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IDENTIFYING THE FEATURES IN HISTOGRAMS OF INCREMENTS IN HAZARDOUS PARAMETERS OF THE GAS ENVIRONMENT AT THE IGNITION OF MATERIALS IN UNHERMETIC PREMISES

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The object of this study is the histograms of increments in hazardous parameters of the gas environment in a leaky room in the absence and presence of fires of materials. The task of early detection of fires of materials in rooms was addressed. A methodology for determining the histograms of increments of arbitrary hazardous parameters based on samples of arbitrary size from controlled parameters was substantiated. A laboratory experiment was performed to identify the features of the histograms of increments of carbon monoxide concentration, specific optical density of smoke and temperature of the gas environment at intervals of reliable absence and occurrence of fires of alcohol, paper, wood, and textiles. The results indicate that hazardous parameters change over time non-stationarily and are of a complex nature. It was found that for the concentration of carbon monoxide, the specific optical density of smoke and the temperature of the gas medium in the interval of alcohol ignition, the number of modes of the histograms of increments is 9, 8, and 4, and the spread is 0–(+0.3), –0.07–(+0.09), and 0–(+0.32), respectively. When paper ignites, the histograms of increments of hazardous parameters have 10, 3, and 4 modes and the spread of increments is –0.06–(+0.21), ±(0.02), and –0.16–(+0.32), respectively. When wood ignites, the shape of the histogram of increments for the concentration of carbon monoxide is characterized by 4 modes and the spread is 0–(+0.09). The shape of the histograms of increments of the specific optical density of smoke and the temperature of the gas medium during the ignition of wood does not change significantly. The shape of the histogram of the increments of the carbon monoxide concentration during textile ignition is characterized by 3 modes and a spread of ±0.03, and the temperature – by two modes and a spread of 0–(+0.16). These features of the histograms could be used in practice as a sign of early detection of fires for their prompt extinguishing and prevention of fire evolution

Keywords: histogram of increments, ignition of materials, hazardous parameters, gas environment, fire in the room

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1. Introduction

The stable development of the economy and society is connected with the guaranteed provision of safe functioning of objects under the conditions of various threats. Under peaceful conditions, fires should be considered the source of the greatest threats. Fires lead to human casualties, destruction of property, and damage to objects [1].

Fires at energy facilities are particularly dangerous [2]. Combustion products and fire-extinguishing substances have a negative impact on the environment, leading to pollution of atmospheric air, soils, and water bodies. World statistics show that the majority of fires occur at residential, public, and industrial facilities [3]. At the same time, the number of victims as a result of fires in residential buildings is about 80 %. In this regard, the reduction of the threat of fires in the premises becomes especially relevant. Any fire occurs due to the ignition () of the material. In this regard, timely identification of materials ignition (II) is one of the urgent problems for reducing the threat of fires in premises.

