TECHNICAL TRANSACTIONS | **CZASOPISMO TECHNICZNE**
ENVIRONMENT ENGINEERING | ŚRODOWISKO
1-Ś/2014

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AN INTRODUCTION TO AN INSTALLATION FOR THE PRODUCTION OF ALTERNATIVE FUELS FROM WASTE POLYOLEFIN

INSTALACJA DO PRODUKCJI WYSOKOENERGETYCZNEGO ALTERNATYWNEGO PALIWA Z ODPADOWYCH POLIOLEFIN

A b s t r a c t

Plastic waste is material that can not only be repeatedly processed into other products, but also the energy contained within it can be recovered through burning.

This article presents an installation for the thermal utilization of waste plastics. The installation allows for the production of high energy fuel from waste polyolefin.

Keywords: *plastic waste*, *energy*

S t r e s z c z e n i e

Odpady z tworzyw sztucznych to materiał, który może być nie tylko wielokrotnie przetwarzany na inne produkty, ale również poprzez spalanie można odzyskać zawartą w nim energię.

W artykule przedstawiono instalację do termicznej utylizacji odpadów z tworzyw sztucznych (poliolefin). Umożliwia ona wytworzenie dwóch wysokoenergetycznych produktów – karbonizatu oraz regeneratu.

Słowa kluczowe: *odpady z tworzyw sztucznych*, *energia*

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1. Introduction

Global plastic production in 2011 was 280 million tons, Europe alone produced 58 million tons. Europe's demand was at the 47 million ton level (Russia excluded). This number represents a 1.1% increase in comparison to the previous year. Particular usage segments remain the same and packaging remains number one at 39% of total orders. The construction industry is number two followed by the auto industry, electrical and electronics industries [9, 11, 13]. The table below shows the demands for plastics in some European countries with the highest demand.

Table 1

The demand for plastics in Europe by country (kt/year) (Source: Plastics Europe Market Research Group (PEMRG))

Country	Germany	Italy	France	Great Britain	Spain	Poland
Demand around (kt/year)	11,800	7,110	4,600	3,700	3,600	2,800

As is shown, Germany has the highest requirements followed by Italy, France, Great Britain, Spain, and Poland in sixth position with a demand of 2,800 kt.

From among many different types of plastics, about 80% of the plastic market in Europe belongs to the following:

- Polyethylene (PE),
- Polypropylene (PP),
- Polyvinyl chloride (PCW),
- Polystyrene (solid-PS, foam-ESP),
- Polyethylene terephthalate (PET),
- Polyurethane (PUR).

It can be concluded from the data shown above that the needs for plastics are systematically growing and therefore, it is imperative that ways are found to reuse polymer plastics at the end of their life cycle.

As the packaging industry remains the highest user of such plastics, most polymer plastic waste that goes through the process of recycling originates in the packaging industry.

The growing awareness in regards to the utilization of any waste product decreases the amount of plastics being simply thrown out at dump sites. In Europe in 2011, more than 25.1 million tons of post-consumer plastics were collected. This represents an increase of 2% compared to the previous year, 2010. From this amount, a little more than 10 million tons ended up in the dump sites, but almost 15 million tons were reprocessed or used as a source of fuel. Plastics in general are perceived negatively, having a negative effect on the environment. The recycling of plastics limits greenhouse gas emissions and decreases the energy need to make new plastics. The methods used play a major role in achieving these goals [3, 13].

2. Plastics Recovery Methods

Proper natural resource management and maintaining adequate energy usage and production methods play a vital role in utilizing discarded plastics precisely because of their particular properties. From among many different substances, plastics can be reused in two different ways. Firstly, they can be remolded into new products and secondly, the energy they contain can be retrieved as an alternative source of fuel.

There are three possibilities of plastics recovery, as shown in Fig. 1. These are: mechanical recycling; stock recycling; energy recovery.

MECHANICAL RECYCLING involves sorting and shredding leaving the chemical structure unaltered in order to achieve a granulated form that can be reprocessed for remodeling. This kind of recycling is possible when the plastic is ‘clean’ and chemically homogenous. Proper sorting selection processes must be maintained in order to be able to collect desired plastics which meet the strict criteria.

