Center for Future Energy Technologies Strem

DUAL-FLUIDIZED-BED-GASIFICATION

Description of the Technology

Version 1.0

Center for
Future Energy
Technologies
Strem

1. INTRODUCTION

In addition to classical combustion, solid and liquid, carbon-containing substances can also be converted via a thermochemical transformation into a secondary energy carrier – the synthesis gas or also product gas – which has considerable advantages over combustion in terms of handling and further conversion possibilities in useful energy.

In this case, the same conversion processes happen, that are also given during combustion. The individual stages of the thermochemical transformation, however, are realized separately from each other spatially and temporally.

Due to the increasing global demand for energy and the replacement of fossil fuels, it is becoming more and more important to convert many different raw materials and residuals with a high overall efficiency into several forms of energy. This is only possible with the help of this special thermochemical transformation, the gasification.

2. GASIFICATION TECHNOLOGY

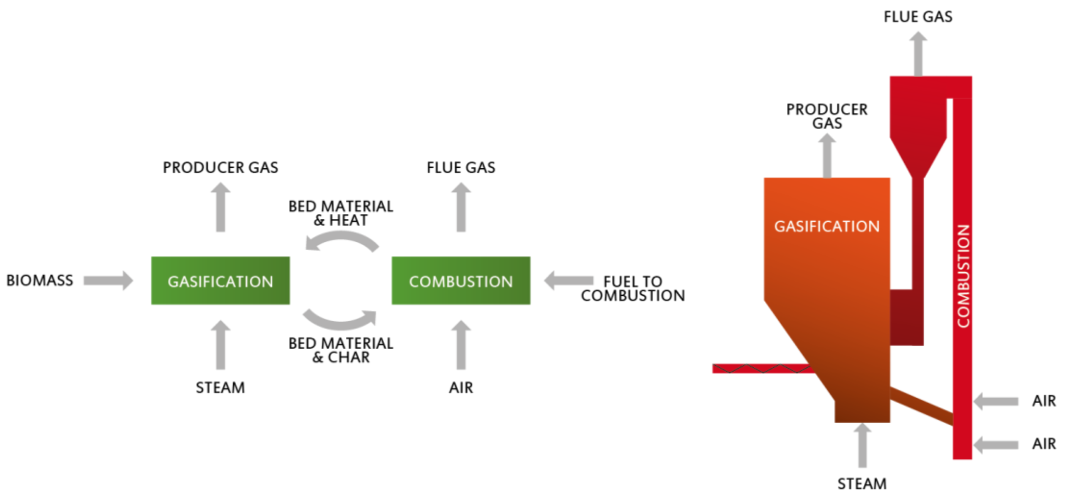
Gasification is the thermochemical conversion of a solid or liquid fuel into a combustible gas mixture. The current methods for the gasification of carbon-containing substances can in principle be distinguished by four categories:

- type of reactor used: fixed bed, fluidized bed (stationary, circulating, twin), flow or hydrothermal gasification reactor.
- gasification medium used: air, oxygen, water vapor
- operating pressure: atmospheric or pressure-charged
- type of heat supply: allothermic or autothermic

Of all these gasification processes, twin-bed fluidized bed gasification (DFB technology) is recognized as the most mature process worldwide.

In the case of dual-fluidized-bed-gasification, the basic idea is to spatially separate the gasification- and combustion reaction in order to obtain a largely nitrogen-free product gas (without the use of oxygen) (allothermal gasification). The gasification takes place at surrounding pressure with steam as a gasification medium.

In the DFB process, the gasification reactions are distributed over two reactors. The actual gasification takes place in a reactor (fluidized bed of a circulating fluidized bed) and in a second reactor (recycling of a circulating fluidized bed) combustion of the coke formed during the gasification and other process residues such as tar occurs. In the gasification reactor, the fuel is transferred together with steam at a temperature of approximately 850°C into a virtually nitrogen-free raw gas. The heat supply for the endothermic reactions is effected by means of hot fluidized bed material. In the combustion chamber, residues such as coke, filter cake (tar-containing) and recirculated raw gas are combusted at about 890°C, thereby heating the bed material. The bed material (e.g., olivine sand) circulates between the two fluidized beds, which transfers a large portion of the heat of combustion from the combustion chamber to the gasification reactor. In addition to the main components H_2, CO, CH_4, CO_2 and H_2O, the crude gas produced contains various impurities such as particles, tar and sulfur compounds, which must be separated before the gas is used.



