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Górniak Aleksander,
Janicka Anna,
Skrętowicz Maria,
Trzmiel Kamil,
Włostowski Radosław,
Wrobel Radosław,
Zawiślak Maciej

Conditioning of a biomass gasification product gases for supplying a combustion engine

Abstract: The consequence of biomass gasification is generation of a gas mixture composed mainly of hydrogen, carbon mono and dioxide, and methane, called SNG (Substitute Natural Gas) which can be utilized as an alternative fuel for internal combustion engines. However, the product gas mixture cannot be directly supplied to the engine due to variability of its composition as well as its impurities. This brings the necessity to conduct a series of procedures of gas purification and conditioning before supplying the engine. This paper therefore deliberates a concept of gas conditioning method.

Key words: *biomass gasification, SNG, gas conditioning.*

Kondycjonowanie gazów podawanych do silnika spalinowego powstałych w procesie zgazowania biomasy

Streszczenie: W wyniku procesów zgazowania biomasy powstaje mieszanina gazów składająca się między innymi z wodoru, tlenu węgla, ditlenku węgla i metanu, tzw. syngaz, który może zostać wykorzystany jako paliwo alternatywne do silnika spalinowego. Powstały syngaz, ze względu na swój skład (występowanie zanieczyszczeń) i parametry nie może być jedna podany do silnika w sposób bezpośredni. Niezbędne jest więc przeprowadzenie szeregu zabiegów kondycjonowania i oczyszczania gazu syntetycznego. W pracy przedstawiono koncepcję i metody kondycjonowania gazów.

Słowa kluczowe: *zgazowanie biomasy, syngaz, kondycjonowanie gazów.*

1. Introduction

Inasmuch the most common engine fuel is still fossil fuel, researches all over the world are working on alternative ones. The conventional fuels has a short future, due to its limited resources, and they are also a net source of green house gases and other air pollutants. Nowadays, a lot of alternative fuels are used in internal combustion engines. These include various type of vegetable oils, alcohols (e.g. bio-ethanol, glycerol), biodiesel, hydrogen (fuel cell), etc. [1].

There are also technologies such as alternative routes to equivalents of conventional fuels. Example of that could be coal gasification [2]. This technology is discussible, because generally, coal is not clean energy source.

Recently, it is attempted to obtain alternative combustion engine's fuel as a result of the biomass gasification process. The composition of this gas indicates that it is possible to use it in an combustion engine. The reaction of biomass gasification produces gaseous mixture of hydrogen, carbon mono and dioxide, and methane. That mixture is called SNG (*Substitute Natural Gas*). The gasification process however, is burdened with formation of undesirable products like for example tar, particulate matter, light hydrocarbons, sulfur oxides, chlorine compounds, as well as nitrogen compounds like nitrogen oxides or ammonia [3-4]. It is necessary to appropriately and accurately perform the process of gas purification and conditioning before supplying the combustion engine. Therefore in this paper concepts of gas conditioning method are presented.

2. The test station

The laboratory gasifier was designed of metal container with volume of $1\,dm^3$. This container was equipped with a tapping valve through which the gaseous products of gasification can escape. During each experiment the container was fillet with the same amount of biomass and was heated by a gas burner. The experiment was conducted until the gas composition was energetic enough to sustain the flame. When the composition of gaseous products of the gasification process was not flammable the experiment was ended.

In addition the test station was equipped with the systems of gas conditioning and suction pump installed between reactor and the burner. During each experiment the gas was filtrated by means of a vertical dolomite reactor. This reactor was designed of ceramic cylinder enveloped with isolated heating wire. All of those members were enclosed within a cylinder made of resistant steel, equipped with inlet and outlet valves located on opposite sides of the cylinder. The interior of the ceramic cylinder was filled with dolomite bed. Each experiment assumed reactor operation within the range of temperature of $700 - 800$ ℃. Moreover, the test station was equipped in a set of laboratory gas scrubbers with various filling materials for gas conditioning. When the experiment was completed, the content of gas scrubbers was subjected to chemical analysis in order to determine the contaminates removed from the gas by particular filling material. The test station for gasification process and gas conditioning is depicted in Figure 1.

