**CHEMICAL ENGINEERING TRANSACTIONS** Volume 18, 2009
Editor Jiří Klemeš
 ISBN 978-88-95608-04-4 ISSN 1974-9791
DOI: 10.3303/CET0918108

# Removal of tar in biomass gasification process using carbon materials

Sausan Salem Kadam AL-DURY*

Email: susan_kadam2004cz@yahoo.com

Faculty of Mechanical Engineering – Department of Power Engineering

The Energy Institute

Brno University of Technology (BUT) – Czech Republic

Abstract: This paper describes relevant details of the experimental techniques and the procedures of the utilization of the some carbon materials separately for tar removal and gas cleaning in the biomass gasification process.
The main contaminants in the product gases of biomass gasification are dust and soot particulates; alkali metals, acid gases, alkaline gases, the level of contamination depends mainly on two factors, the type of gasification process employed and the type of feedstock used. The organic contaminates, polyaromatic hydrocarbons, which are very difficult to convert and there relative proportion increases with the gasification process temperature. Tar is undesirable because of the various problems associated with condensation, formation of tar aerosols and polymerization to form more complex structure, which causes problems in the process equipment as well as engines and turbines used in the applications of the fuel gas. However, the minimum allowable limit for tar is highly dependent on the kind of process and the end use of application.

Key words: Biomass Gasification, Gas cleaning, Tar removal, Carbon materials, Active carbon

## 1. Introduction:

Different carbon materials were used as an additive filter in order to achieve a completely clean syngas. Three types of carbon materials were used, active carbon, char coal and the black coke. All these materials show excellent results either in tar removal or the gas purification.
Activated carbon is a form of carbon that has been processed to make it extremely porous and have a very large surface area available for adsorption or chemical reactions.
There are three main forms of activated carbon. Granular activated carbon – irregular shaped particles with size ranging from 0.2 to 5 mm. Powder activated carbon – pulverized carbon with size less than 0.18mm. Extruded activated carbon – cylindrical shaped with diameters from 0.8 to 5 mm.

Please cite this article as: Al Dury S.S.K., (2009), Removal of tar in biomass gasification process using different carbon materials, Chemical Engineering Transactions, 18, 665-670 DOI: 10.3303/CET0918108

Black coke is a solid carbonaceous residue, gray, hard, porous and has a heating value of 24.8 million Btu/ton (29.6 MJ/kg). Some coke making processes produce valuable by-products that include coal tar ammonia, light oils, and gas.
Coal gasification can be used to produce syngas, a mixture of carbon monoxide (CO) and Hydrogen ($H_2$) gas.

## 2. Experimental work:

All the experimental work carried out within the Institute of Power Engineering, Department of Mechanical Engineering at The University of Technology in Brno, Czech Republic. Experiments carried out at fluidized bed atmospheric gasifier with stationary fluidized bed called Biofluid 100 (Fig. 1).
The unit can be operated in both gasifying and combustion modes. Fluidized bed gasifier start-up to steady state is carried out by way of combustion mode. Process temperature control is carried out by changing the fuel to air ratio with temperature control range being within the 750°C to 900 °C brackets. Average heating value of the produced gas ranges from 4 MJ/$m_n^3$ to 7 MJ/$m_n^3$, the content of solid particles is in the region 1.5 g/$m_n^3$ to 3 g/$m_n^3$ and the content of tars from 1 g/$m_n^3$ to 5 g/$m_n^3$ depending on fuel used and operating conditions. A simplified layout of the gasifier connections is in (Fig.2). Steam/oxygen mixtures were utilized as gasification agents. Dolomite was chosen as the bed material in order to be used as a dust removing filter. In all the experimental setup, wood chips were gasified in order to obtain reference data.

