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A modified distributed activation energy model for the pyrolysis of South African solid fuels

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Abstract

A mathematical model is used to describe the pyrolysis of South African coal, biomass and coal-biomass blends. The model makes use of a modified form of the Distributed Activation Energy Model (DAEM) to predict and characterize the underlying distribution of reactions occurring during the pyrolysis process. The DAEM was successfully applied to determine the Activation Energy, *E*, and Pre-exponential Factor, *A*, for each reaction during the pyrolysis of coal as well as biomass. The results obtained showed for a Medium Rank 'C' coal, 23 underlying reactions occurring within the given temperature range, with activation energies in the ranges of 29 - 198 kJ/mol and pre-exponential factors in the ranges of $1x10^{5}$ – $1.2x10^{13}$ s^{-1}. Results for biomass showed the three distinctive reactions underlying the pyrolysis process, with activation energies of 17.3, 86.8 and 209 kJ/mol obtained for the decomposition of lignin, hemi-cellulose and cellulose, respectively. The returned pre-exponential factors corresponding to the activation energies were 0.0154, $5.28x10^{5}$ and $1.13x10^{15}$ s^{-1}, respectively.

The model was also used to show the clear distinction between coal and biomass blends undergoing pyrolysis, and the non-dependence of the two fuels on each other. The synergistic effect of their pyrolysis products on pyrolysis is noted and this was found to be the observation of other researchers within the literature. The results obtained compare favorably with similar results for biomass given in the literature.

The model was also successfully applied to obtain high resolution images of the pyrolysis profile by simulating low heating rates, or high heating rates. The images obtained utilizing the DAEM model for coal tested at the heating rate of 20 K/min returned a relative error of 0.587 when compared to actual TGA data, whereas at 5 K/min, this error was minimized to 0.786. This lack of confidence in the DAEM model at heating rates above 5K/min for coal is a direct result of the effect of secondary reactions between the primary pyrolysis products, and the use of the selected heating rate for purposes of prediction used in the model. The results for biomass obtained at the heating rate of 10 K/min returned a relative error of 0.991 whilst at the high heating rate of 100 K/min, this decreased slightly, to 0.923. This is attributed to the simple chemical nature of the fuel and lack of interactions between pyrolysis products.

The model was also used to show how the area under the curve of the representative peak lies on a straight line of calculable gradient, for increasing biomass concentration.