Composition research of generator gas for application as motor fuel

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Abstract. The problem of the lack of currently approved methodology for determining chemical composition of generator gas and the effect of gas composition when using it as a motor fuel on the operational and environmental performance of an internal combustion engine is discussed. A method for determining chemical composition of generator gas has been developed and tested, in which it is proposed to measure mass concentrations (volume fractions) of the determined components in the generator gas by the indicator (linear-colour) method. Experimental studies were carried out to determine chemical composition of the generator gas according to the developed technique. The studies were carried out on an experimental gas generator of original design, the novelty of which is confirmed by a patent for the invention. Charcoal and wood chocks were used as raw materials for production of generator gas. The composition of the generator gas in a parametric gas generator depends on the type of fuel (raw material), the temperature in the gasification zone, the number and spatial location of the injectors included in the operation and varies in the content of combustible components: H2 from 7% to 18%; CnHm - from 0.1% to 0.3%; CO - from 18% to 31%; CH4 - from 2% to 2.5%. The content of ballast in the generator gas also changes, so the O2 content is from 0.2% to 1.9%; N2 - from 48% to 57.3%; CO2 - from 3.2% to 10%. Experimental studies have confirmed the sufficient accuracy of the proposed methods.

Key words: technique, generator gas, chemical composition, linear coloristic method, indicator method, experimental studies.

Introduction
Generating gas is one of the most promising types of alternative fuels due to its renewability and attitude to the so-called "local" fuels.

Despite this, at present, generator gas is not a standard fuel and, therefore, there are no approved standard methods for determining its composition. In this regard, developing methods to determine composition of the generator gas and their testing is very important [1-12, 16-18].

It should be noted that there are a certain number of existing methods to determine composition of various gases in the atmosphere, industrial and other emissions, etc. [13,14,15 and others]. However, they all have different tasks and are not standard for determining composition of the generator gas.

One of the problems at the same time is the insufficient knowledge of the chemical composition of the generator gas itself, obtained under various conditions and process parameters, from various raw materials, and especially its mixtures with other fuels, as well as its effect when used as a motor fuel on operational and environmental performance of an internal combustion engine [1-6,8,9]

Chemical and element-wise composition of the generator gas is an important characteristic and determines the rate of combustion of the air-fuel mixture, temperature and maximum pressure in the cylinder of the internal combustion engine, and therefore various power and environmental indicators. So, for example, with an increase in the content of hydrogen or heavy hydrocarbons in generator gas, a sharp increase in maximum pressure in the cylinder occurs. When comparing the chemical composition of gasoline and generator gas, it can be noted that an increase in hydrogen leads to an increase in detonation resistance. The presence of a large amount of nitrogen in the composition of the generator gas should reduce the rate of combustion of the mixture. [1-6,8,9].
The composition of the generator gas differs significantly from the composition of traditional hydrocarbon fuels, which causes changes in the operational and environmental performance of the engine converted to generator gas and justifies the need to compare their chemical compositions [1-6]. Also, taking into consideration, the need to increase the reaction rate of an internal combustion engine, operating on a generator gas to an increasing load, the use of generator gas in a mixture with other light fuels in appropriate modes becomes relevant with gasoline, the combustion processes of which also require study [3,5-7].

Description of the ways to determine composition of the generator gas

It is suggested to use a method for determining chemical composition of generator gas, with the development of which some requirements were taken into account, which, in our opinion, were close to the standard STO MI 2606-2018 “Method for measuring mass concentrations (volume fractions) of carbon monoxide, nitrogen oxides, sulfur dioxide, hydrogen sulfide, formaldehyde, acrolein in the air of the working area, industrial emissions by the indicator (linear-coloristic) method using chemical gas detectors of the GC-E type” [13].

