The aspects of combustion and co-combustion biomass

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Abstract

Growing world population, increasing energy use, emission carbon dioxide (CO_2) and climate changing are the reasons for searching alternative sources of power. Recently we are vested with numerously alternative sources of energy but biomass is considered as a most powerfull and easiest to access.
The bigest problems with burning raw biomass are: first the calorificvalue of biomass is average half compare to coal, second problem is a big contents of moisture for example in coal 10% of weight is water but biomass include even 35% of water.
For these reasons in huge power plants complete displacing stone fossil and lignite by biomass is not workable. Coal-fired furnaces which are used in power plants are not adapted to burn raw biomass, hence in powerplants co-combustion biomass and coal for power production is most efficiency because this process does not require additional energy. Precious advantage of co-combutstion is that technical range of change the fuel feed system is less. Preparing the fuel mixture based on blending biomass with coal on storehaus or in coal mills. The most efficient dose biomass to coal is about 10% weight.
Otherwise in small domestic heat furnace burning a raw biomass with high efficience is possible for example wood pellets furnaces are popularly used in onefamily houses. These kind of combustion occure, because the furnaces are specific adapted. The calorific value of wood pellets is near 19 MJ/kg which is compare to coal. Wood pellets are assembled for example numerous from energy willow or other kinds of waste wood and preparing the pellets form reqires energy addition.

In this paper I demonstrate two ways of burning biomass: combustion and co-combustion. I try to show that selecting the way of burning is depended by size of furnace.

I. INTRODUCTION

Today human life is becoming very mobility and more comfortable, because it is representative aspect of modern civilisation. In different point of view, more comfortable life influences on level of energy consumption. We are aware that increase energy using is the main reason of growing the greenhouse effect and warming the atmosphere which symptom as the unpredictable changes in climate. In this issue only one effect emission of carbon dioxide and other greenhouse gases by the combustion of fossil is predicted. Currently 90% energy which population use becomse from fossil supply. It dimishes coal and oil amount. From these reasons we require alternatives to fossil sources of energy, which can be renewable.
In table I are presented the sources of renewable, which were used in Germany in 2007. It shows that biomass is the bigest share of renewable energy and it amounts 48,6%, where 37.9% was used as a source for heating and 10.7% for producing the electricity.

TABLE I
SHARE OF RENEWABLE ENERGY CONSUMPTION IN GERMANY 2007

Nr.	Groups of renewable energy sources	Share %
1.	Biomass (heating)	37.9
2.	Biomass (electricity)	10.7
3.	Biofuels	20.0
4.	Hydropower	9.3
5.	Wind energy	17.8
6.	Solarthermal energy	1.7
7.	Geothermal energy	1.0
8.	Photovoltaic energy	1.7

Potencial of using biomass as a source of energy is huge compare to the other kind of renewable fuels. The second improtant subject of debate is race of energy, which can be produced from biomass. The most share is heating and electricity and these are most usefull in today's life. In oder to produce heating or electricity from biomass it is necaessary to use the burning process, which converts chemical capacity of biomass to thermally kind of energy. Biomass could be burn as a main fuel which is considered as a combustion or the alternative is co-combustion where biomass is only added as a share to fossil fuel for example in 10% amount.

II. BIOMASS

Biomass is regarded as material of organic origin. In this group count not only plants but also animals excrements, plant components, paper, cleulose, organic waste and vegetable oil.
There is a lot of method to use these various organic materials as a source of energy. In some technical solutions raw biomass can be turn into liquid or gaseous form before converting to other kind of energy. Raw organic materials can be burn in furnace to prepare heat. The second way is use the fermantation process by anaerobic digester to yield biogas, which can be latter burn. Third variant is using thermochemical gasification to convert biomass into synthetic gas. But this paper focused only on aspects of combustion and co-combustion.

A. Sources of biomass

Important source of biomass is the forestry. For example in Germany 80% of timber, which is annual growth become felled and used. Felling and preparing timber consequence in a big amount of waste timber, which left in the forest. Timber waste is no useful as a construction timber or for celulose production, so it is adequante oppotunity to use it as a biomass for energy production.

Second source of biomass is agriculture. Currently for production the same amount of food farmers need less and less land. From this reason cultivation of energy crops can increase and in the future it could be great energy potential. Today the residues materials like a straw are used prevalent and are converted for heat in specific furnance. Also the fast growing groups of trees and grass are tested to increase these efficiency, because in the future these could be the main sources of biomas. Production energy crops and plants by farmers becoming greater because using new method of cutivation being economically.

Third source of biomas is food industry. For example in process of preparing fruits or vegetables produce a lot of green waste, wchich can be used as a biomass. But the bigest disadvantage of using this kind of biomass is large amount of moisture. Before using green waste as a fuel for furnace, it should be dry or mixing with other king of organic materials, which contain less amount of water.