The synthesis gas produced during the gasification in the DFB gasifier contains little nitrogen and has an appropriate H2/CO ratio. The gas with this H2/CO ratio and the lack of nitrogen has a much higher heating value than the product gases of other gasifiers and is also very well suited for chemical synthesis. Due to the high calorific value, the gas is particularly well suited for use in motors for generating electricity.

The following table shows the composition of the synthesis gas from the DFB carburetor in Güssing:

MAIN GAS-COMPONENTS		
H_2	%	35-45
CO	%	22-25
CO_2	%	20-25
CH_4	%	~10
C_2H_4	%	2-3
tar	mg/m³	20-30

Based on the experience gained so far, the following advantages of the FICFB process can be mentioned:

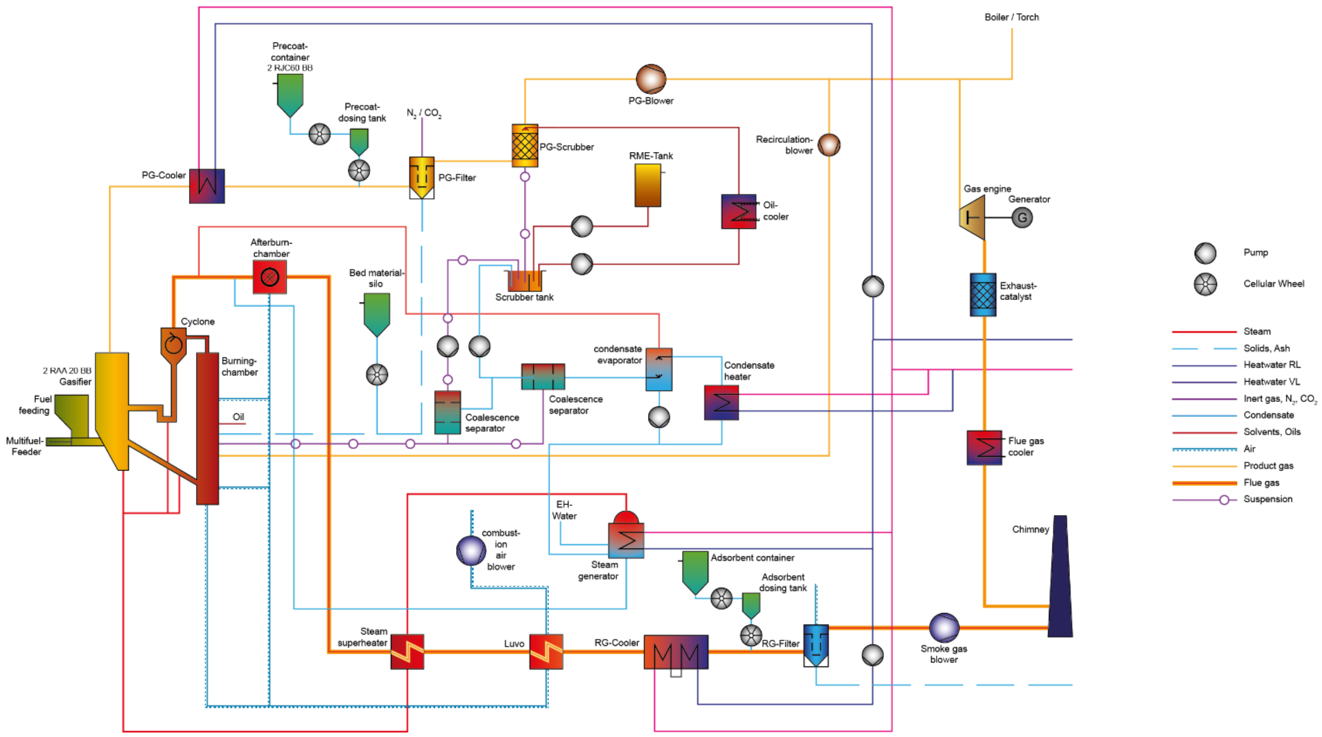
- product gas almost free of nitrogen
- high calorific value of the product gas
- wide application fields for the product gas
- a wide range of raw materials for gasification
- in the normal case, a few, slightly contaminated waste
- no waste water
- well scalable
- proven technology
- high efficiency (85%).

The main product of the DFB gasifier represents the synthesis gas with high quality. In addition, a number of by-products are generated: a flue gas, a tar-containing filter cake from the fabric filter in the product gas stream, loaded RME and dust from the cleaning of the smoke gas stream. Both the filter cake and the loaded RME can be used after processing. They contribute to the heat supply for the gasification in the combustion chamber. Thus they are not going to waste, since they do not leave the process. Only the flue gas and the dust separated from it are discharged from the plant.