It is proposed to carry out the measurement of mass concentrations (volume fractions) of the determined components in the generator gas by the indicator (linear-coloristic) method. The indicator measurement method is based on measuring the length of the reagent layer, placed in transparent indicator tubes, which has reacted with the detected component in the test sample and has changed color. The length of the reacted filler layer depends on the content of the component being determined and the volume of the sample taken for analysis. The content of the determined component in the analyzed sample can be determined by the scale applied to the indicator tube. When measuring the mass concentration of NO2, NOX and CO, the atmospheric pressure, the temperature of the generator gas at the inlet to the indicator tube and the overpressure or vacuum at the sampling point are measured.

Measurements are proposed to be carried out in the following order. The indicator tube 7 filled with reagent is installed in the connector of the aspirator 8 (Fig. 1), and the opposite end of the indicator tube is connected to the duct 1 with the test generator gas through a gas intake tube with a condensate collector 2 and a tee 4 with a thermometer.

![Figure 1. Installation for determining composition of generator gas: 1 - gas duct; 2 - gas intake pipe with condensate collector; 3 - rubber tube; 4 - thermometer tee; 5 - clamp; 6 - rubber tube; 7 - indicator tube; 8 - aspirator [13]](image)

A general view of the instruments used to determine the composition of the generator gas is shown in Figures 2 and 3.
Before conducting research on the composition of the generator gas, the gas intake path is washed with ten times the volume of the investigated generator gas by using an aspirator when connecting it to the tee of the thermometer with the indicator tube removed. Before disconnecting the aspirator, the gas intake must be sealed with a clamp.

Sampling of the generator gas is carried out at a steady state operation of the gas generator and internal combustion engine. It is necessary to use a new indicator tube, in which it is necessary to break off both ends without violating the provisions of the filter pad and reagent layer, for example, using a knife on the aspirator body. Then the indicator tube is installed with an unmarked end into the aspirator connector, and the end of the marked tube is connected to the tee 4. The direction of movement of the generator gas sample should coincide with the direction of the arrow marked along the scale of the indicator tube.
To determine the content of the analyzed component, the aspirator bellows is quickly compressed with one or two hands to the stop, and then released. The aspirator should open until the restriction chains are fully tensioned. In this case, there should be a sharp movement of the lever associated with the valve. Then, the indicator tube is disconnected from the aspirator and 1-2 minutes later the mass concentration (volume fraction) of the analyzed component of the generator gas is determined according to the calibration scale applied to the indicator tube. In this case, it is necessary to take the value that corresponds to the boundary of the layer that has changed colour. In the case where an uneven boundary of the coloured layer is observed, an average value should be taken.

In the process of determining mass concentrations (volume fractions) of the analyzed components, it is necessary to fix the values of the temperature of the generator gas, as well as atmospheric pressure and humidity.

In preparation for making measurements in the laboratory according to GOST 15150-69, the following conditions must be fulfilled: the ambient temperature must be within 20 ± 5 °C; relative air humidity - not more than 80% at a temperature of 25 °C; atmospheric pressure - 84.0 - 106.7 kPa (630 - 800 mm Hg). In the process of determining the mass concentrations of the analyzed components, it is necessary to comply with the conditions adopted according to [14] and indicated in table 1.

| Parameter                                      | Value               |
|------------------------------------------------|---------------------|
| Environment temperature, °C                    | 0 … 50              |
| Atmospheric pressure, kPa                      | 80 … 113,3          |
| Humidity at temperature of 25 °C, %            | up to 100           |
| Generator gas temperature at the sampling point, °C | up to 250          |
| Overpressure (depression) of the analyzed gas sample, kPa | not more than ± 5   |
| Relative humidity at a temperature of 100 °C, % | up to 10            |
| Sample temperature of the generator gas at the inlet to the indicator tube, °C | up to 50          |

Calculation of volume fractions of the component content in the generator gas should be taken according to the following formula:

\[
Cv = \frac{A}{Ka}
\]

where \(Cv\) is the volume fraction of the analyzed component, %; \(A\) is the value determined on the scale of the indicator tube; \(Ka\) is a coefficient taken depending on the number of strokes of the aspirator and the volume of generator gas passing through the indicator tube. It is recommended to take into account the data [13].