## 3. Operating conditions:

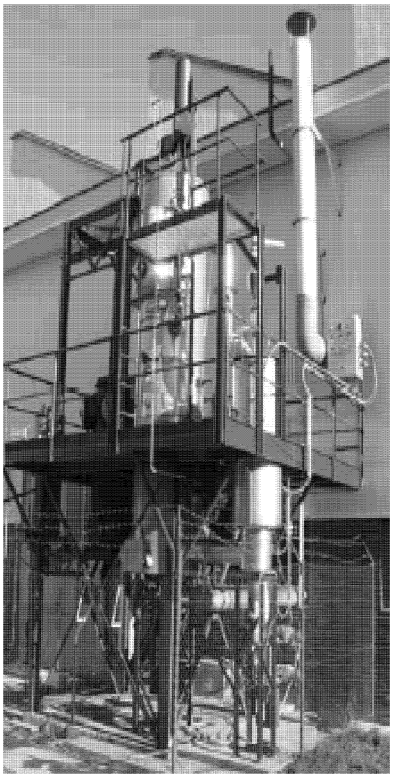
Active carbon, char coal and the black coke were used for filter filling. Experiments have shown that the material tasted showed a good effect on tar elimination and a different gas contaminants absorption. Table No. (1) & (2) Show some operation conditions and the experimental program of the experiments.

## 4. Description of Testing program and procedure:

The char coal, activated carbon and the black coke were used as filters separately at temperature ranges (70-120 Cº) where the gasification temperature is 800 °C and the catalytic filter temperature is 400°C.

| | EXP.No.1 | EXP.No.2 |
|---|---|---|
| Duration | 18hr | 18hr |
| Biomass | wood chips | wood chips |
| Gasification temperature | 800 Cº | 800 Cº |
| Bed Temperature | 100 Cº | 70 Cº |

*Table1 (1): Experimental program for gas cleaning*



*(Fig. 1) Atmospheric fluidized bed experiments*

| | |
|---|---|
| Gasification temperature | 800 C° |
| Primary air temperature | 150 C° |
| Mass flow rate of Primary air | 30m³/h |
| Mass flow rate of secondary air | 2m³/h |
| T1 | 70 C° |
| T2 | 100 C° |
| Volume of carbon materials | 400 ml |
| Weight of carbon materials | 100 g |
| Size of particles | 0,2 ml |

*Table No. (2): operation conditions of Gasifier Biofuel 100*

In order to be able to test the gas cleaning system under different conditions, test series were conducted Steam/oxygen mixtures were utilized as gasification agents. Several experiments were carried out in different working temperatures; all the experiments show an approximate tar removal between 95% - 100%, in addition the gas samples analyses show the advance ability for the char coal, activated carbon and the black coke for the absorption of combustible gases consisting of Carbon monoxide (CO), Carbon dioxide (CO2) and traces of Methane (CH4) as shown in the Graph No. (1).

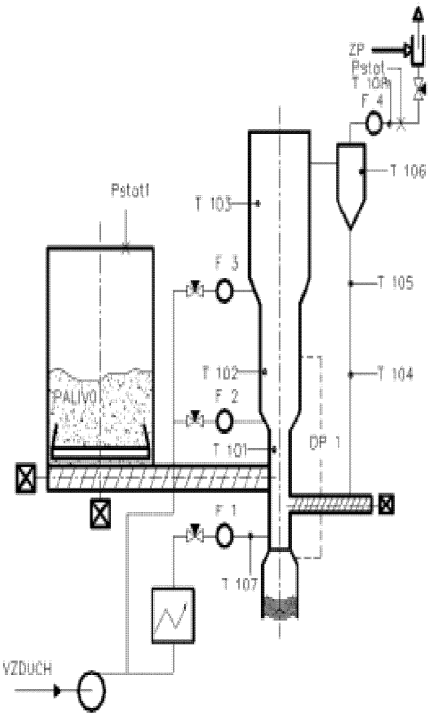
T106: temperature inside the cyclone
T107: temperature of the incoming primary air
T108: gas temperature at jacket outlet
F 1-3: air flows
F4: gas flow

