IMPROVEMENT OF GAS MONITORING METHODS IN WATER OF THE HYDROGEN-WATER COOLING SYSTEM OF NPP’S TURBINE GENERATOR

S. V. Zaitsev¹, A. Yu. Tykhomyrov¹, V.V. Chychenin¹, V.P. Kyshnevskyi¹

¹Odessa State University «Odessa Polytechnic», email: sdjavdet@ukr.net

DOI: https://doi.org/10.20535/2218-930012021233705

The relevance of research is to ensure and improve the reliability of turbine generators (TG) with a hydrogen-water cooling system by monitoring the content of dissolved gases in the water of a hydrogen-water cooling system with monoethanolamine (MEA) – C₂H₇NO and water vapor in the cooling hydrogen of the turbine. In this work, the influence of ultrasonic vibrations on the decomposition of a mixture of water and turbine oil, organic acids (acetic acid - C₂H₄O₂, formic acid - CH₂O₂, oxalic acid - C₂H₂O₄) or monoethanolamine was determined. The distribution coefficients values were defined for the following dissolved gases H₂, O₂, N₂, CO, CH₄, C₂H₂, C₂H₄, C₂H₆, C₃H₆, C₃H₈, which are of degradation products of water mix components when exposed to ultrasonic oscillation in the following system: «dissolved gas – mixture «water + monoethanolamine» – extractant argon (Ar)». The obtained values of the Kᵢ distribution coefficients for dissolved gases in systems «dissolved gas – mixture «water + C₂H₇NO» – extractant argon (Ar)» at a temperature of 293 K and a concentration of C₂H₇NO at the level of 1 g/dm³ are close to similar values for dissolved gases in deionized water. The principle flow chart of multichannel gas chromatograph for detecting dissolved gases in water and steam of water in hydrogen was developed. Developed flow chart of 4-chennel gas chromatographer for defining dissolved gases in water includes the one gas chromatographer with conductivity detector, methanator, flame ionization detector, argon gas-bearing and supplementary gases of hydrogen and air.

Key words: cavitation, chromatography, gases, hydrogen, monoethanolamine, turbine generator, water.

Received: 8 June 2021   Revised: 15 June 2021   Accepted: 25 July 2021

1. Introduction

To producing electricity, the TBB –type turbine generators are widely used at Ukrainian NPPs.

The following cooling media are used: water (H₂O) for stator coil, hydrogen (H₂) for rotor core and winding [1]. Application of H₂ requires arrangement of special oil sealing of turbine generator shaft.

Herewith, the steam of water from moistened oil ingresses in volume of turbine generator hydrogen that often results in electric-based deficiencies in rotor winding and leads to corrosion of internal elements of turbine generator. While being operated, a turbine generator is affected by vibration in wide frequency range that may lead to cavitation mode in the cooling water flow [1]. It may lead to high-rise short-term temperature and pressure increasing in cooling water [2]. Herewith, pressure can reach 1000 MPa and the temperature 5000 K [3]. Cooling water often contains monoethanolamine (C₃H₇NO), which characterizes the monoethanolamine water-
chemistry [4]. In case of oxygen (O₂) availability, C₂H₇NO may be subjected to thermal and oxidative degradation [5].

Reference [1] defines that the monitoring of H₂ supply in cooling H₂O in TBB-type TG may be performed by gas chromatographer method (GC method). Herewith, the technical and metrological requirements for the implementation of this GC method are not established. This reference also defines that the monitoring of steam content in water and gases, O₂, N₂ in cooling H₂ in turbine generator may be carried out by using the different measurement methods. It is also defined in reference [1] that the monitoring of hydrogen supply in cooling water of TBB-type turbine generator can be carried out by using gas chromatographer method. This method was developed in 1968 and is thought to be outdated – measurement duration may last 1.5 hours. This method requires improvement according to up-to-date measurement tools.

In reference [4], it is outlined, that the man-made organic impurities (oil products) might be available in cooling water. Herewith, the possible products of their degradation under the impact of vibration and cavitation mode in the cooling water in case of monoethanolamine availability are not determined.

