Pyrolysis Technologies in Branch of Energy Recovery from Tyres in the Czech Republic

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Abstract

The article deals with the application options of pyrolysis technologies and energy recovery from waste tyres in the Czech Republic (CR). It discusses pyrolysis facilities that may be used to process waste tyres. Apart others, attention is paid to the innovated facility produced by the Czech company HEDVIGA GROUP plc. The next section of the article describes the disposal of pyrolytic oil that is problematic according to the Czech state authorities. Some operators of pyrolysis plants have decided to address the problem of pyrolytic oil utilisation by recovering the energy in cogeneration units combusting the oil, or a mixture of pyrolytic oil and gas. Specific facilities produced in the CR are presented that are piloted in Great Britain. The article includes a section dealing with the results of emission measurements of one pyrolysis plant for energy recovery from waste tyres, and a section dealing with the determination of specific emission limits for such facilities in the CR combusting pyrolytic gas, or pyrolytic oil. The conclusion discusses the situation in environmental impact assessment of pyrolysis technologies for energy recovery in the CR.

Keywords: pyrolysis, waste, tyres, energy recovery, pyrolytic gas, pyrolytic oil

Introduction

At present, a number of energy recovery pyrolysis plants are being prepared in the Czech Republic (CR), which are to process predominantly waste tyres, plastics, or municipal waste free of the biodegradable component.

Despite the fact that plenty of expert communications declaring the preparedness for the production and commercial use of the technology have lately been published, the offer of really applicable facilities in the CR is still very limited. Likewise, the majority of the foreign facilities offered are either very demanding in investment or operation, or their operation is low in reliability, especially those operating in the continuous mode.

It shows that more promising are the batch pyrolysis facilities. In the neighbouring countries, e.g. Poland, a batch pyrolysis facility by the Chinese company Shangqiu Jinpeng Industrial Co., Ltd. is well-established. Nevertheless this company offers both continuous and discontinuous (batch type – Figure 1) pyrolysis plant. The facilities can recycle and utilize waste plastics, waste rubber, tyres and waste engine oil. According to the actual situation in every country and district, it was developed by company Shangqiu Jinpeng Industrial Co., Ltd. series of machine for disposing scrap tyre and plastics that includes 4 tons, 6 tons, 8 and 10 tons (at most about 30 tons per batch) of different capacity [1]. Unfortunately, emission values measured by an accredited laboratory are not available. At the same time, it is important to say that the supplied facilities often suffer from 'child diseases', such as overall under-sizing of the construction, low-quality engines and bearings, etc. Nevertheless, having removed the stated defects, the declared parameters are met.

Pyrolysis Technology for Energy Recovery from Waste in the Czech Republic

Out of the facilities produced in the CR, the facility made by HEDVIGA GROUP a.s. appears as the most suitable. Originally, the company offered a facility PTR 1000 that mostly worked with a cogeneration unit TEDOM Cento 180.

Nowadays, the company HEDVIGA GROUP a.s. offers an innovated facility PTR 1000 kW6 [2]. Each PTR 1000 kW6 unit comprises six PTR modules and accessories, and it is designed for the maximum daily capacity of 36 tonnes of processed crushed feed material (processed fuel from waste tyres in this case). The maximum annual capacity for one unit is designed for 11,500 tonnes of waste for energy recovery with subsequent direct energy recovery from the produced gaseous and liquid fuels. The operation of the feed material processing and energy recovery supposes a working regime 6+1 (6 workdays and 1 day off), or 320 workdays.

The unit PTR 1000 kW6 includes two basic modules: thermal (heating) and cooling (see Fig. 2). The modules have the shape and size of a 20-

