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Biomass Gasification and Microcogeneration Unit – EZOB Technology

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Abstract**—**This paper deals with the issue of biomass and sorted municipal waste gasification and cogeneration using hot-air turbo-set. It brings description of designed pilot plant with electrical output 80 kWe. The generated gas is burned in secondary combustion chamber located beyond the gas generator. Flue gas flows through the heat exchanger where the compressed air is heated and consequently brought to a micro turbine. Except description, this paper brings our basic experiences from operating of pilot plant (operating parameters, contributions, problems during operating, etc.). The principal advantage of the given cycle is the fact that there is no contact between the generated gas and the turbine. So there is no need for costly and complicated gas cleaning which is the main source of operating problems in direct use in combustion engines because the content of impurities in the gas causes operation problems to the units due to clogging and tarring of working surfaces of engines and turbines, which may lead as far as serious damage to the equipment under operation. Another merit is the compact container package making installation of the facility easier or making it relatively more mobile. We imagine, this solution of cogeneration from biomass or waste can be suitable for small industrial or communal applications, for low output cogeneration.

Keywords**—**Biomass, combustion, gasification, microcogeneration.

I. Introduction

It is in the interest of the Czech Republic (CR) to develop a stabilized and functional energy sector ensuring heat and power supplies to both industry and citizens under conditions enabling competitiveness and sustainable development of the Czech economy. Further development of the Czech energy sector needs to be seen not only from technical point of view but also in the context of international, political and geographic conditions. Power engineering in the Czech Republic enjoys a long-standing tradition and ranks among advanced branches of Czech industry employing a fair percentage of the population. Seen from long-term perspective, it is its focus on local energy sources that is advantageous and that boosts energy independence and security of the Czech Republic. In terms of the so-called gas crisis that hit Europe in early 2009, further efforts to preserve or deepen energy independence will become increasingly topical [1], [2].

Mankind uses renewable energy sources in the form of solar radiation, wind energy, tidal energy, potential energy of water, geothermal energy, and biomass. Geographic and climatic conditions determine the use of the individual forms of renewable energy. The greatest energy potential in the CR is that of biomass. Energy use of agriculture and forestry wastes is considered in the CR to be the bulk of renewable energy sources as purpose-planted biomass faces a series of problems both in terms of cost-effectiveness and ethics of foodstuff production. Use of biomass may also include the use of energy potential of municipal waste, the major part of which is biological by nature. The volume of waste produced by the society in the future will grow in spite of systemic measures and hierarchy in waste management. In spite of minimized waste production, substance and material recycling and re-use, energy use of waste shall constitute part of waste management [3].

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II. Microcogeneration

The highest growth potential in the structure of the Czech energy mix based on RES is that of biomass and waste. Unlike the energy of the sun and wind, RES-based energy mix enables stabilized supplies unaffected by climatic conditions. Another undisputed benefit of biomass is its ability to accumulate solar energy. On top of that, biomass cultivation has impact on landscape shaping and promotes agricultural production. To make the use of these fuels really a cost-effective one, it is necessary to process them by cogeneration technologies. In 2007, the share of heat produced from cogeneration amounted to 42 per cent and, in medium and large district heating plants, the figure was as high as 75 per cent [2]. Generating power in the course of cogeneration based on biomass and waste, it often is a problem to use the produced heat. It is therefore advantageous to build small output units, the so-called micro-cogeneration systems, in which the problem is not so prominent. Moreover, these units are built near fuel sources mostly coming from logging, woodworking industry, or farming. This does away with fuel transport costs, which, at greater distances, may, in a very negative way, affect operational cost-effectiveness of these units. The research activities of the Brno University of Technology have focused of late on research of these very units.

III. Gasification

Gasification is a complex thermal and chemical conversion of organic matter in conditions of oxygen deficiency into a low heating value (LHV) gas (4 MJ/ m^3_n to 15 MJ/ m^3_n) consisting of a series of simple reactions. The produced gas is subsequently fired in boilers or combustion engines, i.e. in combustion turbines [4]. The main effort in the process of gasification is to convert as much of the fuel's energy as possible into the highest possible energy content of the gas [5].

