Plasma Gasification For Waste Treatment And Energy Utilization

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ABSTRACT

Thermal plasma gasification has been demonstrated as one of the most effective and environmentally friendly methods for solid waste treatment and energy utilization in many of studies. It handles all sort of wastes such as MSW (Municipal solid waste), hazardous waste, medical waste, etc. and helps to derive energy from it. In this paper we have enlisted various ways to procure energy from MSW and the process of doing it. On gasification of MSW in plasma gasifier by plasma torches in oxygen starved medium, organic matter was converted into syngas and inorganic matter was converted into an inert vitrified slag. Syngas was used for generation of electricity using a compressed gas-steam turbine cycle. It was also used for recovery of H2. It was successfully demonstrated that the thermal plasma process of solid waste gasification, combined with the WGS and PSA, produced high purity H2 (20Nm3/h (400 H2-Nm3/PMW ton), up to 99.99%) using a plasma torch with 1.6MWh/PMW-ton of electricity. The results suggest that the thermal plasma process of solid waste gasification for the production of high purity H2 may provide a new approach as a future energy infrastructure based on H2. Vitrified slag which was formed from inorganic matter was used for construction works. Glass ceramic foams were prepared from MSW slag by plasma gasification process. The results showed that the glass–ceramic foams with 70wt% MSW slag sintered at 920 1C exhibited an excellent strength-to-density ratio (crushing strength exceeding 2.5MPa, with a density below 0.3g/cm3), due to the precipitation of micro-crystals. The report deals with the conversion of solid waste into usable products and energy by various processes.

Key Words: *Plasma gasification, MSW, hazardous waste, medical waste, syngas, vitrified slag, glass ceramic foams, energy.*

1. INTRODUCTION

A factor common to all developed countries is the generation of excessive amounts of waste per capita. As societies developed, the amount of waste material generated has increased to a level that is becoming unmanageable. This, together with increasing awareness of the general public for the damage caused to the environment, explains the need to plan for and implement sustainable and integrated stategies for handling and treating wastes.

Plasma gasification is a technologically advanced and environmentally friendly process of disposing of waste and converting them to usable by-products. It is a non- incineration thermal process that uses extremely high temperatures in an oxygen starved environment to decompose completely the input waste material into very simple molecules. The products of the process are a combustible gas, known as synthesis gas, and an inert vitreous material, known as slag. Furthermore, it consistently exhibits much lower environmental levels for both air emissions and slag leachate toxicity than competing technologies, e.g. incinerationPlasma gasification technology has attracted increasing attention as an environmental friendly alternative to fuel burning systems for the treatment of waste due to the following unique advantages: (1) the high energy density and temperature, (2) the treatment of a wide range of waste, and (3) the high heat flux density at the reactor boundary that lead to the fast attainment of steady state condition, etc. Therefore, over the past decade, the thermal plasma process has been regarded as a viable alternative for the treatment of highly toxic waste, such as the residue from MSW incineration (bottom ash + fly ash), radioactive, and medical wastes. Conventional waste landfills occupy large amounts of land and lead to serious environment problems. As for incineration technology, the emissions of NOx, SOx, HCl and harmful organic compounds are high in the incineration process.The inorganic substances of the feed stock that are melted to form an inert vitrified slag in which undesirable materials such as heavy metals are trapped in the Si–O network structure. This vitrified slag is glass-like and leaching resistant, which is basically composed of CaO–SiO2–Al2O3 system with a considerable amount of Fe2O3.Thus the vitrified residue can be used as raw materials in the manufacture of glass works, saving several millions of tons of natural materials and dramatically reducing landfill-related problems. The production of glass foams with MSW slag is a useful way of recycling large amounts of vitrified slag. However, few researches have been done on their utilization of MSW slag generated by plasma gasification process by the preparation of glass foams.

