AIR GASIFICATION OF MIXED WASTE FRACTIONS

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Abstract. This paper presents the results of an experimental research concerning the packaging waste air gasification. The experimental study of light packaging waste gasification was carry out in a modified lab-scale rotary kiln with external heat input that can reproduce laboratory-scale industrial processes such as incineration and gasification. The operating temperatures of the experiment range between 800°C -900°C using air as gasifying agent with an ER varing between (0.2-0.3). The char content is presented even at higher temperatures and part is discharged as unconverted carbon in the unusable ash. The maximum conversion energy efficiency up to 60% rate it's registered at higher temperature of the experiments and maximum ER rate.
Keywords: energy; gasification; plastic; paper; waste.

1. INTRODUCTION

At present the annual total solid waste generation worldwide is approximately 17 billion tonnes and is expected to reach 27 billion tonnes by 2050, by cause of population growth, increasing urbanization and socio-economic development [1].

Overall, about 50- 70% of the total plastic waste is packaging materials derived from polyethylene, polypropylene, polystyrene, and polyvinyl chloride. On average, polyethylene makes up the greatest fraction of all plastic wastes (69%), especially plastic bags, and polyethylene comprises 63% of the total packaging waste [2].World paper and paperboard demand and production are increasing; annual paper and paperboard production is expected to grow from approximately 365 million tonnes (Mt) in 2006 to between 700 Mt (low estimate) and 900 Mt (high estimate) in 2050. However, increasing concerns related to the presence of potential harmful chemical substances in paper have been voiced within recent years, for example in relation to the migration of chemicals from packaging materials into food [3].

Today, worldwide this type of wastes is still mainly landfilled. In the last years, much effort has been focused to develop environmentally friendly technologies that use waste feedstock as alternative to fossil fuels. These types of products have two major advantages for power generation sector: reduction of specific primary energy consumption which has a direct effect on air pollution and reduce energy resource demand in accordance with rapid reduction of fossil fuel reserves. Even if the waste sources have a high energetic potential, the power sector is reluctant to major structure modifications because of: waste availability and homogeneity, technological and economical block that have to be overcome before alternative energy can replace even a small portion of the power provided by fossil fuel.

Amongst the treatment options for solid waste into fuels, energy or valuable chemicals conversion, thermal treatment processes have the highest conversion efficiencies. Thermal treatment plants can convert the energy value of solid wastes into different energy forms (mainly electricity and process heat for industrial facilities or district heating) by means of three main thermo chemical processes: combustion(incineration, co-combustion), pyrolysis and gasification. While mass-burn waste incineration generally is the most robust technology accepting a wide range of waste materials (size, sources), also other technologies such as fluidized-bed incineration exist (a more homogeneous waste input is needed here). Due to technological and economical restriction, co-combustion, gasification, and pyrolysis are generally less widespread and mainly applied on pre-treated waste, sub-streams of urban waste or biomass (e.g. Solid Recovered Fuels, or Refuse Derived Fuels)[4].Regarding the environmental benefits, in this terms becoming also a social one, Joelsson and Gustavsson show that a integrated solid waste to energy system, considering a polygeneration thermal process scheme, reduces CO2 emission and dependence on oil [5].

The waste-fuelled combustion systems have benefits from the technological simplicity point of view. The waste incineration have improved significantly over the last two decades, mainly due to utilization of sophisticated flue gas cleaning equipment which have proven robust and capable of meeting strict emission regulations. However, the waste thermal disposal poses potentially serious air pollution problems due to the release of harmful gases such as dioxins and hydrogen chloride (chlorine content), airborne particles (high treatment temperature) and carbon dioxide, [6]. Over more, unlike fossil-fired power plants, solid waste incinerators are still featuring several constraints mainly the high capital and maintenance costs (about three times higher than a coal plant of the same nominal capacity) and have significantly lower energy conversions efficiencies (13–24%) mainly due to lower steam temperatures to prevent severe boiler corrosion, fouling and slagging (fireside problems) and high air excess (up to 1.8) [7].

In the last years, pyrolysis and gasification technologies have emerged to address these issues and improve not only the energy output, but also the greenhouse emissions. These modern technologies offer an alternative process that devolatilizes solid or liquid hydrocarbons and convert them in by–products as energy carries, offering both upstream (feedstock) and downstream (product) flexibility. Currently, for solid waste pyrolysis in one single stage, information on technology development, characterization of products and byproducts usage and their correlated pollution is not sufficient to support technology application and system design [8].

