PLASMA REACTORS FOR PROCESSING OF INDUSTRIAL WASTES

G. Paskalov[1], V.E. Messerle[3], A.B. Ustimenko[4] , A.L. Mosse[5],

[1]Plasma Microsystem LLC, Los Angeles, CA USA; [2]Combustion Problems Institute, Almaty, Kazakhstan; [3]Plasmotechnika Ltd., Alma-Ata, Kazakhstan; [4]Luikov Heat and Mass Transfer Institute, Minsk, Belarus.

Abstract: Experimental and theoretical results of arc plasma torches, plasma reactors design is presented in this study. Arc plasma system was developed for industrial waste processing.

Keywords: DC plasma, torch, reactor, mixing chamber, waste.

PLASMOCHEMICAL PROCESSES.

The development of the theoretical bases of plasma chemistry as well as successful development of special plasma equipment is necessary for industrial implementation of different types of plasma technology into industry. These are pyrolysis of hydrocarbons, obtaining simple and complex oxides, carbides, nitrides, borides and other composite materials (catalysts, sorbents, ferrites, magnetic carriers, ceramics and others). The processes of plasma cutting, welding, heat treatment, spheroidization, plasma etching of surface is widely used in industry. The number of large-capacity processes are now in the stage of experimental-industrial tests: generating nitrogen oxides from air with subsequent obtaining of nitric acid, obtaining of hydrocyanic acid, processing of natural phosphates, direct reduction of iron from ores and etc.

Great possibilities are opened for plasma-chemical technology for synthesis of new materials for machine building, rocket and space technology, atomic industry. The new materials are capable to work under the extreme conditions. The utilization of low-temperature plasma for creation of fundamentally new technological processes in chemical, metallurgical, radio-electronic, machine-building and other branches of industry is the subject of studying of different enterprises and firms. This is caused by the fact that plasma makes it possible to repeatedly intensify technological processes, to make them uninterrupted, to obtain materials with the predetermined special properties. Plasma processing considerably raises strength, hardness, wear resistance, cleanliness of surface of different materials, improves their adhesive and other properties.

Considerable attention in recent years is given to processing of different forms of household, industrial, and special waste such as toxic industrial waste, which contain chlorine, fluorine, bromine and other substances, pesticides, liquid and solid radioactive wastes, medical and biological substances due to conversion of waste, which are generated upon the liquidation of armament and others.

During the processing of dispersed powders in the flow of low-temperature plasma the important moment is their dosage, which ensures the necessary ratio (concentration) of solid and gaseous phases. After introduction of the raw material (in powder form) and their mixing with plasma flow the processes of heating, vaporization, dissociation or chemical reactions were observed in the reactor. Then the gas flow is cooled, the solid phase is condensed and collected in cyclones or filters. Thermal decomposition of natural ores, reduction of oxides by hydrogen or by hydrocarbons, nitration or carbonizing of metals as well as their oxides are accomplished. Particle size/dimensions of raw material is limited by size of the reactor and feeding system. Processing of such materials and articles occurs in the mobile or fixed bed and is accomplished in plasma furnaces, shaft or rotating chamber. The process is based on electric arc plasma torch of indirect or direct action. The quantity of plasma torches installed in one furnace, is determined by its power and design features. Propagation and utilization of plasma-chemical processes is impeded not only by technical difficulties but also by economic factors. The main one is relatively high cost of electric energy. However, tendencies towards the increase of thermal energy cost, and also towards advantageous utilization of electric energy in technological processes contribute to the development of electrothermal productions, including the plasma technology.

2. Multi-jet plasma reactor and mixing chamber.

To set up plasma reactors for gas processing as well as dispersed materials and solutions, some specific problems must be solved regarding the ways of heating, heat-transfer efficiency, plasma interaction with the material and the reactor channel walls.

It has been demonstrated that series of plasma generators with a power ranging from 20 to 200 kW can be used as plasma heaters. Typical plasma module is in the range of total power of up to 0.5 to 0.6 MW. Besides, single prototypes of plasma generators with a power up to 0.5 MW have been designed for 1.5MW plasma system. At present time, such parameters can only be achieved by using electric arc plasma torches.

For efficient treatment of liquid and dispersed solutions, we developed and use plasma reactor with a multi-jet mixing chamber.

The plasma reactors with a multi-jet mixing chamber are characterized in certain cases by fairly uniform temperature and velocity profiles in the initial section of the reactor, i.e. plasma jet injection area, by the possibilities of organizing an axisymmetric or distributed injection of raw material, and of raising the reactor power by increasing the number of plasma torches. Advantages of the plasma reactors of such type are the possibility of arranging single-, two-, and multi -jet (multimodule) reactor scheme, based on the multi - jet mixing chamber. This types of reactors permit to increase of their power and efficiency and broadens the scope of their application due to the generation of a plasma flow with a definite temperature distribution over the cross section of the reactor and lengthwise. Of special interest is the passivity of controlling the structure of the plasma flow, formed in the mixing chamber, by varying the mixing chamber geometry, the way of injecting plasma jets and the operating regimes of plasma generators.

The structure of the plasma flow is studied when it is formed in cylindrical and conical mixing chambers with radial and tangential injection of the plasma jets. Investigations have been carried out in multi – jet reactor for air, nitrogen and hydrogen plasma flows in the cylindrical channels of plasma reactors which are axisymmetric to the mixing chambers. These and other results have been used to modeling plasma reactors and processes of liquid and dispersed materials.

Using the experimental data, engineering specifications have been developed and a series of designs of plasma units with reactors of Atol, Pluton, and UP modifications with a power input of up to 1.5 MW has been developed. Different schemes and designs of electric arc plasma generators were tested, and 1.5 MW plasma system were chosen as module for industrial use, which corresponds to the mean capacity of the system of approximately 0.5 t/h waste feeding rate.

3. “Flooded Jet” plasma reactor

The original design of a plasma reactor operating according to the “submerged jet” scheme with a low-temperature plasma generator — a plasma torch operating on various gases and their mixtures — has been developed and is being investigated. The final products: synthesis gases of different composition, hydrogen and hydrocarbon gases. .Various methods for the implementation of processes have been tested. They are implemented by flooding a plasma jet into liquid hydrocarbons. Studies are conducted on the installation, which include:

- The upgraded plasma torch type PL-01/30.
- Partitioned reactor.
- Quenching hopper.
- Plasma gas supply system.
- The gas sampling system

The main advantages of the system:

• Small heat losses, since the processed products do not have direct contact with the walls of the reactor.

• The quenching process is performed without introducing additional gases or liquids.

• Coarse purification of synthesis gas from soot is performed directly in the reactor.

• The raw material can be various liquid hydrocarbons — from light gas condensates to fuel oil, crude and synthetic oil, as well as waste from oil-producing and oil-refining industries and used toxic oils.

• High degree of conversion of raw materials - gaseous and liquid hydrocarbons - 95-99%.

• Low energy consumption (up to 1.0 -2.0 kW · Hr / kg, The technological process is based on DC and AC plasma torches. Process is well optimized for diesel fuel and crude oil. The technology and equipment can be used for industrial applications when using liquid hydrocarbons or wastes containing liquid hydrocarbons as recyclable materials.

4. Conclusion

Efficient DC and AC plasma torches for industrial waste treatment were tested within the power range of 50 to 1500 kW and it is used in different industries.