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Design of Equipment and Methodology for Secondary Tar Removal after Gasification in Low Heat Output Generators

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Abstract : This paper described tar formation and its removal methods. There are analysed at the base on measurements realized on the department of heat engineering and gas industry by gasifying of wood pellet and wood chips for a gasification reactor. It is proposed a dry method to tar removing with the cascade configuration filtration cartridges.

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1 Introduction

The most important technical measures for achieving air pollution reduction include reducing emissions from individual sources to the surrounding atmosphere.

During the gasification of the fuel after its drying (below 150°C), pyrolysis occurs to remove volatile combustible material. Biomass thermal pyrolysis products are process gas, tars and pyrolysis coke. The pyrolysis gas partially burns and the released heat is consumed to run the endothermic reduction reactions to form CO, CO_2, CH_4 and H_2, which are the main component of the generated gas in gasification with air [1].

The resulting generator gas can be combusted in gas turbines or in cogeneration piston combustion engines.

2 Wood biomass gasification

2.1 Fuel used during gasification

The basis for stoichiometric calculation is elementary fuel composition (Table 1). The fuel components affect the thermal efficiency and heat loss of the fuel conversion equipment.

Table 1 Average elemental composition of incoming wood biomass used for experimental gasification reactor (% by weight)

Composition %	Type of fuel	
	Chips	Pellets
Ash	0,67	0,4
C	46	50,3
H	5,56	5,7
O	39,5	33,05
N	0,27	0,22
S	0	0,03
Moisture	8	10
Calorific value, MJ/kg	16,84	17,5

In the thermochemical conversion of biomass, the input moisture of the fuel most judged is the value of which varies depending on the source of fuel, the season and the storage conditions. For some types of equipment, it is necessary to pre-dry the fuel, which increases input costs.

2.2 *The experimental updraft gasifier*

The measurements were performed on an experimental updraft gasification reactor with an expected 15 kW heat output. The composition and fuel consumption, the amount and enrichment of the gasification air (atmospheric air - pure oxygen mixture), the backfill level of the fuel layer in the reactor and their effect on the amount and quality of the generator gas produced were monitored. After stabilization of the reactor temperature, samples of the produced gas were taken for analysis 20 cm from the reactor outlet.

Taken samples were analysed by absorption analysis. The CO_2, O_2, CO content was determined, followed by combustion and re-absorption of the CO_2 and CH_4 concentrations, and the H_2 concentration was determined. The residual gas is considered pure N_2. In the analysis, it was considered that all hydrocarbons in the gas phase were in the form of CH_4.

The biomass is fed to the top of the updraft gasification reactor. Air is fed under the grate. The flue gas (1000°C) passes upwards, supplying heat to the endothermic gasification reactions, cooling to 200°C - 300°C at the top of the reactor.

Typical wood gas composition is 40 – 50 % N_2, 15 – 20 % H_2, 10 – 15 % CO, 10 – 15 % CO_2 and 3 – 5 % CH_4, its calorific value is 4 - 6 MJ/m^3, if pure oxygen is used with water vapour, increases to 10 -18 MJ/m^3. Applying the process of gasification on the solid biomass, mainly the waste wood in form of wood chips, achieved is the transformation of the solid combustible biomass into the gaseous fuel - wood gas. This can than be utilised in the system of the combined electricity and heat production (Figure 1). The gasifying process takes place in the counterflow type gasifier, operating on the solid bed [2].