Recalculation of volume fractions of the analyzed component in mass concentrations can be carried out according to the formula:

\[
Cm = k \times Cv
\]

where \(Cm\) is the mass concentration of the analyzed component, mg/m³; \(k\) is the conversion factor.

The conversion factor should be taken depending on the analyzed component according to [13].

**Experimental research**

To test the proposed methodology and in full accordance with it, experimental studies of the composition of the generator gas have been carried out. The studies were performed on generator gas obtained by using charcoal (\(\omega = 20\%) and wood chocks (\(\omega = 20\%) as raw materials on an experimental parametric gas generator of the original design (Fig. 4) [19].
Figure 4. Parametric gas generator with regulation of the working process in the volume of the gasification chamber: a) - diagram; b) - view of the tuyere belt:

1 - air pipe; 2 - gasification chamber; 3 - air collector; 4 - electromagnetic valves; 5 - gas outlet; 6 - tubes; 7 - gas tank; 8 - thermal case; 9 - protective casing; 10 - tuyere belt; 11 - ash pan grate; 12 - ash pan hatch; 13 - supports; 14 - technological hatch.

This gas generator makes it possible to obtain generator gas of various chemical composition during various gasification processes (direct, reverse and horizontal), which is due to the peculiarity of gasification chamber 2 and the presence of controlled tuyeres 10.

The results of experimental studies are presented in table 2.

Table 2 – Chemical composition of the generator gas

| Names of raw materials and gasification process parameters | Combustible components, % | Ballast, % |
|---------------------------------------------------------|---------------------------|------------|
|                                                         | H₂  | C₆H₁₄ | CO  | CH₄ | O₂  | N₂  | CO₂ |
| Wood chocks, ω = 20%                                    | 14-18 | 0,1-0,3 | 18-22 | 2,1-2,5 | 1,4-1,8 | 48-52 | 8-10 |
| Charcoal, transverse gasification process                | 7,0-8,0 | 0,2-0,3 | 30,3-31,0 | 2,0-2,5 | 0,2-0,3 | 55,0-57,3 | 3,2-3,5 |
| Wood chocks, reversed process                            | 16,1-16,8 | 0,2-0,28 | 20,1-21,2 | 2,1-2,4 | 1,6-1,9 | 48,7-50,4 | 8,2-9,3 |

As is seen from the table, the composition of the generator gas in the parametric gas generator varies widely enough and depends on the type of fuel, the temperature in the gasification zone, the number and spatial location of the injectors included in the operation.

Analyzing the chemical composition of the generator gas taken using an experimental gas generator and comparing the obtained values of the chemical composition of the generator gas with the same values given in the technical literature, we can conclude that the proposed method allows us to determine the chemical composition of the generator gas with an allowable error.

Conclusions
1. At present, there are no approved standard methods for determining composition of generator gas.
2. Composition of the generator gas, obtained under various conditions and process parameters, from various raw materials, and especially its mixtures with other fuels, which is very important due to the need to increase the reaction rate of the internal combustion engine to an increasing load, as well as the influence of the composition of the generator gas when using it as a motor fuel, the operational and environmental performance of an internal combustion engine are not sufficiently studied.
3. Composition of the generator gas in a parametric gas generator depends on the type of fuel (raw material), the temperature in the gasification zone, the number and spatial location of the injectors included in the operation and varies in the content of combustible components: H2 from 7% to 18%; CnHm - from 0.1% to 0.3%; CO - from 18% to 31%; CH4 - from 2% to 2.5%. The content of ballast in the generator gas also changes, so the O2 content is from 0.2% to 1.9%; N2 - from 48% to 57.3%; CO2 - from 3.2% to 10%.

4. Proposed methodology for determining the chemical composition of the generator gas based on the indicator method allows to determine the chemical composition of the generator gas with an allowable error.

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