It was shown in [5] that the thermal and oxidative destruction of C₂H₇NO in water accumulates the following aggressive organic acids, such as HCOOH, CH₃COOH, HOCH₂COOH, HOOCCH₂OH, HOCH₂CH₂COOH, H₂NCHCH₃COOH are build up in water. The possibility of a chemical reaction of these organic acids with metal structural elements of the turbine generator and pipelines under vibration and cavitation conditions in cooling water is not shown in this work.

It was shown in [6] that, provided that MEA is present in water, acetic and oxalic acids are accumulated in it. The possibility of chemical reaction of these organic acids with metal elements of TG construction and pipelines is not demonstrated in this work.

The purpose of the study is to ensure the reliability of a turbine generator with a hydrogen-water cooling system with monoethanolamine (C₂H₇NO) by monitoring the content of gases such as H₂, O₂, N₂, CO, CH₄, C₂H₂, C₂H₄, C₂H₆, C₃H₆, C₃H₈ and of water steam that contains in the cooling hydrogen of the steam generator.

In order to achieve the purpose, the following tasks have been performed:

– defining the ultrasonic oscillation effect on degradation of water mixture with petroleum turbine oil, organic acids, (acetic acid formic acid and oxalic acid) or with monoethanolamine;
– defining the values of distribution coefficient for dissolved gases such as H₂, O₂, N₂, CO, CH₄, C₂H₂, C₂H₄, C₂H₆, C₃H₆, C₃H₈, in the system: «dissolved gas – mixture «water + monoethanolamine» – extractant argon (Ar)»;
– development of principal flow chart of multi-channel gas chromatograph for detecting dissolved gases and water steam.

2. Tools, materials and methods

The research has been performed by using: fresh mineral turbine oil of Tp-30 brand; deionized water; monoethanolamine aqueous solutions: Mixture №1 («water + C₂H₄O₂ + CH₂O₂ + C₂H₂O₄»); Mixture №2 («water + monoethanolamine»); Mixture №3 («water + monoethanolamine + mineral turbine oil of the Tp-30 brand»).
Концентрация каждого компонента смеси (кроме масла турбины) — 1 г/дм³. Концентрация масла турбины — 5 мг/дм³. Объемы смесей — 15 см³. Смеси № 1, № 2, № 3 перед использованием были насыщены воздухом при температуре T = 293 К. В отдельном эксперименте смесь № 2 была насыщена водородом при температуре T = 293 К. При проведении измерений были использованы следующее оборудование: газохроматограф «Crystal 2000M» (Россия) с газовыми дозаторами, метанатор (для конверсии CO и CO₂ в CH₄), теплореактивный детектор (TCD), и пламенно-ионизационный детектор (FID); газохроматограф «LHM-80» (Россия) с газовыми дозаторами и TCD детектором.

Ультразвуковой генератор «Rodnychok» (Украина) (частота излучения 35 до 125 кГц, мощность 20 Вт) для акустического излучения Микс № 1, № 2, № 3; устройство (высокое место) для ускорения равновесия (Россия) с вращающимся барабаном для кранов в объемах 20 см³ или 50 см³ с анализируемыми образцами. Миксы № 1, № 2, № 3 и газообразные растворители для ускорения равновесия в системах «Микс — растворимый газ — газообразный растворитель»; растворитель аргон (Ar); газообразные смеси H₂, CH₄, C₂H₆, C₂H₄, C₃H₆, CO, CO₂, O₂, N₂, C₃H₆, C₃H₈, в аргоне; насыщенный дистиллированная вода. Аргон выбран как растворитель, учитывая его газообразующему свойство в газохроматографе. Измерения были проведены при температуре (293±0,5) К. Продолжительность: извлечение компонентов из смесей № 1, № 2, № 3 – 10 минут; ультразвуковой эффект на Микс № 1, № 2, № 3 – 2 часа при температуре T = 293 К. Сигнал газохроматографа по компонентам был проведен с помощью: TCD – для H₂, O₂, N₂, водяной пар; FID – для CH₄, C₂H₆, C₂H₄, C₂H₂, CO, CO₂, C₃H₆, C₃H₈. Фигура 1 демонстрирует разработанное оборудование для проведения измерений.