2. Literature review and problem statement

Work [4] reports the results of research on II based on the application of video technologies. It is shown that the II is possible based on the analysis and comparison of flame images. However, the problem of II remains unsolved in the absence of a flame characteristic of burning materials. In addition, it is noted in [5] that the effectiveness of II based on video images significantly depends on the degree of shading of materials with foreign objects in the room and can decrease by 50–80 %. At the same time, the presence of various interfering factors that appear on the images can lead to an increase in the probability of a false II up to 20 % or more. In general, the use of video technologies of II is a complex and too expensive method that requires significant computing and intellectual resources for implementation. This significantly limits the realizable operational efficiency and reliability of II based on video technologies in difficult conditions. An option to overcome the specified limitations under real conditions may be the technology of current control over OP GS in the premises [6]. It is shown that the controlled values of OP GS in the room contain all the information necessary for prompt and reliable detection of materials. However, it is not easy to get such information since it is hidden and turns out to be completely individual for each room and type of material I. Therefore, an important direction of ensuring an operational and reliable II on the basis of control of OP GS should be considered the study of ways to reveal such information when using various materials in the premises. In [6] it is proposed to reveal hidden information on the basis of first- and second-order statistics of OP GS. However, such statistics contain complete information only in the case of Gaussian distributed OP GS. So, for example, the study of the real process of burning wood is characterized by significant unevenness and complexity of the process of releasing heat into the environment. Such a process is significantly different from the Gaussian process [7]. At the same time, the statistics of temperature changes and other OPs of the HS remain unexplored. This increases the practical interest in the study of OP GS statistics not only at the stage of advanced combustion but also at the stage of materials I (before the appearance of an open flame). In [8], it is proposed to use several sensors of the same type and a neural network to reveal hidden information about the controlled values of OP GS. However, the application of a neural network turns out to be difficult and expensive since it requires preliminary training of the network for specific conditions. This significantly limits the implementation efficiency of such a technology of II. At the same time, in practice, the neural network analyzes the OP GS values taking into account the presence of a trend caused by the initial conditions of I, which are unknown and change in the premises. Under these conditions, it is expedient to preliminarily exclude the trend by corresponding transformation of the controlled absolute values. However, the statistics of transformed controllable absolute values of OP GS in [8] are not considered or studied. A variant of overcoming the shortcomings of the above-mentioned technologies is the study of the statistical features of the controlled OPs of GS with materials in the premises. In [9], the II technology is investigated based on the use of various types of sensors and the application of fuzzy logic processing methods for controlled OPs. However, the obtained results are limited to the consideration of first- and second-order statistics. The disadvantage of such an approach is the complexity of implementing methods and algorithms of fuzzy logic, which require a large amount of a priori data, which are usually unknown and change during the control of the values of OP GS. Other statistics of the controlled OPs of GS or their first increments are not considered at the same time. An important direction of ensuring the operational efficiency of the materials in the premises should be considered the use of forecasting on the basis of data on the controlled OPs of GS with the help of traditional sensors. Paper [10] reports a study in this area based on the Brownian model. However, the model used does not take into account the individual dynamics of increments of controlled values of OP GS and is limited only to first-order statistics. This significantly limits the predictive capabilities of real I in the premises.

Thus, two main approaches to solving the problem of the use of materials in the premises are reviewed. The first approach involves the replacement of traditional OP GS sensors with expensive video image sensors and the use of complex image processing algorithms based on machine learning and pattern recognition methods. At the same time, a database with a large volume of reference images, places to store this database, and modern telecommunications technologies are required to exchange information with servers. All this significantly increases the cost of the II process, leads to the loss of operational efficiency and autonomy of II in real premises. In addition, this approach depends significantly on the reliability of network Internet technologies. The second approach involves the use of traditional inexpensive sensors for monitoring the values of OP GS in the premises and the use of modern methods of statistical processing. However, the development of this approach is held back by the insufficient study of the peculiarities of the statistics of the controlled values of OP GS. This is explained by a large variety of conditions and types of materials I, as well as hidden complex mechanisms of interaction of material I with controlled OPs of GS. At the same time, it is known that the most complete statistical information about the values of OP GS is contained in histograms. However, under real conditions, controlled OP values are influenced not only by the material but also by various destabilizing trend and random factors. To exclude such factors, you can use the first increments of controlled OP values. However, the peculiarities of the histograms of incremental controlled values of OP GS at different sampling intervals remain unexplored. Therefore, the study of features of the sample histograms of the first increments of the controlled values of OP GS should be considered an unsolved part of the II problem in the case of the reliable absence and presence of materials I in the premises.

3. The aim and objectives of the study

The purpose of our work is to reveal peculiarities in the histograms of incremented controllable hazardous parameters of the gas environment, belonging to the intervals of the reliable absence and occurrence of ignition of materials in the room. This will allow for the early detection of burning materials in order to prevent fires.

To achieve the goal of the work, the following tasks are set:

– to justify the methodology for determining the histogram increments for the controlled hazardous parameters of the gas environment during the ignition of materials;

– to experimentally determine the histograms of increments of hazardous parameters of the gas medium belonging to the intervals of the reliable absence and ignition of the test materials in the laboratory chamber.