2. MATERIAL AND METHODS

The experimental study leads to the optimisation of gasification process parameters at industrial scale using renewable sources and assess its efficiency and environmental impact [9].

The pilot installation used in this study was developed in the Renewable Source Laboratory, Power Faculty, Politehnica University of Bucharest with the patent number RO127125-A0 and name Process and plant for characterizing/processing fuel and non-fuel products (solids, slimes and liquids) in a thermo-chemical way by combustion, pyrolysis and gasification [10,11].

The experimental study of light packaging waste gasification was carry out in a pilot-scale rotary kiln with external heat input that can reproduce industrial processes such as pyrolysis, combustion and gasification. The operating temperatures of the experiment range between 800°C -900°C using air as gasifying agent with an ER varying between (0.2-0.3).

The flow rate up to 1 kg/h was determined by the feeding rate and its advancement in the reactor due its inclination. The flow feedstock parameter is influenced by the temperature operation conditions. The latter will influence the ER parameter which will enable the material entry and moving from the upper to the bottom of the reactor. This facilitates also the bottom ash/char removal by the end of the process. The packaging waste mixture as well as the solid residue have been fed and discharged from the reactor in a continuous way.

The gases produced are analyzed both with Testo instrument and GS-MS. The Testo instrument use choice was made due to knowledge necessity of the process stabilization moment. When the process was in gasification regime the GS-MS extracted a small amount of gas that was analyseds. During the experiments was observed that the process enters in gasification regime after 10-12 min since the reactor feeding time. The differences temperature between the reactor inlet and outlet is about 100 °C. During the gasification process, heat energy deliver in the reactor due to packaging waste mixture gasification increase the outlet with almost 20-30°C.

However there is an estimated one minute delay from the moment of gas extraction until starting gas chromatographic analysis. Over more one gas sample analysis by GS-MS instruments takes about 20 minutes. For a better accuracy of the results the stable conditions process must be maintain.

The producer gas was analyzed via a gas chromatography using a thermal conductivity detector (TCD) and a flame ionization detector (FID) with helium used as carrier gas. Three runs were made for the same experimental conditions in order to facilitate and increase the accuracy of the results.

3. PACKAGING WASTE AIR GASIFICATION

Figure 1 and 2 presents the gas produced composition function of ER.

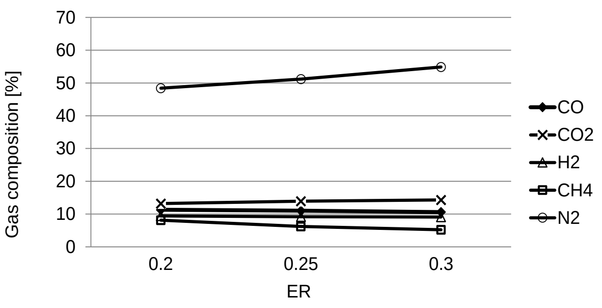

Fig. 1. Gas analysis from gasification of light packaging waste at 800°C

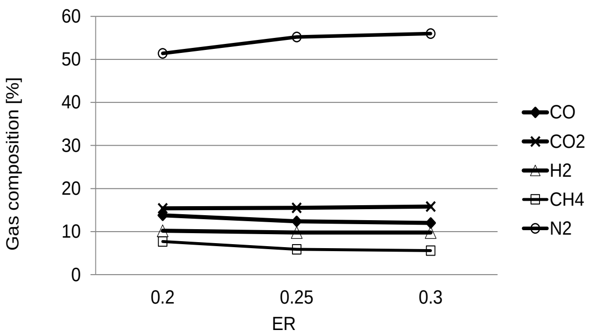

Fig. 2. Gas analysis from gasification of light packaging waste at 900°C

From the results the solid residue amount is strongly influence by temperature and ER as shown in figure 2. The solid residue is composed by char and ash. The char content is presented even at higher temperatures and part is discharged as unconverted carbon in the unusable ash. The latter limit the efficiency conversion given the fact that only 5% of solid residue product represents ash.

