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PLASMA ARC TECHNOLOGY FOR WASTE MANAGEMENT AND SUSTAINABLE RENEWABLE CLEAN ENERGY GENERATION

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Abstract - *Due to rapid growth of human population, wastes are increasing day by day and create pollution in the environment. Conventional waste treatment methods do not solve these problems, because the harmful residues such as ash, dust, gases left behind cannot be filtered off even with the usage of innovative technologies. Plasma arc technology is a modern solution and clean technology for all kinds of wastes. In this application, plasma arc gasifies the carbon based part of waste materials such as municipal solid waste, sludge, agricultural waste, etc. and generates a synthetic gas which can be used to produce energy through reciprocating engine generators, gas turbines and boilers. The non–carbon based part of the waste materials form a vitrified glass and re-usable metal. In this way the plasma technology can also help in lowering down the emission of greenhouse gases from the environment and it a safe place for living*

Key Words: **waste management, plasma arc, gas turbines, plasma gasification, synthetic gas**, etc

1.INTRODUCTION

Waste is anything, which is unacceptable to an owner and directly has no monetary value but its proper utilization can make a business. Municipal Solid Waste (MSW)includes waste from households, nonhazardous solid waste from industrial commercial, institutional establishment (excluding bio-medical waste in present context), Market waste, Yard waste, Agriculture waste & Street Sweepings. Industrial and community hazardous waste and infectious waste is not considered as MSW and should be collected and processed separately. MSW (Management and Handling) Rules 2000 defines MSW as commercial and residential wastes generated in municipal or notified areas in either solid or semi-solid form excluding hazardous wastes but including treated biomedical wastes. Various other definitions related to MSW, which are defined in MSW Rules 2000, are given in MSW management encompasses the functions of collection, transfer and transportation, processing and recycling, and disposal of MSW. Plasma technology was introduced in the 1950s; adaptation of this technology to large-scale waste destruction, including gasification of waste and recovery of energy from the generated gas is new. Plasma gasification of municipal solid waste (MSW) is a fairly new application that combines well-established sub-systems into one new system. Plasma Gasification, the MSW is gasified in an oxygen-starved environment to decompose waste material into its basic molecular structure. As opposed to incinerators, the waste does not combust in the gasifying plant. Plasma may be created in a variety of ways, including passing a gas between objects with large differences in electrical potential, as in the case of lightning, or by exposing gases to high temperatures, as in the case of arc welding or graphite electrode torches. Plasma arc torches utilize a combination of these techniques. A relatively small quantity of ionized gas is produced by an "arc igniter" and introduced between the electrodes contained in the body of the torch. The extremely intense energy produced by the torch is powerful enough to disintegrate the waste material into its component elements. The subsequent reaction produces syngas and byproducts consisting of a glass-like substance used as raw materials for construction and also reusable metals. Syngas is a mixture of hydrogen and carbon monoxide and it can be converted into fuels such as hydrogen, natural gas or ethanol. The Syngas generated is fed into a heat recovery steam generator (HRSG) which generates steam. This steam is used to drive a steam turbine which in turn produces electricity. The cooled gas is then compressed and used to drive a gas turbine which in turn produces additional electricity. The integrated gasification combined circle (IGCC) energy thus produced is used partly for the plant load, while the rest can be sold to the utility grid. Essentially the inorganic materials such as silica, soil, concrete, glass, gravel, including metals in the waste are vitrified and flow out the bottom of the reactor. There are no tars, furans or ashes enough to pollute the environment. Municipal solid waste is believed to be a source of renewable energy, and plasma arc gasification technology is one of the leading-edge technologies available to harness this energy (PouraliM. 2010). The Waste is a sustainable fuel source and increasing day by day as population increases. Therefore Plasma Gasification may be proven as a sustainable source of clean energy and environmentally safe solution for waste management.