B. Porcess of growing biomass and carbon dioxide neutral.

The basic of plants growing reason is the photosynthesis occurence. In this reaction carbon dioxide with water are transfrometed into oxygen and carbohydrates. The oxygen is released into environment. The main force of photosynthesis is solar energy. The main conclusion could be that for the fact of being the sun is possible to use biomass. The efficiency of producing biomad is depended on naturaly differences as the soil and climate opportunieties. It is calculated [1] that every year in the World is growing 400 milion tones of biomass. This amount of material contains $3000 \cdot 10^{18}$ J of energy. For example human use every year about $400 \cdot 10^{18}$J, where only $45 \cdot 10^{18}$ J is producing from biomass. These numbers shows that in the future biomass could be use more intensively as a source of energy.

The carbon dioxide aspect in growing plants is important role, because it is fixed by plants, which are called as a carbon dioxide sink. This phenomenon influences on earth's climate balance. Also raw fossil materials are carbon dioxide sink, but fixing existed milions years before. Now the raw fossil contain large amount of carbon and these are easy used as a fuels in combustion process. Comnining carbon with oxygen produces carbon dioxide which is main reason of greenhouse effect.

Nature biomass growing and using as a source of energy make that the concentration of carbon dioxide is constant and the cycle is closed, but when the fossil are used carbon dioxide concentration rise.

TABLE II
AMOUNTS OF CO_2 EMISSIONS DEPENDING ON THE ENERRY SOURCE

Energy source	CO_2 emission (kg/MWh)	Annual CO_2 emission (kg/a)	CO_2 savings compared with fuel oil (kg/a)
Fuel oil	342	5472	0
Natural gas	228	3648	1824=33%
Wood pellets	68	1088	4384=80%
Firewood	8.8	141	5331=97%

III CO-COMBUSTION BIOMASS

In huge powerplants, where using power coal as a basic fuel is common, because from the energy poiny of view, coal characterises two features: effortlessness to purchase and the calorific value is very high level such as 22 $MJ \cdot kg^{-1}$. Compare biomass to power coal the calorific value is half lower. Second important issue is fuel feed system, which was designed and adapted only for fossil coal. Replacing whole of fuel feed system requires a huge amount of capital expenditure and it is unfounded from economical point of view. The third issue is problem with adapting the steam boilers to new fuel such as biomass. Majority of steam boilers, which are using in huge power plants are adjusted to coal dust. Coal dust is fed to steam boiler as a powder after milling process. Granularity of the fossil dust is depended on standards of quality and for example in polish power plant industry are using coal dust where R_{90} value is 30% and R_{200} is about 3%. It means that for biomass obtaining similar value of granularity is not possible. Another problem with biomass is level of moisture, which is double compare to coal. Bigger biomass particles and high value of moisture need longer time of burning in boiler combustion chamber compare to coal dust. Different is also the bulk density of biomass because the value is only 0.25-0.30 $kg \cdot m^3$, wchich is very low compare to coal powder. Another physical properties, temperatue of burning and amount of ash reason that the furnaces should be fixed apart to different kind of biomass. During designing process of co-combustion biomass with coal is important to consider the share of added biomass, because it influences directly on parameters of working the steam boiler such as: steam temerature, exhaust temperature, amount and chemical composition of ash or burning waste and slaging the heating surface, which operating conditions is important from heating change point of view. Basing on the results of research [1] co-combustion the biomass, showed that the influence share of biomass does not increase emission of nitrogen oxides (NO_x) , sulphur oxides (SO_x) and carbon oxides. For a variety of biomass only adding a rape straw increases contents of sulphur oxides (SO_x) in exhaust gases. Besides adding the biomass to major fuels does not influence on slag and ash properties. Experiments [1] allow for proof that only addind straw changes rheology properties of slag, because especially the corn straw contains high quantity of chlorine. Content chlorine in fuels increas the flow ability of slag which is negativ phenomenon, bacause when the opportunity of slag to flow is higher, it consecuences of becoming overgrown the heater surface by slag. When the layer of slag increase on the boiler's surface, it will decrease the heat exchange between exthaus gas and working medium, such as water or steam, because slag cahracterises high heat resistance. For example when the heat is exchanging in the way of conduction the efficiency is defined by Furrier's law, which is describes by equation (1):

$$Q = \frac{\lambda}{l} \cdot A \cdot \Delta T \qquad [1]$$

where Q is the heat flux, W; λ the thermal conductivity, $W \cdot (m^2K)^{-1}$; l the thickness of layer heat exchange, m; A the heat exchange surphase, m^2; ΔT the temperature difference, K.

Basic on the equation (1) is able to conclude that for the material such as slag, the thermal conductivity is less, so when layer of slag become higher, the heat flux decrease.