4. The study materials and methods

4. 1. Studied materials

The object of our research was histograms of incremental samples of the dynamics of the main OPs in the presence and absence of test materials (TM) in the laboratory chamber. The working hypothesis assumed that the histograms of samples incremented by the current dynamics of OP GS at specified intervals had distinctive features. The choice of test materials (TM) for conducting experimental studies was determined by the prevalence and significant difference in the properties of such materials. The main parameters that significantly affect the amount and intensity of OP GS with materials I include the combustion speed (V) and the lower heat of combustion (Q) [11]. In this regard, we used the following TMs:

– alcohol (technical, V=0.037 kg/(m^2·s), Q=27.2 MJ/kg);

– paper (crumpled standard A4 sheet, V=0.008 kg/(m^2·s), Q=13.4 MJ/kg);

– wood (pine chips, V=0.014 kg/(m^2·s), Q=13.8 MJ/kg);

– textile (fragment staple fiber, V=0.0067 kg/(m^2·s), Q=12.6 MJ/kg).

Temperature, specific optical density of smoke (SODS) and concentration of CO were investigated parameters [12]. A gas piezo igniter was used as a source of forced ignition. For all TMs, the same round burning site with an area of 38 cm^2 was used.

4. 2. Research methods

As a research method, we used the method for determining histograms, adopted in mathematical statistics, but applied to the current values of the incremental OP GS, controlled at two known intervals of time (absence and presence of I). An experimental laboratory chamber simulating a leaky room of reduced dimensions (0.81*0.81*0.80 m) was used for the study of OP GS with materials I. The model site was located in the lower part of the laboratory chamber. It was assumed that any of the material changes the physical parameters of the material and HS. At the initial stage, a convective flow appears above the site of I, which carries combustion products and heat to the upper part of the room. As a result of this transfer, the parameters of HS under the ceiling change [13]. Therefore, control of the studied OP GS was carried out by sensors located in the upper region of the laboratory chamber above the site of I. The temperature of HS in the chamber was controlled by the DS18B20 sensor (°C), the SODS HS by the IPD-3.2 sensor (dB/m), and the CO concentration by the Discovery sensor (ppm) [14]. The sensor polling interval was 0.1 s. The study of the features of the sample histograms of incremental OP GS was carried out for two specified time intervals containing 100 discrete values each [15]. During the research, the first 100 values belonged to the interval of the reliable absence of I, and the second to the reliable presence of I. The burning of TM in the laboratory chamber was carried out approximately in the first half of the second interval. The values of OP GS from the sensors at specified intervals were stored in the computer's memory through a special coupling device. After each measurement, the chamber was naturally ventilated for 10 minutes. The current value of the incremental OP was determined by subtracting its previous value from the current value of OP.

5. Investigating histograms of increments of hazardous parameters of the gas environment during ignition of materials

5. 1. Justification of the methodology for determining the histograms of increments for monitored hazardous parameters

The study of the spectra of OP GS in the intervals of absence and presence of materials I is considered in [16]. It was found that the differences in the spectra are more pronounced for the high-frequency region. In [17] it was shown that the bispectra of the OP GS, unlike traditional spectra, are sensitive to the nonlinearity of the OP dynamics. The study of the bicoherence of the OP in the specified intervals is reported in [18]. However, the results are limited to studies only in the frequency domain. Traditionally, control over OP GS is carried out in the time domain. However, under conditions of non-stationarity and uncertainty of real changes in the OP GS, it seems problematic to correctly implement the transition from the time domain to the frequency domain. The use of histograms should be considered more constructive in this case.

Traditionally, a histogram is a graph that approximates the sample density of distribution of random sample data. When constructing a histogram, the range of values of a random variable is usually divided into a given number of segments, and then the number of times the values of the random variable fall into each segment is counted. The study of the features of sample histograms of OP GS at intervals of reliable absence and presence of materials I in a laboratory chamber was performed in [19]. However, these studies are limited to the concentration of CO in GS taking into account the existing trend, and do not allow us to identify the features of the dynamics caused directly by materials I. Therefore, it is more appropriate to use the current increments of OP GS and study the corresponding sample histograms. We shall assume that an arbitrary OP is monitored on the time interval $[0, T]$ and is described by the implementation $x(t)$, $t\in[0,T]$. Discrete polling of the corresponding monitoring sensor at equal intervals of time transforms the original implementation $x(t)$ into the corresponding sample $(x_0, x_1, x_2,..., x_n)$. Here the index n defines the sample size $(x_0, x_1, x_2,..., x_n)$ and corresponds to the end of the control interval $[0,T]$. In the general case, the sample $(x_0, x_1, x_2,..., x_n)$ may belong to both the absence of I and its presence, or it may be composite, in which one part of the sample belongs to the absence of I, and the other to the beginning of the material I. Further, we shall consider the case when the sample $(x_0, x_1, x_2,..., x_n)$ is composite. This case reflects the objectives of the study to the greatest extent.