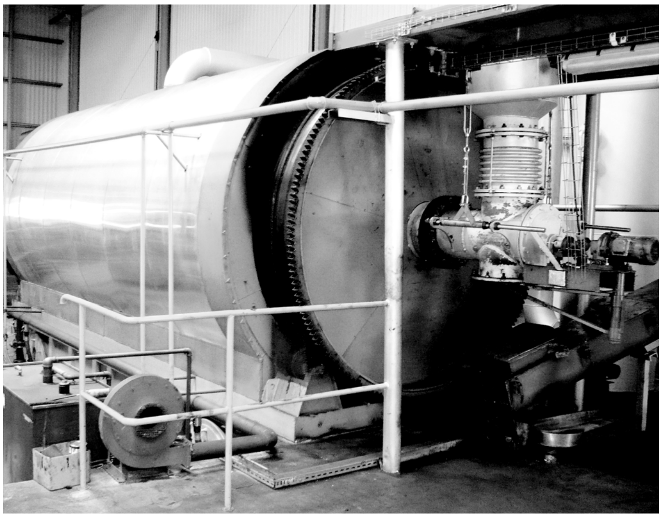

Fig. 1. Discontinuous pyrolysis plant (batch process) of company Shangqiu Jinpeng Industrial Co., Ltd. – reactor or rather rotary pyrolysis kiln (photo - author)

Rys. 1. Zakład pirolizy okresowej (proces nieciągły) Shangqiu Jinpeng Industrial Co., Ltd. – reaktor (piec obrotowy do pirolizy)

feet transport container for the capacity of 1.5 tonnes per hour.

The feed material is handled by an automatic transport system AGV to handle the fuel cells (including the loading and unloading). The handling of PTR cells is ensured by a system of at least two handling devices with an electric drive, travelling along the magnetic track on the shopfloor along the marked route. The cell motion between the single positions is controlled automatically, in the regime of the so-called timing, which ensures the continuous production of primary thermal gas.

The system PTR 1000 kW6 forms a separate technological whole. It is technically fitted for the heating and cooling of a fuel cell within all three processing phases of the batch in the fuel cell (heating – phase of hydrocarbon vapour release, active thermal process, phase of fuel cell cooling) [3].

Each PTR module has three zones: the pre-heating zone, the zone of active process, and the zone of passive process, plus a mutually interconnected heat-carrier system to ensure the transfer and circulation of secondary heat.

In the pre-heating zone, the fuel cell is pre-heated along with the feed material to reach the maximum temperature of 120°C. In the zone of active process, a slow thermal reaction occurs (PTR) during 120–180 min and temperature of up to 500°C. In the zone of passive process, the fuel cells are cooled and at the same time, the heat is transferred to the PTR heat-carrier system.

The system PTR 1000 kW6 is an electric facility with the maximum input of 240 kW. The thermal aspects of the PTR process in the PTR system are ensured by a combined system of heating using an electric heating system in the zone of active process (3) all the way to 500°C and transfer of the heat-carrier medium between the zones (2, 3, 4) and the heat-carrier system of the oil exchanger KGJ at the maximum temperature of 300°C. The volume of the heat-carrier medium in the system is 18 m^3.

In all the zones, the PTR module is connected to the collecting lines leading into the cooling system – heat exchanger, where the gaseous hydrocarbons condense into the liquid fraction that is collected in the liquid fraction tanks, and the light non-condensed fraction of gaseous hydrocarbons is conducted into gas tanks, where they stabilize as gas fuel.

The fuel cells are gas-tight and have a cylindrical shape (see Fig. 3) in the innovated PTR facility [3]. They comprise of a lid and vessel made of stainless steel of class 17, they are equipped with a set of sensors, including a combined magnetic and pneumatic actuating system. Heating, decomposition and subsequently cooling of the feed material occurs in the cells under a slow thermal reaction and temperature range from 20°C to 500°C.

The PC 1000 fuel cell volume is 1.5 m^3. The overall number of fuel cells for one PTR unit is 18 pieces to ensure the continuous mode.

The weight balance of the fraction production from the PTR 1000 kW6 process differs according to the raw material: approx. 330 kg of gas, 450 kg of pyrolysis oil and 220 kg of the carbon rest

Fig. 2. Pyrolysis plant PTR 1000 kW6 (HEDVIGA GROUP plc) – cooling module [3]

Rys. 2. Zakład pirolizy PTR 1000 kW6 (HEDVIGA GROUP plc) – moduł chłodzący [3]

Fig. 3. Pyrolysis plant PTR 1000 kW6 (HEDVIGA GROUP plc) – cylindrical fuel cell [3]

Rys. 3. Zakład pirolizy PTR 1000 kW6 (HEDVIGA GROUP plc) – komora cylindryczna [3]