In the case of flue gas, all emission requirements are met by means of dedusting. The flue gas is completely burnt out and accounts for between 0.3% and 1% of the total input. Condensate is not produced. The water in the process is recycled in the process. Since the water-vapor gasification has a net water consumption, it can be assumed that no wastewater leaves the plant for treatment.

The process principle of DFB gasification thus leads to a clear advantage over other gasification processes.

The main components of DFB gasification are shown in the following scheme:



3. POTENTIAL OF THE PROCESS

For an economical operation of a gasification process, it is necessary to be able to use as large a range of fuels as possible. Given today's framework conditions for the market for biogenic fuels, the use of residual and waste materials is of particular importance. The DFB process is very well suited for all types of biomass but also for various residual and waste materials, such as, for example, plastics, sorted household waste, scrap tires, sewage sludge, etc. Coal can also be used efficiently in this technology.

A decisive criterion for the use of solid fuels is the ash melting behavior. An ash melt must be safely prevented in order to avoid agglomeration of the fluidized bed. For reasons of efficiency and thus to maximize the economic efficiency of the process, pre-drying must be provided before introducing the fuel into the gasifier.

The special properties of the synthesis gas offer various variations for energy supply. In addition to efficient cogeneration by means of gas engines, gas turbines or fuel cells, numerous applications in chemical syntheses enable the production of all products based on the synthesis gas, such as synthetic natural gas, liquid Fischer/Tropsch fuels or hydrogen. All procedures necessary for this have been known for many decades.

The following figure shows the great potential of the DFB process both from the variety of the input material and the possibilities for generating different energy forms.

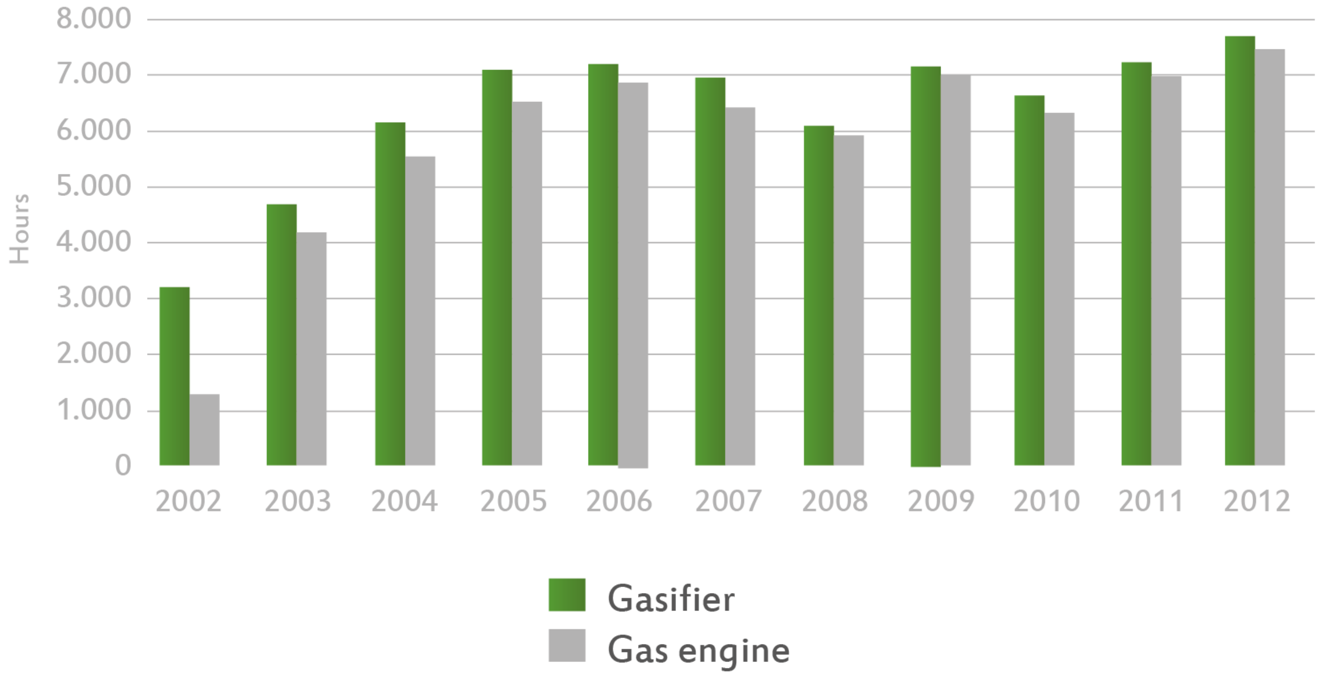
4. MATURITY OF THE TECHNOLOGY

In the city of Güssing the DFB technology was installed by Family Koch, in the form of an industrial pilot- and demonstration plant in cooperation with Prof. Hofbauer from the Vienna University of Technology.

