Modelling of tyre and biomass combustion under rotary kiln: Devolatilisation model

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In order to simulate tire and biomass devolatilisation in a rotary kiln under the steady-state regime, a mathematical model has been developed. This model permits to calculate the temperature profiles in the charge, the gas and furnace walls and gas, tar and char composition along the bed. This model was coupled with a dynamic model [1], which enables the calculation of the height of the bed in cases of inert or reacting bed.
The scope is to model physicochemical and thermal phenomena of tire and biomass wastes devolatilisation within a rotary kiln.

Introduction

The pyrolysis technique is an alternative for reducing waste tires and biomass and leads to the production of oils, steel, gas and black carbon. Tires are mainly composed of different rubbers, such as natural rubber, butile rubber or styrene-butadiene rubber, as well as mineral oils and black carbon [2]. The thermal degradation of tires has been studied by [2, 3].
From a chemical point of view, biomass is mainly composed of cellulose, hemicellulose and lignin. It contains also other compounds.
Biomass pyrolysis can be found elsewhere in literature concerning biomass particle to bed of biomass.
The purpose of this work is to study the dependence between the particles transport and heat and mass transfer within the rotary kiln. The paper is organized in two parts. The first part is a numerical validation of the dynamic model. The second part carries out the coupling between the dynamic model and the combustion of shredded tires and wood pellets wastes but the gaseous and char combustion. The latter to be modelled in our laboratory are underway.

Dynamic and devolatilisation models

The model proposed in order to study the dynamic of the solid flow in a rotary kiln can be divided in three stages: the first stage is the determination of the bed height h(z) along the kiln (see Fig.1), the second one lies on the determination of the half angle ? . These two stages are govern by differential equations. The last stage involves the determination of the solid residence time inside the kiln by considering Lee *et al* [5] correlation and Saeman model [1].

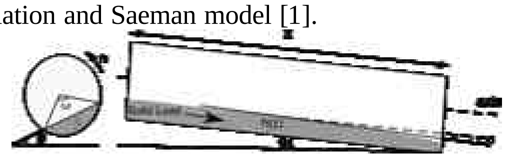

Fig.1: Geometrical description of a rotary kiln

The devolatilisation model treats shredded tire and wood pellets wastes decomposition as chemical pseudo-species. The proposed model constitutes the first part of wastes combustion modeling. The latter is based on the coupling between CFD and mathematical models in order to get modeling of waste within rotary kiln.
Tire and biomass particles are heated, dried and pyrolysed, the resulting volatile products being ignited by the radiation heat transfer from the gas phase and walls.
The model presented consists of 12 nonlinear differential equations and algebraic equations systems.

Experimental

Experimental data were obtain in industrial and pilot rotary kiln for the dynamic model with different wastes such as bituminous, tire and biomass but only in the pilot rotary kiln concerning the devolatilisation model.
For the dynamic model, measurements are based on the variation of the kiln rotation speed. The obtained

experimental results enable to analyze the material residence time with the influence of the rotation speed, the chord length, the half angle and the filling degree. The influence of the slope of the solid bed is also showed. These experimental data combined with an analysis permit also to propose relations for the residence time and the axial velocity according to the geometrical parameters of the kiln in industrial operating conditions.

Experimental and data and the ultimate, proximate analysis obtained permit the development of the devolatilisation model for the shredded tire and wood pellets wastes.

Results

The analyses were made in nominal operating conditions by variation of one variable such as flow rate, kiln rotation, heating gas flow rate while others were maintained constants.

The solid flow rate variation, which was due to weight losses by reaction, along the axial length is shown in Fig. 2. During drying, the temperature turns around the boiling point (fixed here at 100 °*C*) due to the endothermic process; and when the particles are dry, temperature starts to increase. The volatile particles escape from the solid particles which prevent more or less the diffusion of oxygen in the load; oxygen is also consumed by the combustion of hydrogen resulting from volatilized gases (Fig. 2) (gases come from solid particles and from tar; two steps formation).

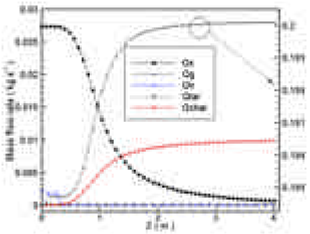

Fig.2: Profiles of gas, solid, tar and char flow rates along the kiln (tire waste)

The drying model which is based on Peters' model [4] correlates the fact that with an equal flow rate (load), drying efficiency is function of the temperature reached by the walls.

Conclusions

The numerical combustion model developed allows modelling of drying and endothermic degradation of the tire and wood load.

This study makes possible estimation of an optimal length of drying according to the pre-heating gas flow rate (time), a temperature distribution in the furnace walls and the flow of energy absorbed by the bed material. This simple correlation remains a very important step at the industrial level and makes it possible at the same time to remove the need of a two dimensional resolution.

Experimental validation of the dynamic model has been obtained under the pilot kiln but also under industrial scale.

An additional modelling is under development in order to take into account of all the stages for solid waste combustion inside rotary kiln.

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