Application of Industrial Wood Residues for Combined Heat and Power Production

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Abstract: *The paper discusses combined production of heat and power (CHP) from industrial wood residues. The system will be powered by wood residues generated during manufacturing process of wooden floor panels. Based on power and heat demands of the plant and wood residues potential, the CHP system was selected. Preliminary analysis of biomass conversion in CHP system and environmental impact was performed.*

Keywords**:** *wood residues, cogeneration*

1. INTRODUCTION

According to the EU legislation Poland should reduce carbon dioxide emission by 20%, reduce energy consumption by 20% and increase consumption of energy produced from renewable energy sources (RES). The target for Poland is to account for 15% in 2020 [11]. As it follows from [11] share of renewable energy in gross final energy production in Poland in 2013 was 11,3%. In order to increase energy produced from RES in Poland by 3,7% compared to 2013 it is necessary to introduce a goals for RES research and development initiatives: environmental sustainablity of applied biomass energy systems, development of biomass and biomass residues conversion methods and systems, improvement of efficiency of new and existing biomass conversion systems.Therefore, Polish legislation and EU directives support activities concerning application of renewable energy sources [3], particularly combined heat and power production [6].

Combined production of heat and power (CHP) is one of the methods leading to improvement of energy production cost-effectiveness. Compared do separated production of heat and energy CHP enables better utilisation of the fuel chemical energy and finally to reduce fuel consumption and emission of pollutants. CHP systems are the most effective, when applied for energy production for a local region energy demands because energy transmission costs are relatively low. In view of large biomass potential (energy crops, residues) easy accessible, it is possible to expect that in the nearest future Poland will rapidly develop combined heat and power systems with direct combustion of biomass or co-firing with fossil fuels. Lower emission of pollutants is an additional, important factor deciding about method of biomass conversion.

Biomass can be used in combustion processes in the different forms as: firewood, sawdust wooden chips, crops, industrial and agriculture residues. There are some practical problems concerning conversion of biomass: high bulk volume which results in high transportation costs and requires large storage capacities. Therefore, biomass used as the fuel is usually converted into densified products: briquettes, pellets. Densified biomass is of high quality and can be used in a fully automatic operation, in household appliances and combined heat and power (CHP) plants. Net and gross calorific value ,moisture content and chemical characteristics are the most important characteristics of biomass. Net calorific value of wood of w=60% moisture is of Q_i = 6-8 GJ/t and for dry wood is of Q_i =19 GJ/t [1],[10].The other properties of the size reduced wood residues affecting: combustion, transportation, storage and emission of pollutants are as follows: bulk density, ash content and properties, volatile matter, chemical composition (sulphur, nitrogen, hydrocarbons and chlorine content).

2. APPLICATION OF BIOMASS IN A SMALL HEAT AND POWER GENERATING PLANTS

Biomass can be applied for bioenergy in the following processes: combustion in the stoker fired or fluidised bed boilers, co-firing with fossil fuels, gasification, pyrolysis and esterification. Combustion of biomass is the most popular technique for energy production. Special types of furnaces of the different constructions have been developed for combustion of solid biomass: the stoker fired, moving grate furnaces, conventional grate furnaces, cigar burners and stationary or circulating fluidised bed boilers. The devices used for combustion of solid biofuels range from small domestic stoves (1 -10 kW) to the large boilers used in power and CHP plants (>5 MW). Combustion of biomass in the stoker fired boilers or conventional grate boilers are the most popular applications for biomass combustion. In case of low biomass calorific value, the fluidised bed boilers are recommended. Gasification, pyrolysis and biomass co-firing with the fossil fuels are the other technologies for conversion of biomass. Combined heat and power production from biomass can be realised in the following processes:

- direct combustion of biomass in the stoker boilers or fluidised bed boilers, connected with the low power steam turbine,
- generation of wood distillation gas and then gas combustion in steam boiler assembled with steam turbine coupled with generator,

- generation of wood distillation gas and then gas combustion in Diesel engine (or gas turbine) with heat recovery system, coupled with generator.

The other technologies for combined heat and power generation: the Stirling engine system, the direct biomass combustion system with gas turbine and heat recovery system or biogas engine are still in research.

3. COMBINED HEAT AND POWER GENERATION SYSTEM WITH DIRECT COMBUSTION OF BIOMASS IN A STEAM BOILER

Combined heat and power generation can be realised not only in a large CHP plants but also in a small and medium local CHP plants [2], [4], [9].,[10]

Large biomass resources and industrial residues that can be converted into energy, new energy policy, regarding CHP and economy cause that local authorities in the rural regions and management of the plants are looking for relatively cheap and advanced technologies for combined heat and power generation. The total efficiency of heat and power generating plant is related to the biomass conversion technology, the type of biofuel, conversion efficiency and costs-effectiveness indicators. There are many different plants (lumber mills, furniture plants, the floor panels plants) generating a large amount of wood residues that are easy available often at very low or zero costs.

