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# Problems OF Plastic Recycling in the Aspect of the Applications of Energy Methods

**Krzysztof Jesionek[1], Grzegorz Wieczorkiewicz[2,3], Michał Rychlik[4], Robert Roszak[4], Jarosław Markowski[5], Marcin Nowacki[5], Damian Olejniczak[5] and Krzysztof Wasiński[6]**

*[1]Wroclaw University of Science and Technology, Faculty of Technical and Engineering, Wroclaw, Poland*
*[2] CAD-MECH Company Ltd, Wroclaw, Poland*
*[3]Center of Modern Technologies Ltd, Wroclaw, Poland*
*[4]Poznan University of Technology, Chair of Virtual Engineering, Poznan, Poland*
*[5]Poznan University of Technology, Institute of Combustion Engines and Transport, Poznan, Poland*
*[6]Institute of Non-Ferrous Metals Division in Poznan, Central Laboratory of Batteries and Cells, Poznan, Poland*

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***Abstract***

The current development of the plastics production technology is focused on the use of full recycling in the final phase of the product life cycle. Recycling of plastics is related to the use of many processing methods related strictly to the type and chemical composition of the material. The precision of material identification is crucial for the properties of the components produced from the recovered raw material. This reason enforces the use of selective collection of raw material and the need to ensure the cleanliness of the elements. Such requirements translate into an increase in organizational and financial expenditures on the recycling process. As a result, the required process is often discontinued and the process of storing the obtained raw material takes place. During storage, the most common is the initiation of the impact of biological factors that degrade the quality of the raw material, which is the reason for the disqualification of the raw material for chemical processing. In the current situation, energy methods remain as the final raw material processing. The article presents an analysis of several known methods of energy recycling of plastics focused on the issues of assessment of process efficiency and the adopted technological processes of recycling.

*Keywords:* Biomass; recycling; gasification process; plastics;.

## 1. Introduction

The current civilization and social development is connected with the continuous increase in the demand for energy raw materials in terms of energy production itself and for the production of new materials for the production of various objects and goods that meet the needs of people. One of such materials are plastics. Their advantages over other materials in the form of low manufacturing costs, simplified production process, the possibility of giving any shape and physicochemical properties and the possibility of their reuse in recycling technologies have caused their widespread use in all areas of life regardless of the place and wealth of societies around the world.

Since 1950, in which about 2 million tons of plastics were produced, production increased almost 200 times, reaching 381 million tons in 2015 (Fig. 1). By 2015, 7.8 billion tons of plastic was produced worldwide. Which corresponds to over one ton of plastic per one person living on our planet [1].

A special advantage of plastics is the possibility of recycling them. According to the idea, the recycling process is to ensure the re-use of used materials to produce new and, ultimately, energy recovery. Thermoplastic plastics have the greatest potential for reprocessing. However, the reprocessing process requires high physico-chemical compatibility of the material. This is facilitated by the recycling policy regarding the introduction of product identification in the form of individual codes at the time of their creation. In spite of this organizational treatment, the recycling process of these materials requires additional high purity of used products. This condition is difficult to meet and as a consequence these materials are not recycled in significant quantities. They often fall into the landfills and constitute a hard-to-decomposition waste, which creates a great ecological threat. In the United States, only about 9 % of plastic waste is recycled. A larger share of plastic waste is recycled in China (25 %) and in Europe (30 %). However, these are very small values of the share of processed plastics in relation to the quantity of plastic produced.

Plastics have a relatively high calorific value, depending on the physicochemical composition from 15 to 25 MJ/kg. Therefore, it is justified and as it turns out, it is necessary to apply energy recycling processes. Presently, its simplest form is widespread as burning and recovery of thermal energy in the form of heat. however, the conventional oxidation process is associated with the emission of harmful compounds contained in the exhaust. Introduced exhaust gas cleaning systems are associated with the capture of basic compounds such as sulfur oxides, nitrogen oxides, solid particles. On the other hand, there is an uncontrolled

* E-mail address:grzegorz.wieczorkiewicz@cadmech.pl
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emission of other compounds containing such elements as chlorine, mercury and arsenic, which are harmful to the natural environment in small amounts. That is why many scientific and research works are being carried out related to the search for other thermal processes of plastic waste utilization.