Let a sample of smaller size p be selected from a composite sample, starting with an arbitrary discrete value. This means that the selected sample will be defined as $(x_i, x_{i+1}, x_{i+2},..., x_{i+p})$, where i is the starting number of the selected sample. For the selected sample, i and p must satisfy the conditions: $0\leq i$ и $(p+i)\leq n$. It is known that for a sample of any size, the most complete statistical characteristic is its histogram [20]. However, the histogram, being a visual display of the statistical features of the sample, does not find such a wide application in practice compared to sample moments, which are approximate numerical characteristics of histograms [19, 21]. For the selected sample $(x_i, x_{i+1}, x_{i+2},..., x_{i+p})$, we define the corresponding sample of the first increments of the form: $(y_i, y_{i+1}, y_{i+2},..., y_{i+p})=$ $=(x_i-x_{i-1}, x_{i+1}-x_i, x_{i+2}-x_{i+1},..., x_{i+p}-x_{i+p-1})$. We represent the sample of increments $(y_i, y_{i+1}, y_{i+2},..., y_{i+p})$ as a vector $\mathbf{V(i,p)}=(y_i, y_{i+1}, y_{i+2},..., y_{i+p})^T$. Then, to determine the histogram of the vector $\mathbf{V(i,p)}$ we use the special function histogram histogram**(int,V(i,p))** in the Mathcad environment (USA) [22]. Here, **int** is the number of intervals into which the entire range of data of the vector **V(i,p)** is divided. In this case, the histogram**(int, V(i,p))** function returns 2 columns. The first column defines the average values for each of the **int** intervals, and the second column defines the number of hits of the vector **V(i,p)** data in each of the corresponding **int** intervals. Taking this into account, the histogram for an arbitrary selected sample of the first increments of the vector **V(i,p)** data will be determined by the matrix:

$$His=\text{histogram}(\mathbf{int}, \mathbf{V(i,p)}), \quad (1)$$

where His is a matrix in which the first column $His^{\langle 0\rangle}$ defines the average values of each of the **int** intervals, and the second column $His^{\langle 1\rangle}$ defines the number of times the data contained in the vector **V(i,p)** hits each of the corresponding **int**. Usually, to display histograms, the **int** values are plotted along the abscissa axis, and the corresponding $His^{\langle 1\rangle}$ values are plotted along the ordinate axis. Function (1) of the Mathcad computing environment allows you to define histograms for arbitrary selected samples of the first increments of data **V(i,p)**. By specifying the start i and the size p based on (1), one can define histograms for arbitrary selected samples of the first increments of data. Therefore, to study the statistical features of the histograms of the first increments in the dynamics of OP GS in the reliable absence and appearance of I based on (1), it is necessary to determine the specific values of the start i and the size p for two selected samples corresponding to the intervals of the reliable absence and appearance of I. It should be taken into account that for the optimal display of statistical features in the histograms of data **V(i,p)**, the number of necessary data intervals is determined by the value $\sqrt{p}$.

Thus, the use of relation (1) for a given number i of the beginning and a given size p allows us to isolate the part of the dynamics of increments of an arbitrary OP GS of interest and determine the corresponding histogram for this part of the dynamics. By specifying characteristic parts for the dynamics of increments and determining the corresponding histograms for them, we can identify their statistical features. If the studied parts of the increments of the dynamics of OP GS correspond to the reliable absence and presence of I, then information about the identified features of the specified histograms can be used for early II of materials.