2. PLASMA GASIFICATION PROCESS

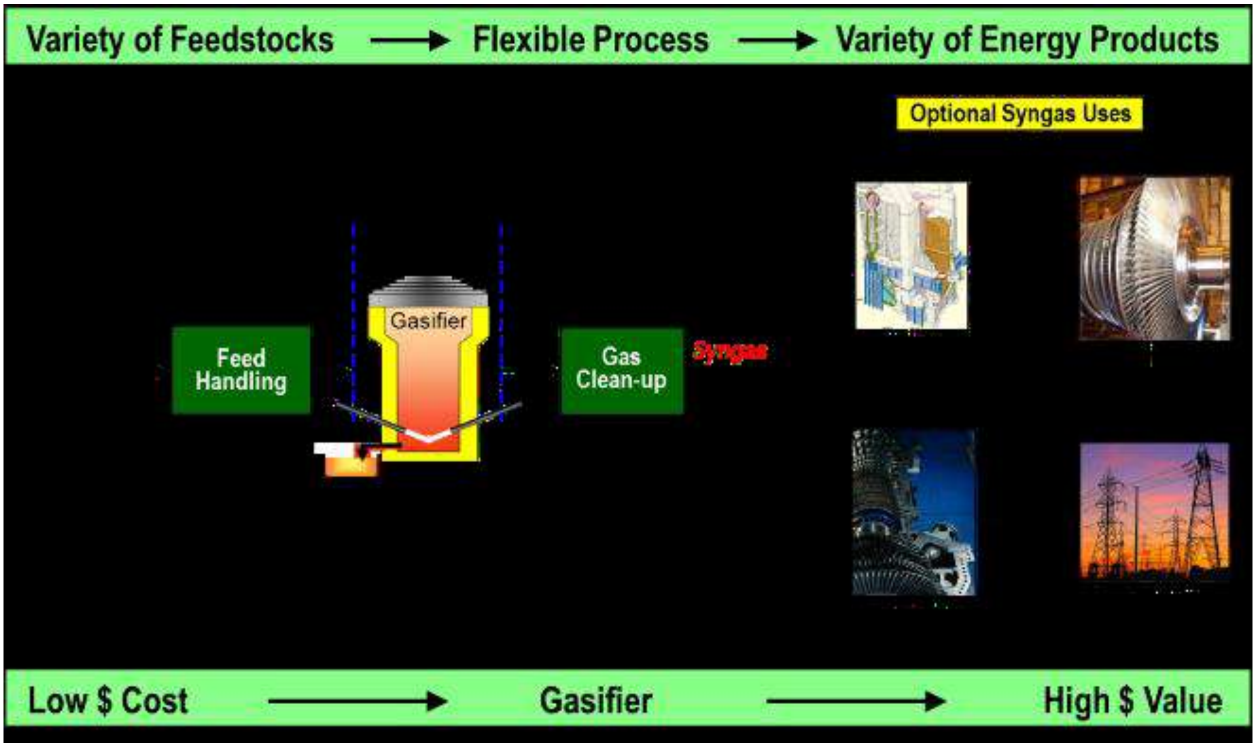

Fig.1 Block Diagram of Plasma Gasification Process

The block diagram presented in Fig above includes the main sections of a plasma waste treatment plant. In more details, each section, apart from the energy recovery system, consists of the following compartments:

1.Feed pre-treatment subsystem :The waste feed sub-system is used for the treatment of each type of waste in order to meet the inlet requirements of the plasma furnace. For example, for a waste material with high moisture content, a drier will be required. However, a typical feed system consists of a shredder for solid waste size reduction and a sealed hopper along with a screw feeder to drive the solid waste into the furnace.

2. Plasma gasifier: The plasma gasifier is the central component of the system where gasification/vitrification are taking place. Two graphite electrodes, as a part of two transferred arc torches, extend into the plasma furnace. An electric current is passed through the electrodes and an electric arc is generated between the tip of the electrodes and the conducting receiver, i.e., the slag in the furnace bottom. The gas introduced between the electrode and the slag that becomes plasma can be oxygen, helium or other, but use of air is very common due to its low cost.

