Numerical analysis of size reduction of municipal solid waste particles on the traveling grate of a waste-to-energy combustion chamber

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Abstract

The size reduction of municipal solid waste (MSW) particles on the reverse acting traveling grate of a waste-to-energy (WTE) combustion chamber was estimated by means of a numerical model combining the particle size distributions (PSD) of MSW and combustion residues and the Shrinking Core Model (SCM). This new integrated model was used to simulate the particle behavior on the grate. During their travel on the moving grate, the sizes of the particles are reduced by combustion, breakage, and compaction. This study shows the calculation of the particle size change using this model and comparison of the numerically derived PSDs of MSW and ash particles with experimental data. There is good agreement between calculated and measured values.

1. Introduction

The size and volume of municipal solid waste (MSW) particles is reduced during the combustion process in the waste-to-energy (WTE) combustion chamber. As they travel over the length of the grate particles are subjected to drying, volatilization, and char oxidation and finally turn into ash (Figure 1). The Martin reverse-acting traveling grate depicted in Figure 1 controls the rate of flow and also enhances mixing. The grate operation is necessary because MSW is much more heterogeneous than coal and other fuels.

Major factors in the size reduction of MSW particles are the physical and chemical transformations occurring on the grate, including drying, volatilization, and combustion. In addition, because of the motion of the moving bars of the Martin grate, some MSW particles break up and their size is reduced. This breakage process can be numerically expressed as a breakage matrix based on experimental data. For example, Campbell and Webb [1] analyzed roller milling performance and developed a breakage equation. Before the MSW enters into the inlet of the combustion chamber, the MSW particles are accumulated in the feed hopper from the bottom of which they are pushed into the combustion chamber by the ram feeder. The resulting compaction process can be estimated by means of a ram pressure-density curve, because MSW varies greatly in both densities and compressibility. After the drying, volatilization, and combustion processes in the chamber, MSW particles become ash consisting mostly of non-combustible residues. The particles that are on the surface on the bed, where the temperature rises above 1100 °C, are subjected to some fusion and agglomeration, and they form larger particles (clinker). Due to the motion of the traveling grate, clinker particles of ash can break again and their size is finally reduced to the PSD of ash at the outlet of the combustion chamber (Figure 1).

In order to simulate the size reduction of MSW particles, we modeled the PSD of MSW particles and ash particles and applied the shrinking core model (SCM) to these distributions. Also, Image Analysis was used to determine the PSD of MSW and ash samples. Finally, thermogravimetric analysis (TGA) was applied on particles of the main constituents of MSW in order to examine the effect of thermal decomposition on particle size.

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