LOCATION	Güssing, Austria
PRODUCTION	Gas engine
OUTPUT in MW	8,0 $_{fuel}$ / 2,0 $_{el}$ / 4,5 $_{th}$
ELECTRICAL EFFICIENCY	25 %
TOTAL EFFICIENCY	81,3 %
START-UP	2001
CONSTRUCTOR	Austrian Energy
STATUS	In operation

.

The DFB concept is characterized by this plant with the highest number of operating hours under all current gasification concepts. A stable operation of the system over long periods has been demonstrated. Today, annual operating hours over 7,600 are self-evident.



4. PLANT SCALING

After the first plant in Güssing with an output of 8 MW, further plants with a higher fuel heat output were installed. The achievable electrical performance shows, that plants for generating electricity, based on the DFB gasification in the single-digit and low double-digit range, are economically very attractive. Gasifiers for the production of synthetic natural gas, Fischer/Tropsch fuels and hydrogen will be rather larger.

An increase over the so far realized power range is no problem for the technology of a circulating fluidized bed. In the case of fluidized-bed combustion boilers, the 200 MW fuel heat capacity mark has already been successfully exceeded several times. In addition, the use in several lines is possible and for many applications also useful. An upper power limit thus results more from the feasibility and the sensibility of the fuel supply than from the viability of the gasifier.

The following images show further DFB gasification plants already implemented:

LOCATION	Oberwart, Austria
PRODUCTION	Gas engine / ORC
POWER in MW	$8{,}5_{fuel}$ / $2{,}8_{el}$ / $3{,}5_{th}$
EFFICIENCY EL	32 %
EFFICIENCY TOTAL	75 %
START-UP	2008
CONSTRUCTION COMPANY	Ortner Anlagenbau
STATUS	in operation

LOCATION	Villach, Austria
PRODUCTION	Gas engine
OUTPUT in MW	15_{fuel} / 4_{el}
START-UP	2010
CONSTRUCTION COMPANY	Ortner Anlagenbau
STATUS	in operation

LOCATION	Senden / Ulm, Germany
PRODUCTION	Gas engine / ORC
OUTPUT in MW	15_{fuel} / 5_{el}
START-UP	2012
CONSTRUCTION COMPANY	Repotec
STATUS	in operation

LOCATION	Gothenborg, Sweden
PRODUCTION	BioSNG
OUTPUT in MW	32_{fuel} / 20_{BioSNG}
START-UP	2014
CONSTRUCTION COMPANY	Repotec
STATUS	in operation

5. G-VOLUTION

The next stage of DFB-Gasification

The use of solid fuels is experiencing a renaissance worldwide due to the ever-increasing energy demand. On the one hand, this concerns energy-containing residues from agriculture and forestry, residues/waste/sewage sludge from industry and municipalities, but also from various types of coal, which are widely available in many regions around the world. All these substances must be disposed of and should therefore be used in an appropriate manner for energy use.

The energetic use of these often very heterogeneous fuels can take place in various ways, the transfer of these heterogeneous solid fuels into a homogeneous product gas by thermochemical gasification with steam at temperatures around 850°C has proven to be very advantageous in recent years. This homogeneous product gas can be easily transported, efficiently converted and used in a variety of ways.

