Researches on energy-efficient plasma conversion of fibreglass waste into new ecological materials for building industry

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Abstract. The paper presents the researches, prototype laboratory equipment and technologies developed by the authors for the plasma conversion of fiberglass waste into useful materials for building industry. The aim was to increase the energy efficiency of conversion processes and to obtain technologies and materials with better properties for civil engineering appliances and reduced impact on the environment.

1. Introduction

Until recent years, fiberglass waste was considered very hard or even impossible to recycle and the only method of disposal was storing in a landfill, having thus a 400 years lifecycle. Nowadays there are three recycling methods for fiberglass waste: mechanical, thermal and chemical [1].

The mechanical recycling process [2] consists in reducing the size of the fiberglass waste by cutting or grinding in hammer mills, followed by centrifugal size sorting into a cyclone, which separates the fine particles in the recycling process.

Incineration, or thermal oxidation, burns the material generating heat which can be used for other purposes, such as producing steam for power plants using turbines that generate electricity. A byproduct of fiberglass incineration is ash, which is usually stored in a landfill. The heat content of fiberglass waste comes from organic materials such as resins. Usually, the organic material content is only of 25% to 30%, so the heat production is low and the resulted quantity of ash is high. The ash composition is largely of calcium oxide, coming from calcium carbonate, boron and other glass components.

Pyrolysis is the process of chemical decomposition of fiberglass waste into several recoverable substances by heating, at high temperatures, in oxygen-free environment. The fiberglass waste, subjected to pyrolysis, decomposes into three recoverable substances: pyrolysis pyro-gas, pyrolysis oil and a solid by-product, all of which are recyclable.

There are various devices and installations for the recycling of fiberglass waste [3], that use a melting furnace which has as heating source electricity (electric furnace with resistors) or chemical energy (flame burners) because in order to melt glass, in general, and fiberglass in particular, temperatures between 1200-1600°C are required. Also for the treatment of the exhaust gases from the reactor, the solution of station of the gas in an enclosure at a high temperature is widely used. Another process of thermal treatment of fiberglass waste is the use of microwaves, as described in [4]. Generally the existing solutions are high energy consuming and pollutant.
The authors have researched and developed a plant intended for use in the waste recycling industry as well as in the construction materials industry, as the material obtained from the destruction of fiberglass waste, with and without adhesive, with the help of hydrogen plasma can be used, as an additive, in the production of bricks, mortar or other materials in the construction industry.

2. Materials and methods

The plant developed by the authors has, in addition to the conversion system of waste in a reactor with the help of hydrogen plasma, a treatment system of the gas resulting from the operation of the reactor with the help of plasma, as well as an energy recovery system. The gases resulting from the exit of the gas treatment system are used to drive a power generator.

The main advantage of this plant is the destruction of fiberglass waste, with or without an adhesive, at a much higher speed than existing installations, due to the use of hydrogen plasma torches. Also, the amount of pollutants released into the atmosphere and the amount of residues resulting from the treatment of fiberglass waste is much lower, and the energy recovery system makes it attractive from an energy and financial point of view.

The installation, according to figure 1, consists of the plasma reactor 1, the feeding and rolling device 2, the hydrogen plasma torches 3 and 6, the tank 4, the gas treatment system 5, the cogeneration system 7, the industrial numerical control system 8, the sensor blocks 9 and 11, the hydrogen plasma torch power supply block 10, the cooling system 12, the terminal equipment 13, the mixing block 14 and the additivation device 15.

![Figure 1. Diagram of the installation for plasma conversion of fiberglass waste.](image-url)

The plasma reactor, according to figure 2, consists of the reactor shell 1, the steam feeding pipe 2, the plasma torch 3, the refractory grate 4, the refractory concrete layer 5, the reinforcing wire net 6, the refractory ceramic masonry 7, the mineral wool insulation 8, the collecting tank 9, the feeding device 10.
The authors have used two research directions in the development of hydrogen plasma torches for the fiberglass recycling plant. First was the modifying of an existent plasma cutting torch which is presented in figure 3. The main challenge of this direction is the transforming of the convergent plasma jet of such a cutting torch into a divergent jet needed for plasma treatment of fiberglass waste, which can be accomplished by modifying the shape of the electrodes and adding of an ancillary water circuit.