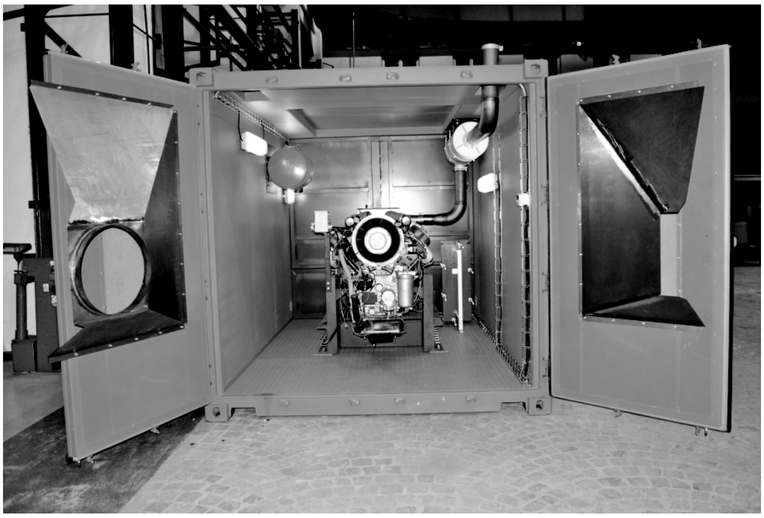

Fig. 4. Cogeneration unit VOPTRA C 250 DUAL for utilization of pyrolysis oil [2, 3]

Rys. 4. Jednostka kogeneracyjna VOPTRA C 250 DUAL do utylizacji oleju pirolitycznego [2, 3]

is produced from 1,000 kg of tyres (raw material) [4]. The metal components in tyres (steel belts and bead wires) add up to about 3% mass of a tyre (it amounts to approximately 345 tonnes of metal per year). Worn tyres do not manifest any fluctuations in quality or material composition, which has been confirmed by the carried out combustion tests of various types of worn tyres. Due to the stable quality of the feed material and the fact that the pyrolysis process is controlled by set temperature curves, the quality of the output products (pyrolytic gas – calorific value over 40 MJ/m3, pyrolytic oil – calorific value about 34 MJ/kg, solid fraction) is guaranteed in the measured values.

For the energy recovery from the gas fraction from a PTR facility, recommended are the cogeneration units made by the following companies: BOSCH (output from 240 kW), TEDOM (output from 200 kW) and ZEPPELIN for gas fuel (output from 500 kW).

For the energy recovery from the liquid, or gaseous and liquid fractions from the PTR facility, recommended are the cogenerations units VOPTRA by VOP & HEDVIGA for liquid and gaseous fuel (minimum output of 200 kW – see Fig. 4) and the cogeneration units ZEPPELIN

Tab. 1. Emissions measured for a cogeneration unit BOSCH 250 (pyrolytic gas from PTR 1000 kW6) – an extract from certificate No. 16/15 of 13th February 2015, pyrolysis of tyres [5]

Tab. 1. Pomiar emisjii z jednostki kogeneracyjnej BOSCH 250 (gaz pirolityczny z zakładu PTR 1000 kW6) – wybrane wartości z certyfikatu No. 16/15 z 13 lutego 2015, [5]

Pollutants	Average mass concentration of pollutants	Emission limits	Remarks
NO_x	90 mg/Nm^3	500 mg/Nm^3	Emission limits for cogeneration units (CR) - piston combustion engine – gas fuel (Appendix 2 to Regulation 415/2012 Coll., as amended, Section II, Article 2, Table 2.2), valid to 31st December 2017
CO	82 mg/Nm^3	650 mg/Nm^3	
PM (Solid pollutant)	11,1 mg/Nm^3	10 mg/Nm^3	Emission limits for incineration of waste (Appendix 4 to Regulation 415/2012 Coll., as amended, Section I, Article 1, Table 1.1)
HF	0,03 mg/Nm^3	1 mg/Nm^3	
HCl	0,04 mg/Nm^3	10 mg/Nm^3	
PCDD/F (Σ TEQ)	0,0095 ng/Nm^3	0,1 ng/Nm^3	Emission limits for incineration of waste (Appendix 4 to Regulation 415/2012 Coll., as amended, Section I, Article 2.3)
Hg	0,00100 mg/Nm^3	0,05 mg/Nm^3	
Cd	0,00030 mg/Nm^3	Σ0,05 mg/Nm^3	
Tl	0,00028 mg/Nm^3		
SO_2	53 mg/Nm^3	50 mg/Nm^3	Emission limits for incineration of waste (Appendix 4 to Regulation 415/2012 Coll., as amended, Section I, Article 1, Table 1.1)
TOC	64 mg/Nm^3	10 mg/Nm^3	
PAU	0,000022 mg/Nm^3	1 mg/Nm^3	Emission limit (EU)

Dual by ZEPPELIN for liquid and gaseous fuel (outputs of 200 kW or 500 kW).

