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TSP IN THE GAS AND THEIR REMOVING IN BIOMASS GASIFICATION PROCESS WITH COGENERATION UNIT

TZL V PLYNU A JEJICH ODSTRAŇOVÁNÍ V PROCESU ZPLYŇOVÁNÍ BIOMASY S KOGENERACÍ

Abstract

This paper describes methods of solid particles (TSP - Total Solid Particles) removing from the gas produced during biomass gasification process in downdraft Imbert reactor. By series of measurements confirmed that it is technically possible to achieve the elimination of solid particles from the produced gas at a level suitable for use in gas cogeneration unit with an internal combustion engine.

Abstrakt

Článek popisuje způsoby odstraňování tuhých znečišťujících látek (TZL) z energoplynu vyrobeného při zplyňování biomasy v sesuvném souproudém reaktoru typu Imbert. Sérií provedených měření bylo potvrzeno, že je technicky možné dosáhnout odstranění TZL z vyrobeného plynu na úroveň vhodnou pro využití plynu v kogenerační jednotce se spalovacím motorem.

1 INTRODUCTION

Interest in biomass is currently booming. Evolving technologies for transforming biomass energy allow its wider use, and offer an alternative to the use of conventional fossil fuels. Support of the utilization renewable energy resources, such as energy from the sun, wind, water and biomass, is one of the priorities of the Czech Republic and European Union energetic conception. This funding has recently been in the forefront once again gets the gasification of biomass. [1]

Advantages of biomass gasification [2]:

- Use of cogeneration
- Conversion of solid fuel with a large specific volume into gaseous fuel with ability to combustion in heat engines
- Co-gasification
- Technological advantages.

The objective of many organizations dealing with these issues is a commercial technology, fully operational, most unattended with low investment and operating costs.

2 GASIFICATION AND USE OF GAS IN COGENERATION UNIT

2.1 Gasification

Gasification is a thermo chemical process, in which there is a gradual oxidation of hydrocarbons and water vapor from the fuel and the subsequent immediate reduction in combustible gases,

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distilling products and mineral residue. The process takes place in the generator with access to controlled volume of gasification agent (usually air or water vapor) and the necessary reaction heat [2].

Produced gas contains incombustible and combustible components. CO_2, N_2, H_2O are incombustible components, H_2, CO, CH_4, C_2H_6 and other hydrocarbons are combustible components.

2.2 Impurities in the produced gas

The main obstacle preventing the extension of gasification technologies is to meet the requirements for quality and purity of the produced gas. Impurities in the gas (TSP, tar, nitrogenous compounds, alkaline compounds, sulphur, chlorine) cause operational problems for the individual apparatus gasification technologies, clogging of pipes and fittings, and tar covering of work surfaces of engines and turbines, which can lead to serious disruption of operated facility [3], [4].

Solid particles contained in the gas from the gasification reactor are defined as solid phase comprising unreacted fuel particles (semicoke), inorganic substances (ash), or fluidized bed material [2].

The main source of TSP is ash material. Wood contains 1-2% of inorganic material, straw of various cereals about 10% [5]. Inorganic base of fuel remains in the bed and is discharged through the grid, or it is carry off from the reactor during biomass gasification. The concentration of solid particles in the gas depends on the generator design (type of reactor and gas speed in generator) and the ash content in fuel. Other major sources of solid pollutants are contaminants in the fuel (inert material incorporated into the fuel during its processing - such as soil, etc.) and incompletely reacted fuel – unreacted rest of carbon. Fuel particles during the gasification process in the reactor reduce its volume and subsequently there are drift by gas. Soot is also part of solid particles. [2]

2.3 The quality requirements for gas

Gas quality requirements vary by type of device using the produced gas and also by the specific manufacturer of the device. Finishing of the gas depends on its use and various types of equipments needs the specific gas quality and purity, viz. Tab. 1. [2]

Tab. 1 List of allowable gas pollution for various devices

Device		The maximum allowable concentration in the gas								
		Tar	TSP	Particle size	HCl	Sulphur compounds	NH_3	Na	K	Alkaline metals
Gas boiler		no problem								
Internal combustion engine		< 100 $mg.m^{-3}$	< 50 $mg.m^{-3}$	< 10 μm	-	-	-	-	-	-
		< 50 $mg.m^{-3}$	< 50 $mg.m^{-3}$	-	-	-	-	-	-	-
Gas turbine		< 5 $mg.m^{-3}$	< 1 ppm	-	< 0,5 ppm	< 1 ppm	-	< 1 ppm	< 1 ppm	< 1 ppm
		0 ppm	< 30 $mg.m^{-3}$	< 5 μm	-	-	-	-	-	< 0,24 $mg.m^{-3}$
		0 ppm	< 10 ppm	< 10μm	-	-	-	-	-	< 0,2 ppm
Fuel cell	PEMFC	0 ppm	low	-	-	-	-	-	-	-
	PAFC	0 ppm	low	-	-	-	-	-	-	-
	MCFC	0 ppm	< 100 ppm	-	-	-	-	-	-	< 10 ppm
	MCFC	-	-	< 1 μm	-	-	-	-	-	-
	SOFC	-	-	-	< 1 ppm	< 1 ppm	< 5000 ppm	-	-	-
	SOFC	no problem	-	< 1 μm	-	-	-	-	-	-