P stat: outlet gas pressure

Pstat1: tank pressure

DP1: fluidized bed pressure difference

| | | |
|---|---|---|
| benzen | 4555.0 | 95.6 |
| toluen | 2050.7 | 159.9 |
| ethylbenzen | 47.5 | 0.1 |
| m-+-p-xylen | 77.4 | 0.5 |
| phenylethyn | 1.5 | 0.0 |
| Styrene | 171.1 | 0.1 |
| 5-(1-methylethylidene)-1,3-cyclopen | 72.4 | 0.8 |
| fenol | 181.9 | 0.0 |
| benzofuran | 50.9 | 0.0 |
| indan | 14.9 | 0.1 |
| inden | 182.2 | 0.2 |
| methylbenzofuran | 5.3 | 0.0 |
| methylbenzofuran | 2.7 | 0.0 |
| methylinden | 10.6 | 0.0 |
| Methylinden* | 7.0 | 0.0 |
| naftalen | 572.7 | 0.0 |



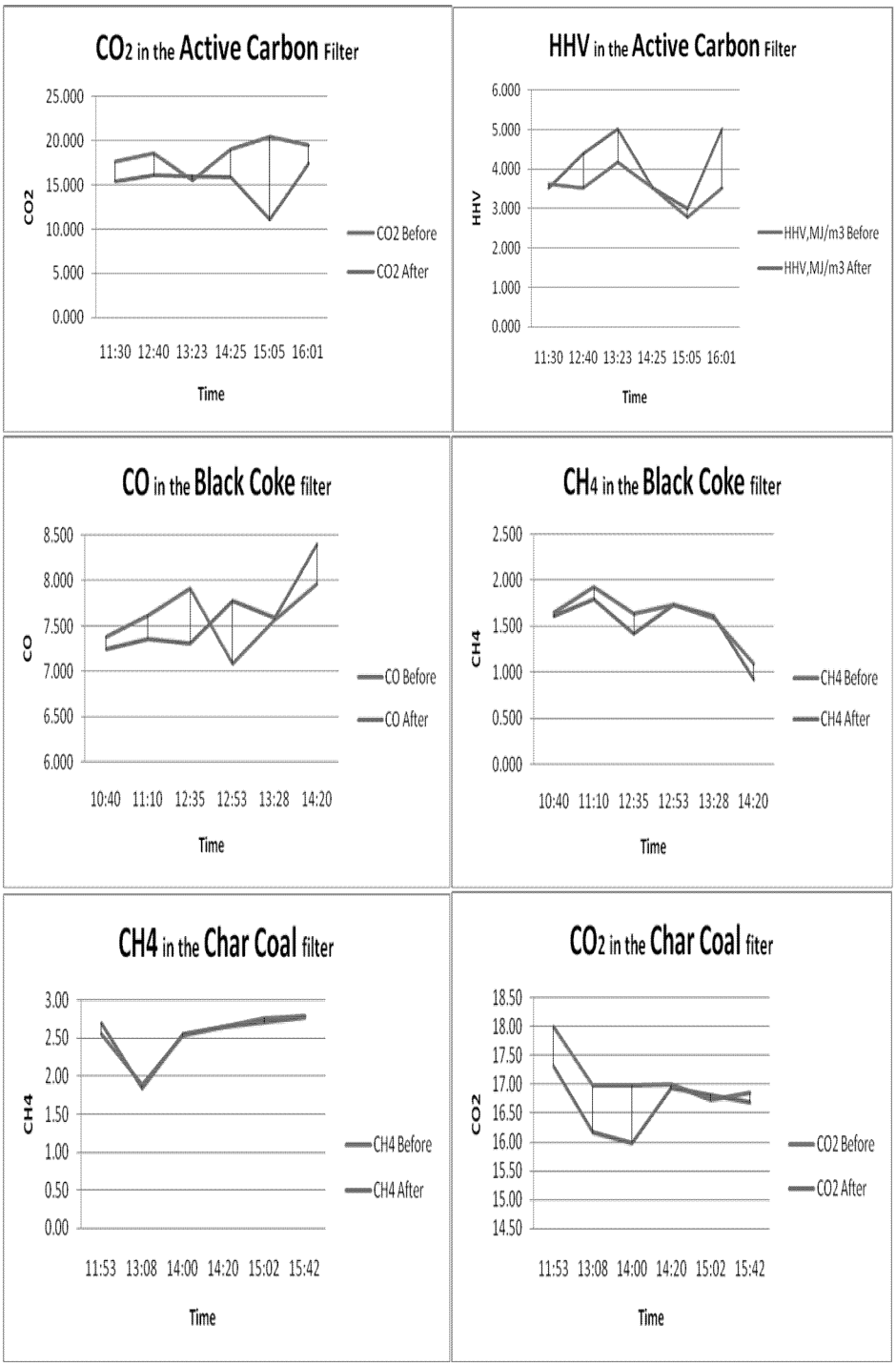

*(Fig. 2): Simplified layout of the gasifier Connections*

*Table No. (3): Some results of the tar components analysis before and after the carbon filter, concentrations in mg/m3:*

## 5. Brief overview of results:

Graph No: (1) summarize the changes in the gas composition before and after the carbon filter and show the amounts of the CO, CO2 and CH4 for each of the three materials separately, char coal, black coke and the active carbon. The best results were achieved in the active Carbon filter at the temperature of 110 C°. Tar was sampled by capturing in organic solvent and then analyzed in a gas chromatograph.

As was mentioned above the carbon materials were used in order to examine the ability of different carbon materials to achieve the objective of tar reduction during the process of the biomass gasification.




*(Graph No. (1)) Gas composition before and after the carbon filters for Active Carbon, Black Coke, and Char Coal*

## 6. Conclusion:

Gas cleaning was performed using particles of different carbon materials at 70-110 Cº. At a gasification temperature of 800 Cº, and bed temperature of 110 Cº, many tar components were effectively removed; adsorption capacity is largely dependent on the particles size of the carbon materials and the gasification temperature. The larger specific