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TRANSFORMATION OF CONSTRUCTION WASTE INTO ENERGY USING A PLASMA HYDROGEN SYSTEM

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1. INTRODUCTION

The general principles of waste construction management are: waste prevention targets to reduce emissions, reduction of hazardous substances in material streams and increase resource efficiency, preparation for reuse involves checking, cleaning, or recovery by which products or components of products that have become waste are prepared for reuse, energy recovery from waste and other recovery activities energy production from waste involves burning waste and using energy content of the waste to produce electricity or to obtain heat and power, heat being used for various services, disposal of waste in landfills in ecologically storage is the least desirable option in waste management hierarchy being the most negative effects on environment and human health.

2. MATERIALS AND METHODS

Classic thermochemical processes for the energetic processing and recovery of recyclable materials from the construction waste:

- direct combustion: it produces thermal energy, large volume of ash and inert materials, a high percentage of dangerous gases with negative impact on the environment,
- gasification: obtaining a gas mixture of H2, CO, CH2 with reduced calorific value, high volume of inert materials,
- pyrolysis: thermal process that takes place in the absence of oxygen, produces combustible gases and thermal energy obtained from the decomposition of material at 700 °C

Plasma gasification is a technology through:

- a mixture of combustible gases H2, CO, CH2, CH3, CH4 (syngas) is produced with a high purity and calorific value,
- a vitrified mineral waste with a volume between 5-10% with minimal impact on the environment, hardness and properties similar to ceramic materials (use in construction),

the syngas obtained can be used to obtain raw materials in the field of chemical industry, fuels or directly converted into electricity and heat,

- the technological installations are compact, the technological processes are carried out in short periods of time, the volume of fuel gas obtained is high.

a) Westinghouse plasma technology, plants use plasma torches on gas, equipment is high working temperatures are about 4,000 °C electricity consumption is high, processed waste requires humidity reduction, syngas obtained has a high percentage (5-10%) of accompanying gases dangerous for the environment with low calorific power, the volume of inert material obtained is high.

b) Plasma hydrogen technology obtained by dissociation of water in plasma jet, the installations are compact of small size, with working temperatures between 10,000-20,000 °C, do not require drying of waste, the syngas obtained has a high percentage of combustible gases $H_2 \approx$ 50-55 %, $CO \approx$ 20-25%, $CO_2 \approx$ 15% and accompanying gases approximately 1-5% with minimal environmental impact.

Table 1. Comparative analysis between plasma gasification and incineration

Incineration - include oxygen	- energy convers to heat - residue is ash which is considered a hazardous waste - residue can be as much as 30% of original solids volume - higher level of emissions of Greenhouse gases and other polluants
Plasma gasification - absence of oxygen	- results in gas which can be used to produce energy - residue is an inert glass like slag - residue amounts to around 6-15% of original solids volume - extremely low levels of emissions

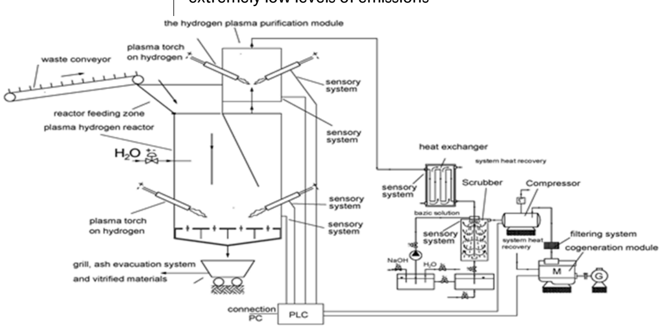
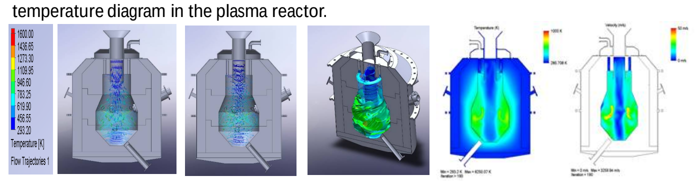


Fig. 1. The schematic diagram of equipment for hydrogen plasma conversion of construction waste

Plasma gasification is a technology for recycling waste as a source of renewable energy: is produced a mixture of combustible gases H2, CO, CH2, CH3, CH4 (syngas) with a high purity and heat output results in a vitrified mineral waste with a volume between 5-10% with minimal impact on the environment, hardness and properties similar to the ceramic materials, the obtained syngas can be used for obtaining raw materials in the field of chemical industry, fuels or directly transformed into electric and thermal energy, the technological installations are compact, the technological processes take place in short periods of time, the volume of gas obtained is high.