The benefit of gasification consists in increasing energy use efficiency of biomass, particularly in relation to power generation. Combustion of the produced gas is a more efficiently controllable process than that of solid biomass combustion, which reduces production of harmful emissions. Using the gas in gas turbines and gas/steam cycle, higher efficiency is achieved in power production. In comparison with combustion, gasification shows lower thermal losses and better energy use of the fuel.

The product of the process of gasification is gas, the main constituents of which are CO, CO_2, H_2, CH_4, higher hydrocarbons, N_2, and impurities. The main focus in the gas is on its quality (heating value, composition) and quantity generated during gasification - plus amount and composition of impurities.

The option to use the gas generated by biomass gasification for subsequent power generation is hampered mainly by the problems related to the cleaning of the product. The content of impurities in the gas causes operation problems to the units due to clogging and tarring of working surfaces of engines and turbines, which may lead as far as serious damage to the equipment under operation. Impurities include dust most of all (airborne solids), alkali compounds, nitrogen compounds, sulphur compounds, compounds of chlorine and fluorine, and tar [6]-[8]. Tar and dust are the main factors limiting the use of fuel gas.

IV. Basic Description of EZOB Technology

Faculty of Mechanical Engineering (FME) at Brno University of Technology (BUT) and ATEKO Hradec Kralove has been collaborating on biomass gasification and produced syngas cleaning since 1999. In 2000, atmospheric fluid generator Biofluid 100 was launched at BUT [9]. Later, gas cleaning systems using catalytic method have been installed, i.e. hot dolomite reactor and track for gas cleaning utilizing metal catalysts. In 2006 cogeneration unit TEDOM MT 22 with combustion engine was added to the stend [10]. Utilization of the produced gas in combustion engine has its disadvantages in the properties of the gas. Main pollutant is definitely tar which in combination with dust creates hard to get rid of deposits but most of all can ruin the engine. In addition to these pollutants compounds of sulphur, chlorine and ammoniac may cause problems as well. It is thus very important to clean gas, which brings about both technical and economic demands. This technology is therefore very hard to progress on the power market. Gas cleaning in gasification has been the biggest issue then and is the most common cause of termination of many promising projects.

Based on this experience, new approach to power and heat cogeneration in gasification process was designed. In cooperation with other entities from academic as well as industrial sphere, a project was launched with head of the research activities being ATEKO Hradec Kralove.

Main target of the project is to design and install conceptually new cogeneration systems. Single shaft turbo set NETZ, supplied by PBS Velka Bites in cooperation with UNIS Brno, is used instead of combustion engine. This turbo set is allowed for easier regulation and control [11].

Basic concept of the technology was designed based on the literary search and research team consulting:

- Gasifying generator (suitable type based on the power desired)
- Combustion chamber for gas combustion linked to flue gas-air heat exchanger
- NETZ single shaft hot-air turbo set

Solid fuel is dosed into gasifying generator. Produced gas is supplied to combustion chamber where it is mixed with combustion air and it burns out. Flue gas-air heat exchanger is installed in the combustion chamber. Air flowing through heat exchanger is first compressed and then supplied to turbine after heating. Air is still of high temperature at the turbine outlet and thus it is used as gasification and combustion air. Residual hot air is supplied into flue gas-air heat exchanger. This allows for 100% regeneration of residual heat beyond the turbine. Dust and tar removal from gas is eliminated since turbine does not get contaminated by polluted air. Gas cleanliness is then no longer the main criterion when opting best gasification technology. Of course, this criterion cannot be eliminated completely as fouling of heat transferring surfaces may occur as well as decrease of their efficiency and overall destruction. Main criterion when opting the most suitable gasification equipment is the desired heat power, simplicity and equipment cost.

Pilot plant is designed only for gasification of pure wood biomass. Disposal of sorted municipal waste and contaminated biomass is considered in the follow-up research. Advantages of two stage thermal disposal of fuel harmful substances should be obvious here [12].