3.Gas cleaning sub-system : The gas cleaning subsystem has to achieve the elimination of acid gases (HCl, SOx) suspended particulates, heavy metals, and moisture from the synthesis gas prior to energy recovery system. To that purpose, a typical gas cleaning system consists of: a) A water quench for the immediate cooling of the hot and dirty synthesis gas to avoid the formation of complex molecules like dioxins. b) A venturi scrubber to remove particulates c) A packed bed tower scrubber using caustic solution to neutralize the acid gases. Moreover, by sub-cooling the scrubbing solution, the moisture in the gas is removed and condensed in the solution, and d) Filters for the entrapment of heavy metals and other fine particulates.

4. Energy recovery system: The energy recovery system can be based on a steam cycle, gas turbine cycle or a gas engine. Depending on the quality of the produced synthesis gas, the best option can be one of the above energy recovery scenarios. In this work, the option of a cogeneration system, based on a gas turbine combined cycle, is selected as the one that allows electrical efficiency of >40% to be achieved. This electrical efficiency is the highest among the other alternative schemes, although the fact that this kind of plant has the need for a good cleanup system that is not essential for other cases, e.g. steam cycle. In addition, studies on the selected cogeneration system confirm its high efficiency, either by reporting simulation results, or by its implementation in commercial scale systems.

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3. METHODS FOR THE RECOVERY OF ENERGY FROM THE GASIFICATION OF SOLID WASTE.

For several years, a pilot test of the thermal plasma process for the purpose of municipal solid waste (MSW) and paper mill waste (PMW) gasification (10 tonnes/day) has been conducted by an institute. However, in their previous study, the utilization of the syngas generated was not considered as a source of energy.

Methods for the recovery of energy from the gasification of solid waste include:

(1) Manufacturing fuels or chemicals from the syngas,

(2) The recovery and utilization of H2 as a fuel,

(3) The recovery of H2 and the production of electricity using fuel cells, and

(4) The production of electricity using a complex gas-steam turbine cycle

Of these, electricity generation from syngas i.e plasma gasification process is discussed in previous section.

It is worth noting that the recovery of H2 from the gasification process has increased, which has motivated the development of H2 recovery technology in several investigations using the thermal plasma treatment of solid waste, while no purification process has been conducted for the recovery of high purity H2.

4. H2 RECOVERY FROM SOLID WASTE.

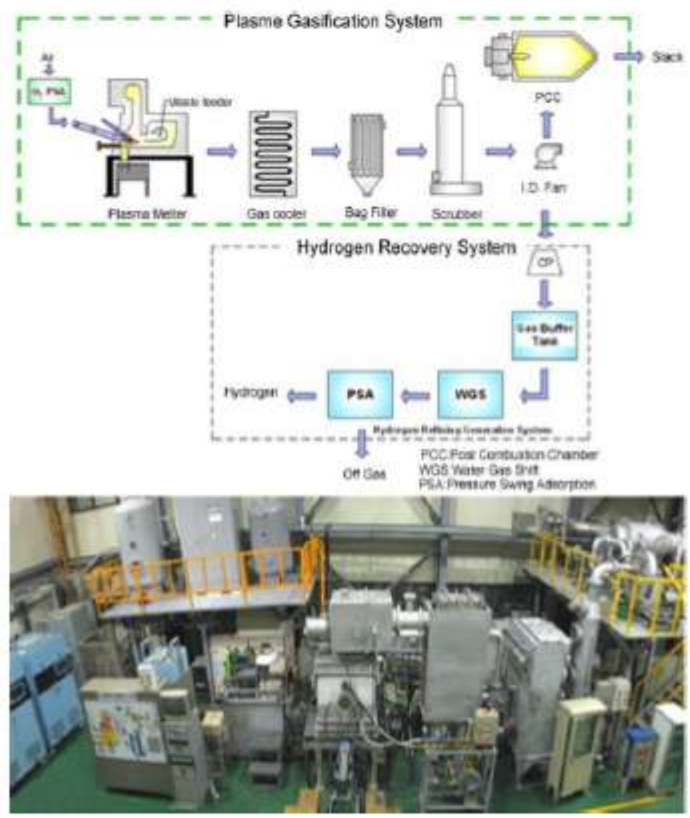

Fig.2 Schematic diagram of the thermal plasma process for the recovery of high purity H2.

