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A Solution for Municipal Solid Waste Treatment

Roberto Iñaki Ponce de la Cruz[1], Gerardo Ortigoza[1], Guillermo Hermida[1], Pedro Javier García[1] and José Hernández[1,2]

1. Instituto de Ingeniería, Universidad Veracruzana, Av. S. S. Juan Pablo II S/N, Zona Universidad, Fracc., Costa Verde 91294, Boca del Río, Veracruz, México

2. Instituto Tecnológico de Veracruz, Miguel Ángel de Quevedo 2779, C. P. 91860, Veracruz, Veracruz, México

Abstract: This article describes MSW (Municipal Solid Waste) management with APG (Arc Plasma Gasification) technology. First, a brief description of the process and reactor configurations is presented, listing some advantages and disadvantages. Then, alternatives for producing electrical energy with the residue of synthesis gas are addressed. Finally, this technology is proposed as an alternative to face the significant problem of eliminating MSW on a large scale.

Key words: Municipal solid water, APG, synthesis gas.

1. Introduction

Currently, our planet is facing difficult situations due to the excess of waste, which in most cases, is not adequately disposed of and produces pollution; it is necessary to take measures to control the problem it represents. The fact that there are still places where waste is dumped into the sea is unheard of, causing immense damage to the ecology and ecosystems.

This article will explain the gasification technique of solid urban waste (MSW (Municipal Solid Waste)) with arc plasma. This method has the advantage that, in addition to processing general waste, it allows the processing of medical and toxic waste, which is very suitable for the current situation in which the world is coming out of a pandemic.

It is essential to mention that the UN (United Nations) has been working to propose 17 sustainable development goals to transform the world. On September 25, 2015, world leaders adopted a set of global plans to eradicate poverty, protect the planet and ensure prosperity for humankind as part of a new 2030 agenda for sustainable development [1]. Goal number nine (Industry, Innovation, and Infrastructure) mentions that priority should be given to financing basic infrastructure projects. However, many developing countries still do not have roads, water, sanitation, and electricity. This article focuses on the goal of sanitation because it is not a problem only for developed countries, since first world countries are suffering from this significant problem for humanity.

2. Material and Methods

APG (Arc Plasma Gasification) processes all kinds of waste, including organic, inorganic, medical, toxic, and hazardous. It produces syngas (synthesis gas), while the inorganic materials are melted and transformed into a green vitrified material.

In physics and chemistry, plasma is called the fourth state of matter, a fluid state like the gaseous state, but its particles are electrically charged (ionized). Plasma has characteristics that do not occur in solids, liquids, or gases, which is why it is considered a state of aggregation of matter. General Motors in Defiance, Ohio, used the APG process for the first time in 1987. Later, in 1989 an arc plasma torch cannon that worked

Corresponding author: Roberto Iñaki Ponce De La Cruz Herrera, Ph.D., research field: renewable energy, energy efficiency.

up to 5,000,000 h was manufactured by Industry Leading Technology. After 1995, it was converted from a pilot plant to a small commercial plant for ash vitrification in Kinuura, Japan. Thus, in 1999 work began on the gasification of waste or MSW at a Hitachi Metals plant in Yoshi, Japan. In this country, future projects reached the status of commercial plants. Subsequently, plants have been built in the United States, India, China, and the United Kingdom, and there are projects for future plants in other countries [2]. In the market, there are the following manufacturers of APG reactors [2, 3]:

- The Alter NRG Corp. has taken over APG System technology developed by WPC (Westinghouse Plasma Corp.).
- InEnTecLLC (Integrated Environmental Technology LLC).
- PSC (Phoenix Solutions Company).
- Plasco Energy Group.
- Solena.
- Europlasma.
- Tetronics.

The Westinghouse Electric Corporation developed this technology in the 1980s, manufacturing arc plasma torches from 16 to 30 MJ [4]. This company, with Hitachi Metals, manufactured the plants in Japan, while the Plasco Energy Group worked on projects in Ottawa, Canada [3]. Westinghouse Electric Corporation manufactures four arc plasma torch systems with a wide input power range. For example, Marc-3a (80-300 kWe, 27 lb/12.2 kg), Marc-3HC (5-150 kWe, 7.5 lb/7.5 kg), Marc-11 Low (300-800 kWe, 450 lb/204 kg), Marc-11 High (700-2,400 kWe, 405 lb/204 kg). An arc plasma torch system creates a plasma current through the interaction of a gas and an arc between two electrodes [5].