Figure 3. Plasma torch modified by authors for melting of fiberglass waste.

The second direction was the research and development of a novel plasma torch, dedicated for the treatment of fiberglass waste, using the rapid prototyping techniques. This novel plasma torch is presented in figure 4.
Figure 4. Novel plasma torch researched and developed by authors for fiberglass waste treatment.

3. Experimental results and discussions
The modification of the existing cutting plasma torch consisted in the adjustment of the shape of the two electrodes and in a study of the changing of the shape and size of the plasma plume with the variation of the distance between the electrodes. The study consisted in the variation, step by step, of the distance between the electrodes, in the range from 1 to 6 mm, and the recording of the plasma plume shape and dimensions, as presented in figure 5.

Figure 5. Recordings of the shape and size of the plasma plume as function of electrodes distance.

Figure 6. Variation of the plasma plume length with the distance between the electrodes.
The variation of the length of the plasma plume with the distance between the electrodes, resulting from the measurements, is presented in figure 6. It was noticed that the maximum length was obtained for a distance of 3 mm between the electrodes.

In figure 7 is recorded the variation of the maximum width of the plasma plume, as a function of the distance between the electrodes, as it resulted from the measurements. It can be perceived that the maximum width of the plasma plume was obtained for a distance of 2 mm between the electrodes.

![Graph showing the variation of plasma plume width](image)

**Figure 7.** Variation of the plasma plume width as function of the distance between the electrodes.

It was also observed, as results from the figure 5, a separation of a secondary plasma jet from the main plasma plume, starting from a distance of 3 mm between the electrodes.

4. Conclusions

In this study was presented a novel plant for plasma treatment of fiberglass waste, developed by the authors, and two directions for developing plasma torches for this plant. First was the modifying of an existent plasma cutting torch, the second was the research and development of a novel plasma torch, dedicated, using the rapid prototyping techniques.

A research was conducted for the transforming of the convergent plasma jet of a cutting plasma torch into a divergent jet needed for plasma treatment of fiberglass waste, which was accomplished by modifying the shape and the distance between the plasma electrodes.

A study of the changing of the shape and size of the plasma plume with the variation of the distance between the electrodes was also done. This study reveals that the maximum length of the plasma plume was obtained for a distance of 3 mm between the electrodes and the maximum width of the plasma plume was obtained for a distance of 2 mm between the electrodes. It was also observed a separation of a secondary plasma jet from the main plasma plume, starting from a distance of 3 mm between the electrodes.

The advantages of the treatment plant for fiberglass waste, using hydrogen plasma torches, researched and developed by the authors are:

- efficient operation, with a low staff compared to existing facilities;
- fiberglass waste, with and without adhesive, treatment times are much lower than existing installations;
- the treatment of the resulting gases is made with a hydrogen plasma system, resulting in lower emissions;
• using of the syngas, resulting from hydrogen plasma treatment, to drive an electric generator for energy recovery;
• from the treatment process of the fiberglass waste, with and without adhesive, in the plant can be obtained, by future researches, valuable materials such as:
  • empty glass microspheres [5] with porous walls or cenosphere can be used as lightweight fillers in composite materials such as lightweight concrete, the storage and slow release of pharmaceutical drugs or radioactive markers for research, and in the field of controlled storage and release of hydrogen;
  • aerogels [6] that can be used as thermal insulators, catalysts or carriers of catalysts, imaging, optical and light guides, filter materials, thickeners in some paints and cosmetics, and as components in solar energy absorbers;
• sealing glass [7] that has gluing and sealing applications between metal and ceramic parts.

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