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THE USE OF REFUSE DERIVED FUEL (RDF) IN THE POWER INDUSTRY

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ABSTRACT

The paper presents the concept of use of fuels produced from production waste (RDF). The usefulness of RDF processed into pellets used in the chemical and power industry was also analyzed. The paper presents the results of research on the quality and content of selected elements in RDF pellets. The values of individual indexes are within the ranges typical for fuels manufactured from plastics. The tested material's humidity was identified as low, as well as the content of chlorine, sulfur and other elements. In the working condition, the calorific value of the tested sample was 25.260 $MJ \cdot kg^{-1}$ and was above the range of typical values for RDF (13-20 $MJ \cdot kg^{-1}$). The moisture content in the tested material was 1% and it was within the required range. In the laboratory tests, the content of chlorine and sulfur was also determined.

Introduction and purpose of the work

The last dozen or so years saw a significant increase in the production of plastics (Jachowicz et al. 2013; Jachowicz and Moravski, 2016; Pieniak et al., 2019). Their growing scale of production increases the amount of generated waste and calls for the need for its management. Due to its availability, sustainability and lower environmental impact compared to fossil energy resources, RDF is increasingly used in the chemical and power industries. However, the chemical composition and physical properties of individual types of plastics may differ significantly (Pasak and Pikoń, 2017a; Pasak and Pikoń, 2017b; Ziora and Pasko 2017).

As a result, test results of the parameters of the same type of plastic are often divergent. Knowledge of the chemical and physiochemical characteristics of plastics is of great importance from an energy point of view, as each parameter affects the course and efficiency of combustion (Górski, 2010; Pasak and Pikoń, 2015a; Journal of Laws 2017.1289).

In the initial stage of development, the Polish plastic waste management policy was limited mainly to the collection of waste from the place of storage and its disposal to landfills located on the outskirts of the city, or outside its borders. Over time, waste management has evolved and its principles began to be reflected in Polish legislation (Pasak and Pikoń, 2017a; Pasak and Pikoń, 2017b; Ziora and Pasko 2017). The main goal of waste management is to strive to optimize the environmental criterion (Górski, 2010; Orynycz, 2017; Pasak and Pikoń, 2015b).

However, the European Union has set new challenges related to the circular economy, opting for an economic model that executes the waste management hierarchy more scrupulously. According to the European Commission, to ensure the development of modern plastic waste management, more stringent requirements should be gradually implemented (Pasak and Pikoń 2015a; Journal of Laws 2017.1289; Journal of Laws 2016.2167, Journal of Laws 2012.676).

The EU's action plan for the implementation of the circular economy was announced by the European Commission on December 2, 2015. Due to its characteristics, the ambitious circular economy package greatly emphasizes plastic waste management. The proposed actions will contribute to closing the product loop by significantly increasing the recycling rates of raw materials and implementing innovative ideas for the re-use of by-products, in particular in the chemical and power industries (Den Boer, 2014; Journal of Laws of 2015; Kraszkiewicz et al., 2018; Marczuk et al., 2015; Wasiak and Orynycz, 2015).

The benefits of the implemented solutions will be visible both in counteracting environmental degradation and in saving primary raw materials.

The morphological composition of plastic waste as a whole is difficult to estimate due to the lack of data and the diversity of waste generated, depending on the characteristics of the country's region or area type (rural and urban areas). However, it is possible to indicate fractions representing approx. 2/3 of the waste stream, namely: paper and cardboard, glass, plastics, as well as food and plant waste, i.e. fractions that can be successfully recycled (Jaworski and Grochowska, 2017; Journal of Laws of 2015). In domestic conditions, plastic waste can be used for power generation by means of incineration and co-incineration in the chemical industry and in multi-fuel units. Co-incineration of plastic waste concerns mainly the flammable fraction left from the RDF or pre-RDF waste treatment plants (http://ec.europa.eu, 01/12/2017). The use of waste fuels in the chemical and power industries amounts to approx. 1 million mg per year. According to forecasts, this stream may increase to 1.2 million mg annually, although it depends to a large extent on the market demand, i.e. mainly on the number of construction investments. So far, the economic situation is very good, but it may change in the long term (http://odpady.net.pl).

Fuel that is obtained from waste with a sufficient energy potential to be an energy source, or with properties that allow processing it into energy, is referred to as alternative or recovered fuel. Refuse Derived Fuel (RDF) is a specific type of the said fuel, characterized by a high calorific value (16-18 $MJ \cdot kg^{-1}$ on average), as well as a homogeneous particle size. The production of RDF consists in separating the combustible fraction of municipal waste (paper, plastics, textiles, wood, rubber) by sorting them, subjecting them to a multi-stage process of shredding and then pelleting.

The aim of the research was to determine the suitability of granular recovered fuel (RDF) for combustion in the power and cement industries, where it is planned to increase the share of alternative fuels. Moreover, the research goal was the analysis of the RDF production line and its suitability for the production of this fuel.

