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Detailed information on energy research

Generating syngas from plastic wastes

New method uses lime in shaft kilns as the carrier medium, catalyst and pollutant binder

BINE Information Service

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A newly developed gasification process utilises waste plastics, carbon-containing sorting residues and rubber parts as well as shredded materials in the automotive industry. It can also process chlorine-containing plastic streams with PVC fractions in an environmentally friendly and efficient manner. It produces a purified syngas without flue gas emissions. In the process, lime serves as a transport medium and simultaneously binds halogens and other harmful substances. The gas generated in the shaft kiln can replace valuable primary energy sources such as natural gas in high-temperature processes or be used to generate electricity in efficient gas engines.

The process utilises diverse residues, including problematic plastic wastes or contaminated materials, without them having to undergo complex processing in advance. Potential feedstocks include sorting residues from recycling bins, heavy and light fractions of shredded materials, plastic composites or contaminated waste wood, miscellaneous biomass, roofing felts, lignite, salt coal, oil shale, tar lakes, contaminated soils, bituminous waste and, in particular, sewage sludge. Some waste, such as sewage sludge or plastic-containing e-waste fractions, contains valuable materials such as phosphorus, precious metals and rare earths. These can be enriched, separated and recycled by binding them with fine-ground lime.

Roland Möller, head of the research project and Director of the Ecoloop company, says: „We make gas from waste. Our technology does not have to limit the use of chlorine-producing feedstocks for the combustion processes as is usually the case. With Ecoloop we want to supplement the waste and recycling technology in a sensible manner.“ The energy efficient utilisation of plastic waste in the new gasification plant provides a cheap alternative to incineration in waste incinerators with the subsequently necessary flue gas cleaning.

Syngas is produced in the shaft kiln

The furnace plant combines proven technical systems and methods that mainly stem from the lime industry to provide an innovative, flexible recycling process. Here the residues are mixed with coarse-ground lime and converted into syngas in a bulk material moving bed using the counter flow principle. The moving bed gasifier system does not require complex rotating parts or fixtures that are susceptible to damage. Under its own gravity, the material is transported from top to bottom in a bulk material moving bed comprising lime and substitute fuels, just as in the lime burning process.

Lime plays key role in the process

Lime plays a crucial role in the conversion process in the shaft kiln: it is both a transport medium for the fuel and gas permeable scaffold within the bulk material moving bed, and its catalytic effect increases the generation of syngas. In addition, the lime absorbs chlorine, preventing not only the formation of dioxins and furans but also the resulting dangerous fumes during the subsequent use of the syngas. Between 400 and 800 °C and in the presence of water vapour as a catalyst, the lime facilitates the reforming of long-chain polymers and polycyclic derivatives. This therefore considerably reduces the formation of undesirable oil and tar-containing cleavage products. Acidic pollutants such as hydrochloric or sulphur compounds are bound to the lime and, after their heat is recovered, they are then separated with the ashes as fines from the course-ground lime. This can then be reused as part of the bulk material moving bed. During the gas cleaning, the raw syngas is freed from flue dust using hot gas filters and is then cooled to room temperature. The purified syngas can replace, for example, natural gas or be used as a raw material to produce basic chemicals such as alcohols or various hydrocarbons.

First large-scale pilot plant

The first large-scale plant was designed to utilise up to 50,000 tonnes of waste plastic per year. This requires around 3,000 to 4,000 tonnes of coarse-ground lime per year. Air and water vapour are blown in as gasification and coolant agents. In the plant‘s vertical shaft kiln and supported by initial base load combustion, the material undergoes partial oxidation and a series of gasification and pyrolysis reactions at reaction temperatures between 450 and 1,200 °C. After the syngas has been cleaned with hot gas filters and cooled down it can be used, for example, as a fuel for industrial processes. This leaves about 8,000 to 12,000 tonnes of fines per year as residue; this mixture of fine-ground lime, ash and pollutants has to be landfilled.

The plant is designed for a rated thermal output of 32 MW. As a counter-flow gasifier it can achieve a thermal efficiency of over 80 % with an external electricity requirement of about 1 MW. The system concept is flexible and can be used in industry and waste recycling. The Ecoloop technology can sensibly complement waste incinerators by materially converting in particular chlorine- and pollutant-containing waste streams into syngas instead of burning it as part of the overall waste mix. In order to utilise such materials thermally, until now these have been mixed with the total waste fed into waste incinerators. Although this prevents certain limit values from being exceeded, in particular the increased chlorine fractions create considerable technical disadvantages. To counteract the high-temperature corrosion that occurs as a result, combustion plants have to be operated at reduced temperatures and vapour pressures. This decreases the efficiency. Other consequences include increased operating