The H2 recovery system is mainly composed of the WGS and the PSA connected in series

The gases entering the WGS are compressed to nearly 700 kPa.

Two stage WGS reactors are used, connected in series: one was a high temperature shift (HTS) reactor operated at about 350 ◦C, with the other being a low temperature shift (LTS) reactor operated at approximately 200 ◦C.

The role of the PSA system is to produce high purity H2 by separating the impurities by the different volatilities and polarities of the gas components. The H2 produced is also used as a purging gas to regenerate the PSA adsorbent after the adsorption cycle.

The optimization of H2 recovery system is conducted focusing on the PSA unit, since the performance of the WGS system was stable

5. RESULTS AND DISCUSSION

Table 5.1

	Avg. CO (%)	Avg. H2 (%)	Sum of CO+H2 (%)
Exp.1	38.77	35.21	73.98
Exp.2	40.58	34.65	75.23
Exp.3	37.65	33.93	71.58
Exp.4	40.38	35.60	75.98
Exp.5	40.44	35.09	75.53
Total avg.(%)	39.56	34.90	74.46

1.) It was successfully demonstrated that the thermal plasma process of solid waste gasification, combined with the WGS and PSA, produced high purity H2 (20Nm3/h (400 H2-Nm3/PMW ton), up to 99.99%) using a plasma torch with 1.6MWh/PMW-ton of electricity.
process of solid waste gasification for the production of high purityH2 may provide a new approach as a future energy infrastructure based on H2.

6. GLASS CERAMIC FOAMS FROM SLAG

The gasification process is performed in an oxygen starved environment to decompose organic input waste into its basic molecular structure. The organic waste is converted to fuel gas that maintains all the chemical and heat energy from the waste. The inorganic substances of the feed stock are melted to form an inert vitrified slag in which undesirable materials such as heavy metals are trapped in the Si–O network structure. This vitrified slag is glass-like and leaching resistant, which is basically composed of CaO–SiO2–Al2O3 system with a considerable amount of Fe2O3. Thus the vitrified residue can be used as raw materials in the manufacture of glassworks, saving several millions of tons of natural materials and dramatically reducing landfill-related problems.

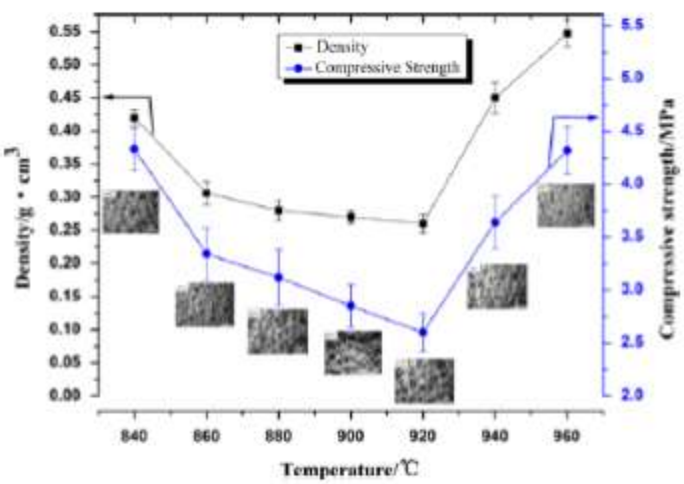

Fig3. Density and compressive strength of samples (P2) with different temperature.

7. RESULTS AND DISCUSSION

The glass–ceramic foams were prepared using high content of municipal solid waste(MSW) slag (50– 70%)
Calcium carbonate and sodium borate were used as foaming agent and flux agent, respectively. The effects of different sintering temperature on the density, mechanical strength and crystalline phases were discussed.