5. 2. Experimental determination of histograms for the increments of controlled hazardous parameters

To determine the histograms of increments in the dynamics of OP GS, the absolute values of the concentration of CO, SODS, and the temperature of GS at I of alcohol, paper, wood, and textile in the laboratory chamber were monitored by appropriate sensors. The monitoring was carried out discretely in time with an interval of 0.1 s. The corresponding discrete moments of monitoring the values of OP GS from the moment of the beginning of the experiment were determined by the values i=0, 1, 2, ... The increments of OP GS at moment i were determined by calculating the difference in values between the i and i–1 values. However, for the case of i=0, it was assumed that the value of OP GS at moment i–1 was equal to the value of OP GS at moment i=0. To achieve the goal of the study, two samples of the same size p=100 were selected from the dynamics of the increments of OP GS in the reliable absence and presence of I. As a result of the laboratory experiment, sample histograms (1) were determined for the increments in the dynamics of the concentration of CO, SODS, and the temperature of GS at I of alcohol, paper, wood, and textile using samples of the increments in OP GS at the specified intervals. In this case, for the beginning of the first sample, the value i=100 (from the beginning of the moment i=0 of OP control), and for the second, i=200. The choice of such values of i ensured that the first sample belonged to the reliable absence of I, and the second to the reliable appearance of I of materials in the laboratory chamber. Forced ignition of materials in the chamber during the experiment was carried out approximately between i=210 and i=240 discrete values. This ensured that the second sample belonged to the general population of the reliable presence of I. Since the sample size in the experiment was set equal to 100 values, then for the optimal display of the static features of the studied increments of OP GS in the histogram, the number **int** was chosen equal to 10.

Fig. 1 shows experimental histograms (1) of increments in the concentration of CO, SODS, and GS temperature in the reliable absence and presence of alcohol I.

Fig. 2–4 show similar histograms of increments of the considered OP GS in the reliable absence and presence of I of paper, wood, and textiles, respectively.

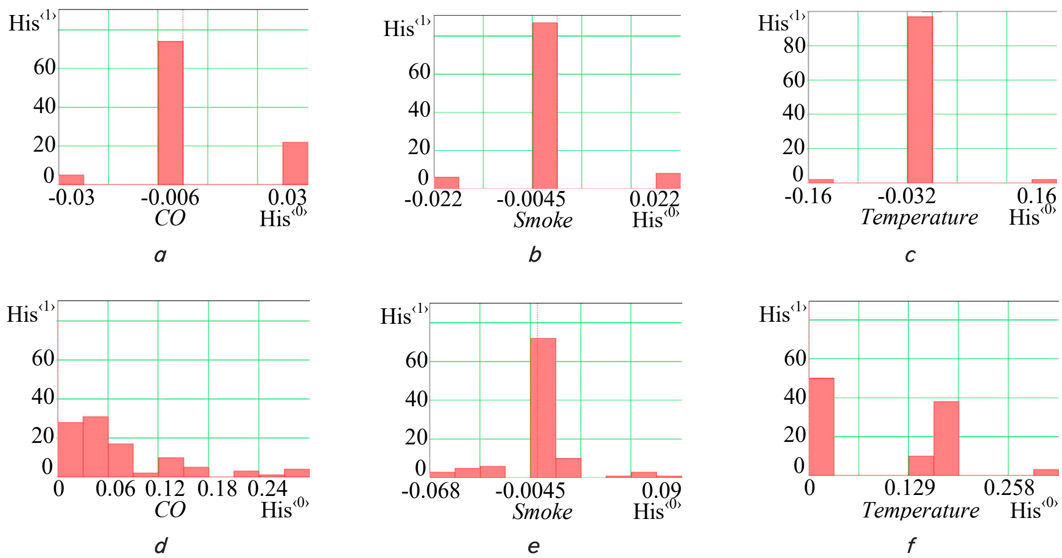

Fig. 1. Histograms of increments in CO concentration, specific optical density of smoke, and temperature of the gas environment in the absence and presence of alcohol ignition:
a–*c* – absence of ignition; *d*–*f* – presence of ignition

