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TEST RESULTS OF A PYROLYSIS PILOT PLANT IN HUNGARY

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Abstract

Experiences obtained in the pyrolysis pilot plant during the Szent István University's pyrolysis research project are described. Eight different raw wastes were treated in a pyrolysis pilot plant in Mezőberény. Test results obtained are suitable as reference in connection with the quality of end products. It is also useful in examining how the environmental emission values of this kind of plants can comply with national legal requirements. By using the objective test results and experiences from operating model conditions, our research group is able to analyze and evaluate test results of a similar system in the following.

Keywords

thermolysis, pyrolysis, waste recycling, secondary raw materials, waste to energy

1. Introduction

This paper gives an account of the experiences obtained during the test operation of the EE-MBPT/01 equipment designed, constructed and operated by the Environ-Energie Kft. in Mezőberény, Hungary within the framework of Szent István University's pyrolysis pilot plant research project. The aim of the project was to serve as basis for comparison regarding the pyrolysis technologies / plants operating in Hungary and obtain comparable experiences. The used low-temperature (450°C) pyrolysis technology is a non-series industrial equipment of the Environ-Energie Kft, which was offered by them (as a cluster member) in the framework of the "Cluster for the Environmentally Conscious Development" cooperation to another member of the cluster, the Szent István University for testing.

The composition of the raw materials processed is monitored continuously. The end-products are stored, and their physical and chemical properties are recorded and analysed separately. The system is monitored continuously regarding both the physical / chemical parameters and the main parameters of the thermolytic process. During the process, temperature and pressure values are measured and registered.

The pilot equipment is capable of neutralizing various raw materials (e.g., wastes) by thermolytic degradation meeting both waste management and environment protection criteria.

2. Literature background

The pyrolysis technology has a wide range of literature throughout the world. The process has many opponents, but also illustrious representatives. At the same time, a need to reduce the quantity of wastes accumulated on the Earth urges for a solution. As it is known, in case of using pyrolysis one ton of tire is comparable with one ton of high-quality hard coal that is proportional to the substitution of almost 750 kg of crude oil.

In the general knowledge there are many conflicting opinions based often on questionable grounds regarding thermal waste recovery, within that especially the thermolysis-based solutions, which could not have been supported for the time being by operating experience of sufficient number.

Several authors study the most general aspects of the impacts by pyrolysis technology and green economy on the society, the regional development policy of waste management as well as the green energetics and its spatial aspects. "Green electricity", reduction of oil imports, reduction of garbage collection fee and job creation could be the great advantage of a newly created pyrolysis plant [1].

Many laboratory methods apply to the analysis of thermolysis residues, such as UV-VIS spectrum that may be a rapid analytical method of the technology in the future. The essence of the rapid methods is to obtain accurate information as soon as possible from the materials generated in due course during the several-hour process [2].

Scientific workshops study the further usability of solid by-products generated during pyrolysis. By mixing bio char into soil, we can return the carbon bound in the biomass to the soil, and the quantity bound this way will not get back to the atmosphere [3].

Many equipment of various sizes have been made throughout the world. In many places there is a continuous production technology set to one type of raw material. However, the joint behaviour of the pyrolysis raw materials arriving as a mixture of various wastes has not been an investigated subject, yet. Some authors report on new opportunities for innovation [4, 5].

The research results of a pyrolysis pilot plant may open new prospects for popularizing energy from waste. There are two ways to view the materials that cannot be used in other ways: we can consider and dispose them as wastes or we can see the potential inherited in them for the further processing and utilizing. The procedures using the energy in the wastes, such as the pyrolysis technologies are critical in order to speed up the deflection of waste flows from final dumping.

3. Materials and methods

The first step of installing the technology is to clarify and specify the plant dimensions based on the plans and documentation prepared. With the knowledge of the technology, after examining the conditions for building up the equipment, selecting the potential locations is one of the fundamental questions of the project. After having organized the delivery of the ordered and procured equipment, machines and equipment, the arrangement of the acceptance on the premises was also a substantial and important task. With the knowledge of the site plan and the technology, the appropriate infrastructure (lighting, water, electricity, IT) must be developed in accordance with local characteristics. After designing the place of the machinery and equipment based on the technology plan as well as finalizing all of them, the assembly of the system and then the placement of the linked auxiliary plants will follow.