![Фигура 1](image)

To determining the dissolved gases content in Mixtures № 1, № 2, № 3, the following was used: static way of GC measurement method by using gaseous extracting solvent and corresponding variants of equilibrium gas phase analysis methods in systems «Mixture – dissolved gas – gaseous extract»; method of absolute calibration in determining of dissolved gases content in gaseous extracts by using gaseous graduated mixtures. In the GC determination of the dissolved gas C₀ concentration in water, the calculation formulas used for two consecutive gas isothermal extractions were used:

\[
C_0 = \frac{S_k}{K_p + \frac{V}{V_m}},
\]  

where \( S_k \) – is GC peak area for the analyzed dissolved gas after its first gas extraction;
$K_p$ – graduated factor for FI detector or TCD of gas chromatograph for the analyzed dissolved gas; $V_{eo}$ – sample volume of analyzed water; $V_e$ – is the volume of gaseous extractant; $K_p$ – is the distribution coefficient for the analyzed dissolved gas in the system «Mixture – dissolved gas – gaseous extract».

The $K_p$ distribution coefficient is determined by the following formula:

$$K_p = \frac{S_1 - S_2}{S_1 - S_0} \frac{V_e}{V_{eo}}, \quad (2)$$

where $S_1$, $S_2$ – are the areas of GC peaks for the analyzed dissolved gas after the first and second successive gas extraction from the Mixture № 1, № 2, № 3.

Each value of the dissolved gas concentration was obtained as a result of five ($n = 5$) parallel measurements with a confidence level of $p = 0.95$.

The coefficient of normalized deviations depending on the number of degree of variance $f = n - 1$, for $n = 5$ matters $t = 2.78$. In determining the $\text{H}_2\text{O}$ content in gaseous $\text{H}_2$, the method of absolute calibration with using the mixtures of water steam in gaseous argon was used.

3. Results and discussions

3.1 Determination of ultrasonic vibrations effect on the degradation of a mixture of water and organic acids, monoethanolamine, turbine oil.

Table 1 provides the results of determining the ultrasonic vibrations effect on the degradation of Mixtures № 1, № 2, № 3, which are saturated with air.

Table 1. The results of determining the ultrasonic vibrations effect on the degradation of deionized water mixtures with organic acids, monoethanolamine, and turbine oil

<table>
<thead>
<tr>
<th>Mixture</th>
<th>Dissolved gas concentration, $C_i$, % by volume</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\text{H}_2$</td>
</tr>
<tr>
<td>№1</td>
<td>0.001</td>
</tr>
<tr>
<td>№2</td>
<td>0.001</td>
</tr>
<tr>
<td>№3</td>
<td>0.060</td>
</tr>
</tbody>
</table>

In the Table 1: $C_i$ – concentration of dissolved $i$-th gas in the mixture, volumetric part, after irradiation of Mixtures № 1, № 2, № 3

The Table 1 shows that the degradation of Mixture №1 or Mixture № 2, saturated with air, under the ultrasonic vibrations leads to the accumulation of dissolved gases such as $\text{CH}_4$, $\text{CO}$, $\text{CO}_2$ in the mixture.

According to the Table 1 it follows that the degradation of Mixture № 3 containing mineral turbine oil Тр-30 brand, leads to the accumulation dissolved gases $\text{H}_2$, $\text{CO}$, $\text{CO}_2$, $\text{CH}_4$, $\text{C}_2\text{H}_2$, $\text{C}_2\text{H}_4$, $\text{C}_2\text{H}_6$ in the mixture. This allows us to conclude that the compound of cooling water used in the equipment of the power plant might be controlled by the content of petroleum product in it after the oil cooling «cooled oil - cooling water» type
turbine generator. For that the sample of this water should be subject to ultrasound treatment. The Table 2 provides the results of determining the ultrasonic vibrations effect on the degradation of the Mixture № 2, which is pre-saturated with hydrogen.