Cogeneration units with internal combustion piston engines are the most common device used to produce electricity from gas produced by gasification of biomass [6], [7]. The main advantage of this system is its simplicity, high efficiency and the possibility of using commercially produced both petrol and diesel engines. The gas must be free of dust and tar before its entering to the combustion engine. Solid particles cause accelerated wear of moving engine parts. Tar is prone to condensation on cold parts of the engine and forming of stable aerosols in cold gas. Requirements of internal combustion engines manufacturers are inconsistent and often incomplete because they manufacturers they have very few practical or negative experiences with the engines operated on the wood gas. [2]

Selected requirements from manufacturers of internal combustion engines are presented in Tab. 2. Values are taken from company documents. [2]

Tab. 2 List of allowable gas pollution for various internal combustion engines

Gas pollutant	Unit	Manufacturer of internal combustion engines		
		Jenbacher	**MAN**	**Caterpillar**
Tar	$mg.m^{-3}_N$	not stated	not stated	not stated
TSP	$mg.m^{-3}_N$	< 6	< 1,4	< 0,8
Particle size	μm	< 5	< 5	< 1
Sulphur compounds	mg (H_2S).m^{-3}_N	< 97	< 2000	< 285
Si	mg (Si).m^{-3}_N	0,03	< 0,7	< 0,75
Oil content (no condensate)	$mg.m^{-3}_N$	< 0,7	< 56	< 6
Cl	mg (HCl).m^{-3}_N	< 14	< 14	< 95
NH_3	mg (NH_3).m^{-3}_N	< 7	< 50 ppm	< 14
Condensate	-	0	0	0

Note: Values are converted to the normal volume of gas with a calorific value 5 $MJ.m^{-3}_N$.
For MAN engines were used documents of Dagger company.
For Caterpillar engines were used documents of TEDOM company - for unusual biogas facilities.

2.4 Removing of TSP from the gas

Technology of removal of solid particles from the gas, we can distinguish [5]:

- Inertial separators (for example cyclones),
- Filters,
- Electrostatic precipitators,
- Scrubbers.

Figure 1 shows the fractional separation efficiency of various devices for removing solid particles from the gas [8].

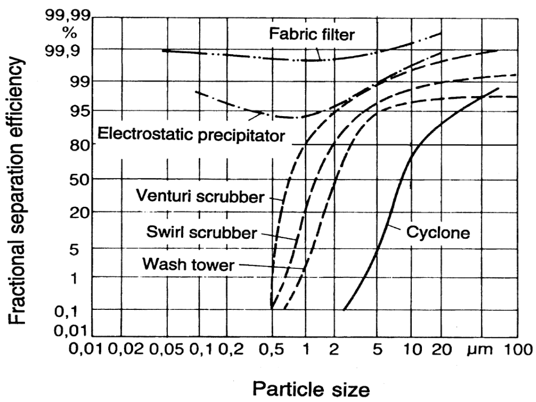

Fig. 1 The fractional separation efficiency of various gas purification devices

3 DESCRIPTION OF TESTED DEVICES AND TSP MEASUREMENT

Detailed construction description of devices which was measured for solid particles emissions can not be given, because of copyright protection.

3.1 Reactor

Downdraft Imbert reactor has a maximum power output of 660 kW. Fuel is supplied to the top of the reactor by trolley and poured through the hole. Filling level of the generator is controlled by ultrasonic range-finder placed above the inlet of the reactor.

Agent used in biomass gasification is air which is preheated in a heat exchanger located on the outer coat of reactor to temperatures of 200-240°C. Localisation of nozzles distributing agent in the reactor on two levels allow reducing levels of field temperature in neighborhood of nozzles.

To reactor has been implemented an innovative method of recycling heat from hot gas from reduction zone (temperature around 850°C) flowing through the drying zone and giving back thermal energy.

3.2 The gas purification devices

- Rotatory separator - swirl separator with built-in rotary equipment.
- Dust filter - dry filter with filter cartridges and pulse-jet regeneration.
- Dry cooler - dry cooler for contactless cooling of produced gas.
- Scrubbers - Water was an agent used in scrubber. Demister installed in scrubber helped to remove all droplets contained in the gas. Two types of scrubbers were tested:
  Scruber – water is sprayed through nozzles inside the separator
  Scrubber with buil-in rotatory equipment

3.3 Cogeneration Unit

Cogeneration unit TEDOM equipped with internal combustion piston engine LIAZ which is modified to burn gas with low heating value and with generator of electricity with nominal output power of 75 kWe.