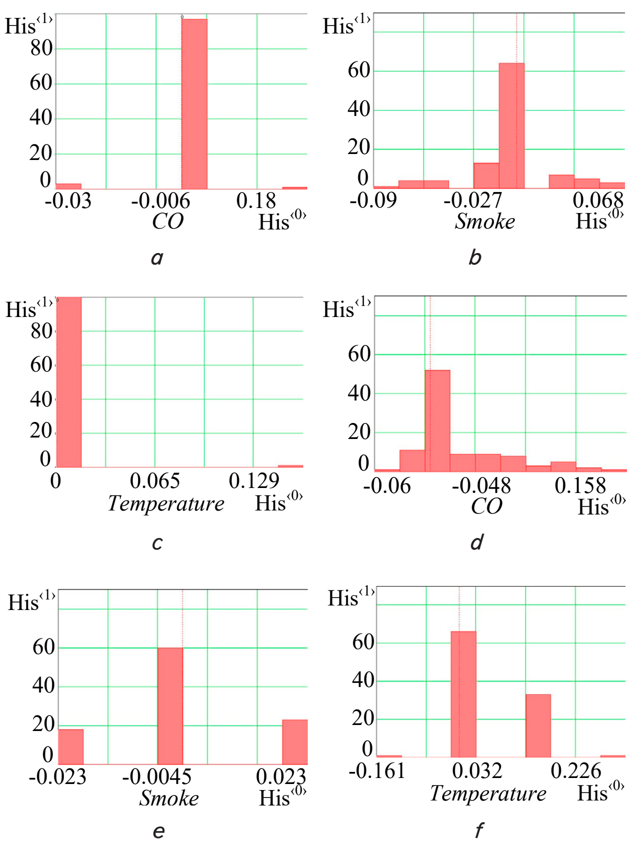

Fig. 2. Experimental histograms of increments in CO concentration, specific optical density of smoke, and temperature of the gas environment in the absence and presence of paper ignition:
a–*c* – absence of ignition; *d*–*f* – presence of ignition

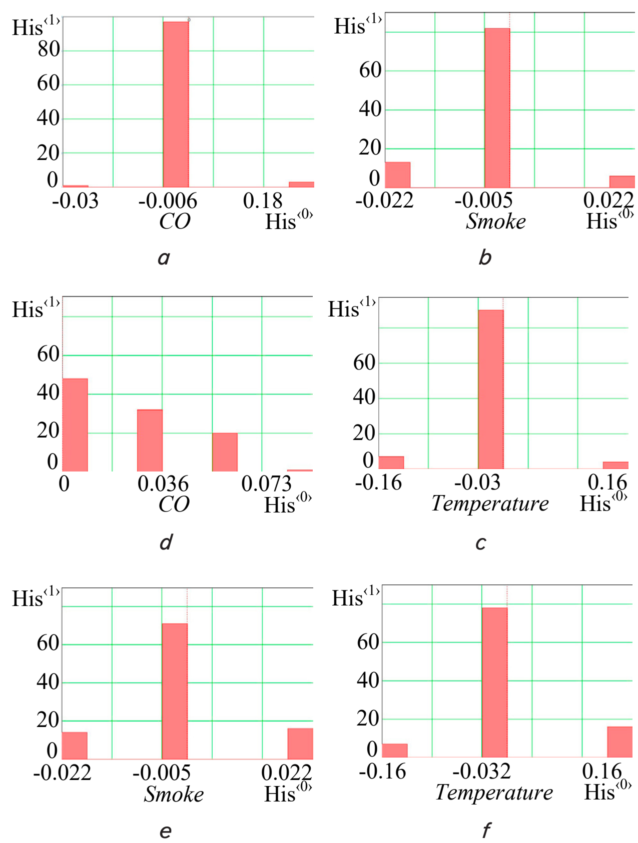

Fig. 3. Experimental histograms of increments in CO concentration, specific optical density of smoke, and temperature of the gas environment in the absence and presence of wood ignition:
a–*c* – absence of ignition; *d*–*f* – presence of ignition

In Fig. 1–4, the histograms of increments are shown for 10 intervals of values of the controlled OP GS and the number of increment values in each of the intervals. The width of each interval is determined by the specific absolute value of the minimum and maximum increment values of the corresponding OP. The numerical values of increments of CO concentration, optical density of smoke, and temperature on the abscissa axes are given in ppm, dB/m, and °C over an interval of 0.1 s, respectively.

