Gasification and Pyrolysis – Reliable Options for Waste Treatment?

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1. Introduction

Pyrolysis and gasification technologies are generally much more valued as alternative waste treatment technologies in Europe than they are in Germany. This is especially valid for the Anglo-American regions, for which consultancies, such as the English Juniper Consultancy Services or the Frost&Sullivan, have been forecasting for decades a breakthrough of gasification and pyrolysis technologies or at least an overall increase of both on the thermal waste treatment market. However, failed predictions, such as the one made by Juniper in summer 1997, according to which pyrolysis and gasification would grow to represent a 20 % share of the entire European thermal treatment market in 2007 (especially in Germany and France), have proven that they are of limited value. In this, what was to be a fortunate period for these technologies, the most promising technology of that kind – Thermoselect disappeared from the European market completely, as it similarly happened decades ago to the American concept Andco-Torrax. Whether possible changes in economic and political conditions could affect the development of these *alternative technologies* for their benefit, is debatable. Before the question on the status of pyrolysis and gasification today is answered and the technological developments of the last 40 years are revealed, a quick glance the current European legislation and the decisions of the European Court is needed. The focus is on the Industrial Emissions Directive – IED, which replaces the IPPC Directive, and on two recent court decisions that could affect the legal classification/description of pyrolysis and gasification when it comes to the incineration and co-incineration of waste. Both deal with the special situation when using gasification or pyrolysis as method for the thermal treatment which is normally covered as incineration or co-incineration of waste. But under special conditions it can be taken out of the scope of waste incineration activities which leads to less stringent emission standards. More details can be found under the described literature.

2. History of pyrolysis and gasification techniques for the thermal treatment of waste

The different steps for the development of techniques for pyrolysis and gasification of waste will be shortly described in the next sentences.

During the last forty years the development of the so called *alternative techniques* for thermal treatment of waste happened in two main steps.

The first step in the 70th and 80th was characterized by a high potential of innovation and the second step in mid of the 90th was more dominated by marketing strategies.

During the innovative step a huge amount technique for gasification and pyrolysis were founded by the government and ended up in different technical solution but a less number of plants working under normal technical conditions.

In the beginning 80th pyrolysis was not only used in Germany for the thermal treatment of household waste but although for the cleaning of contaminated sites (e.g. soil or sand).

Different plants were built for the decontamination of

- oil contaminated soil,
- soil contaminated with mercury or,
- polychlorinated dioxins and furans.

Figure 1:

Waste pyrolysis plant (MPA) Burgau

Source: LfU Bayern

The number of developments in the gasification process is somewhat less than in the field of waste pyrolysis, taking into account that the boundaries between the two techniques are somewhat unclear. Emanating from the experiences with shaft reactors in the coke and steel production, bigger and more facilities were created for the disposal operation. The results with gasification proved to be no better than with pyrolysis, in contrast to financial losses.

The aim of the waste gasification process was to produce a product gas that should be made useful not only for the process itself but also for external use. In this case the sink for heavy metals (if not volatile) was, in contrast to the pyrolysis process, a molten drawn of slag, which after cooling solidified to a glass-like mass and thus, only partially eluted. The organic matrix is at high temperatures up to 1,400 °C almost completely broken down. The energy balance of these processes indicates that the high temperature-induced internal consumption offers only limited potential for the energy recovery, resulting mostly from the utilization of the product gas.

Figure 2:

Plant with *Siemens-Schwel-Brenn-Concept* in Japan

Source: Dr. Jürgen Vehlow, former KIT Karlsruhe

Professor Kolb from the Forschungszentrum Karlsruhe calculated for the most modern plant of this technology – the Thermoselect plant in Karlsruhe, an energy efficiency of less than 8.5 %. Previous waste gasification technologies, such as the Andco-Torrax procedure, also failed because the gasification and melting process could not be maintained without the use of substantial amounts of conventional fossil fuels, such as natural gas. Nevertheless, many are still hopeful for these processes to be able to generate cost synthesis gas and/or liquid fuels from biomass and waste at reasonable effort. The Thermoselect plant in Karlsruhe represents next to the gasification plant of the Schwarze Pumpe in Germany the peak of development, or if considers the history (accurately, the peak of undesirable developments) – a trend that continues worldwide still today.