3.4 TSP Measurement Methodology

Sites for sampling the gas were placed in the output pipeline of tested device.

The principle of measuring method is based on the isokinetic suction of the gas sample from the pipeline according to ČSN ISO 9096.

Gas temperature at the measurement point was measured with a thermocouple type "K" connected to the measuring unit. Differential and static gas pressure was measured using the Pitot tube connected to pressure sensors.

Sampling of the gas was carried out with probe that was connected to an electrically heated trap, where the filter from the glass micro-fiber captured most solid particles from exhaust gas sample. After the capture of solid particles the gas was introduced into the condenser where the water vapor condensed. The cooled gas saturated of water vapor in the measured temperature was introduced into the volume measuring equipment and then into the air pump. The proper flow rate of the gas sample was adjusted by changing of pump speed and monitored using pressure sensors and temperature sensors.

The total amount of solid particles captured on the filter was determined gravimetrically as the weight difference of filter before and after the sampling. Mass concentration of solid particles was determined by dividing the amount of captured solid particles and exhausted volume of wet gas converted to normal conditions (0 °C, 101325 Pa) and it is expressed in $mg.m^{-3}_{N}$.

3.5 TSP Measurement Process

Measurements of solid particles concentrations were carried out on the gasification technology in two stages at different locations of technological complex.

In each measuring site two samplings (about 20 minutes long) were carried out for determining the concentration of TSP and the result is their average.

Technology in the individual measurements was operated at similar conditions (composition of fuel - wood waste from sawmill, the quantity of gas) and output power of cogeneration unit from 55 to 65 kWe.

4 RESULTS

Results are presented as diagrams with commentary. Concentrations of solid particles in the output pipeline of tested device are provided in text boxes with the dotted edge.

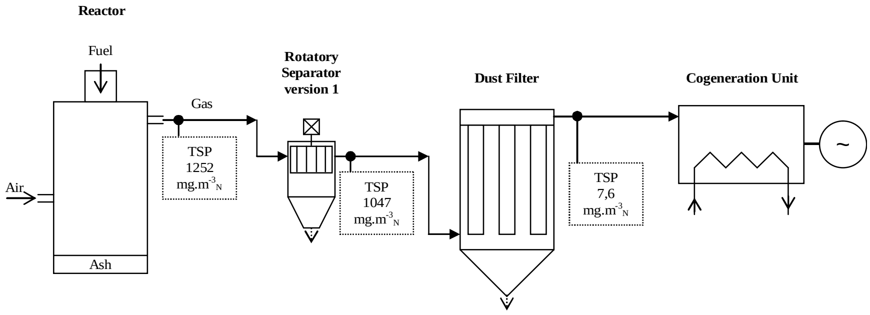

Fig. 2 1st stage of measurements – device configuration 1

Device configuration included the original Rotatory separator. The Dust filter, even at high initial concentration of solid particles could clean the gas to TSP concentration 7,6 $mg.m^{-3}_{N}$.

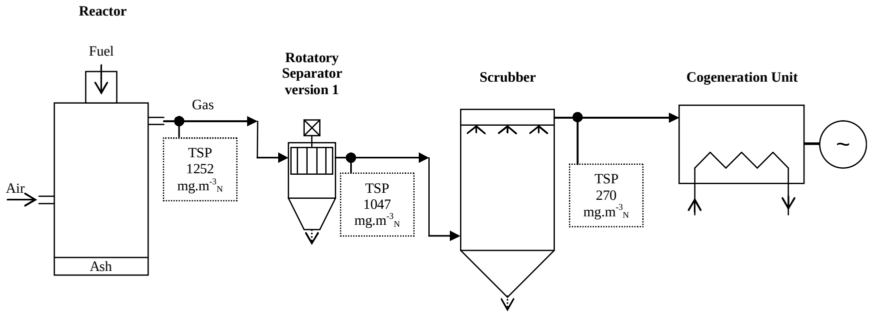

Fig. 3 1st stage of measurements – device configuration 2

The Dust filter was replaced by the Scrubber, which did not achieve purifying the gas to the concentration of TSP comparable to using the Dust filter.

