COMBUSTION OF DRY SEWAGE SLUDGE PARTICLE IN A FLUIDIZED BED REACTOR

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***Abstract*— This paper presents a mathematical model of the cylindrical particle combustion in a fluidized bed reactor. This particle is composed of sewage sludge. The model performs a mathematical description of the physical and chemical phenomena that occur during particle combustion. The uniform particle model without ash accumulation is proposed. Sewage sludge is considered composed of three fractions. Two fractions pyrolyzed forming char. Then, this char is burned. The other fraction is burned without pyrolysis. In order to describe the mechanism and kinetics reaction, data from thermogravimetric analysis were used. The reaction kinetics was proposed as a function of mass loss of each fraction. To validate the model, the particle combustion time obtained by the simulation was compared with the experimental combustion time.**
Also, this work presents the combustion atmosphere temperature and the particle size influence in the combustion phenomena. The model predicts acceptably the combustion time, according to experimental results.

***Keywords*– sewage sludge particle – combustion – fluidized bed reactor – mathematical model**

I. INTRODUCTION

In order to describe the reaction between a solid particle and surrounding fluid, there are several kinetic models. Amongst them, the models of homogeneous and heterogeneous particle can be mentioned. In the first case, the particle is considered as a homogeneous medium. The solid is not porous, the reaction occurs on the external surface of the particle, therefore, during the time, the particle size is reduced. The limiting factors of the global reaction rate can be: the chemical reaction rate, diffusion, or both. There are several variants of this approach: the unreacted core model without release of their products, the unreacted core model with release of their products and model homogeneous porous particle (Ogada and Werther, 1996). In the latter approach, there are two cases: the solid produce or not a residue (ash).

Dümplemann *et al.* (1991) used the homogeneous particle approach for modeling the sewage sludge particle pyrolysis. The phenomenon is controlled by external heat transfer until aconversion equal to 90% and then, it is produced under kinetic control. These authors considered that the solid density varied with the time. Dennis *et al.* (2005) also used this approach in order to describe the sludge char combustion phenomena, but they assumed that the controlling step was the oxygen transfer to the surface particle reaction and its density does not change. The ash does not release, it forms a skeleton, and no attrition or fragmentation. Khiari (2006) worked assuming homogeneous particle, but its combustion was controlled by both, mass and heat transfer and the reactions rate. This author considered that the density varied in terms of bound water and volatiles release. The model presented by Cano *et al.* (2007) supposed a uniform particle and the ash remains attached to it during the combustion phenomenon. These authors considered the attrition of the particle.

In the heterogeneous particle model, a particle discretization in elementary control multiple domains is performed. Each domain is characterized by a set of physico-chemical properties. The mass, heat and quantity of movement conservation equations must be resolved in each one. The macroscopic properties of heterogeneous material to the local level, the initial conditions and limits must be known. Bruch *et al.* (2003) applied this model to a large wood particle during combustion.

According to the reviewed literature, there are multiple models that describe the sewage sludge particles combustion of different sizes and different operation conditions. In this work, a mathematical model was proposed in order to describe the phenomena that occurred during the large cylindrical particle sewage sludge combustion. The simulations were carried out at different temperatures and particle diameter in order to observe these influences in the studied combustion phenomena.

II. MODEL OF A SINGLE SEWAGE SLUDGE PARTICLE COMBUSTION IN A FLUIDIZED BED REACTOR

A. Main assumptions of the model

– The sludge particle is cylindrical. Its size, mass, density and temperature are known. It is considered homogeneous, its properties are identical in any spatial position.

– The particle is not porous. This hypothesis is justified by an estimate of its porosity:

$$\varepsilon = \rho_p \, V_{pores} \tag{1}$$

where ε, ρ_p are the porosity and density of the particle, V_{pores} is the pore volume determined experimentally (Rodriguez *et al.*, 2008). The calculated porosity is equal to 0.0036, confirming the hypothesis.

– The particle is considered composing by organic matter and ash. The decomposition kinetic of each fraction, and their residues have been described by Arrhenius law (Rodriguez *et al.*, 2008). Let suppose the sludge is