Some thermal treatment processes, such as plasma pyrolysis or staged combustion (e.g. the Hoval process) were not counted in as pyrolysis and gasification. One of the reasons is that plasma pyrolysis is highly advertised on one hand however; there is a lack of useful information about the process, such as mass and energy balances about existing plants, on the other. The technology is represented by companies Westinghouse and Plasco (US market) and Plasmox or EnviroArc (European market). In contrast to announcements made in the past, no large waste management facility with this technology exists so far. EnviroArc and Westinghouse use a similar technological concept for a gasification process, where plasma torches are used to generate a high-energy high temperature gas. EnviroArc operates a small shaft reactor as a gasification plant in Sweden for the disposal of tannery waste. The plant melts the solids through the use of a plasma torch with an hourly throughput of 560 kg at 4,000 working hours. Westinghouse and Hitachi Japan Steel developed jointly a shaft reactor for the plasma gasification of mixed wastes with high calorific value (shredder light fraction). This system is possibly the closest approximation to a large-scale implementation of the process principle, considering that this conception can be regarded as a hybrid between plasma and gasification technology for the thermal treatment of waste.

As the author's research in Canada and the U.S. has revealed, the companies that offer the plasma processes are not willing to provide information on mass and energy balances of their procedures. At the same these companies are trying to sell this technology not only in the U.S but also in in emerging industrial countries, such as Turkey and Egypt, as universal thermal treatment process.

In contrast, there have been repeated attempts to revive tire pyrolysis in Europe, by which the new concepts are less focused on the production of pyrolysis out and more on the recovery of the carbon black. Among experts there is, however, no agreement whether the financially most attractive recycling routes can still meet the high quality requirements of the recycled material to enable the manufacturing of toner.

3. Desires and the reality of the New Procedures

The market for the thermal treatment of waste (including the new treatment methods) seems to be re-establishing itself in the neighboring European countries as well as in North America as the new *Conversion Technology* that offers new opportunities. Thus, the British expert authority DEFRA included these technologies in 2005 to be part of a multi-million pound research and development program, which according to the German experience so far failed to establish a functional facility.

Many developers and companies are trying benefit from the recent developments in Eastern Europe, Asian and Arab-speaking developing countries, to which they are trying to sale their technology before the establishment of qualified approval- and monitoring authorities. In practice the response on the demand about data on the technical details, the availability of the technology or about the mass and energy balances is, however, mostly insufficient. The situation in Japan, where many of the pyrolysis and gasification processes are operated on a large scale, is also difficult to assess, raising doubts whether the facilities meet their treatment targets under certain set costs. Some of the plants are built and operated under a license or under a joint holding company (JFE Engineering Corporation, Thermoselect License), while there are also self-developments that occur as a result of operation experiences in the field of gasification or the core business (including iron and steel production), which are to be traded as waste gasification technology in Europe (e.g. Rome).

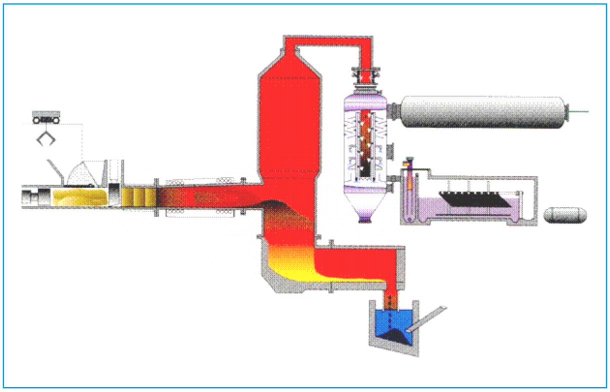

Figure 3:

Technical Concept JFE with license for Thermoselect in Japan

Source: Dr. Jürgen Vehlow, former KIT Karlsruhe

Other interesting approaches arise in waste co-incineration in power plants or in industrial production processes. Pyrolysis was long considered a modern and trend setting, which provides a high calorific gas and a coke-similar solid fraction from high calorific waste. Both products meet the requirements for co-incineration at the power plants. Thus, the conditions to use pyrolysis as a ballast system for the solid-fuel based power plants are fulfilled.