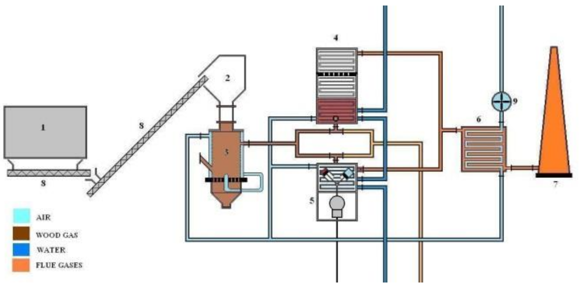


Figure 1 Scheme of low power cogeneration equipment for solid biomass [2]
1- wood-chip storage, 2- hopper, 3- updraft gasifier, 4-hot-water boiler, 5-cogeneration unit, 6-heat exchanger, 7- chimney, 8- conveyor, 9-exhaust fan

The wooden material is supplied into the gasifier, where the thermochemical transformation takes place. The needed heat for the gasification process is supplied by the partial wood combustion. The product of the process operating on air is the wood gas. The main combustible component is hydrogen, carbon monoxide, methane, hydrocarbons and also non-combustible products. This gas is afterwards burned in the CHP unit - thermal engine with the resulting heat and electricity generation. With regard to the properties of the polluted wood gas, it is necessary to apply specially modified thermal engine. Expected electricity output of the CHP unit is 35 kWe.

The sensitive heat of waste gas from the thermal engine will be in the economiser recuperated into the heating water. To balance the non-uniformity in heat consumption, proposed is the hot water boiler operating on the wood gas from the solid biomass gasification [2].

3 Formation of tar and removing them

When air is used as a gasifying medium, the resulting high N_2 content doubles the volume of wood gas. In order to achieve a higher calorific value of the gas, the moisture content of the input fuel should be less than 15 – 20 %, so that it is usually required to pre-dry it where waste heat from the engine can be used. The energy content of the gas produced is up to 75 % of the biomass energy content [3].

The main contaminants of raw wood gas are the particulate matter (soot, dust) and tar. Wood gas may also contain other impurities, namely ammonia (which is converted to NO_x during combustion engine), HCl, H_2S, alkalis and acids [4].

Primary tar is produced at relatively low temperatures (200-500°C). It is a mixture of condensed hydrocarbons. The average value of tar produced by the steam utilization is 30 - 80 g.m^{-3}, steam/air mixture 4 - 30 g.m^{-3} and air 2 - 20 g.m^{-3}. Tar removal is very important in cases where the produced gas is cooled or compressed before use and in mechanical systems such as internal combustion engines or gas turbines

The average tar concentration of the experimental measurements in the raw wood gas is 50 g.m^{-3}. Therefore, it is necessary to implement primary or secondary methods to reduce the tar content of wood gas.

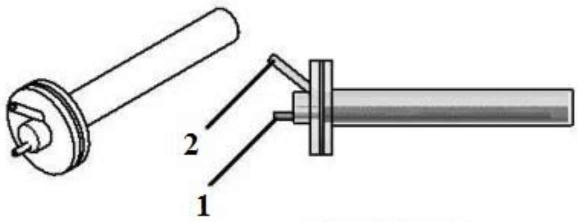
The most commonly used primary methods are the optimum gasification operating conditions, the addition of additives/catalyst (dolomite, K_2CO_3, Na_2CO_3, Al_2O_3) to the gasifier bed and the gasification plant itself [5].

Secondary methods are mechanical separation and thermal or catalytic cracking. The separate tar destruction and reforming reactor is used. Wet and hot gas is cleaned.

With OLGA technology, aerosols, heavy and light tars with a specially developed cleaning agent are delivered to the absorption column. Dust - free gas is required, a hot gas filter is used.

3.1 The draft of filter device

A separate experimental device (Figure 2) was created to monitoring tar formation. The weighed amount of wood chips was placed in a gasification tube (Figure 2), sealed with a flange, and inserted into an electrical resistance oven (Figure 3). There are two inlets on the front of the gasifier, the air needed to the fuel gasification through the bottom, and the gas produced through the filter on the torch, where it is combusted.