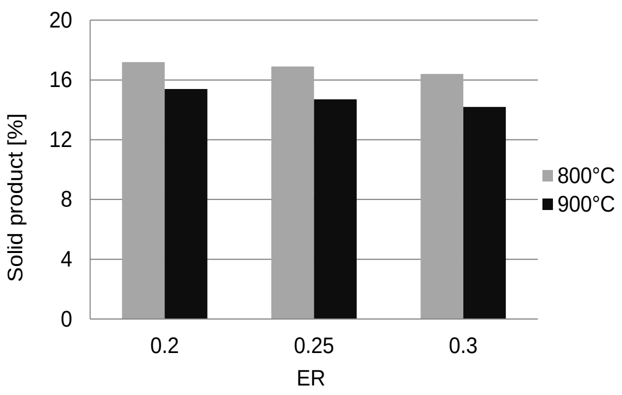

Fig. 3. Solid residue product [%] at 800°C and 900°C.

By increasing the ER the nitrogen provided by air, dilutes the producer gas which in turn results in its low energy content. The latter will be revealed in the LHV syngas production as presented in figure 4.

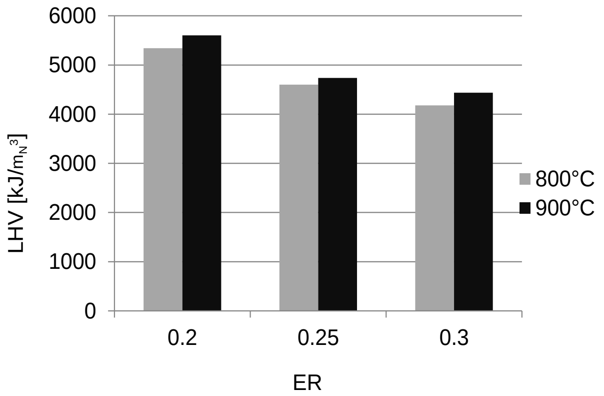

Fig. 4. Low heating value of the syngas produced.

The conversion energy efficiency was calculated by estimating the syngas flow rate from the gasification process. The gas flow rate (Q_{syngas}) was estimated from the data registered by Testo instrument. As figure 4 shows, the gas flow rate at 800 °C and ER ranging between 0.2 -0.3 is 1.5-1.99 m^3_N/kg_{PW}. As it was expected, the gas yield increase with the increasing of temperature and gasifying agent. At 900 °C and 0.2-0.3 ER the gas flow rate registered varies between 1.58-2.1 m^3_N/kg_{PW}.

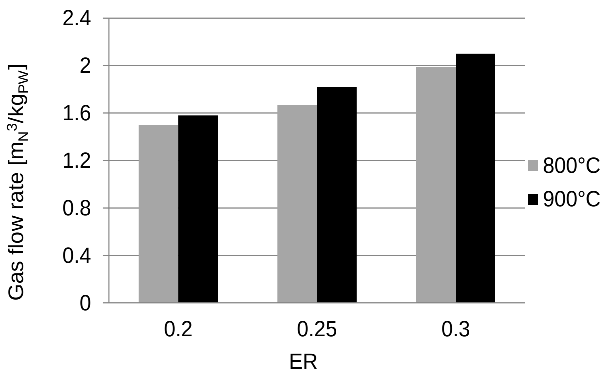

Fig.5. Gas flow rate

Figure 6 and 7 presents the conversion energy efficiency both for cold syngas (CGE) and hot syngas (HGE) production. It is assumed that neither the elutriated carbon nor the tar contributes to the conversion energy efficiency.

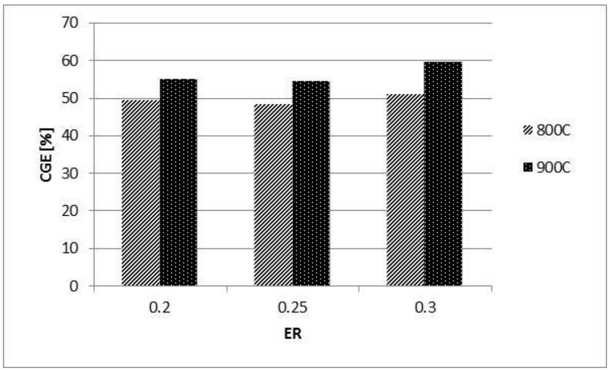

Fig. 6. Conversion energy efficiency for cold syngas.