**Table 2. The results of determining the ultrasonic vibrations effect on the degradation of deionized water mixtures with monoethanolamine**

<table>
<thead>
<tr>
<th>Mixture</th>
<th>Dissolved gas concentration, $C_i$, % by volume</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$H_2$</td>
</tr>
<tr>
<td>№2 before irradiation</td>
<td>1.82</td>
</tr>
<tr>
<td>№2 after irradiation</td>
<td>1.7</td>
</tr>
</tbody>
</table>

According to the Table 2: $C_i$ is a concentration of dissolved $i$-th gas in the mixture.

Table 2 shows the following results: before irradiation of the Mixture №2 saturated with hydrogen, the concentrations of CO and CO$_2$ have values from 0.0001 to 0.002 % by volume; after irradiation of a Mixture № 2 saturated with hydrogen, its degradation under the acoustic oscillations leads to the accumulation CH$_4$, CO, CO$_2$ in the mixture and a decrease of hydrogen concentration. Increasing of CO$_2$ in distilled (deionized) water raise its conductivity, that has undesirable effect for cooled electrical coil of turbine generator. It requires purification of makeup water to be brought (to be filled) in cooling system of TBB-type generator stator coil from monoethanolamine.

3.2 The results of determining the values of the distribution coefficients for dissolved gases in the «dissolved gas – mixture «water + monoethanolamine» – extractant argon (Ar)»

Table 3 shows the results of determining the values of the distribution coefficients of $K_i$ for dissolved gases H$_2$, O$_2$, N$_2$, CO, CH$_4$, C$_2$H$_2$, C$_2$H$_4$, C$_2$H$_6$, C$_3$H$_6$, C$_3$H$_8$ in water in the systems «dissolved gas – mixture «water + C$_2$H$_7$NO» – extractant argon (Ar)» at a temperature of 293 K and a concentration of C$_2$H$_7$NO at the level of 1 g/dm$^3$.

**Table 3. The results of determining the values of the $K_i$ distribution coefficients for dissolved gases in the systems «dissolved gas – mixture «water + monoethanolamine» – extractant argon (Ar)»**

<table>
<thead>
<tr>
<th>Gas</th>
<th>H$_2$</th>
<th>O$_2$</th>
<th>N$_2$</th>
<th>CO</th>
<th>CH$_4$</th>
<th>C$_2$H$_2$</th>
<th>C$_2$H$_4$</th>
<th>C$_2$H$_6$</th>
<th>C$_3$H$_6$</th>
<th>C$_3$H$_8$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$K_i$</td>
<td>0.019</td>
<td>0.033</td>
<td>0.017</td>
<td>0.0244</td>
<td>0.037</td>
<td>1.10</td>
<td>0.13</td>
<td>0.050</td>
<td>0.22</td>
<td>0.038</td>
</tr>
</tbody>
</table>

The Table 3 shows that the obtained values of the $K_i$ distribution coefficients for dissolved gases H$_2$, O$_2$, N$_2$, CO, CH$_4$, C$_2$H$_2$, C$_2$H$_4$, C$_2$H$_6$, C$_3$H$_6$, C$_3$H$_8$, in systems «dissolved gas – mixture «water + C$_2$H$_7$NO» – extractant argon (Ar)» at a temperature of
293 K and a concentration of $C_2H_7NO$ at the level of 1 g/dm$^3$ are close to similar values for dissolved gases in deionized water [1]. This allows using of GC methods to determine these gases in a mixture of «water + $C_2H_7NO$». Thus, the increasing of the dissolved gases content in the flow of the mixture «water + $C_2H_7NO$» after the pump, which ensures the circulation of this mixture in the hydrogen-water cooling system with MEA, may indicate the depressurization of this pump or its pipes.

3.3 The multichannel gas chromatograph structural flow chart for determination of dissolved gases in water and steam of water in gaseous hydrogen.