The essence of the pyrolysis procedure is that from the raw materials fed in, utilizable liquid, gaseous and solid products are generated in a double-walled reactor, in a temperature range of 400-600 °C, by means of agitation, at atmospheric pressure, under oxygen-free conditions. The first step of technology serves generally to treat the various raw materials thermally in order that the various compounds disintegrate suitably, the inert substances would evacuate and the utilizable materials could be recovered.

In this technology, during the pyrolysis taking place in the reactor, the raw material to be processed will be gasified, and the gaseous material created as a result of this demolition phase of the technology consists of oil vapours and flammable gases. Heavy oil is unbound from the steam-gas mixture by skimming, and wins its final end product phase by a number of subsequent technological phases (e.g. cleaning). In the closed cycle technology, combustible gases produced during the gasification of raw waste induced by the heat degradation are returned to the burner of the reactor following various separation and cleaning procedures. Thus, the gas needed for the operation of the burner can be provided at least partly from own source. Sulphur recovery from the gas can be necessary depending upon the pyrolysed raw waste; the technology does not require provision of plus water. The second step is connected to the steam production or other energetic utilisation. Pre- and post-treatments belong to the technology, covering for example the preparation of raw materials, treatment of the remains, water treatment, or flue gas treatment. Figure 1 shows the simplified schematic diagram of this rather complex process.

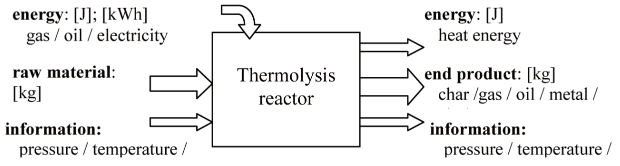

Figure 1. Schematic diagram of the thermolysis process

Technology No. EE-MBPT/01 operating in the Mezőberény plant is suitable for conducting comparative studies with similar thermolytic systems. Figure 2 shows the 3D sketch of realised equipment.

Almost every notable points of the technology are monitorable or suitable for sampling. Monitoring points were determined in the equipment not to interfere with the process, but to provide direct information about the measured parameters. The most important parameters characterising the technology – like the temperature, or pressure – are monitored and recorded by every second on the computer placed in the control room. A PLC system provides simple and fast data communication for the slowly changing thermolysis process. Code system assists the identification of monitoring points, which contains the site of measurement, the measured parameter, and the number of given technological step.

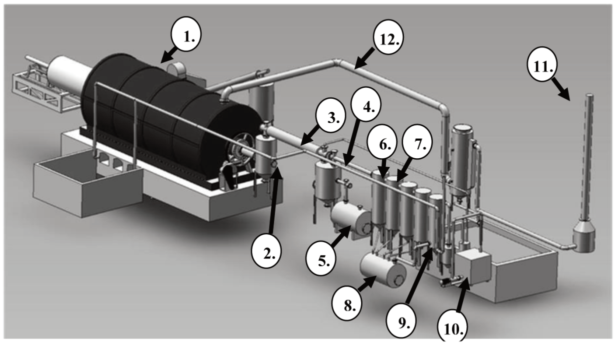

Figure 2. The pyrolysis technology in 3D presentation
1 – Reactor, 2 – Gas holder, 3 – Gas cooler,
4 – Oil-water separator, 5 – Heavy oil tank,
6 – Capacitor I, 7 – Capacitor II, 8 – Light oil tank,
9 – Scrubber tank, 10 – Vacuum pump,
11 – Gas flare, 12 – Combustion gas piping

As an example, the monitoring point No. PT012 measures the pressure of gas exiting the rotary kiln (reactor). Table 1 gives assistance in identifying the monitoring points.

Table 1. Identification of measuring points (PT012)

P		T	01	2
L – fluid level P – pressure	T – temperature Q – gas	T – technology	Serial number of technological step	1 – input data 2 – output data

The process control and visualisation system covers the graphical visualisation, operator's control, interventions, controls, communication, network handling, database handling, and data collection. Information arriving from the process is visualised on high-resolution colour graphic figures in vector graphical form. Process figures can contain various animations, graphs, trends, histograms, and even tables. Unlimited scalability of the system allows for developing new variable-types and components. List of technological monitoring sites, parameters to be measured and the individual measuring limits are given in the Table 2.