In huge power plants when the mainly fuel is coal, the overall efficency of thermal power plant cycle is about 27-36% and the energy consumption is about 9-13.7 MJ/kWh. When the clear biomass is burning in the same steam bioler the efficiency of thermal cycle becomes lower than before and is about 18-27% and the energy consumption is higher compare to clear fossil and is about 13.7- 21.1 MJ/kWh [2]. The differtent between coal and biomass efficiency of thermal cycle cause of moisture value of biomass [1].Tests in power plants proofed that co-combustion becomes most efiiciency way to use biomass by steam boiler. When the share of added biomass is about 7-10% the boiler efficiency is lower only 1% compare to clear coal dust.

In thermal-electric power station of Gorzów the influence of added biomass to steam boiler type OP-140 was researched by [1]. The purposes of investigation was to find the most efficience share value for energetic willow, which is added as a biomass to coal dust. In thermal-electric power plant 30% of energy production is converting into electra energy form and about 42% converting into thermal form (as hot water and technology steam).

As a alternative fuel added to coal is energetic willow, because the opportunity of access huge amount of this kind of biomass is highest compare to other, because the consumption biomass in power plant achives high value. The local market is possible to deliver enough amount of willow's timber, this fact becomes willow timber the most attractive as a biomass. Calorific value of energetic willow is comparable to other kind of timber and it is about 10 MJ/kg. Moisture contents in raw willow's timber determine about 45%. Based on assumption, the maximum of moisture contecnts should be such as 30%, from this reason before adding, the willow has to by dryed. The chemical compopsition of willow is similar to other timber is presented in table III [1] compare to coal fuel.

Costs of production the raw willow's timber is about 10 $/t, after milling and drying the total costs bacomes about 20 $/t, which is still profitable.

TABLE III
CHEMICAL AND THERMAL PROPERTIES OF COAL AND BIOMASS

	Coal dust	Biomass
C	57.39 [%]	35 [%]
H	3.726 [%]	7 [%]
O	6.012 [%]	23.03 [%]
N	0.893 [%]	1.4 [%]
S	0.63 [%]	0.07 [%]
Volatile matter	26 [%]	80 [%]
Calofific value	22,4 [MJ/kg]	13.5 [MJ/kg]

Analysis co-combustion willow's timber in steam boiler OP-140 showed that process of burning two types of fuel together is more beneficial than burning coal and timber apart, because coal stabilizes burning process, which allows to use biomass with variable contents of moisture. Whereas added biomass dimishes emission powders, ashes and gases such as NO_x and SO_x. Timber contains less incombustible parts than coal. The value is about 0.5-3% for timber and almost 12% for coal. When fuel characterises high value of incombustible parts, it causes that exhaust gas contests fixed higher value of powder and ashes. Timber includes only 0.3% of nitrogen, which is two times less compare to coal. Contents of sulphur is near 0.05% where for coal it becomes 0.8%.

In thermal electric power station biomas is added to coal before milling process. The tests [1], which was realized by coal pulverizer type fan MWk-16, showed that the degree of share added biomas till 30% does not influence in negative way on working of coal pulverizer. Blending biomass with coal on coal store before milling decrease the operating costs, because this solution does not need install special kind of feed system for adding the biomass. During milling coals ad biomass together taked place not only milling and mixing but also drying the biomass, which is profitable.

During burning process mixed coal with biomass in steam boiler type OP-140 the temperature of exhaust charactrizes almost constant value. The analysis of working the combustion chamber showed that adding biomass to coal in value about 10 % does not influence in negative way on work parameters. Process of co-combustion biomass with coal share in range about 7-12% does not change the parameters of steam boiler and the work efficiency is comaparable when the same boiler works based only on coal fuel.

IV CONBUSTION BIOMASS IN SMAL-SCALE BOILERS

Biomass contains less energy in proportion to their weight compare to raw fossil materials, from this reason it is better to use them where they occure. Heat and electric energy can be produced in small or medium plants which are decentralized. These kind of boilers are used in blocks, flats, schools, swimming pools or lockal heating networks. The small heat plants which are supplied by biomass can attain power of beteen 500 kW to 30 MW. They mostly use woodchips from thinningor wood pellets from industry.These kind of materials are cheep and ensure as a alternative fuel, because many municipalities use woodchips from their own woodland.

For example in rural areas there are more and more used smal-scale household biomass boilers supplied with biomass. These kind of burners are generaly instaled for log and pellets. They get more benefits, because for example pellet boilers run fully automaticly.

Log boilers can attain heat capacity from five to several hundred kilowatts. The disadvantage of log burners is that the wood has to be put into furnace still by hand. The combustion is very efficient and cleaner, because a lot of them fixed lambda probe, which controll there is enough oxygen for completly burning process and less air polution such as carbon monoxide.

Pellets are in pressed form object 6 or 8 mm thick and about 10 to 30 mm long. Pellets calorific value is about 18 MJ/kg (2 kg of pellets are eqivalent of 1 litre of oil fuel). They are also very easy to transport and take up less space to storage. Pellet boiler are equiped with screw conveyor anf fan, which can adjust the lewel of required heat.

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