An example of the practical implementation of such combination is the power plant in Hamm-Uentrop , which in August 1998 hired VEW Energie (Dortmund) and Mannesmann Demag Energie- und Umwelttechnick to build a pyrolysis plant as an integral part of the power plant. From early summer 2000 and until the year of the damaging event (end of 2009), 100,000 tons of high calorific residues were pyrolyzed. The resulting products gas and coke were used in the power plant to generate electricity, replacing up to 10 % of coal.

In comparison to conventional waste incineration plants the higher thermal efficiency of coal power plants enables a better utilization of the calorific value of the waste under the condition that the main process is not adversely affected by a higher risk of corrosion.

However, a number of technical difficulties appeared in practical operation, which culminated in a major incident in late 2009, of which the main cause could have been corrosion. According to the plant operator, no commercial operation was possible after the incident in December 2009, because the residues from the used high calorific waste are not being sorted anymore in a way that would be necessary for the process. Instead, the materials (often content of recycling bags) landed often in waste incinerators. The in the incident overturned steel chimney of the plant, was not rebuilt. An economic evaluation has shown that such an investment would not pay off.

Figure 4:

ConTherm-Plant after the incident

Source: http://www.wa.de/nachrichten/hamm/stadt-hamm/contherm-anlage-hamm-wird-nicht-weiter-betrieben-667645.html

4. New concepts or new markets?

Experiences from the last 40 years show that in addition to the technical problems, pyrolysis and gasification companies also often have to deal with economic problems. The utilization of the above mentioned techniques in the combination with resource recovery led in most cases to shut downs in the operation, since no adequate revenues could be obtained for the additional costs of product preparation so far. Meanwhile, also plants with direct disposal technologies are now subject to significant cost pressures. The example of the BKMI in Burgau shows that both the investment and the operating costs are higher than in comparable combustion plants.

What also needs to be counted in is the direct energy use through the co-incineration of waste in power- or cement plants, as far as it is possible to use with regard to the chemical and physical properties and limitations. In addition, the use of high calorific value waste as refuse derived fuel in newly established refuse-derived fuel plants, and the increased energy recovery in conventional municipal waste incinerators, needs to be taken into consideration.

Despite being a competition for the co-combustion projects, processes such as the Contherm or other similar ones under development, can represent an opportunity for gasification and as a ballast process for the utilization of waste as:

- Household or residual waste,
- Household waste fractions with higher calorific value
- Sorting residues from the plastic waste recycling,

which because of their heterogeneous composition cannot be burned easily.

Therefore, a homogenizing treatment may be necessary to convert this waste into a form that allows co-incineration, and thus make the energy content of the waste usable. It also seems no universal measure for achieving self-sufficiency in waste treatment exists. Although the disposal measures can be linked with the measures of electricity and heat supply, in principle they still need to operate independently economic activities and individual needs of the industry.

The niche of alternative techniques of gasification and pyrolysis (thermolysis) of waste appears to be very small in fully developed and well organized waste management, but it should not be excluded completely. As a complement to established techniques, such as material recycling and energy use at waste incineration plants, it can in some cases even improve the energy recovery.

The problem with the use of *alternative procedures* is when no infrastructure for a comprehensive waste management exists (with the exception of the landfill) and when the waste pyrolysis or gasification is taken as the basis for the establishment of a modern waste management. Such an approach is usually the result of ideological policy decisions, which often, when one examines the background of such decisions, prove to be the result of a no incinerator policy. However, in most cases the no-incineration policy is not fulfilled through the implementation of such technology, since in order for the gasification or pyrolysis processes to produce heat and electricity, their products must be incinerated in the end to utilize their heating value. To understand and explain why highly industrialized member states like France or Great Britain are keen on making their own negative experiences with the mentioned technologies under the financial support of the state, and considering the fact that Germany just 5 years ago suffered significant financial losses following similar steps, one can only assume that when such policy decisions are made, foreign experiences are very likely to be ignored.