Based on literary research, fluid atmospheric generator was opted for power exceeding 5 MWt [13], [14]. More effective method for lower power is incorporation of gasification chamber by Gemos Company. Gasification chamber is equipped with sideways or horizontal bed which enables fuel motion in the chamber. Primary gasification air is supplied under the bed and it allows for partial fuel oxidation. Oxidation then releases heat necessary for initiation of pyrolitic and gasification reactions. Produced gas leaves chamber through outlet nozzle where it is mixed with combustion air and is further combusted. Unit is highly efficient, with low emissions, universal as to the fuels used (moisture, ash content) and large range of power.

V. Pilot Plant EZOB

On the basis of performed information search the basic conception of the unit (as described in previous chapter) was developed and a pilot unit was designed. Its realization was introduced in the second half of 2010 in the premises of landfill of municipal waste in Lány (Ekologie s.r.o.). The unit is called "the EZOB unit" according to the name of the project.

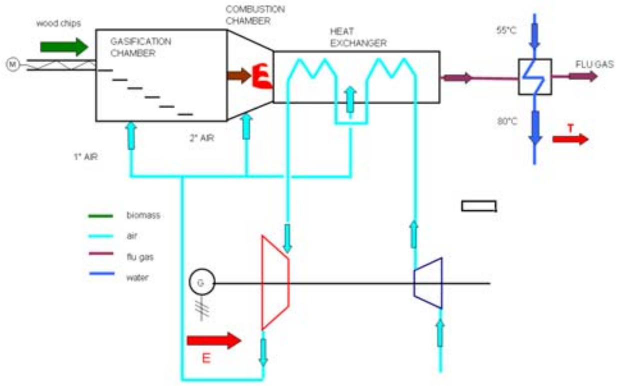

Fig. 1 Scheme of Gemos gasification chamber and EZOB technology

The unit is pictured schematically in Fig. 1. The fuel is drawn pneumatically in the intermediate storage bin and from here it is dosed via conveying screw to the gasifying chamber. Air is led into the gasifying chamber in three levels. Primary air is led under the grate, secondary air above the grid and tertiary air is led in the filler neck between gasifying and combustion chamber and it serves to combust generated gas. All of the led air is taken from the exhaust of the turbine, so it has high temperature – over 400°C. For this reason, external water cooling system was attached to the grid so that it won't overheat. At the output of the gasifying chamber is attached a combustion chamber. Hot flue gas (with temperature up to 1200°C) enters the cyclone for dust elimination. The cyclone was added to the technology additionally to protect the exchanger from fouling. Flue gas further flows through first high-temperature part of the exchanger. In the middle part the flue gas flow and residual expanded air are mixed. The mixture then enters the second section of the exchanger. The rest of the heat from the flue gas may be used to heat up water in economizer. In this particular technology are the outgoing flue gas used in nearby biomass dryer. Clean cold air is taken in by the compressor from the surrounding of the unit and after compression to the pressure of 0.38 MPa it enters the colder section of the exchanger. Then it follows to the high-temperature part where it is warmed to the input temperature of the turbine (750°C). After expansion, the air is divided to flows and introduced in the gasifying chamber, in the combustion chamber and in the exchanger.

In the applied technology a single-shaft high-speed turbine from a Czech supplier TGU 100B with high-frequency generator is used. After adjustment of the schema the input temperature of the air before the turbine was lowered to 750°C, due to this, the nominal power of the turbine was lowered to 80 kW.

On the Fig. 2 is pictured a photograph of the whole cogeneration unit after its introduction in December 2010. It is a modular and robust equipment. To its advantages belongs variability of fuel basis that enables testing of different types of fuels. Primary goals of this unit are to verify the functions of its particular technological parts (high-temperature exchanger, turbine, gasifying/combustion chamber), discover particular operational structures and parameters of these parts and develop control system.

Fig. 2 Pilot plant of EZOB technology [15]

Pilot tests of automatically controlled system were introduced in the end of 2010 and they showed its fundamental operability. The experimental works were up to now focused on attesting basic operational characteristics and optimizing the regulation system and operation of the whole equipment. It was also discovered that the gasifying chamber can be operated without problems also in purely combustion mode that enables its use for combustion of wide range of low-value solid fuels. The fuel is dosed into the chamber continuously from the intermediate storage bin and its amount is controlled by continuously regulated turns of the screw feeder. The advantage of this way of combustion were also very low values of CO and NOx emissions observed when combusting wooden fragments. The temperature of the hot compressed air at the output of the high-temperature exchanger was during the pilot tests limited to 750°C, which naturally influenced the overall lower efficiency of the system (<18 %).