1 - air input
2 - wood gas output

Figure 2 The experimental gasifying device

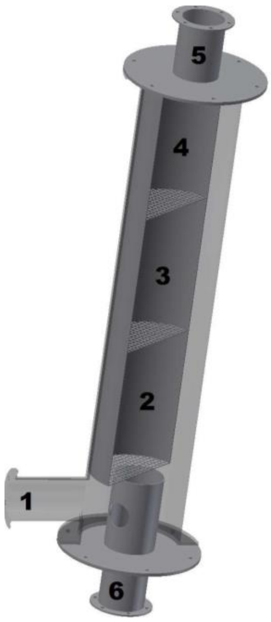
Figure 3 The electrical resistance oven

The furnace temperature is controlled by a potentiometer with a range of 100°C by 1200°C. Dust particles and condensed tars (already at 300°C) are trapped on the filter. With a charge weight of 17 – 20 g and airflow of 1dm^3.min^{-1}, the gas flow is so slow that it is not necessary to cool the gas. The measurement results are shown in Table 2.

Table 2 Measurement results for tar formation

measurement	1	2	3	4
fuel	wood chips			
moisture (w. %)	25		0	
gasifying (min)	15		9,2	10
air excess	0,25			
charge (g)	15	15	9,5	9,8
gasifying temperature (°C)	770	870	770	870
air amount (dm^3)	15	15	9,2	10
weight of captured components (g)	3,5	2,8	1,8	1,9

Based on the obtained results, a filtering device was designed and constructed (Figure 4), which supplemented the basic experimental scheme (Figure 5) [6,7].



1 - gas input
5 - gas output
2, 3, 4 - filter cartridges
6 - condensate output

Figure 4 The filter device design [6]

The wood gas enters the filter at the bottom and flows upward through the filter material. The outgoing gas passes through the pipe to the combustor torch.

After removing the lower part of the filter, the filter material, which is stored in the containers - is inserted into the filter cartridge. The filter height is 110 cm and the tube diameter is 180 mm.

The filter cartridges are three with a diameter of 170 mm and a height of 30 cm. It is possible to give different kinds of filter material to each cartridge, or use their mixtures. Glass beads with a diameter of 2 cm, wood chips and wood pellets were used as filter material [6].

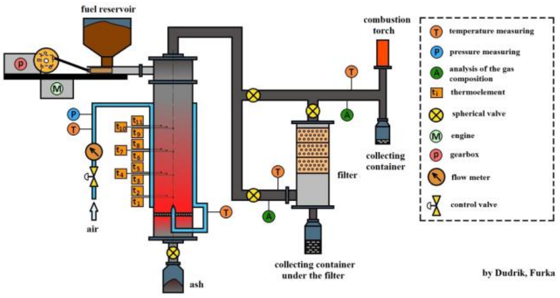


Figure 5 Scheme of the filter device with measuring points [6]

For correctly operation of the device, the following procedure has been proposed for practical measurements:

1. Visual inspection of the gasification generator, filtering equipment and the conveyor path - inspection of the measuring points, check of the functionality of the ball valves and checking the tightness of the filtering device.
2. Cleaning - begins with the dismantling of the bottom of the gasification reactor, followed by cleaning of the grate from unburned parts of the fuel from the previous experiment, control, resp. removing stickers formed around the periphery of the gasifier generator and checking the nozzle functionality.
3. Ignition - a small amount of fuel is supplied to the grate, which is ignited by the gas burner. By monitoring the temperature, the supply of fuel and gasification air slowly increases to the required amount.
4. Temperature stabilization in the reactor. The total rise and stabilization time of the gasification process is 1.5 to 2.5 hours. A steady state is taken when the temperature difference does not change by more than 20°C within 10 minutes.
5. After steady-state temperatures have been reached in the reactor, samples of the generated gas are taken. The measurement ends by weighing the last measured weight of the filter cartridge, disconnecting the gasification air and terminating the fuel addition. Fuel pyrolysis and partial cooling of the whole plant are partly taking place.

The efficiency of the filtering device is determined by the ability to separate the mixture of tar, dust particles and water vapour from the product gas.

4 Conclusions

It is important to consider stick formation of condensed hydrocarbons for all types of gasification equipment. The formation of tar and removing them reduces the efficiency of thermal equipment. Cascading arrangement of filter cartridges it allows flexible exchange during the process. The adjustment of the filter material depends on the type of used fuel and the gasification conditions.

5 The reference list

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