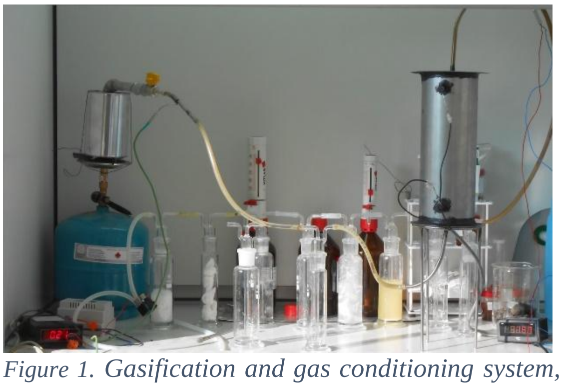

Figure 1. Gasification and gas conditioning system, used in experiment no. 2

3. The experiment

A total of 7 experiments in which always 200 g of wood pellet with humidity of 6% was gasified. The resulting syngas was directed to the system of gas conditioning. The first and unchanged in every experiment system for gas conditioning was the vertical dolomite reactor. Subsequently the gas was conditioned by the laboratory gas scrubbers filled with various substances and solutions in various configurations. Each scrubber contained 150 ml of substance. The filling material of gas scrubber considered here was for example distilled water, aqueous solution of Na_2CO_3, methylidyne ester of rapeseed oil, active coal etc. Moreover, additional laboratory gas scrubbers was used at the inlet and outlet of dolomite reactor in order to gather condensate. On the end of the conditioning system a gas scrubber with a white, clean material (e.g. gauze) was installed in order to verified if the gas was cleaned from the tars. The example of conditioning systems configuration used in experiment 5 is described in Table 1

Table 1. gas conditioning system configuration used in experiment 5

Gas scrubber 1	condensate prior to the catalyst reactor
Gas scrubber 2	condensate after catalyst reactor
Gas scrubber 3	rapeseed oil methyl ester (RME)
Gas scrubber 4	distilled water
Gas scrubber 5	aqueous solution Na_2CO_3 (condens. 99,0%)
Gas scrubber 6	methanol
Gas scrubber 7	rapeseed oil
Gas scrubber 8	material (bandage)

4. Analytical methods used

Due to utilization of various materials and solution for gas scrubber fillings it was necessary to conduct virus analytic method related to the particular scrubber. The colorless material, or materials with minor coloration, (e.g. straw-colored) such as distilled water, aqueous solution of Na_2CO_3, or methanol was analyzed by method of spectrophotometry, UV-VIS. For those sample a quantitative ion (SO_4^{2-}, S^{2-}, Cl^-, NO_2^-, NO_3^- and NH_4^+) was used. Identification of those ions informed about reduction of for example sulfur oxides, nitrogen oxides, hydrogen sulfide, chlorines, etc. Tests were performed using a spectrophotometer cuvette tests HACH LAN GE DR 3800

The samples with active carbon which was used in experiments 6 and 7 was analyzed in terms of qualitative and quantitative content of volatile organic compounds in the gas, due to the fact that active carbon is excellent sorbent of those compounds. VOCs identification was performed by means of gas chromatography (GC) method. In total 4 samples was analyzed - two on each of the two experiments in which active carbon was used. Chromatographic analysis was performed using a Varian gas chromatograph GC-450. The column used was a Varian VF-WAXms (30mx0,25mm ID DF: 0.25 .mu.m) and determination of concentrations of volatile organic compounds in the solutions was carried out in the following conditions:

- Temperature of the furnace (column) - 110 ° C for 10 minutes,
- Injector temperature - 250 ° C,
- Split - 1:20
- Detector temperature - 250 ° C,
- Carrier gas - helium,
- Injection volume - 1 ml.