STOCK RECYCLING is a process where plastics are down-cycled into three basic components (gases, hydrocarbons and monomers) by chemical reaction or thermal treatment. The basic components can in turn be used to create new products. This kind of recycling allows for the reuse of mixed or contaminated plastics. Technologies most often used are gasification, pyrolysis, and depolymerization. One of the new stock recycling methods is the blast furnace smelting reduction process. During the smelting reduction process, a synthesis gas is released comprised of carbon monoxide and hydrogen. The synthesis gas released in the process additionally increases the efficiency of the iron reduction process through bringing the cost down by limiting the amount of natural resources needed.

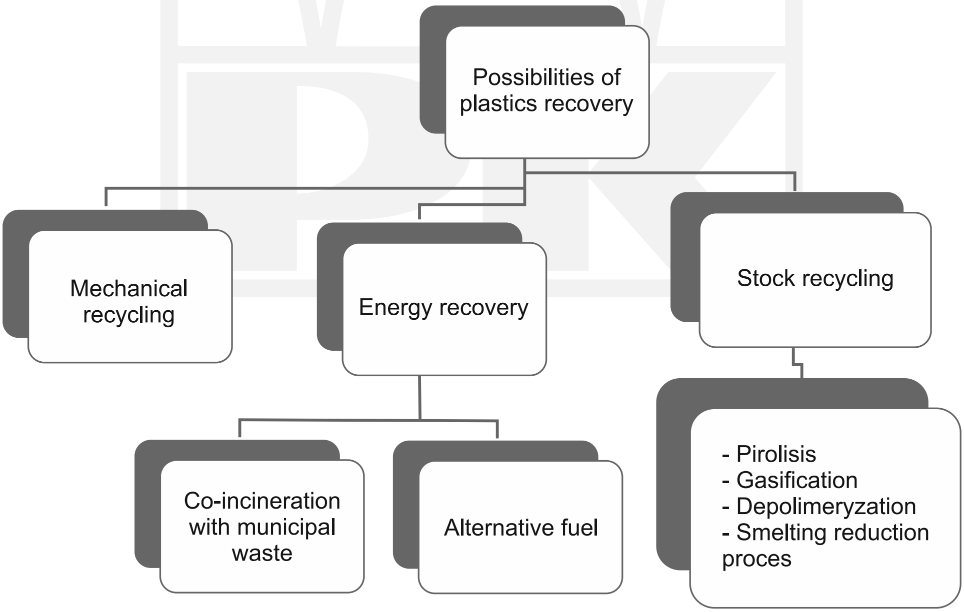

Fig. 1. The possibilities of plastics recovery

Technologically speaking, the above methods are well proven. In reality, only the smelting reduction in blast furnaces is economically profitable on an industrial scale. One of the methods to recover the energy from plastics is their co-incineration with municipal waste. This method is recommended whenever we are dealing with mixed or contaminated plastics and the intention is heat and/or electricity production. Stock recycling also represents an alternative high power energy source. Waste polyolefin can be successfully implemented in the production of high-grade ingredients needed to make diesel fuel, gasoline, and fuel or heating oil. The processes mentioned above are highly advanced, but because of catalyst implementation significantly increasing cost, this renders the process economically ineffective. Without any subsidies, this process is unprofitable (eg. in Poland, after the removal of excise tax incentives in 2007) [1, 2, 5–7, 10, 12].

3. Polyolefin – alternative fuel production system

Some of the components in stock recycling are being used for the production of diesel fuel, gasoline, and heating oil. The existing technologies don't allow for the production of high-energy alternative fuel in solid or semi-fluid state from so called 'polluted' polyolefin scrap material [6].

The innovation developed at Cracow University of Technology, is based on utilizing contaminated waste plastics by retrieving two components char and the reclaim which in turn may be employed in two ways; either as an alternative source of fuel or as a paraffin fraction for further processing [8].

The depolymerization block represents the main part of the installation and comprises of: the heater (4); melter (5); cracking furnace (6); set of burners (7). The remaining elements of the block are: segregation appliance (1); prefabricator (2); buffer (3); boiler (10); char container (9); reclaim reservoir (8). The depolymerization process starts with the segregation of the waste plastics. Municipal and non-municipal waste must be separated first. Next, the segregator enables the separation of the polyolefin fraction from any other undesired solid state waste. From the remaining material, we must isolate products that do not require any more treatment, among them are: rubber; polyvinyl chloride (PVC); polyurethanes (PU); polyamides (PA); polyimides (PI); ABS; others like nitrogen in polymer molecules or ferrous and non-ferrous metals.