It would be therefore sensible to slowly accept the fact that thermodynamics and entropy are not bound to national borders and thus, have to be considered always.

After Carbo-V/Choren, the Canadian company Enerkem based its concept on the desire to produce fuels from organic materials. They offer a solution by which both waste as well as biomass is thermally converted.

The presentation if the technology is involuntarily reminiscent of the Thermoselect case, where the technology has been marketed worldwide without having an implemented system that worked.

When requests and promises take over facts, an engineering technical correction is in urgent need. In many cases it may be necessary to determine the level of development of a new or modified process and the related plant for the thermal treatment of waste in order to be able to make correct decisions on further actions. This is particularly important in discussions and decision-making between clients, vendors and investors and, ultimately, for the communication process with the authority that gives out the approval. The crucial question is always related to the development stage of the process, including the conditions within and also outside of the planned projects' frame.

The assessment criteria are as follows a description of:

- the process and the plant,
- the inputs and outputs,
- the market opportunities,

- the opportunities and uncertainties – Scale-up and
- the operating experiences.

The scope and verifiable details of the description of the assessment criteria determine the real development level. Excuses such as confidentiality or patent disputes are usually an indication of lack of development or of an inadequate accounting of the process.

A realistic and pragmatic description of the criteria is of great importance to all concerned, in order to be able to minimize bad decisions and bad investments.

5. Summary and Outlook

Future-oriented waste management concepts should combine economic and ecological requirements. Within this context, the pyrolysis or gasification of high calorific waste fractions can, in combination with the existing or newly built power plants and industrial furnaces, offer an alternative technical solution, provided that it is mainly used for selected high calorific waste and waste fuels.

Such integration enables, in spite of the still existing technical problems, the thermal recovery of waste, with the following advantages:

- lower capital and operating costs,
- synergies through the use of existing infrastructure and the machine technology of the power plants and industrial furnaces,
- use of heat and power generation with high efficiency,
- substitution of fossil fuels and the resulting avoidance of additional sources of emissions.

The aforementioned technical approaches represent something like a possible choice within an already fully organized waste management system, which already fulfills its main aim to organize a waste management based on proven techniques and the use of meaningful composite solutions for thermal and non-thermal processes, including the use of existing co-incineration plants. A waste management planned from the start on the basis of insufficiently proven techniques can be only seen as being motivated by political decisions on one hand and on the *gold rush* agenda on the part of the process provider, on the other. As the description of the different methods in the tables shows, such practice quickly gives way to a bad ending. Because, in order to produce high-quality products from heterogeneous mixtures of waste, such as chemical raw materials and fuels, we need not only the right raw materials, but also the right process technology and the necessary amount of experience coupled with some luck.

Belief may indeed move mountains, but the modern period cannot afford to ignore the physical laws of thermodynamics and entropy. A full recovery of raw materials may be a highly anticipated wish; nevertheless it will not come true without it if we ignore first or the second law of thermodynamics, which only leads to failure and ultimately to unnecessary costs. In addition to following the physical laws, the laws and demands of the market for any form of recycling products must be taken into consideration. Recycling products are accepted by the market only when a certain quantity and quality of the demand exists or when a demand structure can be built quickly. Temporarily, the costs of the increased recovery costs can be offset by subsidies, however, this may only serve as a jump start, if the approach is to be sustainable.

Most commonly, the waste pyrolysis and gasification providers have little to show other than their *gold rush* mentality, suggesting the sustainability of the concepts. Maximum attention is necessary where the media reporting and the advertising outlay serious engineering planning. More critical distance from policy-makers and potential investors paired with an engineering-technical expertise, which is also based on the experiences of others, may help shorten that the so far long list of failures, bad luck and mishaps in the development of alternative waste treatment processes.The review past events leaves, however, the author in doubt that such developments will come true in the future.

6. Literature

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