Figure 2 shows a structural flow chart of a 4-channel gas chromatograph for the determination of dissolved $H_2$, $CO$, $CO_2$, $CH_4$, $C_2H_2$, $C_2H_4$, $C_2H_6$ in water and water steam in gaseous hydrogen. If petroleum products are available in the water, their presence can be determined by the presence of dissolved gases $C_3H_6$, $C_3H_8$, $C_4H_{10}$, $C_4H_8$ in $H_2O$ after treatment of water by ultrasonic oscillations according to the method described in reference [2].

![Fig. 2. Principle structural flow chart of 4-channel gas chromatograph for the determination of dissolved gases in water and water steam in gaseous hydrogen: 1, 5, 7, 12 – gas dispenser taps with dosing loops; 2, 6, 8, 13 – chromatographic columns; 3, 9 – heating block; 10 – methanator; 4 – thermal conductivity detector (TCD); 11 – flame ionization detector (FID); Ar, H, A – argon, hydrogen, air.]

<table>
<thead>
<tr>
<th>Table 4. The main characteristics of the 4-channel gas chromatograph measurements elements</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Characteristics of chromatograph measuring channels elements</strong></td>
</tr>
<tr>
<td><strong>Measuring channel № 1</strong> to determine the water steam content in hydrogen. Elements: chromatographic column pos. 2 – sorbent «Polysorb-1»; gas tap-dispenser pos. 1; $t_{xk}=393$ K, $t_{mm}=423$ K; working chamber TCD pos. 4</td>
</tr>
<tr>
<td><strong>Measuring channel № 2</strong> to determine the $H_2$, $O_2$, $N_2$ dissolved gases content in water. Elements: chromatographic column pos. 6 – sorbent «NaX»; gas tap-dispenser pos. 5; $t_{xk}=333$ K, $t_{mm}=373–423$ K, comparative chamber TCD pos. 4.</td>
</tr>
<tr>
<td><strong>Measuring channel № 3</strong> to determine the $CO$, $CH_4$, $CO_2$, $C_2H_2$, $C_2H_4$, $C_2H_6$ dissolved gases content in water. Elements: column chromatograph pos. 8 – sorbent «Porapak N 80/100»; gas tap-dispenser pos. 7; $t_{xk}=313$ K, $t_{a}=598$ K, $t_{mm}=473$ K, $v=12$ K/min. $t_{xx}=313$ K to $t_{xx,кон}=453$ K, FID pos. 11, Ar gas – carrier line.</td>
</tr>
<tr>
<td><strong>Measuring channel № 4</strong> to determine the content of $CH_4$, $C_3H_6$, $C_3H_8$, $C_4H_{10}$, $C_4H_8$ dissolved gases in water. Elements: chromatographic column pos. 13 – sorbent «Al_2O_3»; gas tap-dispenser pos. 12; $t_{xk}=313$ K, $t_{a}=598$ K, $t_{mm}=473$ K, $v=12$ K/min from $t_{xx}=313$ K to $t_{xx,кон}=453$ K, FID pos. 11, $H_2$ line</td>
</tr>
</tbody>
</table>
According to the table 4 table: $t_\text{tx}$, $t_\text{bn}$, $t_\text{mod}$, $t_\text{d}$, $t_\text{tx,kon}$, $t_\text{kon}$ – temperatures of chromatographic columns ($t_\text{tx}$ – initial, $t_\text{tx,kon}$ – final), TCD, FID, methanator, K; $v$ – is the heating rate of GC columns, K/min.

During the development of the structural flow chart of 4-channel gas chromatograph for the determination of dissolved gases in water and water steam in gaseous hydrogen, was defined the following:

1. The developed structural flow chart includes: gas taps-dispensers with calibrated dosing loops; GC columns; thermostats; detectors – TCD and FID; gas supply lines Ar, H2, air. This technical solution allows measuring the content of gases H2, N2, O2, CO, CH4, CO2, C2H4, C2H6, C3H2, C3H6, C3H8, C4H4, C4H10 y H2O in water and water steam taken from one sample of water or gaseous hydrogen by the using of one 4-x channel gas chromatograph.