As mentioned above, the output from the pyrolysis process is a pyrolytic gas, pyrolytic oil and solid residue. The use of pyrolysis process energy differs in the EU countries. In the CR an exploitation of pyrolytic gas in cogeneration units is planned, and the majority of entrepreneurs build their business plans on the revenue from the generated electric power, being one of the major motives to build such facilities in the CR (Czech Republic). The solid residue usually has a high carbon content and thus may find a number of applications and various customers (e.g. production of tyres). More problems, including those with state authorities, are associated with the pyrolytic oils. It comes as a surprise because in the neighbouring EU countries (e.g. in Poland) there are a number of pyrolytic plants processing, for example, waste tyres, and their basic final product is pyrolytic oil sold to refineries for favourable 11 CZK per a litre of pyrolytic oil (Poland).

Some operators of future pyrolysis plants may dispose of pyrolytic oil in cogeneration units that combust pyrolytic oil, or a mixture of pyrolytic oil and gas. This option is also offered by HEDVIGA GROUP plc, which successfully tested the facilities VOPTRA C 220 and C 250 Dual (VOP & HEDVIGA) [3].

The cogeneration unit VOPTRA C 250 DUAL (container type – see Fig. 4) may be characterised as follows - possible fuel: pyrolytic oil, pyrolytic gas, natural gas, biogas, diesel oil (fuel proportions - gas : oil from 80 : 20 to 0 : 100); electric output of max. 255 kW for pyrolytic gas with calorific value 40 MJ/Nm^3; nominal electric output: 240 kW. The engine is an air-cooled, 12-cylinder engine TATRA 930. The facility is placed in a 20-feet container with the maximum height of 3.25 m and average weight of 3.1 tonne.

The Measurements of Emissions from Cogeneration Units Combusting Pyrolytic Gas and Pyrolytic Oil

Tab. 2. A proposal of specific emission limits for a cogeneration unit combusting pyrolytic gas [7]

Tab. 2. Propozycja limitów emisji dla jednostki kogeneracyjnej do spalania gazu pirolitycznego [7]

Pollutants	Emission limits	Remarks
NO_x	500 mg/Nm^3	Emission limits for cogeneration units (CR) - piston combustion engine – gas fuel (Appendix 2 to Regulation 415/2012 Coll., as amended, Section II, Article 2, Table 2.1), which will come into force on 1st January 2018
CO	650 mg/Nm^3	
PM (Solid pollutant)	20 mg/Nm^3	Proposal of specific emission limit
HF	1 mg/Nm^3	Emission limits for incineration of waste (Appendix 4 to Regulation 415/2012 Coll., as amended, Section I, Article 1, Table 1.1)
HCl	10 mg/Nm^3	
PCDD/F (Σ TEQ)	0,1 ng/Nm^3	Emission limits for incineration of waste (Appendix 4 to Regulation 415/2012 Coll., as amended, Section I, Article 2.3)
Hg	0,05 mg/Nm^3	
Cd	Σ0,05 mg/Nm^3	
Tl		
SO_2	90 mg/Nm^3	Proposal of specific emission limit
TOC	90 mg/Nm^3	Proposal of specific emission limit

The Energy Research Centre at VSB–Technical University of Ostrava measured emissions (certificate of accredited test No. 16/15 of 13th February 2015) in the premises of company HEDVIGA GROUP plc in the Czech Republic on 4th February 2015 using an innovated facility PTR 1000 kW6 combined with a cogeneration unit BOSCH 250 combusting pyrolytic gas. Table 1 gives an extract of the taken emission values for the cogeneration unit [5].