The batch may consist of single packaging plastics or wrapping plastics made out of polyethylene, polypropylene, polystyrene or ethylene polytherephtalate (PET, PETE, PETP). As pointed out before, the above mentioned plastics have the largest share of around 80% of the European waste plastic market. Volume wise, they are of great importance but too often they end up being sent to landfills. Having the potential of being an alternative fuel source, they lie dormant in the dump. The useful polyolefin fraction must be prefabricated because of undesired physicalities like size or shape and also must be stored in the form of a buffer to be used as a batch ingredient in the depolymerizer. By heating and gluing, the material can be shaped into desired size and form by the prefabricator for ease of storage and depolymerizer insertion. Depolymerization and prefabrication modules are therefore independent of each other. Any polyolefin surplus buffer allows for the equalization and/or compensation of the not always equal efficiency of either the prefabricator or the depolymerizer devices.

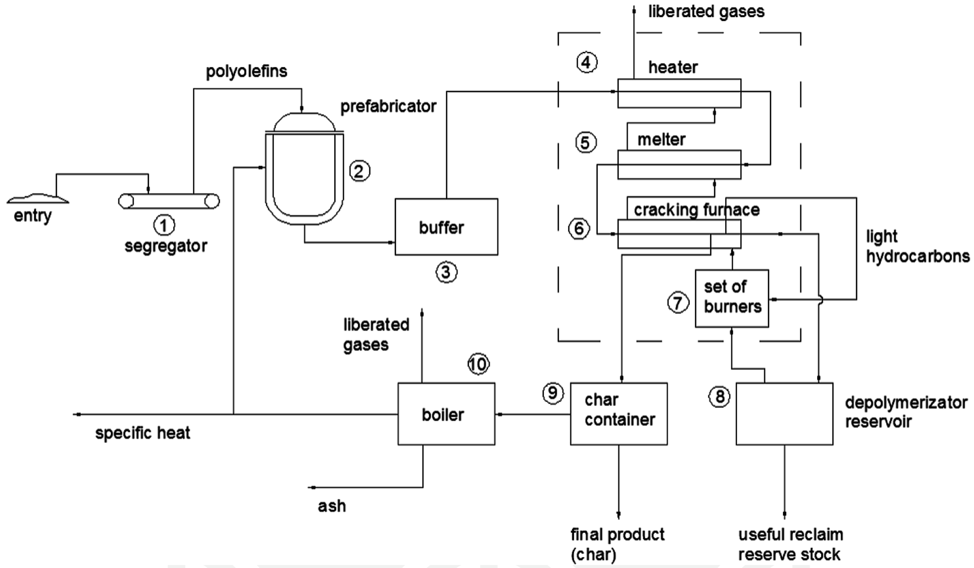

Fig. 2. Installation diagram for the production of high energy fuel from waste polyolefins

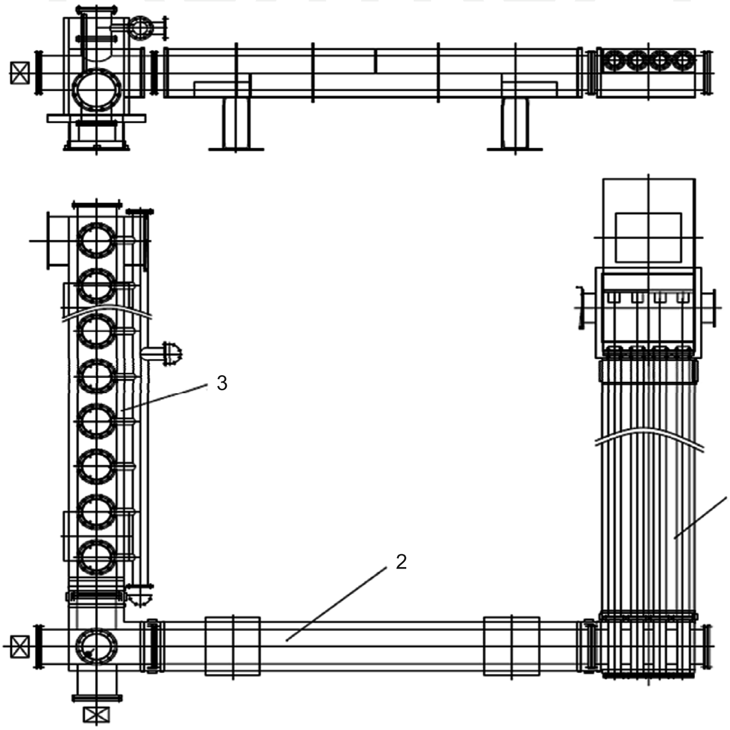

Fig. 3. Depolymerization block (1 – heater, 2 – melter, 3 – cracking furnace)