5. Results and discussion

The results of the pollutants concentrations identified in the absorbers are converted to virtual volume of gas which passed through the system, and given as the amount of impurity (mg) in one dm^3 of gas. Experiment 1 was carried out in order to verify the validity of the analytic concept and to test the system operation. In this experiment the amount of gas that has passed through the system was not investigated, and therefore it was not possible to calculate the total amount of impurities in syngas. Therefore, results are shown for all experiments except for experiment 1.

Studies in which the method of UV-VIS spectroscopy was applied allowed to determine the content of analyzed ions in various scrubbers. This enabled the assessment of a particular substance ability to purify syngas. The amount of ions was also summed in order to obtain information about the total contents of impurities in the gas.

All of the marked ions was identified inside of the scrubbers. Furthermore, based on the test results it can be specified which scrubber removes pollutants with better accuracy. It has been found that in distilled water scrubber nitrogen compounds (ion NO2$^-$, NO3$^-$ and NH4 $^+$) are well absorbed. The scrubber containing a solution of Na_2CO_3 removes very well the gas sulfur compounds (SO42- and S2- ions) and chlorine (Cl ions). Scrubber with methanol, although absorbing small quantities of impurities, does not show such effectiveness as the previous one. This could be due to the fact that it was usually at the end of the system, however in the experiment 4, in which it was located before the scrubber containing a solution of Na_2CO_3, also did not give satisfactory results. The amount of retained ions individual in scrubbers are shown in Figures 2-7.

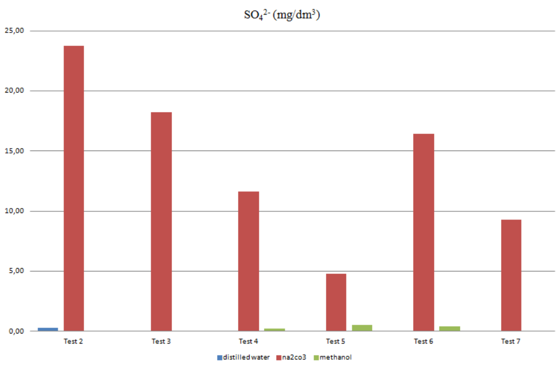

Figure 2. The amount of absorbed ions SO_4^{2-} in the individual absorbers in subsequent experiments.

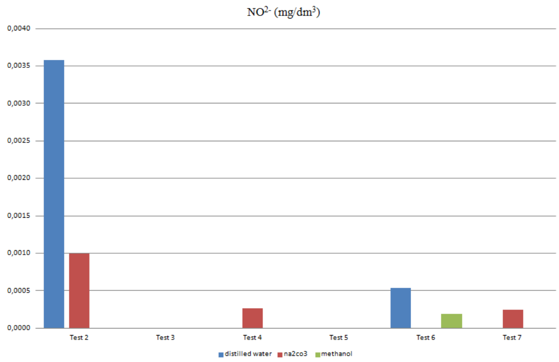

Figure 3. The amount of absorbed ions NO^{2-} in the individual absorbers in subsequent experiments

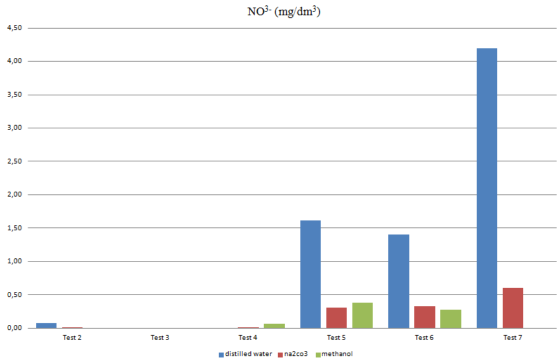

Figure 4. The amount of absorbed ions NO^{3-} in the individual absorbers in subsequent experiments