VI. Conclusions

Gained operational experiences still holds up hopes to be competitive and vital after solving several problems that occurred and that have to be eliminated. Although the nominal power of the turbine is after adjustments over 80 kWe, on the terminal connections of the exchanger was reached 70 – 75 kW at most so far. It is necessary for the producer to modify and adjust the whole turbomachine, which will increase its efficiency. Because of operational problems the turbine still did not work at its maximal turns (56 000 turns/min); so far the turbine worked at 54 000 turns/min.

Also the water-cooled grid causes greater heat losses than it was originally thought. That is why water cooling of supporting pipes of the grid will be substituted for air pipes. Also the construction of these supporting pipes will be adjusted, the material will be changed and the pipes will be partly isolated. This way the loss caused by grid cooling should be lowered without lowering its vitality and functionality.

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REFERENCES

[1] Update of State Energy Policy of the Czech Republic, http://www.mpo.cz/kalendar/download/71707/priloha002.pdf, cited 10.11.2009
[2] National program thrifty handling energy and using of their renewable and waste sources during 2006–2009, http://www.mpo.cz/dokument38954.html, cited 10.11.2009
[3] Report of Independent Expert board for appraisal of long-term energy requirement of Czech Republic, version for review from 30.9.2008
[4] Bridgwater, A. V.: The Technical and Economic Feasibility of Biomass Gasification for Power Generation. Energy Research Group, Aston Un., Birmingham, (1995) Fuel Vol.74 -No. 5
[5] Lisý, M.; Baláš, M.: Acta Metallurgica Slovaca, Vol.11, 2005, SI 1, p.14-20, ISSN 1335-1532
[6] Neft, J. P. A. at al: Guideline for Sampling and Analysis of Tar and Particles in Biomass Producer Gases. Energy project ERK6-Ct199-2002 www.tarweb.net
[7] Stevens, D.J.: Hot Gas Conditioning: Recent Progress With Larger-Scale Biomass Gasification Systems, NREL/SR-510-29952, Colorado, USA, (2001)
[8] Hofbauer, H. a kol.: Biomass CHP Plant Güssing – A Success Story, TU Vienna, Biomass Kraftwerk Güssing – Austria. Proceedings of Expert Meeting „Pyrolysis and Gasification and Waste“ edited by A.V. Bridgwater, chapter 54. CPL Press, (2003),ISBN 1-872691-77-3
[9] Kohout, P., Ochrana, L., Baláš, M., Lisý, M.; Pavlů J.: Acta Metallurgica Slovaca, Vol.13, 2007, SI 3, p.166-172 ISSN 1335-1532
[10] Lisý, M. Baláš, M., Moskalík, J.; Kohout, P.; Skála, Z. Biomass Fluid Gasification and Cogeneration. In Energetika a biomasa 2008. 1. Praha: 2008. s. 59-68.
[11] Citováno z: Low-emission Microturbine Source of Electricity (NETZ). http://www.unis.cz/Level2.aspx?page=Netz.aspx, citováno 10.11.2008
[12] Lisý, M. Baláš, M. Skála, Z. Jelínek, M. Gasification of Biomass and Waste. All for Power, 2009, roč. 3, č. 2, s. 62-64. ISSN: 1802- 8535.
[13] Ochrana L., Dvořák P., Nguyen Van Tuyen: Gasification of Biomass and Solid Waste in an Atmospheric Fluid Layer. Energetika č. 4/2002, str. 102 – 106, ISSN 0375-8842
[14] Cited from: Biomass Gasification, U.S. Department of Energy, Energy Efficiency and Renewable Energy, http://www1.eere.energy.gov/biomass/gasification.html
[15] Cited from z: http://www.gemos.estranky.cz/archiv/uploaded/2, date 9.9.2008