As was said before, the heater, melting and cracking furnace and set of burners represent the main depolymerization block. The heater brings the temperature up to the melting point. The gravity forces the semi-fluid substance into the melter where the matter assumes a fully liquid state. At this stage, all mineral and metal pollutants that could not be cleared out before settle at the bottom of the apparatus and the process of thermal disintegration starts. Some of the sediments on their way to the cracking furnace will be extracted at this point. The actual process of depolymerization occurs in the cracking furnace. A small amount of liberated gases are being used in the counter-current as a heating fuel in the heater, melter and cracking furnace. At the bottom of the cracking furnace, the char will accumulate together with some mineral matter. The primary product, the reclaim, will accumulate in the reservoir next to the depolymerizator. Part of the reclaim (gas) will be used by the set of burners in the heater, melter and the cracking furnace.

The continuously heated depolymerizator reservoir plays the role of a buffer to be used later when the need arises. Any surplus of the buffer stock can be stored in a solid state (as an alternative fuel) or in the form of a liquid paraffin.

Installation is designed for continuous operation and will have an efficiency of around 200 kg/h. The char will be accounted for approximately one third of total final production. The remaining portion will be considered as a regenerate.

4. Products

The primary product, either in a solid form or as a liquid paraffin, may be used in two ways. The solid state serves as an alternative fuel and has superior characteristics if compared to conventional heating fuels such as heating oil.

The basic characteristics of the reclaimed fuel are:

– high calorific value ca. 42–47 MJ/kg,
– self-ignition elimination,
– mechanical stability,
– dimensional stability,
– diminished humidity absorptivity.

The reclaimed fuel can be burned in all functioning fluid boilers. High energy output (above 90%), and the possibility of cinder reimplementation [4], both play a positive role in environmental conservation efforts. High-heat output plants and high-power generating plants use the reclaimed fuels. Paraffin as a by-product represents a highly desired commodity that, after some further processing, is widely used in the cosmetic, medicine and pharmaceutical industries.

The boiling and self-ignition temperature of paraffin is above 300°C. Liquid paraffin ignition temperature equals 175°C and the solid state paraffin ignites above 220°C. Paraffin doesn't need any specially marked transportation equipment as it is not the subject of any traffic regulations.

The second by-product, char, maintains a solid state with optimum parameters when technological and environmental conservation aspects are taken into consideration. Most important is the high caloric output ca. 20 MJ/kg and an additional positive characteristic is the lack of NOx, SO_2 and HCI.

5. Conclusions

The proposed installation enables the production of high-energy alternative fuel. The installation makes it possible to utilize polluted scrap plastics by the regeneration of two by-products – the char and the reclaim.

The reclaimed fuel is used in two ways; as an alternative fuel and as a paraffin fraction for further processing. The burning process of the reclaimed paraffin is a clean burning process as the paraffins are comprised of oxygen, hydrogen and carbon.

Polyolefin, being an end product of the depolymerization, is free from any nitrogen and sulfur, therefore, during the incineration process, a minimal emission of NOx and SO_2 occurs. Except for natural gas, (needing purification from any remnants of the crude oil or any solid pollutants) there aren't any cleaner hydrocarbon fuels on the market. The paraffin must be melted before it can be burned. Unlike heating oil, paraffin may be available locally from the waste segregation facility. On a small scale, it represents a good alternative to the costly importation of any liquid fuels.

After further processing, the paraffin fraction can be used in the production of paraffin, candles, torches, waxes etc.

It is imperative that we underline an important fact that the reclaimed fuels, either as an alternative source of fuel or as paraffin, are not classified as dangerous goods. There are no danger codes: NDS (chemical compound, highest permitted toxic concentration); NDSCH (chemical compound, highest momentarily permitted toxic concentration level); NDSP (chemical compound, highest permitted toxic threshold concentration) established for the above chemicals.

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