1.1 Origin of Plasma

Plasma is one of the four fundamental states of matter. Plasma was first identified in a Crookes tube, and so described by Sir William Crookes in 1879 (he called it "radiant matter"). The nature of this "cathode ray" matter was subsequently identified by British physicist Sir J.J. Thomson in 1897.The term "plasma" was introduced as a description of ionized gas by Irving Langmuir in

1928.Plasma can be artificially generated by heating a neutral gas or subjecting it to a strong electromagnetic field to the point where ionized gaseous substance becomes increasingly electrically conductive. The resulting charged ions and electrons become influenced by long-range electromagnetic fields, making the plasma dynamics more sensitive to these fields than a neutral gas. Neon signs and lighting are examples of partially ionized plasmas. Natural plasma can be seen in lightning, sun, stars, comet etc.

1.2 Gasification Process

Gasification is a technological process that can convert any carbonaceous (carbon-based) raw material such as coal into fuel gas, also known as synthetic gas (syngas for short). It occurs in a gasifier, generally a high temperature/pressure vessel where oxygen (or air) and steam are directly contacted with the coal or other feed material causing a series of chemical reactions to occur that convert the feed to syngas and ash/slag (mineral residues).

1.3. Need for Plasma Arc technology

Humans are machines for turning the world into waste – at least that's how it seems. Recycling is one option, but not everyone does it and there are lots of things (such as electronic circuit boards) made from multiple materials that cannot be easily broken down and turned into new things. That's why much of our waste goes where it's always gone, buried beneath the ground. But we're running out of landfill space to land that problem is bound to get worse. Another possibility is to incinerate waste, as though it were a fuel, and use it to produce energy but incinerators are deeply unpopular with local communities because of the air pollution they can produce. A relatively new type of waste treatment called plasma arc recycling (sometimes referred to as "plasma recycling," "plasma gasification," "gas plasma waste treatment," "plasma waste recycling," and various other permutations of the words plasma, gas, arc, waste, and recycling) aims to change all this. It involves heating waste to super-high temperatures to produce gas that can be burned for energy and rocky solid waste that can be used for building.

2. Process of Plasma Gasification Process

Plasma gasification is an emerging technology which can process landfill waste to extract commodity recyclables and convert carbon based materials into fuels. It can form an integral component in a system to achieve zero waste and produce renewable fuels, whilst caring for the environment. Plasma arc processing has been used for years to treat hazardous waste, such as incinerator ash and chemical weapons, and convert them into non-hazardous slag.

Plasma gasification is a multistage process that feeds inputs ranging from waste to coal to plant matter, and can include hazardous wastes. Steps of this process are as follows.

1. Waste feeding system
2. Plasma gasifier
3. Plasma generating devices
4. Waste processing facilities
5. Yields and byproducts
6. Syngas cleaning facilities

2.1. Waste feeding system

The feedstock for plasma waste treatment is most often refuse-derived fuel, biomass waste, or both. Feedstock may also include biomedical waste and hazmat materials. Content and consistency of the waste directly impacts performance of a plasma facility. Pre-sorting to extract treatable material for the gasification provides consistency. Too much organic material such as metal and construction waste increases slag production, which in turn decreases syngas production. However, a benefit is that the slag itself is chemically inert and safe to handle (certain materials may affect the content of the gas produced, however). Shredding waste to small uniform particles before entering the main chamber is generally required. This creates an efficient transfer of energy which enables sufficient breakdown of the materials. Steam is sometimes added into gasification processes to increase the generation of hydrogen (steam reforming).

2.2. Plasma gasifier

The plasma arc furnace or plasma gasifier or plasma reactor is a device to melt a substance by low-temperature plasma flow, typically created by an electric arc heater (plasmatron). It can be constructed with different materials, which in turn decide the life of operation. It is a vertical refractory lined vessel into which the contaminated waste material is introduced near the top. It contains plasma generating devices which helps to produce plasma which converts wastes into useful byproducts.