Due to the large amount of wood residues generated during manufacturing process of the floor panels, the plant management decided to start preparation for implementation of CHP system powered by wood residues. An example of CHP system powered with wood residue for production of high – pressure steam, which is used via turbine to produce heat and power will be presented.

Selected CHP system consists of the boiler with mechanical grate, installation for dust separation equipped with the cyclone of efficiency η=90%, extraction turbine, generator, condenser, and reduction-cooling steam bleeder station.

Wood residues of the following properties: net calorific value Q_i=18 MJ/kg, moisture content W = 6%$_m$, the bulk density ρ = 130 kg /m^3, volatile content V=70 %$_m$, ash content A= 0,5% is to be burned in the boiler of thermal efficiency η_{EK}=0,85. The calculations were performed for the nominal parameters of the turbine.

The scheme of cogeneration system is presented in Fig.1.

The condensation turbine set with steam extraction, of the type P1.5/24,5 manufactured by Power Electric Co. Ltd [12] is characterised with:

- nominal power output – 1500 kW
- the nominal inflow steam parameters:

- absolute pressure - 2,4 MPa, (operating range 2,3 ÷ 2,5 MPa),
- temperature - 370 ^{0}C, (operating 320 ÷ 400℃),

- the nominal parameters of extracted steam:
  - the total pressure - 0,5 MPa, (operating range 0,4 ÷ 0,6 MPa),
  - steam flow - 4,0 t/h (operating operating range 0 ÷ 9 t/h),
- the nominal pressure of steam extracted of the turbine – 8 kPa

Heat produced by CHP plant will be used for heating and preparation of the warm water in the plant. It was assumed that 10% of heating power will be used for preparation of the warm water. Heat requirement depends upon the ambient temperature that is usually given in a form of the systematic diagram. In order to simplify calculations, it was assumed that the heating system operates during heating season and thermal efficiency corresponds the mean temperature of the heating period for climatic zone of the manufacturing plant i.e. t= 4 °C . Mean heating demand of N_T= 3200 kW was determined from the relationships given in [9]. In case of situation that can occur during heating season, extraction steam will not meet the heating plant demand, cogeneration system is equipped with reduction–cooling station, that plays role of peak load device.

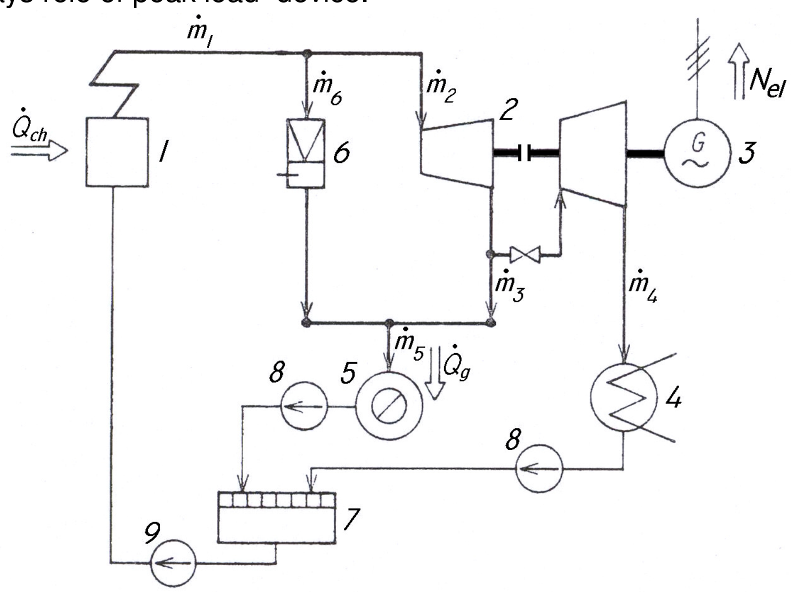

Fig.1:Scheme of thermal cycle:1-the boiler, 2-turbine, 3-electric generator,4 -condenser, 5-heat sink, 6-reduction–cooling station, 7–the condensate tank, 8-the condensate pumps, 9-feed water pump

Fuel energy conversion efficiency is one of the basic indicators determining efficiency of heat and electric energy production. For cogeneration system in question, the total efficiency of combined heat and power production is of 69,5% wat-hour efficiency of 14,5% and thermal efficiency of 54,5%.

During the floor panels manufacturing process a large amount of zero costs wood residues is being produced, therefore conversion of wood residues to heat and power will contribute to better material and energy management in the plant and to reduce an impact on environment by reduction of pollutants emission. Wood residue exchange price is variable and depends upon many factors: availability, transport, storage conditions, etc.

Assuming that the plant would have to purchase m =10 150 t/year biomass of trading price approximately 90 €/t, the annual costs would amount 984 448 €.

Comparing combustion of wood residues with combustion of hard coal of price 150 €/t it can be concluded that the total annual exploitation costs would increase to 1 053 930 €, it means that cost would be about 15% higher compared to conversion of wood residues.