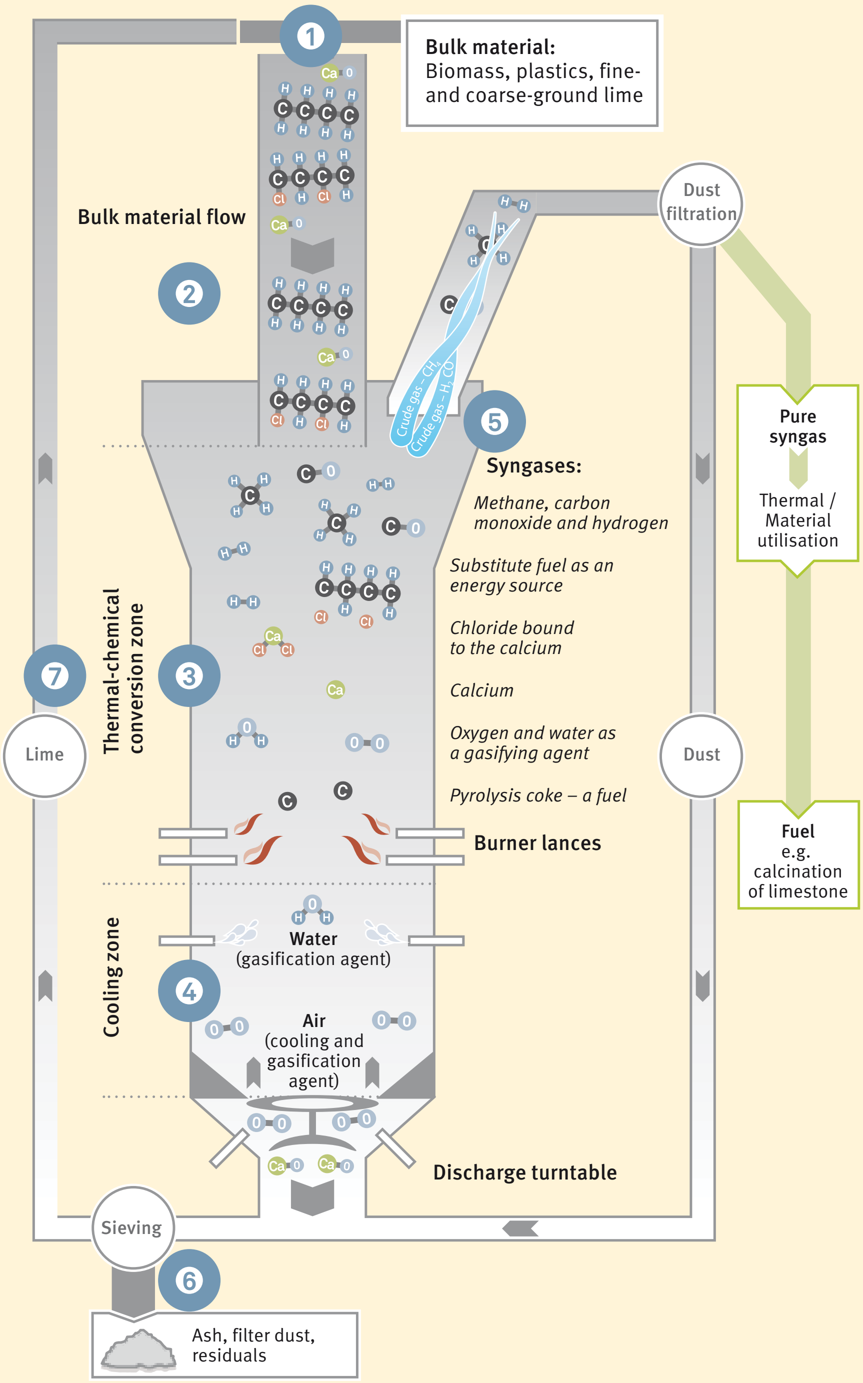

Fig. 1 Schematic diagram of the shaft reactor: 1 Input material is mixed with lime before it passes into the hot reactor zone. 2 Material is fed by gravity and controlled by a turntable discharge system. 3 After the gasification in the upper zones, the remaining pyrolysis coke moves into the combustion zone and provides energy for the process. 4 In the cooling zone, the lime is cooled by air and water. 5 Syngas is suctioned off at the upper reactor head and pollutants remain bound to the fine-ground lime. 6 Pollutants are sieved out with the fine-ground lime and ash. 7 Coarse-ground lime is recycled in the process.

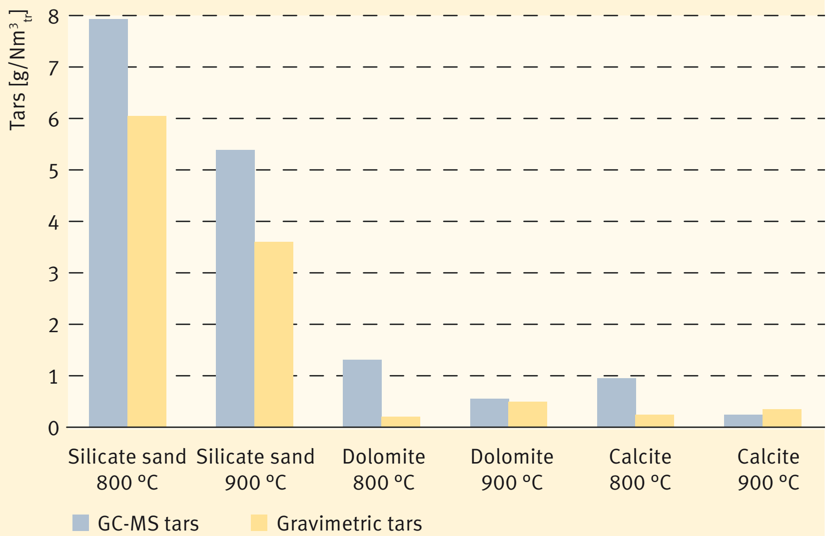

Fig. 2 *The catalytic influence of the lime (CaO) significantly reduces the formation of tars.*