The values in Table 1 imply that the overwhelming majority of the taken emission values of pollutants comply with the set specific limits. In accordance with Article 2.3, Section I, Appendix 4 to Regulation 415/2012 Coll., the specific emission limits (for PCDD/F, Hg, Cd, and Tl) are fully complies with; in case of Cd, Tl and PCDD/F they are two orders of magnitude lower. In case of Hg the measured emission values are 50 times lower than the given emission limit (EL). In line with Article 2, Section II, Appendix 2 to the Regulation (i.e. the EL for NOx and CO), the emission limits fall behind 5.5 times (NOx) to 8 times (CO). The remaining pollutant limits for which the Appendix 4, Article 1.6 of Act 201/2012 Coll., on the protection of air, prescribes continuous measurements of emissions (the EL for PM, TOC, chlorine as HCl, fluorine as HF, and SO_2) are met in the majority of cases with reserve for the emissions limits for thermal processing of waste according to Section I, Article 1, Table 1.1 of Appendix 4 to Regulation 415/2012 Coll. For example, the measured emissions of HCl are 250 times lower than the set emission limit, and the emissions of HF are 33 times lower than the EL. The emission limit (meant for the thermal processing of waste) will be slightly exceeded for PM (measured in dry gas of 1.1 mg/Nm^3; in wet gas the EL will be met – 9.7 mg/Nm^3) as well as for SO_2 (by 3 mg/Nm^3). A slightly higher excess in TOC was observed.

Considering the above mentioned facts the facility under assessment may be used in practice as higher emissions values were measured only in SO_2 and PM (a very slight excess) and in TOC. For such substances it is the relevant regional authority that may stipulate higher specific emission limits in a source operation permit. This solution is viable as it is not the case of waste incineration plants, but stationary sources thermally processing waste, other than waste incinerators, cement kilns and stationary combustion sources (in line with Article 2.3, Section I, Appendix 4 to Regulation 415/2012 Coll.), where mostly emissions of PCDD/F, Hg, Cd, and Tl, are observed. In the given case, the emissions are fully complied with and they range in very low values (see Table 1). In other pollutants the set specific limits of general emission limits, the values of which are high, need not be used (see Table 2).

Accredited company measured emissions using an innovated facility PTR 1000 kW6 combined with a cogeneration unit VOPTRA 220 Dual combusting pyrolytic oil. The measurement

Tab. 3. A proposal of specific emission limits for a cogeneration unit combusting pyrolytic oil [7]

Tab. 3. Propozycja limitów emisji dla jednostki kogeneracyjnej do spalania oleju pirolitycznego [7]

Pollutants	Emission limits (for thermal input > 5 - 50 MW)	Remarks
NO_x	400 mg/Nm^3	Emission limits for piston combustion engine - liquid fuel -CR (Appendix 2 to Regulation 415/2012 Coll., as amended, Section II, Article 2, Table 2.1), which will come into force on 1st January 2018
CO	450 mg/Nm^3	
PM (Solid pollutant)	20 mg/Nm^3	

of emission values of NOx, CO and PM showed that the facility under examination produces low emissions that reach 20.9 to 48.5% of the emission limit.

A Proposal of Specific Emission Limits for Facilities Combusting Pyrolytic Gas and Oil in the Czech Republic

When processing the documentation of the pyrolysis facility environmental impact assessment, emission limits for combusting pyrolytic gas were set, which are grounded in the formulation of the air protection bureau of the Ministry of the Environment, and the bureaus of the environment and agriculture of competent regional authorities.

Based on the formulation of the Ministry of the Environment, for a pyrolytic facility it is not possible to adhere to specific emission limits in line with Article 2.4.1., Section II of Appendix 8, for a stationary source 3.6, to Regulation 415/2012 Coll., on permissible level of pollution and its identification, and on the execution of certain other provisions of Air Protection Act, as amended, because the given stationary source (pyrolytic unit) does not have an air outlet [6,7].

In a stationary source linked onto a pyrolytic unit, i.e. a cogeneration unit (labelled as 1.2), the relevant specific emission limits are determined according to its total rated heat input, namely in Article 2, Section II of Appendix 2 to Regulation 415/2012 Coll. (i.e. emission limits for NOx and CO - Table 2.1).