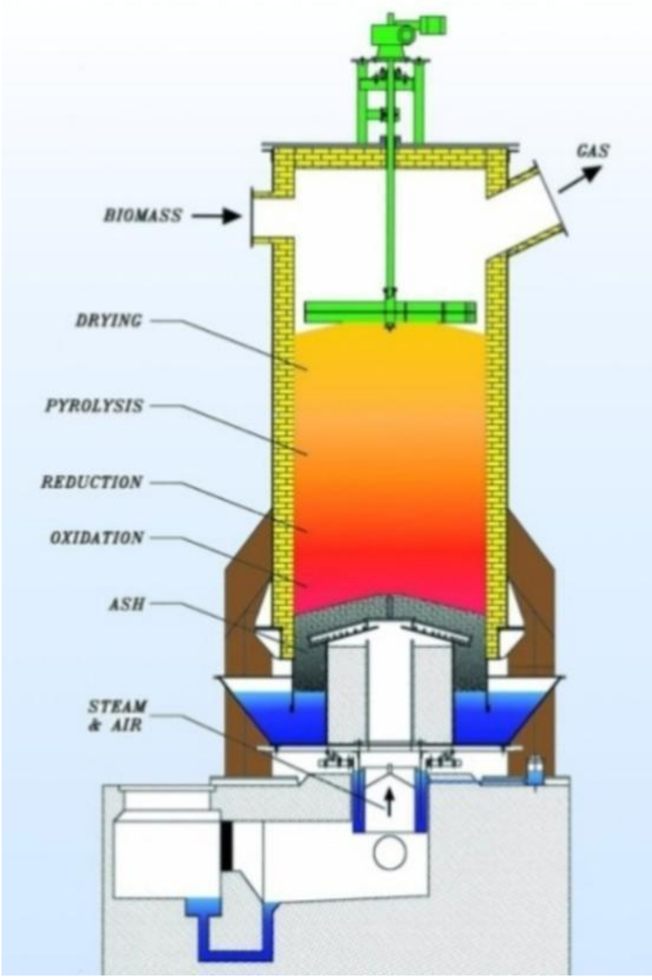

Fig: 1. Plasma gasifier

2.3. Plasma generating devices

Most thermal plasma is generated by either an electric arc or by a radio frequency induction (RFI) discharge. In this, plasma torch is used, which is powered by an electric arc is used to ionize gas and catalyze organic matter into syngas, with slag remaining as a by-product.

Types of plasma torches are;

a. DC Plasma Torches

b. RF Plasma Torches

c. AC Plasmas Torches

DC torches are the most commonly used and researched, because when compared to AC. There is less flicker generation and noise, a more stable operation, better control, a minimum of two electrodes, lower electrode consumption, slightly lower refractory (heat) wear and lower power consumption.

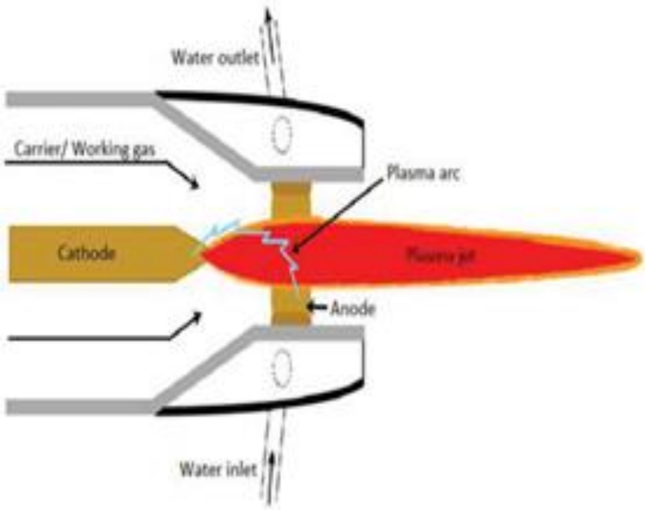

Fig: 2. Plasma torch

2.4. Waste processing facilities

Small torches typically use an inert gas such as argon where larger torches require nitrogen. The electrodes vary from copper or tungsten to hafnium or zirconium, along with various other alloys. A strong electric current under high voltage passes between the two electrodes as an electric arc. Pressurized inert gas is ionized passing through the plasma created by the arc. The torch's temperature ranges from 2,000 to 14,000°C (3,600 to 25,200ºF). The temperature of the plasma reaction determines the structure of the plasma and forming gas.