2. The calculated value of the limits for determining the humidity of gaseous hydrogen has a value of 0.16 g/m3. Relative error of the measurement result is no more 40% with a confidence level $p = 0.95$. The estimated value of the detection limits of water steam is $1.6 \cdot 10^{-7}$ g. Calibration samples of water steam in gaseous argon are introduced into the chromatograph using a gas tap-dispenser pos. 1.

3. To determining the content of CO, CH4, CO2, C2H4, C2H6, C2H2 y H2O gases in water, the equilibrium gas sample (or calibration mixtures of gases) is introduced into the chromatograph using a gas tap-dispenser pos. 7.

4. To determining the content of CH4, C3H6, C3H8, C4H10, C4H8 gases in water, equilibrium gas sample (or calibration mixtures of gases) is introduced into the chromatograph using a gas tap-dispenser pos. 12.

5. To determining the content of H2, O2, N2 gases in H2O, equilibrium gas sample (or calibration mixtures of gases) is inserted into the chromatograph using a gas tap-dispenser pos. 5.

Table 5 provides the limits of allowable relative error values of the detecting of measuring gases concentrations ($\delta_i$, % Rel) and water steam, depending on the range of their concentrations of $C_i$.

<table>
<thead>
<tr>
<th>The range of measuring dissolved gases concentrations of $C_i$, % by volume,</th>
<th>$\delta_i$, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>H2, O2, N2 in water; water steam in hydrogen</td>
<td>C2H2</td>
</tr>
<tr>
<td>&lt; 5 \cdot 10^{-3}</td>
<td>&lt; 10^{-3}</td>
</tr>
<tr>
<td>(5–25) \cdot 10^{-3}</td>
<td>(1–3) \cdot 10^{-3}</td>
</tr>
<tr>
<td>(25–50) \cdot 10^{-3}</td>
<td>(3–50) \cdot 10^{-3}</td>
</tr>
<tr>
<td>&gt; 5 \cdot 10^{-2}</td>
<td>&gt; 5 \cdot 10^{-2}</td>
</tr>
</tbody>
</table>

The value of standard deviation of the output signal (RSD, % Rel) for TCD, FID gas chromatograph (height, area, retention time for the measured dissolved gas) depending on

Table 5. The value of the allowable relative error $\delta_i$ and determining the concentrations of measuring gases and water steam depending on their concentrations range
the range of concentrations of the measured dissolved gas (Ci, %) given in Table 6.

**Table 6. The value of the standard deviation of RSD**

<table>
<thead>
<tr>
<th>Ci, % by volume</th>
<th>&lt; 0.002</th>
<th>0.002–0.01</th>
<th>0.01–0.1</th>
<th>0.1–1</th>
<th>1–10</th>
</tr>
</thead>
<tbody>
<tr>
<td>RSD. % rel.</td>
<td>&gt; 10</td>
<td>10</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 7 shows the experimentally obtained values of the limits for the determination of Cno (volumetric %) the concentrations of dissolved gases in water to performing measurements.

**Table 7. Limits of dissolved gases concentrations values in water**

<table>
<thead>
<tr>
<th>№</th>
<th>Dissolved gas</th>
<th>Cno, % by volume</th>
<th>№</th>
<th>Dissolved gas</th>
<th>Cno, % by volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>H2</td>
<td>2·10⁻⁴</td>
<td>4</td>
<td>CO, CO₂</td>
<td>5·10⁻⁴</td>
</tr>
<tr>
<td>2</td>
<td>CH₄, C₂H₆, C₂H₄</td>
<td>1·10⁻⁴</td>
<td>5</td>
<td>O₂, N₂</td>
<td>1.5·10⁻⁴</td>
</tr>
<tr>
<td>3</td>
<td>C₂H₂</td>
<td>5·10⁻⁵</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

To determine the limits of measuring of the concentrations of water steam in gaseous hydrogen and calibration of the chromatograph, mixtures of water steam in gaseous argon at concentrations of water steam from 0.16 g/m³ to 17 g/m³ were used. To determine the limits of measuring the concentrations of gases H₂, CH₄, C₂H₆, C₂H₄, C₃H₆, CO, CO₂, O₂, N₂, C₂H₆, C₂H₈, C₃H₁₀, C₄H₈ in water and calibrate of chromatographic mixtures of these gases in gaseous argon at concentrations for each of the measured gases on the level of 0.5%.