Sampling points for raw material, end-products and scrubber water were determined by the trial plans following the detailed analysis of technology. Carry-out of sampling was determined separately. Measurement and sampling points are seen in the Figure 3.

Data of pyrolysis of various raw wastes were recorded by the trial plans, covering also the operation of pilot plant. The most important data of the technology were summarized in table format, namely the following: date, raw waste to be pyrolysed, sampling date of raw material, starting and end-time of pyrolysis process, starting and end-time of gas- and oil-formation, the maximum temperature and pressure values during the process, the ambient temperature. Energy-type values used during the pyrolytic process were also summarised in the table, as well as, time of sampling of raw waste and the end-products, point of sampling, sampling temperature, and other parameters of sampling.

Table 2. Identification of measuring point, measured parameters and measuring ranges

Sign	Equipment unit	Measured parameters	Measuring ranges	Type of measuring
LT080	Light oil tank	Oil level	min / max levels	L
LT230	Cooling water tank	Cooling water level	min / max levels	L
PT012	Rotary kiln	Outlet gas pressure	0-100 mbar	P
PT041	Oil / gas separator	Inlet gas pressure	0-100 mbar	P
PT061	Still capacitor	Inlet gas pressure	0-100 mbar	P
PT100	Water seal	Tank pressure	0-100 mbar	P
PT102	Water seal	Gas outlet pressure	0-100 mbar	P
QT010	Gas danger at the rotary kiln	Hydrocarbon meter and gas danger warning	Signal processing / digital	Q
QT100	Gas danger at the scrubber	Hydrocarbon meter and gas danger warning	Signal processing / digital	Q
TT012	Rotary kiln	Outlet gas temperature	0-600 °C	T
TT034	Tube capacitor	Cooling water outlet temperature	0-100 °C	T
TT041	Oil / gas separator	Inlet gas temperature	50-500 °C	T
TT044	Oil / gas separator	Cooling water outlet temperature	0-100 °C	T
TT061	Still capacitor	Inlet gas temperature	50-500 °C	T
TT064	Still capacitor	Outlet cooling water temperature	0-100 °C	T
TT080	Light oil tank	Oil temperature	0-100 °C	T
TT102	Water seal	Gas outlet temperature	0-100 °C	T
TT131	Dust separator	Flue gas inlet temperature	100-800 °C	T
TT132	Dust separator	Flue gas outlet temperature	100-800 °C	T
TT233	Cooling water tank	Cooling water temperature	0-100 °C	T

Monitoring tools were used in multiple steps in order to reach the research results and as set in the trial plans. For the pyrolysis pilot runs, temperature measurements were carried out at 11 points, pressure measurements at 5 points, liquid level measurement at 2 points, hydrocarbon level measurement at 2 points. The primary consideration was to assure safe, troubleproof, and stable operation of the equipment for carrying out the research measurements.