Fig. 3 *Above: The lime moving bed leaves the reactor, the ash and pollutants are then filtered out. Below: Raw gas pipes with safety discs.*

and maintenance costs. In particular, high chlorine concentrations in combustion processes lead to the formation of highly toxic dioxins and furans, which have to be laboriously filtered out and deposited via flue gas cleaning plants.
The prevention of chlorine peaks in the overall waste increases the efficiency of the waste incineration, reduces the formation of pollutants and simultaneously enables the separate utilisation of problematic materials though their flue gas-free conversion via Ecoloop into purified syngas.

Syngas generation

The generated syngas (synthesis gas) is purified lean gas, comparable with town gas or coke oven gas. The combustible main components are CO, H_2 and light hydrocarbons; inert components such as CO_2 and N_2 are mainly absorbed into the syngas through the use of air and water as gasifying agents. Its calorific value ranges between 2 and 2.4 kWh/Nm³, while its dust content is less than 1 mg/Nm³. When it is combusted temperatures up to 1,900 °C are achieved. Syngas is therefore also suitable for supporting high-temperature processes that require fossil fuels, such as in the cement industry, in glass foundries or in iron and steel production. It is also possible to use the gas as a chemical feedstock, depending on the recycled materials and the means of operation of the reactor. A plant that processes about 50,000 tonnes of waste a year generates up to 15,000 Nm³ of syngas per hour. That results in an average annual output of 250,000 MWh syngas, which corresponds to about 20,000 tonnes of natural gas.

Current research and development work

In the first large-scale pilot plant, numerous gasification campaigns were carried out with plastic- and chlorine-containing substitute fuels, whereby 2,000 tonnes of different types of material flows have already been used: mixed plastics and sorting residues from the yellow recycling bins and shredded heavy fractions from car recycling. The operating results and experience are being incorporated in research and development collaborations to optimise and further develop the technology.
Together with Clausthal Technical University, researchers are developing a comprehensive simulation model of the gasification process. Processing parameters and measurement data from the large-scale pilot reactor provide the input basis for much of the data.
The model is complemented by experimental results and data from laboratory and pilot plants.
Meanwhile, the programming of the simulation model is well advanced and the validation of different settings and model tests has already begun.
It is ultimately intended that the simulation model shall provide reliable process data from different input data. This will make it possible, for example, to simulate the use of different waste materials and to determine the expected syngas composition and the efficiency of the system without such tests having to be carried out on the large-scale plant.
Using the simulation model, it is intended to improve the method and the reactor design. The developers see the focus of their further work in optimally adapting the process for different reactor geometries and design sizes.
The medium-term goal is to develop an optimised, large-scale plant type that can efficiently utilise a large number of problematic waste streams on the spot, in different design sizes and without relying on expensive „waste tourism“.

Syngases for the chemical industry

Syngases (synthesis gases) are produced and used in many areas of industry, for example in steel and chemical production. CO-rich syngas provides an important raw material for many chemical products, such as fuels and plastics. Linde AG is testing a new dry reforming process in a new pilot plant at its site in Pullach. For this purpose, the scientists have decisively changed the standard steam reforming method. In addition to methane and some water vapour, carbon dioxide (CO_2) is also fed into a tubular reactor at high pressure. At temperatures between 800 and 1,000 degrees, the CO_2 reacts with the methane to form hydrogen and carbon monoxide. This process is more energy efficient than the standard version: firstly, the dry reforming technique requires much less water vapour to prevent catalyst coking; secondly, the syngas is produced under high pressure, which eliminates the need for prior gas expansion and, following the reaction, further compression. A further advantage is the use of large amounts of CO_2. This is produced as a waste product in many industrial processes and can be usefully deployed instead of being discharged into the environment.

The high proportion of CO enables the gas to be directly used for many synthetic processes without hydrogen having to be separated beforehand. It therefore rivals the partial oxidation process, which also achieves high carbon monoxide fractions due to the reaction of methane with oxygen. However, the pure oxygen that is required with this variant has to be produced with considerable energy costs. Moreover, the dry reforming process in particular provides relevant cost advantages over partial oxidation when used in small and medium-sized plants.

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Links and literature

- Ecoloop GmbH | www.ecoloop.eu
- Video: The Ecoloop technology at the Fels-Werke plant (in German) | https://youtu.be/GPCIhkdc_kI
- DryRef dry reforming process: www.the-linde-group.com
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