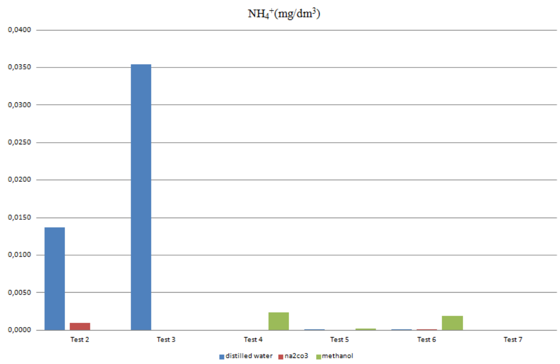

Figure 5. The amount of absorbed ions NO_4^+ in the individual absorbers in subsequent experiments

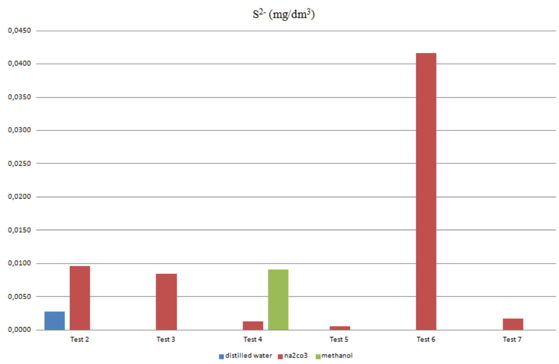

Figure 6. The amount of S^{2-} ions absorbed in each scrubbers in subsequent experiments.

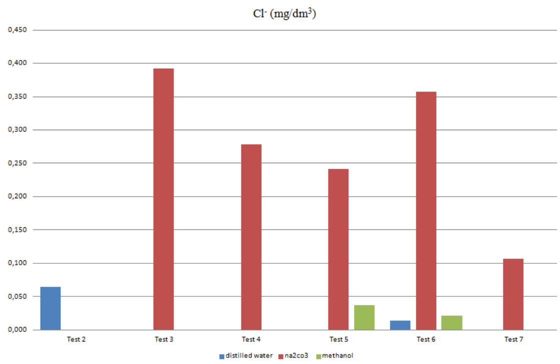

Figure 7. The amount of Cl⁻ ions absorbed in each scrubbers in subsequent experiments.

The results of chromatographic analysis are presented in the form of the chromatograms, and tables. Only one organic compound in all analyzed samples have been identified, and that was n-pentane, whose retention time (RT) under the conditions of analysis was 2.11 min. The result of qualitative analysis indicates the presence in syngas of light hydrocarbons given basing on the n-pentane (e.g. alcohols, ketones). No known heavier volatile organic compounds were detected. Figure 8 shows the chromatogram of the sample gathered during experiments 6.

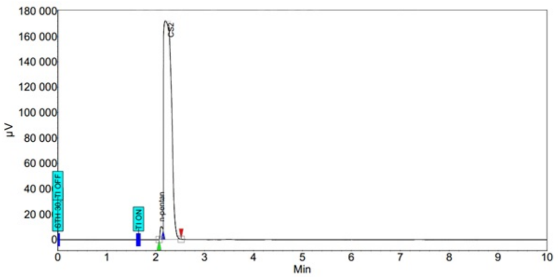

Figure 8. The chromatogram obtained from the chromatographic analysis of the experiments 6

The results of the analysis initially presented in ppm (parts per million), were recalculated on the total amount of gas passed through the scrubber and reported in mg / dm^3. The calculated concentrations of total hydrocarbons based on the n-pentane are presented in Table 2

Table 2. The values of the concentration of hydrocarbons in the samples of experiments 6 and 7 (mg/dm^3).

Repetition.	Exp. 6		Exp. 7	
	Sample 1	Sample 2	Sample 1	Sample 2
1	1120,0	1077,8	2222,5	3775,0
2	1067,0	1160,7	3028,7	2930,5
3	1038,6	1012,8	4103,0	2987,3
average	1075,2	1083,8	3118,1	3230,9

As is apparent from Table 2, the concentrations in the two samples taken from the active carbon used in experiment 6 were the same. The samples from the experiment 7 showed an insignificant difference. Samples were taken at various layers of the activated carbon, it is possible, therefore, that in different places different amounts of impurities was absorbed.