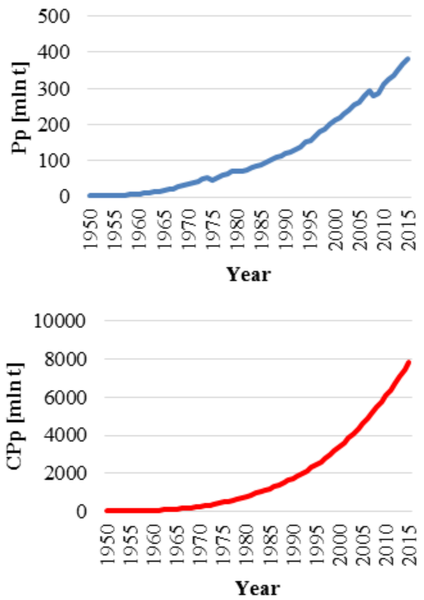


**Fig. 1.** Global production of plastics since 1950 [2]: Pp – annual, CPp – cumulated

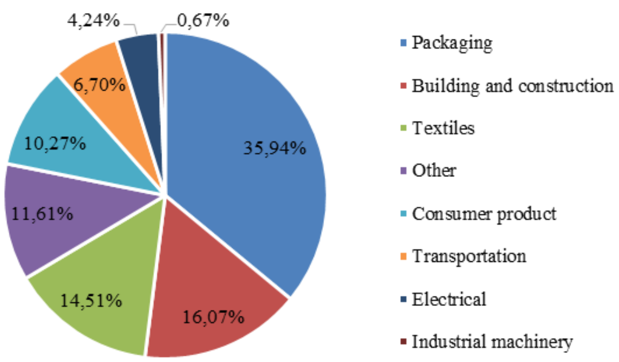


**Fig. 2.** Percentage of industries in the production of plastics [2]

One of them is gasification technology. This technology is increasingly disseminated in the field of biomass gasification for the purpose of obtaining thermal and electrical energy using the sets of electric power generators driven by combustion engines, which are fed with synthesis gas obtained in the gasification process. On the other hand, the implementation of the gasification process for plastics requires the development of new technologies in the field of gasification reactors for liquid substances and systems with elements resistant to aggressive compounds contained in plastic, such as chlorine. It is also necessary to adapt the synthesis gas treatment systems that will enable the neutralization of other harmful compounds. Currently, there are many exhaust gas cleaning technologies that can be adapted to the needs of the gasification process. Therefore, it is necessary to analyze the possibility of modifying the technological line for the needs of gasification processes for plastics. The article presents the concept of modification of the previously developed device dedicated for gasification of waste RDF (Refuse Derived Fuel) for the needs of gasification processes for plastics.

## 2. Gas treatment technologies – adaptive potential for a gasifier for plastics

An undoubted problem in the gasification of plastics is the content of aggressive compounds such as chlorine and sulfur in synthesis gases. Their influence on the construction element of the installation may cause excessive wear and contribute to the necessity of frequent replacement. Therefore, it is necessary to purify the gases at the earliest possible stage. Currently, there are developed installations for the removal of sulfur compounds from the exhaust gases of combustion engines fueled with sulfur-containing fuels. To a large extent, these are installations dedicated to engines used for propulsion of ships and for energy purposes. Among the many methods of interest due to the use of chlorine compounds is the lime method, the final result of which is gypsum. This method was developed by the German company Saarberg-Hölter. It uses calcium chloride and buffer „Absorben 75", thanks to which the SO2 absorption product is soluble calcium bisulfite. The absorbent solution initially has a pH = 8÷12, and after absorption pH = 1÷5. In the sorption liquid preparation node and in the scrubber reactions take place [3]:

$$Ca(OH)_2 + 2HCl \rightarrow CaCl_2 + H_2O$$

$$CaCl_2 + 2SO_2 + 2H_2O \rightarrow Ca(HSO_3)_2 + 2HCl$$

The hydrosulfite is oxidized to calcium sulphate in a separate installation node in order to prevent overgrowing of absorbers and pipelines [3]. Particularly interesting in this type of reaction is that the desulfurization process also uses hydrochloric acid in its composition containing chlorine. Thanks to this, it is possible to simultaneously use the system for sulfur and chlorine reduction from synthesis gas obtained in the process of gasification of plastics. The place of introduction of the scrubber in the current installation should be considered considering two issues. The first is the temperature of the reaction process taking place in the scrubber and the second is the need to protect the plant against aggressive chlorine compounds. Considering the above, the introduction of the scrubber will be considered as close as possible to the exhaust gas exit from the gasifier reactor (Fig. 3).

