Efficiency Improvements in Waste-to-energy Combustion Processes
Method Development and Evaluation

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Abstract

The current increase being experienced in the generation of waste endangers human health and the environment. One possible way of addressing this issue is to minimise it by reusing or recycling large fractions of waste materials. A suitable approach for treating undesired end products remaining after recycling is the energy recovery method. The electrical efficiency of this technology, however, is generally low when compared with other solid fuel-fired combustion plants as a result of low steam properties. Furthermore, there is lack of efficient methods to evaluate the performance of this system. The energy method, normally used, does not account for exergy destruction due to entropy generated within the system.

In this thesis, an exergy model for estimating the maximum available energy in a municipal solid waste and a modified exergy-based method for calculating the improvement potential in a waste-to-energy plant are developed. The exergy model was obtained from estimations of the higher heating value and standard entropy of municipal solid waste from the elemental compositions of the waste using statistical analysis. The improvement potential was derived by comparing the exergy destruction of the real process with its corresponding theoretical process. It was applied in a solid-waste fired heat and power plant to investigate possible improvements in the system as well as the cost of the improvements. The different improvement modifications considered include the re-arrangement of air heaters, the introduction of a reheater, flue gas condensation and an integrated gasification-combustion process. Modelling, simulation and cost estimations were performed with the Aspen Plus software.

The results showed that the present proposed exergy model was more accurate than the previous models for estimating the maximum available energy in waste material, as the proposed model incorporates all the major elemental constituents as well as the physical composition of the solid waste. Moreover, the results obtained from the higher heating value model show a good correlation with the values measured, and are comparable with other recent and previous models. Furthermore, it was found that 64 % of the total exergy destruction in the process plant investigated can be reduced, while the boiler was identified as a component with the greatest potential for making improvements to the plant. Although the integrated gasification-combustion technology with flue gas condensation has the highest exergy efficiency, its higher capital cost exceeds all other alternatives. The improvement modifications with flue gas condensation not only provide the highest heat production but also the highest net present value. This indicates that flue gas condensation has a significant impact on the overall income generated by waste-to-energy combined heat and power industries.

Keywords: Solid waste, exergy, entropy, higher heating value, improvement potential, waste-to-energy plant, efficiency improvement, cost evaluation, simulation, modelling