The waste is heated, melted and finally vaporized. Only at these extreme conditions, molecular dissociation occur by breaking apart molecular bonds. Complex molecules are separated into individual atoms. The resulting elemental components are in a gaseous phase (syngas).

Fig: 3. Waste processing in gasifier

2.5. Yields of plasma arc technology

Pure highly calorific synthetic gas consists predominantly of carbon monoxide (CO) and hydrogen (H_2). Inorganic compounds in the waste stream are not broken down but melted, which includes glass, ceramics, and various metals.The high temperature and lack of oxygen prevents the formation of many toxic compounds such as furans, dioxins, nitrogen oxides, or sulphur dioxide in the flame itself. However, dioxins are formed during cooling of the syngas.Metals resulting from plasma pyrolysis can be recovered from the slag and eventually sold as a commodity. Inert slag produced from some processes is granulated and can be used in construction. A portion of the syngas produced feeds on-site turbines, which power the plasma torches and thus support the feed system.

2.6.Syngas cleaning facilities

In any gasification process, the production of clean synthetic gas (syngas) –free of contaminants such as particulates, sulphur, ammonia, chlorides, mercury, and other trace metals, and possibly carbon dioxide –is crucial to final product quality, to protecting downstream units such as gas turbines, catalytic reactors, and fuel cells, and to ensuring low environment emission levels. Therefore, gas cleanup steps are indispensable, but do have a sizeable impact on plant economics, as they can account for a substantial portion of the overall capital cost and operational costs. Although raw syngas leaving the gasifier is at high temperature, conventional gas cleaning is typically carried out at low temperature by scrubbing the syngas using chemical or physical solvents (these require cooling the gas to typically below 100º F). The cooling equipment required, and the need to reheat the syngas before making use of it in a combustion turbine or synthesis reactor, result in economic and thermodynamic penalties that decrease the efficiency of a gasification plant. Accordingly, gas cleanup that would operate at high temperature while still removing contaminants would provide a significant efficiency improvement in gasification-based processes.