For this reason, DFB gas generation was further developed on the basis of the operating results from the Güssing plant, with the following focus:

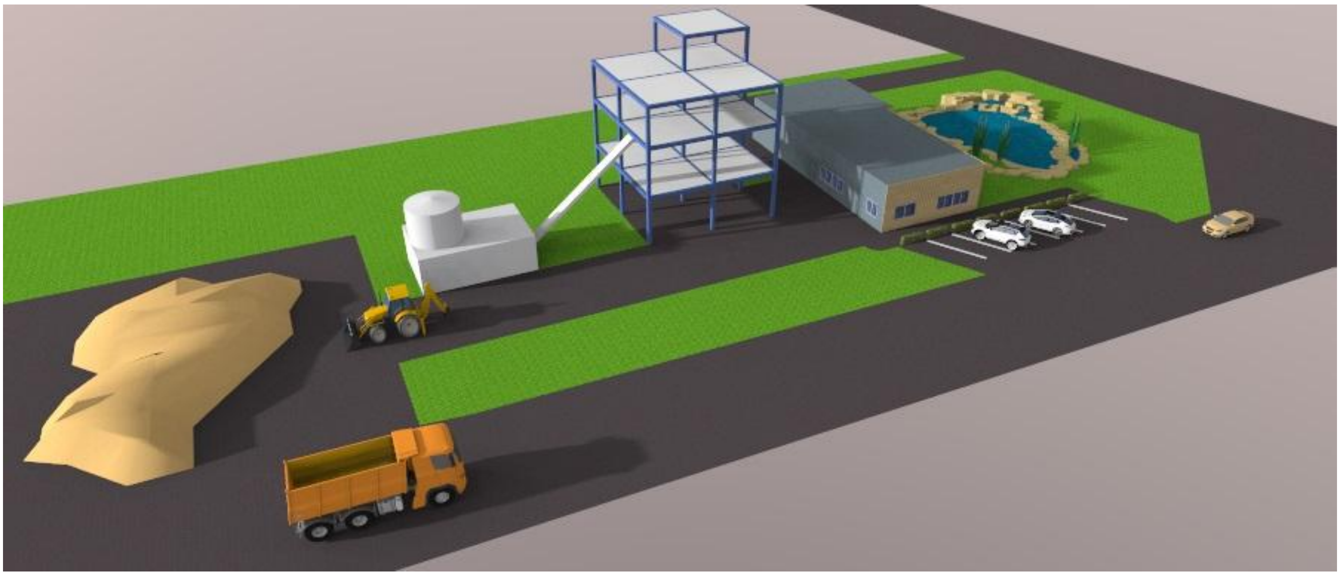
- usability of many fuels (type, piece size, water and ash content, etc.)
- product gas with low tar content
- product gas as nitrogen free as possible
- versatile application of the product gas (electricity, heat, synthetic natural gas, fuels liquid fuels, hydrogen)

To this end, a new DFB gas generating system was installed in the pilot plant of the Institute for Process Engineering, Environmental Technology and Technical Biosciences at the Vienna University of Technology to carry out the necessary tests for the design of a new pilot- and demonstration plant

The objective of CeFET GmbH is now - in cooperation TU Vienna and other partners - to upscale this plant and to build and operate an industrial sized pilot- and demonstration plant.

Several areas will be covered by the G-Volution plant:

- feed-in of green electricity into the grid (500 kW)
- heat supply of the district heating system
- feed-in of synthetic natural gas into the biogas- and natural gas grid
- production of hydrogen for the industrial sector
- applied research of the Fischer/Tropsch system
- national and international research projects for the evolution of the technology
- patents and licenses
- pilot plant for new FICFB-plant projects



6. PILOT-& DEMONSTRATION-PLANT

Center for
Future Energy
Technologies
Strem

State of the art

With steam gasification of solid fuels through the dual fluidized bed system, a solid fuel can be converted into a high-quality, nitrogen-free product gas (syngas) at high temperatures within the specially designed, so-called "dual fluid" fluidized bed equipment.

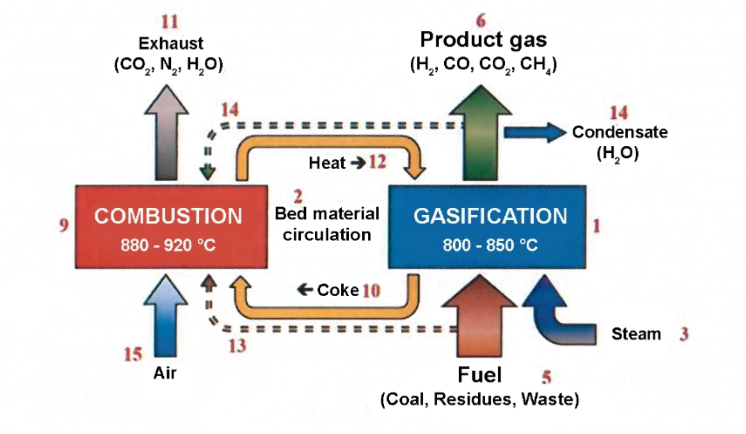
In the case of the dual fluid technology (see image), steam is used as a gasification resource (3) in the gasification reactor (1) for converting the fuel (5). The necessary energy for the gasification is provided by the heating of the sand (2) (bed material) in another part of the overall system (combustion part (9)).

