CHARACTERIZATION OF FLUIDIZED BED PYROLYSIS OF SEWAGE SLUDGE BY TIME-RESOLVED PRESSURE MEASUREMENTS

Piero Salatino, Dipartimento di Ingegneria Chimica, dei Materiali e della Produzione Industriale - Università degli Studi di Napoli Federico II P.le V. Tecchio, 80, 80125, Naples, Italy
salatino@unina.it
Mirco Della Volpe, Dipartimento di Ingegneria Chimica, dei Materiali e della Produzione - Università degli Studi di Napoli Federico II P.le V. Tecchio, 80, 80125, Naples, Italy
Roberto Solimene, Istituto di Ricerche sulla Combustione - Consiglio Nazionale delle Ricerche P.le V. Tecchio, 80, 80125, Naples, Italy

Key Words: sewage sludge, pyrolysis, fluidized bed, devolatilization rate.

The management of sewage sludge in an economically and environmentally acceptable manner is one of the critical issues facing society today. Due to industrialization and urbanisation, production of wastewater sludge has dramatically increased in the last years and this is expected to continue in the future. The environmental legislation is becoming more and more restrictive as regards landfilling of this biodegradable waste and the use of sewage sludge in agriculture is often hindered due to the possible presence of heavy metals and pathogens. The disposal of wastewater sewage sludge by means of thermochemical conversion appears to be a potentially useful strategy to avoid landfill disposal and, at the same time, to exploit sludge as a source of energy and valuable chemicals. Fluidization technology applied to thermochemical processes, like combustion, gasification and pyrolysis, is an attractive option, due to its favorable characteristics: inherent operational flexibility, high efficiency, low pollutant emissions, ability to effectively accomplish destruction of micro-pollutants and pathogens (Werther and Ogada, 1999). Devolatilization of sewage sludge granules during thermochemical processing in fluidized beds plays a crucial role in the design and performance of fluidized bed converters. Uneven axial and radial distribution of volatile matter in the fluidized-bed combustor/gasifier is commonly experienced in industrial units and is determined by in-bed emission of volatile matter which is responsible for the enhancement of axial fuel particle segregation. On the other hand, the competition between fuel devolatilization and radial solids mixing crucially affects the radial distribution of volatile matter across the reactor and emphasizes the relevance of the devolatilization kinetics to volatile matter segregation. Short devolatilization times promote the release of volatile matter above the bed and close to the fuel feeding points.

An experimental technique for the characterization of the devolatilization rate of solid fuels in fluidized beds developed by Solimene et al. (2012) has been adopted to investigate the behavior of sewage sludge particles during pyrolysis. The diagnostic technique is basically based on the analysis of the time series of pressure measured in a bench-scale fluidized-bed reactor as volatile matter is released from a batch of fuel particles. The experimental data are elaborated in the light of a mathematical model of the experiment developed to determine the time-resolved devolatilization rate, the devolatilization time and the volume-based mean molecular weight of the emitted volatile compounds. A remarkable feature of this technique is the possibility to follow fast devolatilization with excellent time-resolution. Devolatilization kinetics has been characterized for different size of the solid fuel and different bed temperature. The experimental apparatus (Fig. 1) consists of a stainless steel fluidized-bed reactor 0.5 m high, 0.017 m ID. The reactor was operated at a pressure slightly larger than atmospheric pressure by means of a calibrated flow restriction at the exhaust consisting of an orifice with an adjustable cross section. A steady-state overpressure of about 10mbar in the reactor, dictated by the flow rate of fluidizing gas and by the calibrated flow restriction at the exhaust, has been chosen and it allows to accurately determine the time evolution of pyrolysis phenomenon of sewage sludge. Figure 2 reports the typical pattern of the time-resolved reactor overpressure recorded during the devolatilization of a batch of sewage sludge. The time-resolved overpressure have been worked out according to a postprocessing procedure to calculate the devolatilization rate and to estimate: (1) the time interval (td95) corresponding to 95% volatile matter release; (2) the mean molecular weight (Mvol) of the emitted volatiles. Figure 3 reports tD95 as a function of initial sludge particle size for the different operating pyrolysis temperatures investigated. As expected, the devolatilization time clearly increases with the initial sewage sludge particle size and similar trends are observed for all the bed temperatures investigated in this study.

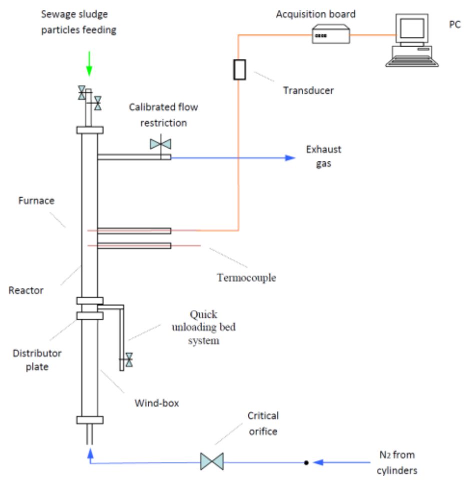

Fig. 1 – Experimental apparatus

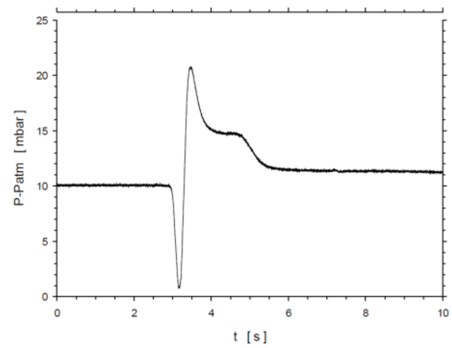

Fig. 2 – Typical time-resolved relative pressure profile measured in the reactor during the devolatilization of a batch of sewage sludge particles (total mass of the batch: 100.4 mg; particle size range: 1.18–1.40 mm; bed temperature: 700 °C).

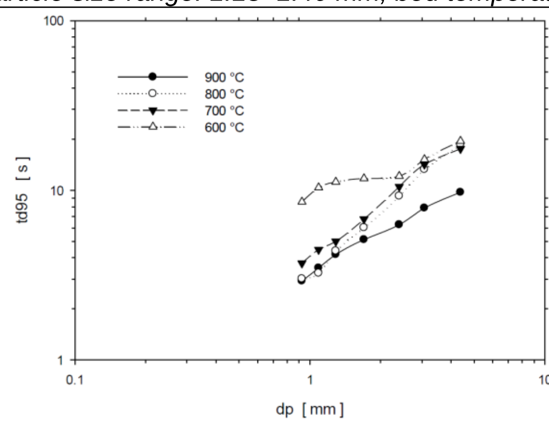

Fig. 3 – Devolatilization time as a function of the initial fuel particle size and bed temperature.

References

Solimene, R., Chirone, R., Salatino, P., 2012. Characterization of the devolatilization rate of solid fuels in fluidized beds by time-resolved pressure measurements. AIChE J. 58, 632–645.

Werther, J., Ogada, T., 1999. Sewage sludge combustion. Prog. Energy Combust. Sci. 25, 55–116.