The "EKOMPAKT" machines is a device designed to process biomass in the amount of 300 kg/h and consists of the modules. Separate parts of the installation are built in 20-foot containers, which allows easy expansion of the system by multiplication of individual modules (Fig. 4, 5).

Demonstration installation allows verification and optimal selection of the gasification process for the given fuel type by means of the possibility of checking the gasification process downstream and upstream, and also with recovery and without recovery of heat from the exhaust. Demonstration installation allows to verify and optimum gasification process for a particular type of fuel by checking the simultaneous and counter-current gasification process as well as with recovery and without heat recovery from exhaust and non-recovery. Such a real-time verification of the process gives great security to obtain and develop optimal gasification parameters for a given fuel and achieve optimum financial benefits from this process. Commercial installations that are currently in a very advanced design stage will also be equipped with a remote monitoring system and a remote monitoring system. Information about the level of emissions can be made available to individual institutions and local governments, giving them the opportunity to apply for the "EKO" status, i.e. environmentally friendly [4].

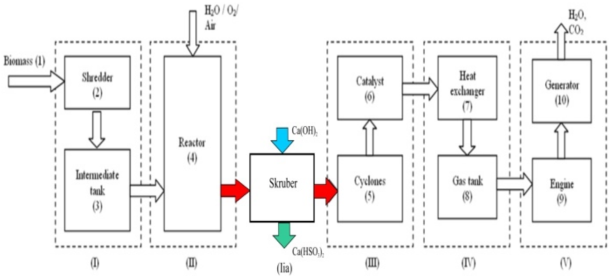


**Fig. 3.** Idea of "EKOMPAKT" gasification machine biomass preparation module: I –shredder and intermediate tank, II – reactor module, IIa – Skruber, III – gas cleaning module (cyclones, catalyst), IV – gas conditioning module, V – generator module

**Fig. 4.** Real construction of gasification machine "EKOMPAKT"

The experience gained from the operation of the device indicates a high dependence of the processes on the quality of fuel [4]. The chemical composition and stability of this composition are important here. The heterogeneity of the fuel in terms of chemicals necessitates changes in the gasification process and in particular in the treatment of synthesis gas.

It is still necessary to use systems for cleaning exhaust fumes from particulate matter, which are produced in the gasification process. In the developed device such systems were designed and applied just behind the reactor. The need for gasification of plastics is also associated with the development of a new reactor design. The problem here is the early liquefaction of the fuel supplied to the reactor. Thermoplastics liquefy depending on the chemical composition from 120 ºC, and the temperature of the gasification process is about 850÷950 ºC. This makes it necessary to adapt the gasification chamber to gasify both the liquid material and the solid material in the case of thermosetting plastics.

**Fig. 5.** Real construction of gasification machine "EKOMPAKT"

The reactor as well as the gasification chamber itself is currently under development and due to the prescribed patent protection procedure it can not be presented in detail. On the other hand, gaseous compounds closely related to the content of harmful elements in fuel, i.e. sulphur, chlorine, remain a problem. In order to remove them, the introduction of crackers to reduce sulphur emissions is being considered. With regard to the problem of chlorine content in fuel, it is necessary to use additional systems enabling the removal of this element. The problem here is the high aggressiveness of chlorine in the impact on the walls of the installation. Concepts and solutions are being sought that meet the required operating criteria. At the very end of the proposed technology just behind the combustion engine, the exhaust gases should be subjected to final treatment using existing catalytic exhaust gas cleaning reactors.

## 4. Conclusions

The method of neutralization of sulfur and chlorine compounds proposed in the synthesis gases obtained during the process of gasification of plastics is interesting in terms of the amount of hydrochloric acid in neutralization reactions of sulfur compounds. This situation allows the direct use of chlorine contained in the synthesis gas. There is a need to refine the technological process in terms of the shares of particular compounds in the process and the temperature and pressure range in which these processes are to be implemented. Determining the process parameters will ultimately point to the place where Skruber is installed in the existing installation. The second problem to solve is due to the specificity of plastics and their thermoplastic and thermoset properties. It forces design work aimed at developing a new reactor and a gasification chamber. These activities were undertaken by the authors and will be presented in the near future.

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