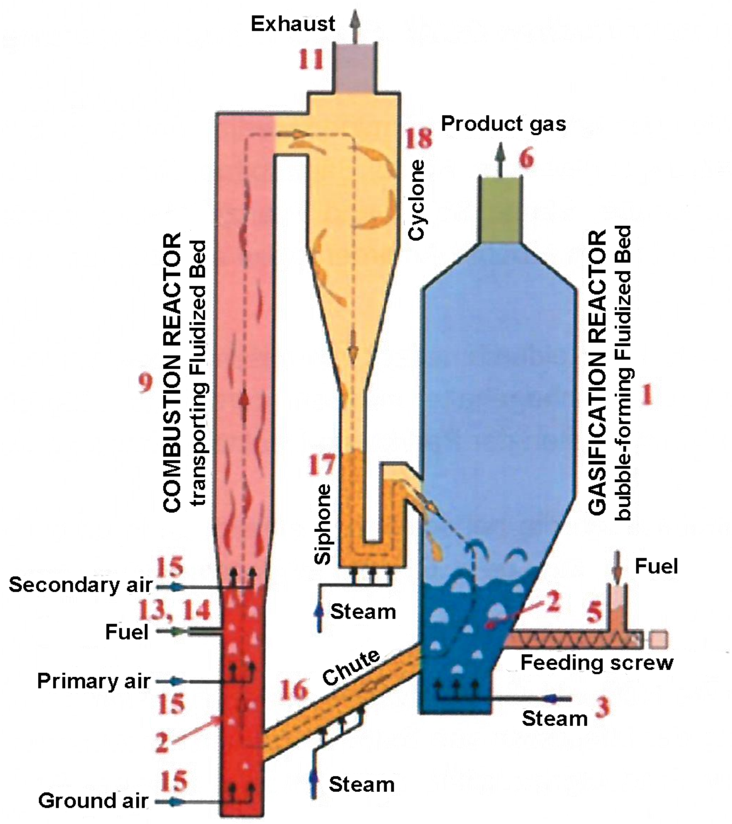
The two plant components (gasification reactor (1) and combustion reactor (9)) only interfere with the circulating solid (sand (2) as bed material and coke (10)). The outgoing gas flows (product gas (6) and exhaust gas (11)) are not mixed together. To separate the two reaction chambers (1,9) gas-proof, so-called syphons (16, 17) or chutes (16) are provided. Only solids can get pass the siphons, not the gases of the reaction chambers.

The heat (12) for the bed material (sand) is generated by the burning of residual coke (10), which slides into the combustion part during the gasification. However, fuels, that are brought in directly (13) or product gas (14) can be used for combustion. The bed material (2), which is now heated in the combustion reactor (9), is separated from the exhaust stream in a gas/solids-separator (18) and fed to the gasification reactor. Air (15) is used as the oxidant in the combustion reactor (9). The word "dual fluid" is derived from the term "dual fluidized bed system".

For the gas mixture (product gas, syngas) generated in the gas generation reactor, a number of already demonstrated and promising possibilities for its use are available. From simple conversion to electricity and heat in gas engines, gas turbines or fuel cells, through the production of synthetic natural gas or hydrogen, to high-quality synthesis products such as Fischer-Tropsch diesel, kerosene and benzine, or methanol. In principle, many other chemical products can also be produced up to various plastics.

)


11
Exhaust
(CO_2, N_2, H_2O)
6
Product gas
(H_2, CO, CO_2, CH_4)
14
Condensate
(H_2O)
14
Heat → 12
9
COMBUSTION
880 - 920 °C
2
Bed material
circulation
GASIFICATION
800 - 850 °C
1
← Coke 10
13
Steam 3
15
Air
Fuel 5
(Coal, Residues, Waste)


Exhaust
11
18
Product gas
6
Cyclone
COMBUSTION REACTOR
transporting Fluidized Bed
9
GASIFICATION REACTOR
bubble-forming Fluidized Bed
1
17
Siphone
Secondary air
15
13, 14
Fuel
Primary air
15
2
Ground air
15
Steam
Chute
16
Steam
Fuel
2
5
Feeding screw
Steam 3

Advanced Dual-Fluidized-Bed-Gasification system: G-Volution

Based on the classical dual fluid concept, a system was developed at the TU Vienna and in Güssing to ensure the use of a wide range of input material, product gas of higher quality, increased overall efficiency and the best possible prerequisites for large plant capacities. An improved fluidized bed concept was developed to achieve all the objectives.

