

The reactivity of waste and biomass varies widely among the different types of fuels. To know the reactivity is important for various reasons. When designing a fluidised bed combustor or gasifier, it is desirable to know the reactivity of the fuel in order to estimate the char hold-up, the optimum particle size, the location of the feeding point and combustion emissions such as NO_x. The fuel reactivity also affects the dynamics of the combustor or gasifier and is therefore important when designing a control system. Furthermore during operation, the ability to measure fuel reactivity allows one to buy appropriate fuel.
Traditional methods to measure fuel reactivity include thermo-gravimetric analysis, shock tube experiments and heated grid experiments. All these methods, however, have the disadvantages that they do not accurately represent the conditions in a fluidised bed and they only use small amounts of fuel. The latter is especially disadvantageous for biomass and waste, because they are very inhomogeneous substances. TNO has developed a new measurement technique, which allows one to measure the reactivity of a large batch of biomass or waste directly in a fluidised bed.

Figure 1 The experimental setup: a fluidized bed, heated by the fluidizing medium and placed on a balance.

Experimental setup

The setup (cf Figure 1) consists of a fluidized bed, heated by the fluidizing medium. At the moment, the medium can be either air or nitrogen or mixtures of air and nitrogen. In the future, steam might also become a possibility. The medium is heated electrically up to 900^o C directly under the fluidized bed. Subsequently, a fraction of the gas flow is passed through the bed for fluidization. The rest is passed through the double-sided bed wall, providing additional heat to the bed. The advantage of this solution is that the heat added to the bed can be adjusted independently from the fluidization conditions. At the top of the bed, special measures have been taken to prevent radiation heat losses to the environment. The whole setup has been insulated. Thus a bed temperature of 800^o C can be reached. The whole setup has been placed on a balance with a weighing accuracy of 2 gr.

Characterization procedure

In order to characterize fuel reactivity and char yield, the following procedure is followed. The bed is fluidized using nitrogen, so that the char yield can be determined. Once a steady state at the desired bed temperature has been reached, the balance is tarred and the weight fluctuations of the bed are monitored for some time. Subsequently a batch of 60 to 200 grams of the fuel to be characterised is entered into the bed. The weight on the balance is monitored continuously with a sampling frequency of 9 Hz. The experiment is completed when no weight changes other then the fluctuations caused by the fluidized bed could be observed any more. The weight fluctuations caused by the fluidized bed still obscure the measurement results. The error due to these

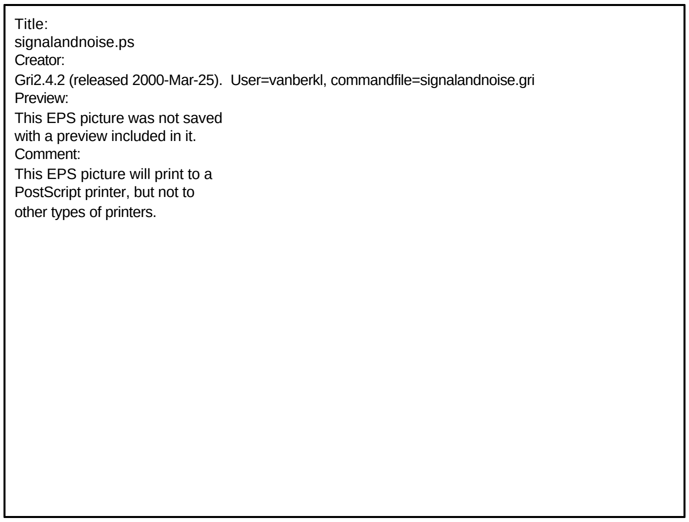

Figure 2 The experimentally determined fluidized bed noise (the "oscillating" line) is prominent at much higher frequencies than the, calculated, biomass reactivity signal (the steeply descending line).

fluctuations can be as high as 40 gr. In order to reduce this error, the fluidized bed fluctuations should be filtered from the signal. The preferred method would obviously be to filter these fluctuations before sampling. This is however not possible due to the balance, which internally samples the mechanical signal offered to it at a frequency of approximately 10 Hz, resulting in an aliasing effect (cf the leftmost peak in Figure 2). Filtering the sampled signal can however be done quite successfully.

Figure 2 shows that the biomass reactivity, as calculated with a mathematical model, is prominent at much lower frequencies than the fluidized bed noise as measured in a hot fluidized bed. Thus a low pass filter should be able to retrieve the reactivity signal while discarding most of the fluidized bed noise. Therefore the sampled data were filtered using a low-pass fourth order Butterworth filter with a cut-off frequency of 1/15 Hz. The resulting data has an accuracy of 5 gr (i.e. < 10% error).

Results

The method has been applied to Ramin wood cylinders. The results have been compared a model developed at TNO. A typical result is shown in Figure 3. The results and the model show good agreement, with respect to char yield and conversion time. Moreover, the method proved to yield reproducible results. Thus a novel technique to characterize inhomogeneous fuels for use in fluidized bed combustors and gasifiers has been developed and demonstrated. The technique offers advantages compared to conventional TGA analysis, since it can use large samples and it is a better representation of the conditions in the fluidized bed.

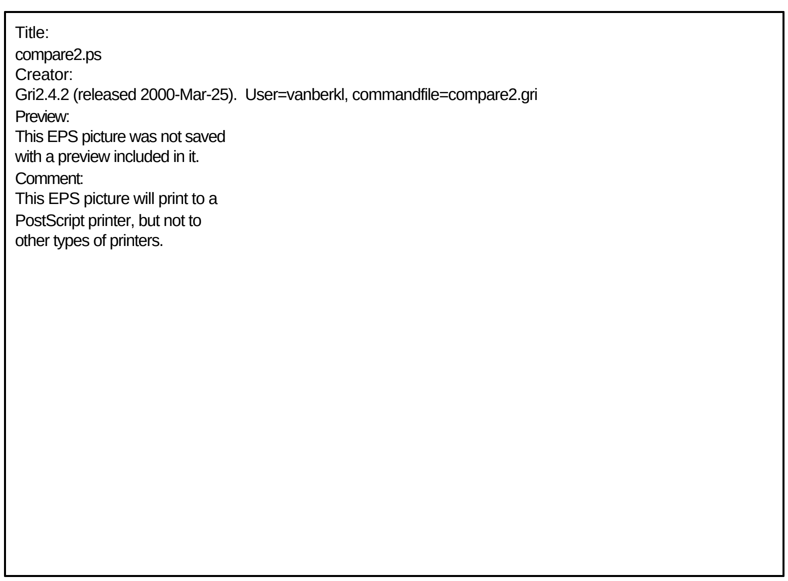

Figure 3 Typical result of the novel characterization method. The experiments were performed at 700º C. The result has been compared to a model that was also developed at TNO