6. Summary

According to the described here research there are many impurities in syngas that must be removed before using it in a combustion engine. In the context of experiments conducted in the laboratory various configurations of conditioning systems have been proposed. The basic pollution generated in the process of gasification include a large amount of tar (liquid pollutants) and gaseous pollutants, such as sulfur oxides, nitrogen oxides, and chlorine compounds. The unchanged member of the conditioning system was a dolomite catalytic agent, which was mainly responsible for removal of liquid and gaseous impurities. It appears that dolomite bed is very effective in removing *inter alia* tar. Furthermore the tar removal was also enhanced by the set of gas scrubbers filled with ester or rapeseed oil.

Basing on the amount of identified ions it was established that the best gas purifications from the gas pollutants was obtained in various scrubbers depending on the type of contamination: nitrogen oxidases are removed by distilled water, sulphur compendious in aqueous solution, chlorides in aqueous solution of sodium carbonate, and with ammonia in distilled water or methanol. Moreover, it was found that due to the low efficiency of contaminants removal the use of methanol scrubber is not necessary.

The chromatographic analysis done in order to identify the volatile organic compounds (VOC) revealed only the presence of n- pentane which would suggest that during the process the hydrocarbons of lower order (alcohols, ketones) are formulated.

Usability of sets o laboratory gas scrubbers filled with various substances are proven to be efficient in terms of gas conditioning and purifying. Therefore such a system can be utilized in further research or even on an industrial scale.

7. Acknowledgment

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Nomenclature/*Skróty i oznaczenia*

SNG Substitute Natural Gas/*syngaz*
RT Retention Time
VOC Volatile Organic Compounds
Ppm parts per million

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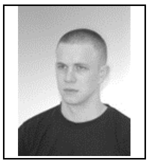
Mr Aleksander Górniak, DSc., DEng. – research assistant in the Faculty of Mechanical Engineering at Wroclaw University of Technology.

Dr inż. Aleksander Górniak – asystent na Wydziale Mechanicznym Politechniki Wrocławskiej.



Mrs Anna Janicka, DSc., DEng. – doctor in the Faculty of Mechanical Engineering at Wroclaw University of Technology.

Dr hab. inż. Anna Janicka – adiunkt na Wydziale Mechanicznym Politechniki Wrocławskiej.

Mrs Maria Skrętowicz, PhD, Eng.. – research assistant in the Faculty of Mechanical Engineering at Wrocław University of Technology.

Dr inż. Maria Skrętowicz – asystent naukowo-badawczy na Wydziale Mechanicznym Politechniki Wrocławskiej.

Mr Kamil Trzmiel, MSc. Eng. – Faculty of Mechanical Engenering at Wrocław Univesity of Technology.

Mgr inż. Kamil Trzmiel – Wydział Mechaniczny Politechniki Wrocławskiej.

Mr Radosław Włostowski, M.Eng. – PhD student in the Faculty of Mechanical Engineering at Wrocław University of Technology.

Mgr inż. Radosław Włostowski – doktorant na Wydziale Mechanicznym Politechniki Wrocławskiej.

Mr. Radoslaw Wróbel, PhD, Eng. – senior lecturer in the Faculty of Mechanical Engineering at Wroclaw University of Technology.

Dr inż. Radosław Wróbel – adiunkt na Wydziale Mechanicznym Politechniki Wrocławskiej

Mr. Maciej Zawiślak, PhD, Eng. – senior lecturer in the Faculty of Mechanical Engineering at Wroclaw University of Technology.

Dr inż. Maciej Zawiślak – adiunkt na Wydziale Mechanicznym Politechniki Wrocławskiej