The kind of the fuel burned in CHP system has an effect on the fuel costs and emission of pollutants [7,8]. Environmental charges are dependent upon emission of pollutants [5,8]. Emission rate of the pollutants during wood combustion were determined on the base of the following emission indicators relevant for the boilers of $N \leq 5MW$ with mechanical stokers and dedusting installation of efficiency η=90%. The indicators are as follows [8] for: carbon dioxide W_{CO2} = 1 330 000 g/Mg ; carbon monoxide W_{CO} =11 000 g/Mg, sulphur oxides $W_{SOx/SO2}$ =20 g/Mg, nitride oxides $W_{NOx/NO2}$ = 800g/Mg and total suspended particulates (TSP) W_{TSP} = 125 g/Mg.

Calculated emission rates of the pollutants: E_{co} = 111,6 Mg/year, E_{CO2}=13498,1Mg/year,E_{SOx}=0,2Mg/year,E_{NOX}=8,1Mg/year, E_{TSP} =1,3 Mg/year. In case of combined heat and power system powered with wood residues environmental charges are less than 5 100 €/year. In case of CHP system powered with hard coal environmental charges are less than 38 000 €/ year, that means that is approximately 7 times higher compared to combustion of wooden residues. In case of combustion of wood residues (of zero cost) being produced on the spot or co-firing with fossil fuels the annual exploitation costs will be significantly lower.

4. CONCLUSIONS

Recently, one can observe increasing interest in combined heat and power generation based on biomass as the fuel. Large quantities of wood residues in the floor boards manufacturing plant can be used in combustion (or co-firing with the fossil fuels) process of biomass. Decision regarding implementation of CHP system in the plant should be preceded with careful technical analysis of local biomass potential, different CHP variants, particularly CHP systems of a small power.

Wood residues generated in the floor panel plant were considered as potential biomass fuel that can be burned in the boiler with mechanical grate and dust separation installation equipped with cyclone. CHP system contained extraction turbine, generator, condenser, and reduction-cooling steam bleeder station. As it follows from an analysis of cogeneration system in question, the total efficiency of combined heat and power production is of 69,5% watt-hour efficiency of 14,5% and thermal efficiency of 54,5%.

There are following evident benefits of the use of wood residues for combined heat and power generation in the floor panels plant: zero costs of the biomass, stable biomass quality, constant and surety of biomass supply, zero storage and preparation costs of wood residues produces on spot, reduction of environmental impact by reduction of pollutants emission, reduction of the total plant's exploitation costs. Further analysis of cost effectiveness of CHP profitability powered with wood residues is recommended. Development of biomass residues powered CHP systems is one of the ways to achieve assumed targets for energy produced from RES to account for 15% in 2020. Production of heat and power in biomass residues powered CHP will contribute to reduce emission of greenhouse gases. This will also keep Poland on track to reduce its overall emissions of greehouses gases by 20% under the Kyoto Protocol's second period, which runs from 2013 to 2020.

5. REFERENCES

[1] *Kogeneracja z biomasy, Przewodnik inwestora, Europejskie Centrum Energii Odnawialnej w Instytucie Mechanizacji i Elektryfikacji Rolnictwa, (2002) Gdańsk, 1-43.*

[2] *Laudyn D., Pawlik M., Strzelczyk F.(2000) Elektrownie, Warszawa, , WNT.*

[3] *Ministerstwo Ochrony Środowiska, Strategia rozwoju energetyki odnawialnej w Polsce, 2001.*

[4] *Portacha, J.(2002) Badania energetyczne układów cieplnych elektrowni i elektrociepłowni, Warszawa, Oficyna Wydawnicza Politechniki Warszawskiej,*

[5] *Obwieszczenie Ministra Środowiska z dnia 11 sierpnia 2014 roku w sprawie wysokości stawek opłat za korzystanie ze środowiska na rok 2015 (Dz.U. RP poz. 790).*

[6] *Rozporządzenie Ministra Gospodarki, Pracy i Polityki Społecznej z dnia 30.05.2003r.:W sprawie szczegółowego zakresu obowiązku zakupu energii elektrycznej i ciepła z odnawialnych*

źródeł energii oraz energii elektrycznej wytworzonej w skojarzeniu z wytworzeniem ciepła, 2003.

[7] *Skorek J., Kalina, J.(2005) Gazowe układy kogeneracyjne, Warszawa, WNT,. 7 teraz*

[8] *Wskaźniki emisji zanieczyszczeń ze spalania paliw , kotły o nominalnej mocy do 5 MW. Krajowy Ośrodek Bilansowania i Zarządzania emisjami., 2015, Warszawa, IOŚ-OIB 7 teraz*

[9] *Ziębik A., Szargut J.(1995) Podstawy gospodarki energetycznej. Gliwice,. Wydawnictwo Politechniki Śląskiej,*

[10] *Zwierzchowski R.,(2005) Technologie energetycznego wykorzystania biomasy w aspekcie budowy elektrociepłowni małej lub średniej mocy, Ekologia-Energie Odnawialne-Ciepłownictwo w Polsce i na Świecie, (XII), 11-146.*

[11] *http://ec.europa.eu/eurostat/web/europe*

[12] *http://www.powerelectric.com.pl*