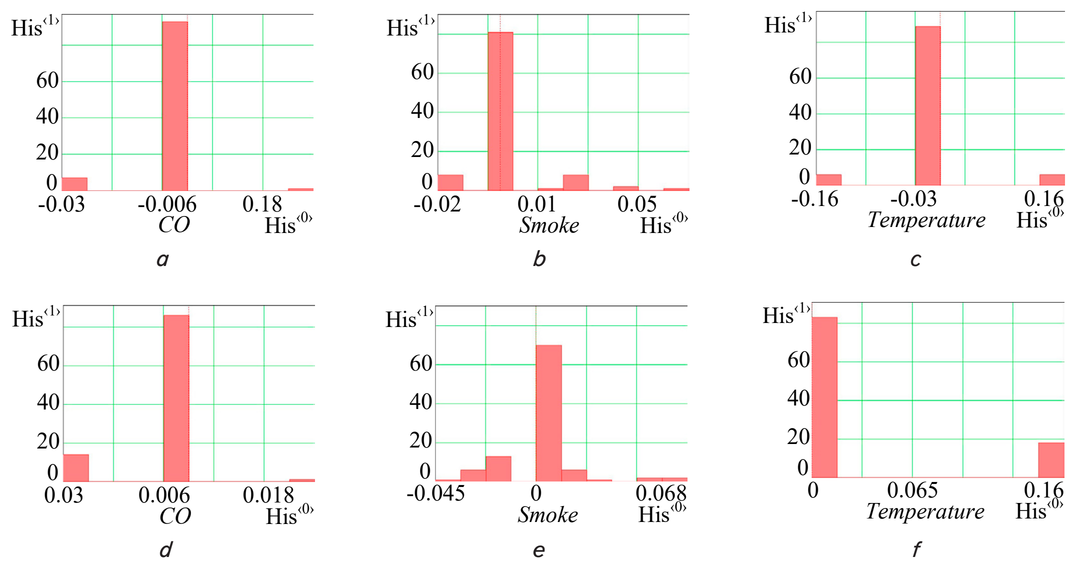

Fig. 4. Experimental histograms of increments in CO concentration, specific optical density of smoke, and temperature of the gas environment in the absence and presence of textile ignition: *a*–*c* — absence of ignition; *d*–*f* — presence of ignition

6. Discussion of features in the histograms of increments for the controlled hazardous parameters of the gas environment

From the analysis of the obtained histograms in Fig. 1–4 it follows that, in the general case, the dynamics of the controlled OP GS is non-stationary and is characterized by increments of different magnitude (speed) and direction (speed sign). This confirms that in the absence and occurrence of materials I, the mechanisms of the formation of OP GS are quite individual, complex, and usually hidden. The study of the histograms of the first increments (rates of change) of OP GS allows us to identify hidden complex mechanisms without taking into account the influence of the trend. Histograms allow us to evaluate the main differences in the distributions of the dynamics of increments, such as the shape, center, and spread.