Sample	Slag (wt%)	Quartz sand (wt%)	Borax (wt%)	Soda Ash (wt%)	Density (g/cm3)	Compressive strength (MPa)
P1	80	9	2.5	8.5	2.60	8.38
P2	70	19	2.5	8.5	0.420	4.33
P3	60	29	2.5	8.5	0.331	1.34
P4	50	39	2.5	8.5	0.265	1.03

Table 7.1
Batch composition of parent glasses, and characteristics of prepared foams sintered at 840 degC

The results showed that the glass–ceramic foams with 70wt% MSW slag sintered at 920 1C exhibited an excellent strength-to-density ratio (crushing strength exceeding 2.5MPa,with a density below 0.3g/cm3), due to the precipitation of micro-crystals.
The preparation of foams utilizing high content of MSW slag eliminates the problem of its disposal and displays huge commercial interests.

8. PLASMA GASIFICATION GOALS
Plasma gasification has certain goals in order to reduce environmental pollution thereby minimizing waste and obtaining maximum amount of energy from it.
The goals are as follows:
1.) Eliminate need for landfills: A major disadvantage to burying trash in landfills is the potential to pollute surrounding soil and groundwater with toxins and leachate. When trash decomposes, it releases methane and other greenhouse gases that contribute to climate change and may also cause health problems to humans and animals.
2.) Reduce solid waste effects on environment. (GHG, air toxins, leachate pollution)
3.) Harvest energy and By-products from waste.
4.) Eliminate pollutants like methane in atmosphere and fly ash which are usually formed in incineration.
5.) Save and protect underground water levels, fertility of land.
6.) Clean destruction of hazardous and radioactive waste which is harmful and can prove fatal.
7.) Processing of organic waste into combustible syngas for electric power and thermal energy.
8.) Production of clean alloyed slag which could be used as construction material
9.) Reduce diesel costs: Diesel is required by trucks in order to collect waste and dump it to different areas i.e. generate landfills. Since plasma gasification eliminates landfills, no trucks are required to carry waste for dumping thereby reducing need for diesel.
10.) Produce chemicals and fuels from syngas.

9. ADVANTAGES
• Clean destruction of hazardous waste.
• Preventing hazardous waste from reaching landfills.
• Some processes are designed to recover fly ash, bottom ash, and most other particulates, for 95% or better diversion from landfills, and no harmful emissions of toxic waste.
• Potential production of vitrified slag which could be used as construction material.
• Processing of organic waste into combustible syngas for electric power and thermal energy.
• Production of value-added products (metals) from slag.
• Safe means to destroy both medical and many hazardous wastes.
• Gasification with starved combustion and rapid quenching of syngas from elevated temperatures can avoid the production of dioxins and furans that are common to incinerators
• Air emissions can be cleaner than landfills and some incinerators.

10. DISADVANTAGES

• Large initial investment costs relative to that of alternatives, including landfill and incineration.

• Operational costs are high relative to that of incineration.

• Little or even negative net energy production.

• Wet feed stock results in less syngas production and higher energy consumption.

• Frequent maintenance and limited plant availability.

• For some early technologies, the plasma torch plume reduced the diameter of the sampler orifice over time, necessitating frequent maintenance.

11. CONCLUSION

The fulfilled computational and experimental investigations demonstrated that during comprehensive plasma processing of solid fuel its organic matter converts to synthesis gas, while its mineral matter to a range of valuable components such as "glass ceramic foams."

The high-calorific value synthesis gas, produced by this process, can be used for synthesis of methanol, or as high-potential reducing gas instead of blast-furnace coke, as well as for power generation at thermal power plants.

Also hydrogen can be recovered from syngas which can be used as fuel.

Plasma gasification is a viable option for treating hazardous waste rather than conventional air gasification.

Plasma gasification is better process for waste treatment as compared to incineration or pyrolysis or landfill.

Glass ceramic foams from slag found major applications in electronics due to its easily controlled porosities and microstructures,

Plasma gasification has an advantage of 40 % over pyrolysis and 50 % over incineration as concerned to electricity generation.

The process has low thermal inertia and easy feedback control.

Plasma gasification process does not release any combustion gases nor does it produces fly ash.

Thus, plasma can offer advantages if high quality syngas with high heating value is needed. Moreover, possibility of electrical storage can be utilized in combination with new renewable power production technologies.

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