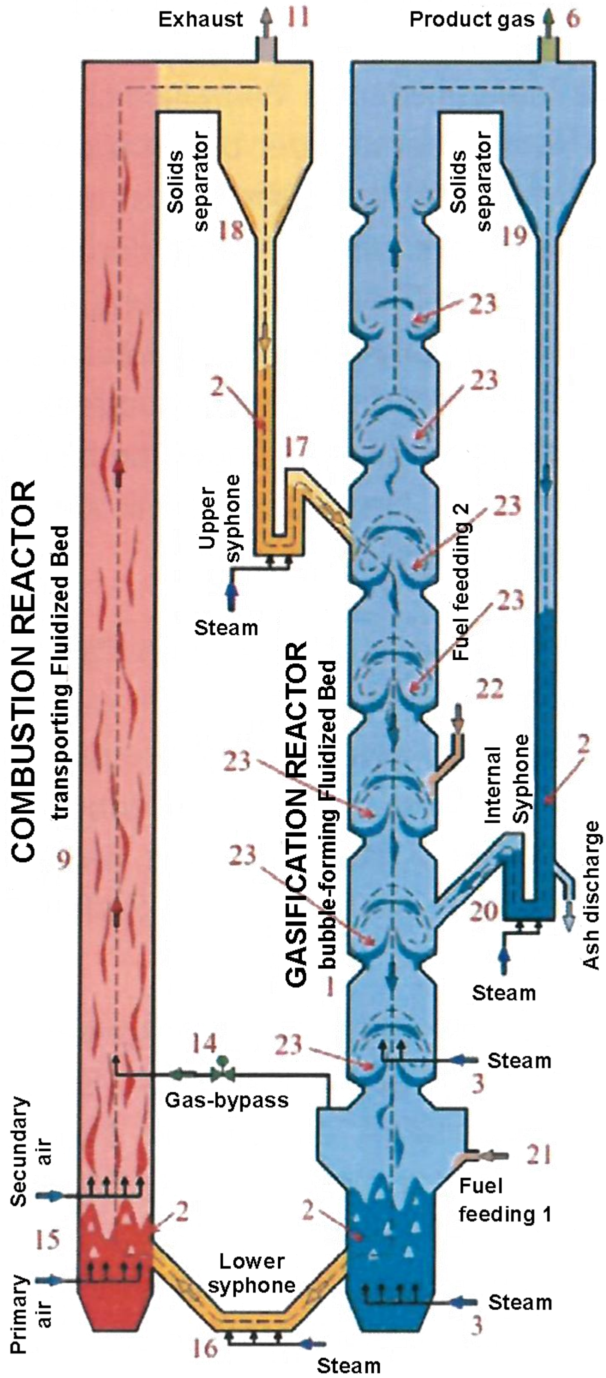
The system is based on the tried and tested - and by now industrially executed repeatedly - technology, and will significantly improve it. The new dual fluid concept now consists of two circulating (fast) fluidized layers, which are connected to one another by a hydraulic connection at the bottom.

In classical DFB-gasifiers, the gasification reactor is designed as a stationary bubble-forming fluidized bed and the combustion reactor is designed as a transporting circulating fluidized bed.

The gasification reactor (1) (see next page) is designed as a countercurrent reactor. Hot bed material particles which are fed into the reactor (1) via the upper siphon (17) are to fall mainly downwards and return to the gasification reactor (1) via the lower siphon (16) to heat up in the combustion part. In contrast to the classical system, a new countercurrent effect and zones with increased turbulence/mixing (23) are present in the new system. Due to the geometric modifications, the desired high residence time and the good gas-solid contact (23) are ensured, which in the classical system was not possible due to the free space above the bubble-forming fluidized bed. The countercurrent effect maximizes the driving thermal and chemical forces across the height of the reactor (1).

In addition, there is also an internal circulation of bed material particles (2) in the gasification reactor itself via a separator (19) and the internal siphon (20). These plant components are necessary because of the high fluidization, since any leaking bed material from the gasification reactor (1) must be kept in the system.

The fuel input can take place in two different points (21, 22). Optimized fuel residence times in the gasification part (1) are thereby possible.