surface area and the smaller particles size of carbon materials were favourable for the effective removal of light tar compounds. The specific surface area and average size particles of carbon would influence the ability of tar removal, and the char coal, activated carbon and the black coke with a large specific surface area and average size particles was the most effective for tar removal. The results achieved show that the using of the carbon material is effective and cheep method of Syngas cleaning during the biomass gasification at very low temperature without any loss of the effectiveness of this materials. Once the operating conditions are optimized, the activated carbon filter will enable efficient and effectiveness of Syngas cleaning to make it usable for the combustion engines.

## References

1- J.P.A Neeft et. al., "Development of a standard method for the measurement of organic contaminants ("Tar") in biomass producer gases - TARPROTOCOL", 2004, www.tarweb.net

2- J.P.A.Neeft, H.A.M.Knoef, et. al., “Guideline for Sampling and Analysis of Tar and Particles in Biomass Producer Gases.

3- Kiel, J.H.A., van Passen, S.V.B., Neeft, J.P.A., Devi, L., Ptasinski, K.J., Janssen, F.J.J.G., Meijer, R., Berends, R.H., Temmink, H.M.G., Brem, G., Padban, N., Bramer, E.A., 2004. Primary measures to reduce tar formation in fluidized-bed biomass gasifiers. Final SDE project P1999-012. Report No. ECN-C-04-014.

4- Devi, L., Ptasinski, K.J., Janssen, F.J.J.G., 2003. A review of the primary measures for tar elimination in biomass gasification processes. Biomass and Bioenergy 24, 125-140.

4- T.A. Milne and R.J. Evans National Renewable Energy Laboratory N. batzoglou Kemestrie, Inc. Biomass Gasifier “Tars”: Their Nature, Formation, and Conversion.

5- Jan Fjellerup, Jesper Ahrenfeidt, Ulrik Henrikson, Benny Gobel, Formation, Decomposition and Cracking of Biomass Tars in Gasification. Technical University of Denmark, 2005.