The scope and methodology of research

Ursus SA together with Bioenergia Invest SA undertook to design and build a technological line for granulating RDF. It consists of a storage (tank), granulating (granulators) and transport (conveyor) unit. The entire technological line consists of machines and devices optimally selected in terms of efficiency and energy production. The line produces pellets approx. 8 mm in diameter and with various random lengths ranging from 3 to 8 cm, depending on the degree of compaction.

The tested object were plastic (RDF) pellets, 8 mm in diameter, supplied by municipal companies to Dobre Miasto by Ursus SA and Bioenergia Invest SA. They were analyzed in terms of chemical, qualitative and physicochemical properties.

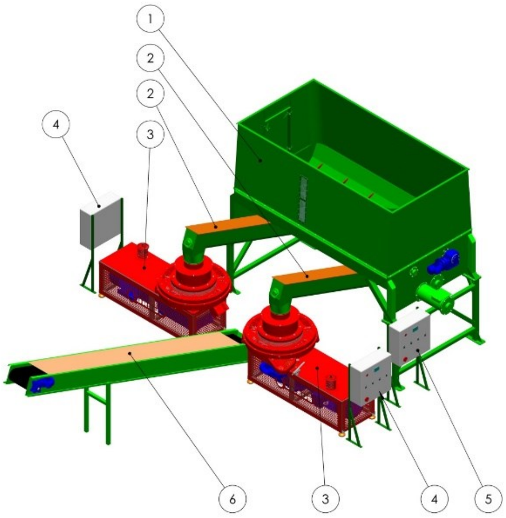
Analyzes of energy parameters and the content of selected elements were carried out in an accredited laboratory, JS Hamilton in Gdynia, at the request of the above-mentioned companies. Chemical, qualitative and physicochemical analysis of the solid fuel (RDF) produced with the use of a specialized pelletizing line was performed at the request of the contractor, in accordance with the contract. The research was carried out according to the methods presented in Table 1.

Table 1.
Characteristics of the analyzed material – type of sample: recovered fuel (waste code: 19 12 10), the analysis was carried out between 2016-12-02 and 2016-12-05

The tests were performed on: 2016-11-30

Sample code number:	416/Z/16
Tested object:	Solid recovered fuel
Sample description:	Solid sample, good condition, fine fraction, pellet form, sample weight approx. 0.15 kg Type of packaging: plastic zip bag
Sample condition:	Meets the requirements
Sample prepared according to:	PN-EN 15443:2011 and PN-EN 15413:2011

Table 1 shows that the tested raw material was properly prepared in terms of the maximum moisture content in the mixture intended for granulation, which should not exceed 30% of absolute humidity. The maximum length of the mixture fraction should be 10 mm, to avoid causing blockage in the granulator conveyors, as well as in the entire production line. The smaller the fraction of the raw material subjected to granulation, the better the quality of the obtained granulate. The output product (granulate) is cylindrical in shape, approx. 8 mm in diameter and with a random length.



No.	Device	No of pcs. per production line
1	Tank	1
2	Screw feeder	2
3	Granulator	2
4	Granulator control panel	2
5	Tank control panel	1
6	Belt feeder	1

Figure 1. View of the granulizer (main component of the RDF processing line)

Table 2.
Analytical methods of the object under study

Tested feature	Test method/Test standard or procedure
Total moisture content	CEN/TS 15414-2.2010 Weight method %
Moisture content of the analytical sample	PN-EN 15414-3.2011 Thermogravimetric method
Ash content	PN-EN 15403.2011
Ash content	Thermogravimetric method
Total sulfur content	PN-EN 15408.2011
Total sulfur content	High-temperature combustion method with IR detection
Total hydrogen content	PN-EN 15407.2011
Total hydrogen content	High-temperature combustion method with IR detection
Heat of combustion	PN-EN 15400:2011

Calorific value	Calorimetric method
Calorific value	Calorific value based on calculations
Chlorine as Cl	The analysis was performed with the WDX RF X-ray fluorescence spectrometer according to the manufacturer's instructions.

The research equipment used for the research was provided by the laboratory and met the recommended requirements. On the other hand, the form of the input material was RDF pre-granulated to a fraction of approx. 10 mm and at a maximum humidity of up to 30%. A very important aspect is to first obtain the smallest possible fraction (approx. 10mm). This allows achieving a higher quality of the granules. In addition, the milling process precipitates moisture from the raw material. The raw material is in the form of granules, approx. 8 mm in diameter and with different lengths depending on the degree of compaction. An important aspect is using a low moisture content of the raw material for granulation (approx. 18%) as it has a large impact on the energy value of the granulate, and thus increases the profit for the obtained alternative fuel. Tables 3 and 4 present selected design parameters of the tested LTGO production line.