ADVANCED DESIGN

7. OUTLOOK/ RECOMMENDATION

Center for
Future Energy
Technologies
Strem

The establishment of this innovative G-Volution gasification technology for the recycling of raw materials and residuals extends the application area of dual-fluidized-bed-gasification away from high-quality, homogenous but expensive raw materials (for example woodchips). This step makes it possible to open up new business areas with this technology. On the other hand, an additional improvement in efficiency is achieved. Thus a high benefit for regional structures is to be expected.

Through the establishment of a regional energy concept such as the ecoEnergyland, unused raw and residual materials can be used to generate energy. Municipal structures such as communities benefit enormously from this.

As a result, CeFET GmbH will in the future be able to build up a global exploitation strategy.

It is recommended that this strategy is implemented in cooperation with CeFET GmbH and the scientific partners TU Vienna and ECE Engineering, as well as details in a cooperation agreement.

The TU Vienna as a partner guarantees the high-quality elaboration of the necessary foundations in the scientific environment. For the Vienna University of Technology, the further development of the technology is of scientific interest and the basis for further research, which in turn is benefiting the installer, CeFET Strem GmbH.

The TU Vienna-based partner company ECE Engineering is responsible for the development of the new technology concept. The special experience of ECE Engineering in process simulation guarantee success in commercial applications.

The company CeFET GmbH can bring its many years of experience in project development, design and engineering, but above all through the long-term operation of the biomass gasification plant Güssing. A major advantage is the know-how of CeFET GmbH in municipal energy concepts. An outstanding example of this is the Güssing model and the new energy strategy of the ecoEnergyland.

Through the first demonstration of the G-Volution technology and the integration of the plant into the energy strategy of the ecoEnergyland, the company CeFET GmbH gains an enormous advantage in the know-how of other competitors on the international market.

8. TECHNOLOGY-PARTNER

Technical University Vienna (TUW)

Institute of Chemical Engineering

Univ. Prof. Dr. Hermann Hofbauer
Research team leader, multiple years of experience in the area of fluid bed technology, international project experience, former long-term head of the institute, member of IEABioenergy for 15 years, more than 300 publications

DI (FH) Dr. Johannes Schmid
Chemical Engineer with long-term experience in the field of plant construction, expert in the sector: engineering of fluid bed reactor systems

DI Florian Benedikt, DI Josef Fuchs
Chemical Engineer with research emphasis on: fluid bed systems, production of synthetic gas, experimental procedure, evaluation and interpretation.

The institute is one of the leading research institutions in the field of processing different resources via seminal energy technologies. For many years, the institute participates in international research topics within EU- & FFG-projects and is embedded in the International Energy Agency (IEA)

The research sector "Sustainable Energy Technologies" currently employs 25 scientific workers, primary with thermal conversion of various resources. Besides several test plants in laboratory scale, the institute operates an accredited test laboratory for combustion plants. Also the institute operates an innovative, patented dual fluidized bed gasifier with a power of about 100kW. This test plant makes it possible to gasify resources, residues and waste.

Energy &
Chemical
Engineering

Energy & Chemical Engineering GmbH (ECE)

Energy & Chemical Engineering GmbH was founded in 2012 as an engineering company, with the purpose to make latest findings from research activities in the institute for chemical engineering available for commercial applications.

Energy & Chemical Engineering GmbH offers the necessary support in the implementation of new processes and technologies in die areas: future energy technology, dual fluidized bed steam gasification, synthetic Biofuel and fuel upgrading, as well as zero emission technologies.

The service portfolio of Energy & Chemical Engineering GmbH includes project management, process simulation, technology consulting & engineering.

Ing. DI Dr. Stefan Müller is industrial engineer & chemical engineer, experienced senior researcher in the field of energy & environmental engineering, expert in the areas process simulation in energy technologies, product development, production management and techno-economic analysis.

01/2015	Senior Researcher, Energy & Chemical Engineering GmbH
06/2013	Senior Researcher (Post-Doc), Institute for Chemical Engineering
03/2010 – 05/2013	Doctoral Program TU Wien, Chemical Engineering
10/2004 – 10/2009	Diploma Studies TU Wien, Industrial Engineering-Mechanical Engineering
09/1998 – 06/2003	HTL-Graduation TGM Wien, Industrial Engineering-Environmental Economy

9. CONTACT

CeFet GmbH

Heiligenbrunn 67

7522 Heiligenbrunn

+43 (0) 664 43 33 061

office@cefet-strem.com

www.cefet-strem.com