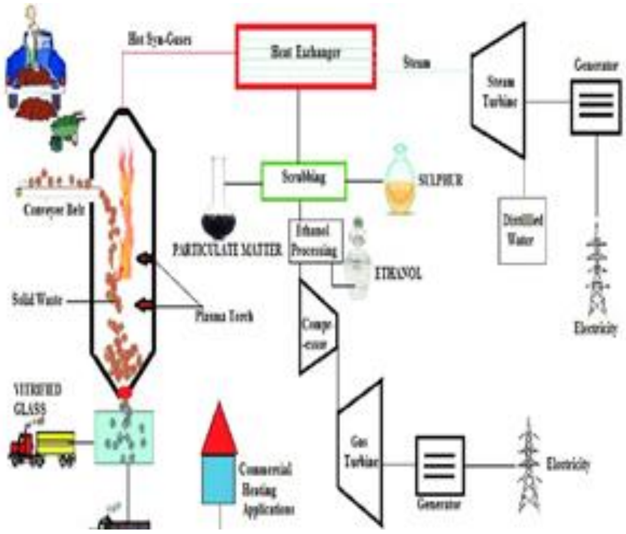

Fig: 4. Process diagram

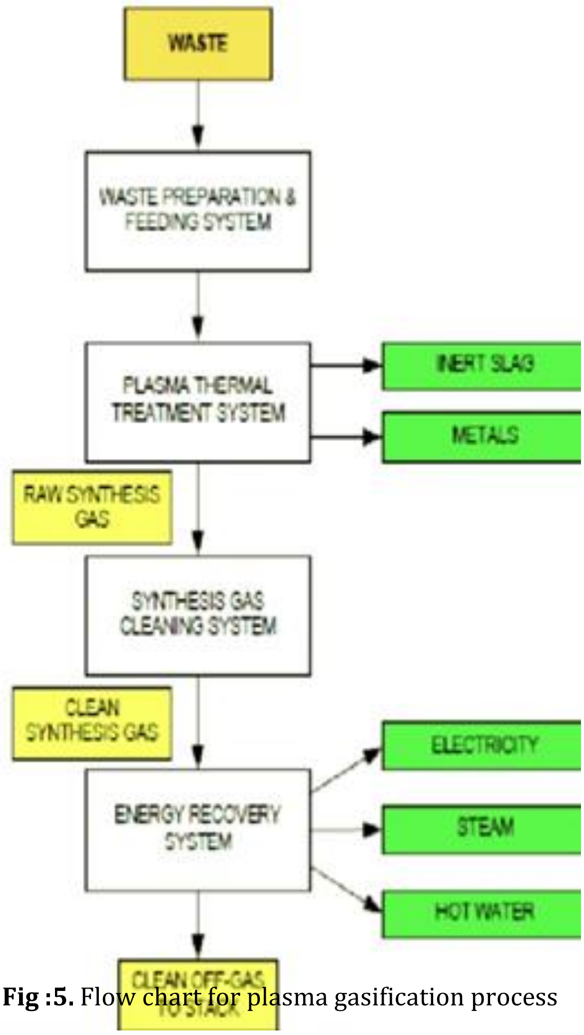

Fig :5. Flow chart for plasma gasification process

Table -1: Comparison between plasma gasification and incineration

CRITERIA	INCINERATION	PLASMA GASIFICATION
Emission of pollutant	High	Very low
Material recovery	Lower	Higher
Energy recovery	Lower	Higher
Formation of ash	Exist	Not exist
Disposal cost for byproducts	Exist	Not exist

2.7. Advantages of plasma gasification

The advantages of the plasma gasification are as follows;

a) Syngas used to generate "green electricity".
b) Slag can be used for road aggregate and building materials.
c) Does not produce hazardous bottom ash and fly ash
d) Very little maintenance and unlike traditional power plants.
e) Efficient in smaller scale systems
f) Can provide a high degree of flexibility over the longer term
g) Does not make difference among input wastes
h) Reduces emissions far below conventional coal plants
i) Limited space requirement
j) Lower carbon footprint.

2.8. Disadantages of plasma gasification

The disadvantages of the plasma gasification are as follows;

a) The lack of standards by national and international organization
b) Initial cost and return of investigation
c) Skepticism on environment effects
d) Confusion between plasma gasification and incineration
e) Complex process control & highly skilled professionals are required

3. CONCLUSIONS

Amount of municipal solid waste is increasing day by day, therefore its management and disposal is becoming difficult. Nowadays, although there are several disposal techniques for all types of waste, new techniques have started to be considered. One of these new techniques is plasma gasification; it is a more innovative and environmentally friendly method than others. Gasification could now be proposed as a viable alternative solution for waste treatment with energy recovery. Independently-verified emissions tests indicate that gasification is able to meet existing emissions limits and can have a great effect on the reduction of landfill disposal options. Government should take the required initiatives to develop this technology for alternative power generation to address power shortages and reduce the use of fossils.

There is a huge gap between demand and supply mainly in India for this technology. Large capacity systems are available but in order to make this technology advanced and widely accepted smaller capacity systems of Pico range i.e. 1-2 MW should be encouraged particularly for rural areas. Such kind of technological advancement can cater to huge gaps.

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