The experimental histograms of increments in the concentration of CO, SODS, and temperature of GS in the absence of I of alcohol, shown in Fig. 1, *a*–*c*, have a similar shape with a clearly expressed central symmetry, characterized by the concentration of increment values in three intervals. In this case, the mode of the histograms of increments belongs to small negative and zero values. However, the histograms of increments for the concentration of CO, SODS, and temperature of GS are characterized by different ranges of values ±0.03, ±0.02, and ±0.16, respectively. With the occurrence of I of alcohol, the shape of the histograms of increments of OP GS loses central symmetry and becomes multimodal (Fig. 1, *d*–*f*). The loss of central symmetry is manifested in an increase in the total number of intervals of non-zero increment values. For the concentration of CO, SODS, and temperature of GS, the number of these intervals is 9, 8, and 4, respectively. In this case, the range of the increment values for the CO concentration, SODS, and GS temperature (Fig. 1, *d*–*f*) is not the same and is 0–(+0.3), –0.07–(+0.09), and 0–(+0.32), respectively. Consequently, the above differences in the increment histograms can be used for the operational II of alcohol. The increment histograms in the absence of I of paper, shown in Fig. 2, *a*–*c*, have different shapes with the absence of an obvious central symmetry characterized by the concentration of increment values in three intervals. In this case, the increment histograms for the CO concentration, SODS, and GS temperature in the absence of paper I are characterized by a spread of values of ±0.03, –0.09–(+0.07), and 0–(+0.16), respectively. This result can be explained by the residual phenomena of GS OP after alcohol I and the limited ventilation time of the chamber. In the case of paper I, the histograms of increments for the CO concentration, SODS, and GS temperature in the chamber have different multimodal shapes (Fig. 2, *d*–*f*), characterized by different values of the spread for increments of –0.06–(+0.21), ±0.02, –0.16–(+0.32), respectively. In this case, the number of intervals of increment values for the histograms is 10, 3, and 4, respectively. The noted features of the histograms can be used for the operational II of paper. The histograms of increments for the CO concentration, SODS, and GS temperature in the absence of wood I, shown in Fig. 3, *a*–*c*, have a similar shape with a pronounced central symmetry, characterized by the concentration of increment values in three intervals. In this case, the mode of the histograms of increments corresponds to small negative and zero values. However, the histograms of the increments of OP GS have different spreads of values of ±0.03, ±0.02, and ±0.16, respectively. At I of wood, the shape of the histogram of increments loses its central symmetry and becomes multimodal only for increments of the concentration of CO GS (Fig. 3, *d*). In this case, the number of intervals with non-zero values of increments is 4, and the spread becomes equal to 0–(+0.09_. The shape of the histograms of increments for SODS and the temperature of GS at I of wood does not change significantly (Fig. 3, *e*–*f*). Therefore, for wood II, only the noted differences in the histograms of increments for the concentration of CO GS can be used. In the case of textile II, the shape of the histograms of increments in Fig. 4, *a*, *d* for the concentration of CO has insignificant changes and is characterized by the same spread of increments of ±0.03. This means that using the difference in the histograms of increments for the concentration of CO GS for textile II turns out to be ineffective. The histograms of increments in Fig. 4, *b*, *e* for SODS GS have a multimodal shape and are characterized by a different number of intervals of non-zero increment values (6 and 8) and a spread of increments of −0.02–(+0.07) and −0.045–(+0.07), respectively. Therefore, using the difference in the histograms of increments for SODS GS for textile II turns out to be more effective than for the concentration of CO. The histograms of increments for the GS temperature (Fig. 4, *c*, *f*) indicate that when textiles are I, there are changes in the shape of the histograms and the spread of ±0.16 and 0–(+0.16), respectively. The indicated differences in the histograms of temperature increments can be used for textile II.

Thus, our experimental data in Fig. 1–4 indicate the specified differences in the shapes of histograms of increments for the concentration of CO, SODS, and the temperature of GS in the reliable absence and presence of materials I. The practical significance of the information obtained is that this information can be used for early detection of materials in rooms for their prompt elimination in order to prevent fires, loss of life, and destruction of objects [23]. The disadvantages of our study include the fact that the histograms of increments, while having the most complete description of the features of the monitored OP GS, are a graphical form of displaying the features. In addition, to determine the histograms, it is necessary to know all the values of the monitored OP GS in the corresponding observation interval. For this reason, the histograms of OP increments cannot be used in the current time of OP monitoring. In this regard, it seems more constructive to use not the histograms of increments but their various sample statistics [24]. Therefore, this study can be advanced by investigating various statistics of OP GS increments.

7. Conclusions

1. We have substantiated the methodology for determining the histogram of increments for arbitrary controlled hazardous parameters of the gas environment during ignition of various materials. The methodology makes it possible to determine the histograms of increments based on samples of arbitrary size from the results of monitoring OP GS. Based on this methodology, it is possible to study the features of sample histograms of increments of hazardous parameters of the gas environment, both in the interval of absence and in the interval of ignition of materials. Such features of histograms can be used in practice as a sign of early detection of fire for its prompt extinguishing and prevention of fire with losses.

2. We have experimentally determined histograms of increments of carbon monoxide concentration, specific optical density of smoke, and temperature of gas environment on intervals of reliable absence and occurrence of ignitions of test materials in the form of alcohol and textile. Identification of the features of such histograms, which indicate that the change of the studied hazardous parameters of the gas environment on the interval from 0 to 200 readings is non-stationary and has a complex nature. At the same time, the resulting histograms differ in the shape and spread of the increment values, which depend on the type of test material of ignition and the controlled hazardous parameter of the gas environment in the chamber. The revealed features of histograms in the form of the modality level and the corresponding spread of the increment values on intervals of absence and presence of ignitions could be used for prompt detection of ignition of materials in premises.

Conflicts of interest

The authors declare that they have no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study, as well as the results reported in this paper.

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Data availability

The data will be provided upon reasonable request.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

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