The main advantages of this technology are [6]:

- Self-stability in arc plasma.
- It works with different types of gases (air, O_2, N_2, Ar, He, H_2, CO, CO_2).
- It has different kinds of arc plasma torch systems for input power (direct current and low-frequency discharges, ignited by radio frequency waves, ignited by microwave discharges).
- High thermal efficiency.
- The arc plasma torch has no moving parts.
- Wear components are easily replaced without shutting down the gasifier.
- The electrodes have a long service life.

There are three types of reactor configuration: updraft, downdraft, and fluidized bed. Regarding the amount of tar in the synthesis gas: the updraft is dirtier, the downdraft is cleaner, and the fluidized bed can operate with intermediate values. The reactor updraft is covered in a refractory lining measuring 60 ft (18.28 m) in height. The arc plasma torches are located in the lower part of the APG Reactor, and these heat a bed of foundry coke, reaching temperatures in the center of the coke bed approximately higher than 5,400 °F (3,000 °C). The temperature at the bottom of the coke bed is 3,000 °F (1,650 °C). In updraft, the solid waste is at the top of the reactor and converted to synthesis gas for plasma temperature (1,650 °F to 1,830 °F; 900 °C to 1,000 °C). The syngas from the side of the APG has to go through a series of cleaning processes before being used to produce energy [7].

Operating the APG at high temperatures and ambient pressure has the following advantages [6]:

- Flexibility to use heterogeneous MSW material.
- It allows you to work with plastics and tires.
- Allows a simple feeding system.
- The arc plasma torch can be serviced.
- Syngas has low amounts of NO_x, SO_x, dioxins, and furans.
- The inorganic components become molten slag called vitrified (glass-like slag), which can be used in the construction industry.

Regarding the generation of electrical energy with synthesis gas, the following can be produced:

- Rankine cycle.
- Internal combustion engines.
- Gas-turbines cycle.

- Stirling engines.

In the first option, it is possible to work with dirtier syngas. In addition, it has the lowest operation and maintenance cost than the other options. A steam turbine can generate 500 kWh to 600 kWh per ton of MSW. Instead, the IPGCC (Integrated APG Combined Cycle System) can generate 1,200 kWh per ton of MSW [8]. Also, syngas can be even used to transform into ethanol.

3. Results and Discussion

This section presents the advantages and disadvantages of this technology. First, the main advantages of this technology are:

- Volume reduction of total waste. The vitrification of inorganic materials can also reuse or relocate these residues.
- MSW organic compounds are broken down into elementary molecules because plasma operates at high temperatures.
- Lower emission levels of pollutants, dioxins, CO_2, and other greenhouse gases. Table 1 shows that the CO_2 emissions per 1 MWh of electricity produced with the gasification of MSW are lower than with different power generation configurations.
- To consider the variability of energy recovery from syngas. The efficiency of the process can be increased depending on the scale, design, and technology for generating energy with the syngas.

After analyzing different developed facilities and projects, we observed the following disadvantages [9]:

- Because the arc plasma torch requires high energy, the electrical energy produced with the syngas cannot be guaranteed a surplus for sale. Therefore, the efficiency of the process will depend mainly on the size of the installation, the configuration of the process, and the type of gasifying agent used to create the plasma, among other parameters.
- It is necessary to consider the cost of cleaning and filtering the syngas to remove tar and other components. In addition, transforming metallic compounds to syngas can contain lead, mercury, and cadmium, so investing in treating wastewater from the gas cleaning system in the scrubbers is necessary.
- Also, the maintenance and operation costs of the APG Reactor must be considered, including the replacement of electrodes and refractory material.

Table 1 Pounds of CO_2 emission per MWh of electrical energy is produced [9].

Technology	CO_2/MWH
Msw Incineration	2,988
Coal Combustion	2,249
Oil Combustion	1,672
Gasification of MSW with arc Plasma	1,419
Natural Gas Combustion	1,135

4. Conclusion

Plasma gasification represents a viable technological alternative to solve the serious problem of excessive waste that our planet faces. This technology can process different types of MSW such as organic, inorganic, medical, toxic, radioactive waste, vehicle tires, plastics, etc. In addition, synthesis gas can be used to generate electricity, and the vitrified material developed with inorganic materials can be reused in the construction industry. Although it is not a technology that helps to generate electrical energy with waste because arc plasma torch consumes a high amount of energy, it is a great advantage because it faces the significant problem of eliminating MSW on a large scale. Therefore, in future research, other methods or viable alternatives must be explored to solve the problem of excessive waste.

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