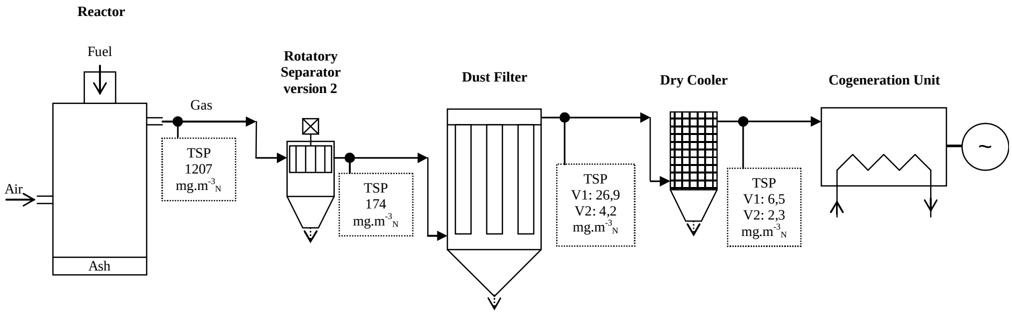

Fig. 4 2nd stage of measurements – device configuration 1

The innovative construction of the Rotatory separator (version 2) had better efficiency separation of solid particles than its original construction (version 1). The Dust filter was operated in two modes: the regeneration of filter cartridges (V1) and the mode without regeneration of filter cartridges (V2). Mode V2 showed lower output concentrations of TSP. Integration of Dry cooler reduces the concentration of TSP to 6,5 mg.m$^{-3}{}_N$ in the regeneration of the filter cartridges and to 2,3 mg.m$^{-3}{}_N$ in mode without their regeneration.

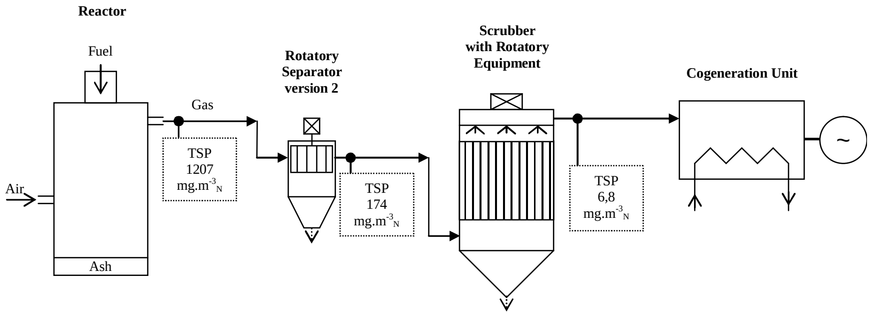

Fig. 5 2nd stage of measurements – device configuration 2

The Dust filter and the Dry cooler were replaced by the new construction of Scrubber with buil-in rotatory equipment. The result was reduction of the TSP concentration to 6,8 mg.m$^{-3}{}_N$ which is comparable to using a Dust filter.

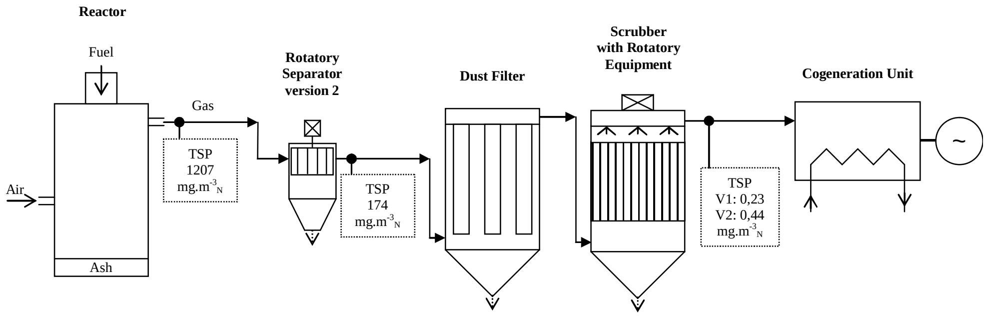

Fig. 6 2nd stage of measurements – device configuration 3

Integration of Dust filter and Scrubber with buil-in rotatory equipment reduces the output concentration of solid particles to the values recommended by the manufacturer of cogeneration unit (<0.8 mg.m$^{-3}{}_N$), both in mode with the regeneration of filter cartridges (TSP = 0,23 mg.m$^{-3}{}_N$) and in mode without regeneration of filter cartridges (TSP = 0,44 mg.m$^{-3}{}_N$).

5 CONCLUSIONS

It was observed removing of solid particles from the gas produced during gasification of wood in downdraft Imbert reactor. Different purification devices were used. The devices were monitored individually and in their series connection. The aim was to determine what procedures can result in reduced concentrations of TSP to a level allowing the use of the gas in the cogeneration unit with an internal combustion engine.

By series of measurements confirmed that it is technically possible to achieve the elimination of solid particles from the produced gas to the concentration 0,23 mg.m$^{-3}{}_N$ which meets the TEDOM cogeneration unit manufacturer's recommendations (<0.8 mg.m$^{-3}{}_N$).

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