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THERMAL PLASMA TECHNOLOGY FOR WASTE TREATMENT

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Abstract
Thermal plasma application in solid waste treatment has been demonstrated. Thermal plasma technology has a potential for transforming organic waste into energy and non-leachable residue. Thermal plasma pyrolysis has several advantages over standard gasification process. plasma gasification uses an external heat source to gasify the waste and hence results in very little combustion.

Introduction
Thermal plasma technology has been in use for a long time. It is well established in various processes, such as metallurgical processing, material synthesis etc. [1]. Only in recent years, it has been employed in treatment of organic waste. Thermal plasma is a promising technology for recovery of resources from non-conventioal sources like Municipal Solid Waste (MSW) and biomass residues [2]. It has various advantages over conventional waste incineration technology. It employs plasma torches to generate extremely high temperatures and transforms waste into synthesis gas, by pyrolysis and gasification chemical processes. Plasma pyrolysis converts organic part of waste into synthesis gas (CO and H2), which can be used in gas turbines for power generation, and non-organic part of waste is transformed into non-leachable residue, useful in construction industry [2]. Plasma pyrolysis is neutral with respect to CO2 emission, whereas conventional waste incineration of organic waste may utilize the energy content of waste but is associated with the generation of SO2, NOx and other hazardous emissions [3]. Thermal plasma reactors are at the core of plasma waste treatment technology.
Design optimization of reactor can play significant role in improving effectiveness and
efficiency of converting waste into useful products. Computational Fluid Dynamics (CFD) has recently proved to be an effective means of analysis and optimization of energy-conversion processes [4].
Plasma is often considered as the fourth state of matter. Gaseous plasmas consist of a mixture of electrons, ions, and neutral particles resulting from electrical discharge. The sun and the lightning are common examples of plasmas. In an electrical discharge the high-mobility electrons pick up energy from the applied electric field and transfer part of this energy to the heavy particles through collisions[5]. Depending on the amount of this energy transfer there are two types of plasmas: Thermal and Nonthermal plasmas. Thermal plasmas approach local thermal equilibrium (LTE) because of high electron densities, resulting in high energy transfer to heavy particles. Whereas non-thermal plasmas have lower degree of ionization and lower energy densities, resulting in a large difference between the temperatures of the electrons and the heavier particles. They are often referred as \cold" plasmas [5]. There are numerous advantages of thermal plasmas: high temperature, high intensity, non-ionising radiation and high energy density. Thermal plasmas can reach temperatures of 20,000 K or more, whereas an upper temperature limit of 2000 K can be achieved by burning fossil fuels [2]. Because of these advantages thermal plasmas are employed in many industrial applications.

Generation of plasma
Plasma is generated by passing an electric current through a gas. Most gases are insulators at room temperature and hence, charge carriers must be generated to make the gas electrically conducting. The process of generating charge carriers in the gas is known as electrical breakdown. There are numerous ways in which electrical breakdown can be achieved. Most common way of generating plasma is by applying electric field between two electrodes, which causes breakdown of originally
non conducting gas and the passage of an electrical current through the ionized gas leading to gaseous discharges. Other means of producing plasma include shock waves,
laser or high-energy particle beams, heated gases in a high-temperature furnace [5].

Thermal plasma pyrolysis
Pyrolysis is the thermal processing of organic substances, like waste and biomass, which are thermally unstable, in the complete absence of oxygen, to split them into gaseous, liquid, and solid fractions, through a combination

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of thermal cracking and condensation reactions [6].Thermal plasma pyrolysis is the technology, which integrates the thermo-chemical properties of plasma with the pyrolysis process. The presence of charged and excited species, together with the high energy radiation, makes the plasma environment highly reactive and it can catalyse homogeneous and heterogeneous reactions [7]. Thermal plasma pyrolysis has several advantages over standard gasification process. In standard gasi_cation technology temperature is in the range 600-1000 K. Mostly they rely on the process itself to sustain the reaction and do not use any external heat source. Although this process produces a fuel gas similar to the gas produced by plasma process, it is much dirtier and contains char, tars and soot, because lower temperatures can not break down all the materials. As a consequence, many materials must be sorted out of the waste stream before reaching the reactor and land_lled or processed in other ways. Also, the char produced is upto 15% of the weight of the incoming material and must be land_lled. In contrast, plasma gasification uses an external heat source to gasify the waste and hence results in very little combustion. Almost all of the carbon is converted into fuel gas. In fact, plasma gasification is the closest technology available to pure gasification. Very high temperatures promote complete break down of all the tars, char and dioxins. Hence the fuel gas is much cleaner and very little ash is generated [8].

When injected into the plasma, particles are heated rapidly, resulting in release of volatile matter, hydrogen, light hydrocarbons (such as methane and acetylene) and a solid residue with varied properties, depending on the feed characteristics and operating conditions. To achieve certain technical purposes, such as monomer recovery stage 3 could be replaced by quench process. Also, additional water or steam can be used in stage 4 to increase syngas (H2 and CO) production. Extremely high temperatures and capability of significantly decreasing the waste volume to a non-leachable residue, have increased development of plasma applications in waste management. Although, initially focus was on the destruction of hazardous wastes rather than energy recovery, in recent years, the interest in energy and resource recovery from waste has grown significantly [3]. The calculations show that if energy is recovered from the pyrolysed gases of medical waste, the destruction of approximately 600 kg waste per day for typically 50 kW system is enough to break even.

Conclusion

Plasma Pyrolysis is a complex phenomena and poses significant challenges for numerical modeling. This being our first attempt, several simplifications and approximations had to be made. The simplified numerical model, developed in this work, demonstrated that CFD can play critical role in design analysis of thermal plasma reactor. It is concluded that thermal plasma is a promising alternative to conventional and industrially mature thermal processes for waste treatment.

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