Beyond the regulation, it is the competent regional authority that determines specific emission limits in a source operation permit. If the case meets the definition of a facility that thermally processes waste, it is at least necessary to determine emission limits for pollutants listed in Article 2, Section II of Appendix 2 (see above) and Article 2.3, Section I of Appendix 4 (emission limits for PCDD/F, Hg, Cd, and Tl), as well as for all substances, in which Appendix 4, Article 1.6 of Act 201/2012 Coll., on air protection [6], stipulates continuous measurement of emissions (emission limits for NO_2, CO, PM, TOC, chlorine as HCl, fluorine as HF, and SO_2).

The proposal of specific emission limits for a cogeneration unit combusting pyrolytic gas (see Table 2 below) was made with regard to the above stated requirement of the Ministry of the Environment and regional authorities, and considering the measured emission values (see Table 1 above).

Within administering the environmental impact assessment process of a pyrolysis plant, emission limits for combusting pyrolytic oil were determined. The proposal of the specific emission limits for a cogeneration unit combusting pyrolytic oil (KJ VOPTRA – see Table 3 below) is grounded in the emission limits stated in the Appendix 2 to Regulation 415/2012 Coll., as amended (Section II, Article 2, Table 2.1).

Closing Remarks

As mentioned above, in case of a pyrolysis plant for energy recovery from waste tyres we do not speak of a waste incineration plant, but a stationary source thermally processing waste, other than waste incinerators, cement kilns or stationary combustion sources (in line with Article 2.3, Section I, Appendix 4 to Regulation 415/2012 Coll.) [7], which predominantly observes the emissions of PCDD/F, Hg, Cd, and Tl. They are complied with in this case and they are extremely low (see Table 1 above) [5].

Still, the situation in environmental impact assessment of pyrolysis technologies for energy recovery in the Czech Republic is not easy in many other aspects.

Some regional authorities that are competent to administer the environmental impact assessment proceedings regarding such facilities require certain construction and operational details of the planned pyrolysis plants which are not later included in the given project documentation.

As mentioned above, authorities are highly distrustful of the application of pyrolytic oil. A potential pyrolysis plant operator is a priori suspected of breaching safety regulations when pumping the oil into tanks, and thus contaminating the ground water and the rock environment. In addition, there is a lack in faith in the question of potential customers for pyrolytic oil, even if abroad pyrolytic oil is a basic final product sold to refineries under advantageous conditions. Therefore, when implementing the waste-to-energy pyrolysis technologies in the Czech Republic the majority of prospective investors considers the construction of further cogeneration units to combust the pyrolytic oil and generate energy, even if the sales of pyrolytic oil to refineries would be more advantageous.

Until recently, there was a problem with determining the emission limits for a cogeneration unit combusting pyrolytic gas. The situation was simpler in cogeneration units combusting pyrolytic oil. The determination of emission limits for a cogeneration unit combusting pyrolytic gas used to be administered for over two years. In the end, the problem was successfully solved by a letter from the new director of the air protection bureau at the Ministry of the Environment (see the text above and Table 2).

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Technologie pirolitycznego odzysku energii z opon w Czechach

Artykuł dotyczy możliwości zastosowania technologii pirolizy do odzysku energii z zużytych opon w Czechach (CR). Omówiono technologie pirolizy, które mogą być wykorzystywane do przetwarzania zużytych opon. Między innymi przedstawiono innowacyjną technologię stosowaną w zakładzie czeskiej firmy Hedviga Group plc. Przedstawiono metody utylizacji oleju pirolitycznego, który jest najbardziej niebezpieczny dla środowiska. Niektórzy operatorzy instalacji pirolizy postanowili rozwiązać problem utylizacji oleju pirolitycznego poprzez wykorzystanie oleju do odzyskiwania energii w jednostkach kogeneracji opalanych olejem lub mieszaninę oleju pirolitycznego i ropy lub gazu. Przedstawiono intsalacje pilotowe w Wielkiej Brytanii oraz wdrożenia w Czechach.

Artykuł zawiera analiże wyników pomiarów emisji z jednego zakładów pirolitycznego odzysku energii ze zużytych opon oraz określenie możliwości spełnienia limitów emisji dla takich obiektów w Czechach. Przedstawiono ocenę oddziaływania na środowisko pirolizy do odzysku energii w Czechach.

Słowa kluczowe: piroliza, odpady, opony, odzysk energii, gaz pirolityczny, olej pirolityczny