It can be noticed the minimum energy conversion efficiency is achieved at ER=0.25 while the maximum one is achieved at ER=0.3 for both temperatures.

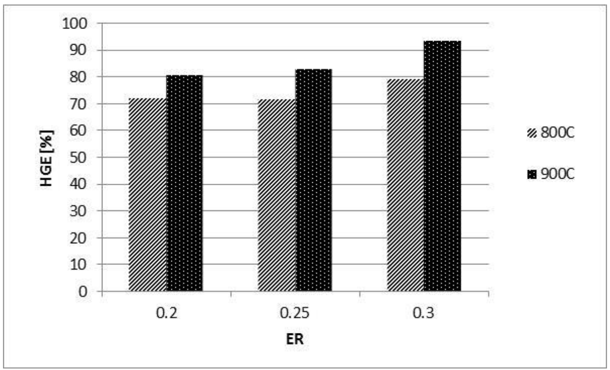

Fig. 7. Conversion energy efficiency for hot syngas.

Even if the combustible gases quota in the syngas decrease due to the air that has dilution effect the conversion energy increase due to the increasing of gas flow rate. The maximum conversion energy efficiency up to 942% rate it's registered at higher temperatures and maximum ER rate considering the sensitive heat of the produced syngas.

3. CONCLUSIONS

This paper presents the results of an experimental research concerning the packaging waste air gasification.

The combustible gas contains CO_2, CO, H_2, CH_4, H_2O, and trace amounts of higher hydrocarbons, inert gases present in the gasification agent, various contaminants such as small char particles, ash and tars. One of the eco-friendly concepts that gasification treatment presents is given by the low temperature process that limits the formation of the dioxins and large quantities of SO_x and NO_x. As a result, the volume of flue gas is low, requiring smaller and less expensive gas cleaning equipment.

At this stage, gasification generates a fuel gas that can be integrated with combined cycled turbines, reciprocating engines and potentially, with flue cells that convert fuel energy to electricity more than twice as efficiently as conventional steam boilers.

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REFERENCES

[1] Laurent A. , Bakas I., Clavreul J, Bernstad A., Niero M., Gentil E., Christensen T., Review of LCA studies of solid waste management systems – Part I: Lessons learned and perspectives, *Waste Manage.*, **34** (3),573–588, 2014.

[2] Bidhya Kunwar, Cheng H.N., Sriram Chandrashekaran R, Brajendra K Sharma , Plastics to fuel:a review, *Renew. Sust. Energ. Rev.*, **54**,421–428,2016.

[3] Pivnenko K., Eriksson E., Astrup T. F., Waste paper for recycling: Overview and identification of potentially critical substances, *Waste Manage.* **45**, 134–142, 2015.

[4] Astrup T.F., Tonini D., Turconi R., Boldrin A., Life cycle assessment of thermal Waste-to-Energy technologies: Review and recommendations, *Waste Manage.*, **37**, 104-115, 2015.

[5] Joelsson J.M., Gustavsson L., Reduction of CO2 emission and oil dependency with biomass-based polygeneration, *Biomass Bioenerg.*, **34**, 967–984, 2010.

[6] Siddiqui, M.N., and Redhwi, H.: Pyrolysis of mixed plastics for the recovery of useful products, *Fuel Process. Technol.*, **90(4)**, 545-552, 2009.

[7] Malkow T., Novel and innovative pyrolysis and gasification technologies for energy efficient and environmentally sound MSW disposal, *Waste Manage.*, **24(1)**, 53-79, 2004,

[8] Arena U., Gasification: An alternative solution for waste treatment with energy recovery, *Waste Manage.*, **31(3)**, 405–406, 2011.

[9] Chen D., Lijie Y., Wang H., He P., Pyrolysis technologies for municipal solid waste: A review, *Waste Manage.*, 34(12), 2466–2486, 2014.

[10] Ionescu, Gabriela (2012) Critical Analysis of Pyrolysis and Gasification Applied to Waste Fractions with Growing Energetic Content. PhD thesis, University of Trento, University Politehnica of Bucharest.

[11] Mărculescu C., Badea A., Process and plant for characterizing/processing fuel and non-fuel products (solids, slimes and liquids) in a thermochemical way by combustion, pyrolysis and gasification, Politehnica University of Bucharest (UYPO-Non-standard), Patent Number(s): RO127125-A0.