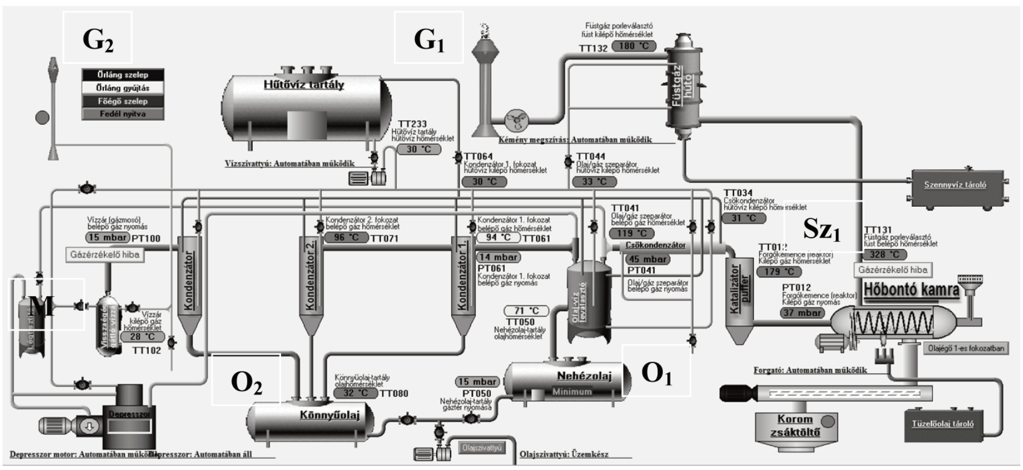

Figure 3. Measuring and sampling points
G_1 – outlet flue gas; G_2 – synthesis gas; O_1 – heavy oil; O_2 – light oil; MV – scrubber water; Sz_1 – residual pyrolysis char

4. Results and evaluation

Several different raw wastes were pyrolysed in the Mezőberény pilot plant of the project according to the trial plans in order to study the thermolytic process in the EE-MBPT/01 technology. The raw wastes to be pyrolysed were tyres, wood shreds (biomass), PET bottles, shredded tyres, industrial plastic waste, mixed plastic waste, municipal solid waste and coal-dust. Origin of the raw materials was known and recorded in every case. In the case of every raw material, two parallel pyrolyses were carried out, which could be characterised by the parameters shown in the Table 3.

Following the feeding of raw waste the system was closed and the heating-up phase initiated, which changed depending upon the characteristics of the waste to be pyrolysed. One of the notable points during the process was the start of gas formation, therefore its exact time was also recorded. Measured values were visualised directly in the monitors of the operation personnel. Sampling for the environmental analytical chemical measurements was carried out by the experts of external laboratory being in charge of the whole task. Due to the research aims of the project, we measured temperature and pressure values at more points than it was necessary in order to gain more detailed information. By increasing the measurement points the given sub-units of the monitored system can be operated better, truer, and safer. Increasing the number of temperature measurement points improved the determination of efficiency of technology sub-units and energetic optimization of the process, which both influenced the productivity indices.

Table 3. Parameters of pyrolyses of different raw wastes

Raw material	1st pyrolysis experiment		
	mass (kg)	**duration (min)**	**max. temperature (°C)**
tyres	500	320	380
wood shreds (biomass)	400	230	270
PET bottles	400	270	350
shredded tyres	600	385	380
industrial plastic waste	350	240	220
mixed plastic waste	500	600	320
municipal solid waste	300	380	245
coal-dust	300	360	265
Raw material	**2nd pyrolysis experiment**		
	mass (kg)	**duration (min)**	**max. temperature (°C)**
tyres	500	295	390
wood shreds (biomass)	400	260	270
PET bottles	400	570	370
shredded tyres	600	385	375
industrial plastic waste	350	355	210
mixed plastic waste	500	465	325
municipal solid waste	300	305	265
coal-dust	300	365	265