4. Conclusion

1. The ultrasonic oscillations effect on the degradation of a water mixture and petroleum turbine oil, organic acids (acetic acid formic acid and oxalic acid) or with monoethanolamine was determined. Degradation products are the following gases H₂, CO, CO₂, CH₄, C₂H₂, C₂H₄, C₂H₆, C₂H₈, C₃H₆, C₃H₈, C₄H₁₀, C₄H₈, C₅H₁₀ and water steam in gaseous hydrogen has been developed. This made it possible to determine these components using a single gas chromatograph, which simplifies and reduces the cost of measurements.
5. These technical solutions enable to ensure and increase the operation reliability of the turbine generator with hydrogen cooling by the monitoring of dissolved gases in the water cooling of hydrogen-water cooling system using ethanolamine and the monitoring water steam in the cooling hydrogen of TG of TBB-type.

References

УДОСКОНАЛЕННЯ МЕТОДІВ КОНТРОЛЮ ГАЗІВ У ВОДІ СИСТЕМИ ВОДНЕВО-ВОДНОГО ОХОЛОДЖЕННЯ ТУРБОГЕНЕРАТОРА ЕЛЕКТРОСТАНЦІЇ

С.В. Зайцев1, А.Ю. Тихомиров1, В.В. Чиченін1, В.П. Кишневський1

1 Державний університет «Одеська політехніка », email: sdjaved@ukr.net

Актуальність дослідження полягає у забезпеченні та підвищенні надійності експлуатації турбогенератора з системою воднево-водного охолодження. Метою дослідження є забезпечення надійності експлуатації турбогенератора з водневим охолодженням за рахунок контролю вмісту розчинених газів у воді системи воднево-водного охолодження із моноетаноламіновим (C2H7NO) водно-хімічним режимом та пару води в охолоджувачі водні турбогенератора. Завданнями дослідження є визначення впливу ультразвукових коливань на деградацію суміші води із турбінною олівою, органічними кислотами ( оцтовою – C2H4O2, мурашиною – CH2O2, щавлевою – C2H2O4) або із моноетаноламіном; визначення значень коефіцієнтів розподілу для розчинених газів H2, O2, N2, CO, CH4, C2H2, C2H4, C2H6, C3H6, C3H8 у суміші «розчинений газ – суміш «вода +моноетаноламін» – екстрагент argon (Ar)»; розробка принципової структурної схеми багатоканального газового хроматографу для визначення у воді розчинених газів та пару води у водні. При визначенні впливу ультразвукових коливань на деградацію суміші води із нафтовою турбінною олівою, органічними кислотами або із моноетаноламіном, продуктами деградації є гази H2, CO, CO2, CH4, C2H2, C2H4, C2H6. При визначенні коефіцієнтів розподілу Kі для розчинених газів в суміші «розчинений газ – суміш «вода +моноетаноламін» – екстрагент Ar» значення Kі при концентрації моноетаноламіну 1 г/дм3 близькі для аналогічних значень у дистильований воді. Розроблена принципова структурна схема 4-х каналного газового хроматографу для визначення у воді розчинених газів та пару води у водні дозволяє визначати вміст розчинених газів у воді та пару води у водні із залученням одного газового хроматографу із детектором за теплопровідністю, метанатором, полум’яно-іонізаційним детектором, газом-носієм аргоном та допоміжними газами воднем і повітрям.

Ключові слова: кавітация, хроматографія, гази, водень, моноетаноламін, турбінний генератор, вода.