The main objective is the design of an eco-innovative plasma-based technology for the recovery of waste as a renewable energy source, improvement of the technical and economic performance of the plasma installation for the waste processing by upgrading some components of the plant (plasmas, adaptive thermal conduction processes from the plasma reactor enclosure, plasma gas purification system) and optimization of the syngas production technology by controlling the plasma conversion of waste depending on the results obtained the modeling and simulation of thermo-chemical processes of plasma waste processing with the help of specialized software.

Mathematical modeling of the process management system in plasma plants for waste processing was made with Solidworks, the figure below shows the gas displacement and the temperature diagram in the plasma reactor.



a) simulation of hot gas flow   b) simulation of the temperature in the reactor and the speed of gas displacement

Fig. 2. Modeling and simulation of the main reactor with plasma on hydrogen

The projected installation has the following technical features:

- raw material is municipal waste (organic substance) 410 kg/h, humidity 35%, caloric power 13.9 Mj/kg and water as vapor 65 kg/h;
- electricity: 0,200 MWe/h of which: plasma torque = 0.142 MWe/h, water / solid separator = 0.050 MWE/h, organic substance carrier in the reactor = 0.005 MWe/h, measurement and control systems = 0.003 MWe/h.
- slag (vitrified) 8.2 kg/h, inert material 141.8 kg/h, residual heat of 0.007 Mwt, syngas 325 kg/h which represents 1,533 MWt chemical energy.

Figures below shows the functional diagram of the plant with hydrogen plasma for processing municipal waste and charts on energy and materials balance.

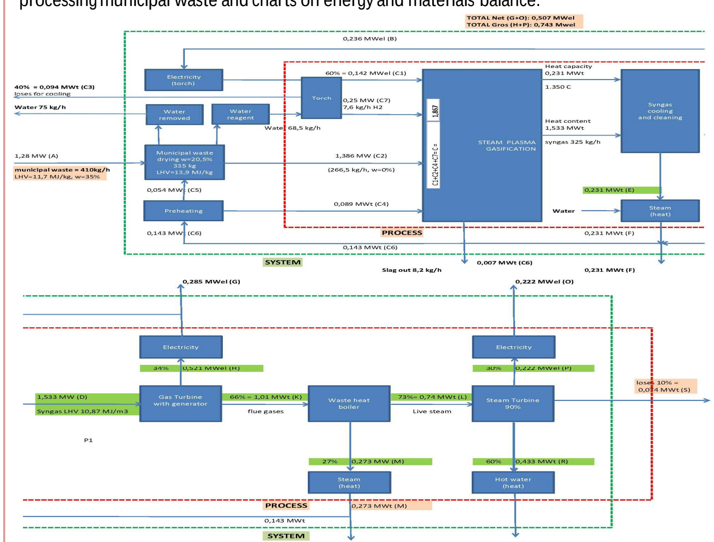


Fig. 3. Functional diagram of the plant and charts on energy and materials balance

3. CONCLUSIONS

The sludge from the used sludge category is largely eliminated, the resulting vitrified material is inert and in minimal quantity, easy to recycle with the possibility of recovering heavy metals.

The installation allows the reduction of greenhouse gas emissions:

- reduction up to 40% CO2 and 100% CH4, efficient filtration without toxic gas emissions;
- reduction of quantity of SO2, SO3, Nox (acid rain factors) dioxins and furans;

Economic advantages:

- the installation eliminates the costs related to the planning and management of the municipal landfills, the surface affected by the landfills is returned to the agricultural circuit;
- costs related to solid / gaseous fuel supply, maintenance and operation of classical district heating plants are minimized;
- significant reduction of the impact of municipal landfills and of district heating plants on the environment;
- the plasma waste conversion facility has no impact on the environment, the resulting inert solid waste volume is between 10-15%;

Acknowledgments

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References:

[1] Hofbauer H., Materazzi M., (2019) Waste gasification processes for SNG production, Editor(s): Massimiliano Materazzi, Pier Ugo Foscolo, Substitute Natural Gas from Waste, Academic Press, Pages 105-160, ISBN 9780128155547

[2] Tavares R., Ramos A., Rouboa A., (2019) A theoretical study on municipal solid waste plasma gasification, Waste Management, Volume 90, Pages 37-45, ISSN 0956-053X