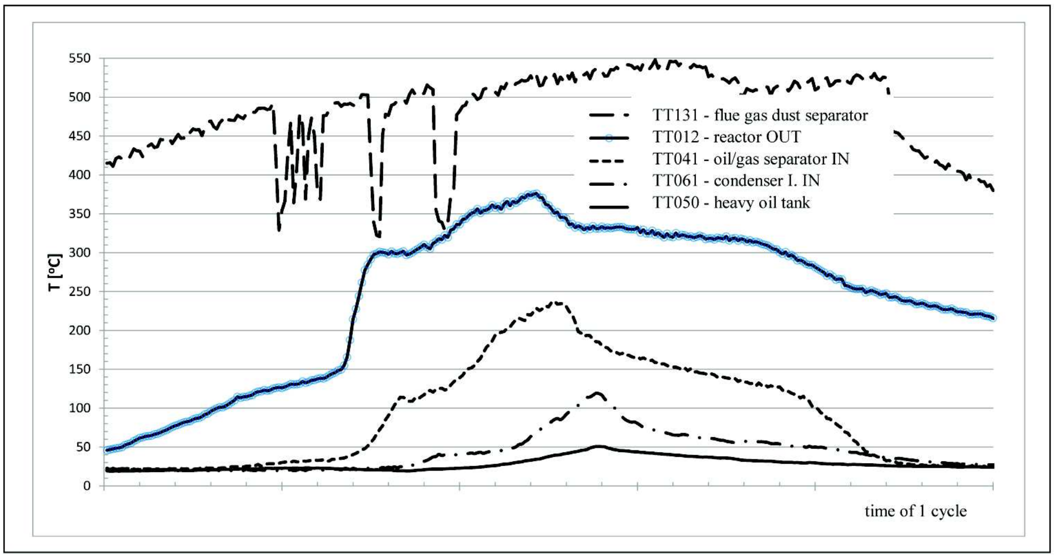

Figure 4. Pyrolysis temperature values for a hypothetic cycle

Figure 4 shows a possible way of visualisation of measured temperature data – in this case this is an edited version.

In order to enable examination of coherent technological parameters during the real-time analysis of technological process simultaneous visualisation of temperature and pressure values was necessary.

Figure 5 shows a possible way of visualisation of measured pressure data – in this case this is an edited version.

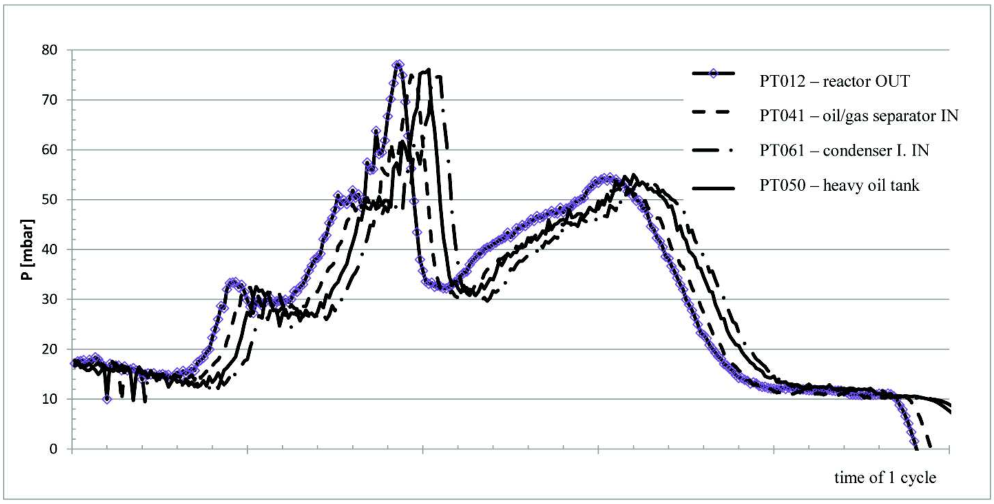

Figure 5. Pyrolysis pressure values fora hypothetic cycle

5. Conclusion

Research aims of the projects were realised through the involvement of Environ-Energie Kft. The EE-MBPT/01 plant in Mezőberény having 3 tons/day nominal capacity can serve as reference plant and is suitable for discontinuous thermolytic recycling of various raw (waste) materials in accordance with both the waste management and environmental considerations. The technology can provide a sustainable alternative for wastes that would be anyway dumped or treated in other less-sustainable way. The obtained end-products can be used as secondary raw materials for chemical industry or as secondary energy resources, fitting in the European Union's waste management approaches. The equipment operates in a well-controllable and troubleproof way by the help of its process control and visualisation system. Every moment of the technology can be handled even by remote control due to the continuous monitoring. The measured data can be visualised immediately, even in real-time in the control display. The plant and the equipment are suitable for conducting comparative examinations and the documented follow-up of the processes.

The plant of Environ-Energie Kft. in Mezőberény is suitable for monitoring and examining pilot and operational experiments under controlled conditions as well as collecting measured data. During the operation of pilot plant and subsequently analysing the results, researchers obtained insight into the details of thermolysis process.

Test results from the project are suitable as reference in connection with the quality of end products in the case of each raw material studied under operating conditions. It is also useful in examining how the environmental emission values of this kind of plants can comply with national legal requirements. By using the objective test results and experiences from operating model conditions, our research group is able to analyse and evaluate test results of a similar system in the following.

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