Table 3.
Technical construction specification of LTGO line machines

Device name	Parameter	Parameter value and measurement unit
Storage tank	Capacity	15 m^3
	Dimensions	Width: 2.2 m Length: 5.1 m Height: 3.8 m
	Installed power	10.2 kW
	No of pcs. per production line	1
Screw feeder	Installed power	1.5 kW
	No of pcs. per production line	2
Granulator	Productivity	Approx. 0.6 t/h
	Installed power	56.1 kW
	No of pcs. per production line	2
Belt feeder	Length	6.3 m
	Installed power	1.5 kW
	No of pcs. per production line	1 (or more depending on warehouse configuration)

Table 4.
Selected technical parameters of LTGO line machines

Device name	Name of the working part	No of pcs. per production line
GR00 granulator	Full roller	6
	Matrix	2
	Main shaft bearings	4
	Main shaft seals	8

	Set of central lubrication lines	2
	V-belt of the discharge	2
Screw conveyor	Bearings	4
Belt feeder	Conveyor belt	1

Results

The results of the analysis presented in Table 3 include tests covered by the scope of accreditation, as well as non-accredited tests. Tests outside the scope of accreditation are marked with (*).

The given test results refer only to the tested sample. Key: ad-analytical condition, d-dry condition, ar-working condition. The calculations were made according to PN-EN 15296.2011.

Table 5.
Physiochemical parameters of the analyzed RDF

Tested feature	Unit	Test result
Total moisture content (A_{ar})	(%)	18.1
Moisture content of the analytical sample (M_{ad})	(%)	1.0
Ash content (A_d)	(%)	13.4
Ash content (A_{ar})		11.00
Total sulfur content (S_{ad})	(%)	0.16
Total sulfur content (S_{ar})		0.13
Total hydrogen content (H_d) (*)	(%)	10.63
Total hydrogen content (H_{ar})		8.71
Combustion heat ($qv,_{gr\ d}$) (*)		33.548
Calorific value ($qv,_{net\ d}$)	($MJ \cdot kg^{-1}$)	31.358
Calorific value ($qv,_{net\ ar}$)		25.260
Chlorine as Cl (*)	(%)	0.447

The calorific value of the tested sample in its working condition was 25.260 $MJ \cdot kg^{-1}$ and was higher than the range of typical values for RDF (13-20 $MJ \cdot kg^{-1}$), whereas the heat of combustion was 33.548 $MJ \cdot kg^{-1}$. The moisture content in the tested material was only 1% and it was within the requirements set for this raw material. High-quality alternative fuels are obtained from materials with high calorific value and low humidity, e.g. plastics, and can be a valuable recovered fuel. In laboratory tests, the content of chlorine and sulfur was determined. The value of the ratio of sulfur to chlorine in the waste is an indicator of the corrosive potential of the fuel; in the analyzed waste samples it was within the range of the specified requirements. The chlorine content in the tested material was determined at 0.447%, therefore, in accordance with PN-EN 15359:2012, the tested fuel can be used in the power and production industries. Pursuant to the regulations, renewable energy from waste can only be produced from non-segregated waste, which was confirmed by testing to have over 42% of biodegradable fraction. The classification system of the tested fuel is based mainly on its calorific value and chlorine content (Malinowski and Chwiałkowski, 2017; Akdag and al., 2017). The obtained results indicate a significant differentiation in the quality of the examined waste in this respect. The calorific value of the analyzed samples was 31.358 $MJ \cdot kg^{-1}$, therefore it is advantageous to use RDF fuel for combustion (Skawińska at al., 2017). However, the negative impact on the environment and on combustion devices may limit the use of RDF with an increased content of chlorine and sulfur.

Conclusion

1. The prepared alternative fuel proved useful in selected sectors of the chemical industry and power engineering. They can be used as a raw material for incineration, co-incineration and pyrolysis.
2. Currently, the only recipients of this type of fuel in Poland are cement plants. However, their ability to manage the amount of alternative fuel that can be obtained is far from sufficient. The constructed thermal waste utilization system could include power and heat production. On the other hand, legal regulations concerning waste management impose obligations on RDF producers that lead to reducing landfilling in favor of other forms of waste management. The preferred directions are: material and energy recovery. The quantitative potential of fuels produced from mixed municipal waste is estimated at 4.5 to as much as 6 million mg per year, depending on the source.

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WYKORZYSTANIE PALIW ALTERNATYWNYCH Z TWORZYW SZTUCZNYCH (RDF) W ENERGETYCE

Streszczenie. Przedstawiono koncepcję zagospodarowania paliw (RDF) wytwarzanych z odpadów w oparciu o ich produkcję. Dokonano również analizy przydatności przetwarzania RDF na pelety stosowane w przemyśle chemicznym i energetyce zawodowej. Przedstawiono wyniki badań jakości i zawartości wybranych pierwiastków w peletach z RDF. Wartości poszczególnych wskaźników mieszczą się w zakresach typowych dla paliw wytwarzanych z tworzyw sztucznych. Stwierdzono dość niską wilgotność oraz zawartość chloru, siarki i innych pierwiastków. Wartość opałowa badanej próbki w stanie roboczym wyniosła 25,260 $MJ \cdot kg^{-1}$ i była wyższa od zakresu typowych wartości dla RDF (13-20 $MJ \cdot kg^{-1}$). Zawartość wilgoci w badanym materiale wynosiła 1% i mieściła się w zakresie wymagań W badaniach laboratoryjnych określono również zawartość chloru i siarki.

Słowa kluczowe: paliwa stałe, tworzywa sztuczne, RDF