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CONTENT

TECHNICAL SCIENCES

SUBSTANTIATION OF THE CORRECTION FACTOR FOR THE INFLUENCE OF WIND SPEED TO ASSESS THE SPREAD OF FIRE TO NEIGHBORING BUILDINGS

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Abstract

In the article, the results of a numerical experiment using mathematical models of computational gas-hydrodynamics reveal the dependence of the time of fire in a neighboring building on wind speed, distance between buildings and fire load, when the building irradiated with a fire torch is located on the windward side. The authors identified the largest and smallest indicators of significant factors. In the course of the study, the authors built a mathematical model that describes the dependence of wind on the time of a fire in a neighboring building. The corresponding constants for the numerical regression equation are determined. To determine the constants of the numerical regression equation, 8 numerical experiments were performed according to the planning matrix of the complete factorial experiment. Due to the constructed regression dependence, a corresponding surface of the distance dependence on the most influential factors was created. Based on the results, an appropriate data table was developed for further calculations of fire effects on neighboring buildings under wind conditions, and by correlating the obtained and existing data, a correction factor for wind speed effects was derived to estimate the spread of fire to a neighboring building.

Keywords: correction factor, wind speed, numerical experiment, neighboring building.

1 Introduction

In Ukraine, more than 70,000 fires occur annually, leading to significant damage, destruction of buildings, structures, technological equipment, property, and death of people and animals. Every fourth fire in Ukraine spread to neighboring buildings and structures, technological equipment and objects of the natural ecosystem as a result of thermal radiation, followed by ignition.

The analyzed works [1-16] do not fully investigate the influence of environmental conditions, including wind, on the value of surface heat flux density and surface temperature of neighboring building in relation to the fire, and the results of research by various scientists have inconsistent data. Also insufficiently studied are the issues of changes in the thermal effect of the fire depending on the direction and speed of the wind in relation to the combustion center and the object irradiated with heat from the fire torch.

In this regard, the discovery of patterns of changes in the thermal impact of fire depending on wind speed and direction is an important scientific problem, the solution of which will create prerequisites for improving the calculation method for predicting the spread of fire to neighboring objects in wind conditions.

2 The purpose and objectives of the study

The aim of the work is to substantiate the correction factor for the influence of wind speed to estimate the spread of fire to neighboring buildings by conducting a full factorial experiment.

To achieve this goal:

- the choice of the most significant factors of influence and their range is carried out; affecting the processes of thermal radiation;
- using the results of experimental studies to build a regression model;
- on the basis of experimental studies to determine the coefficients of regression;
- create data tables to calculate the impact of fire on neighboring buildings in windy conditions;
- obtain the correction factor for the thermal impact of fire on neighboring buildings in wind conditions as a result of the ratio of received and existing data.

3. Presenting main material

The obtained simulation results and graphical data confirm the obtained experimental data on the presence of wind on the thermal radiation of a neighboring building from a fire torch in the case when the object is located on the windward side of the heat source (fire).

This effect can be described by the corresponding coefficient of wind influence.

A complete factor pollination experiment was performed to describe the wind coefficient.

The following are selected as criteria that significantly affect the thermal processes during a fire:

the duration of thermal exposure, fire load and wind speed. The range of these parameters is shown in table 1.

Table 1

Intervals of parameters in the experiment, selected as factors

Wind speed v, (m / s)		The value of the fire load Q, MJ / m^2		The duration of thermal irradiation t, min.	
The smallest value, v	The largest value, v+	The smallest value Q	The largest value, Q +	The smallest value, t	The largest value, t+
2,5	10	20	1800	10	150

The defined intervals show the smallest and largest values of the parameters in the experiment, which are selected as factors.

For further analysis of the obtained data, a regression dependence was used, which has the form of equation (1)

$$y = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_1x_2 + b_5x_1x_3 + b_6x_2x_3 + b_7x_1x_2x_3, \quad (1)$$

where x_1, x_2, x_3 - parameters that take into account the selected factors, which are shown in table 1;

b_0, b_1, b_2, b_3, b_4, b_5, b_6, b_7 are constants of the numerical regression equation.

To determine the constants of the numerical regression equation according to formula (1), it is necessary to conduct 8 numerical experiments [17] according to the planning matrix compiled for this purpose, which is written in the form of table 2.

Table 2

General matrix for planning a complete factorial experiment to build a mathematical model.

Experimental number	x_1	x_2	x_3	x_1 x_2	x_1 x_3	x_2 x_3	x_1 x_2 x_3
1	+	+	+	+	+	+	+
2	-	+	+	-	-	+	-
3	+	-	+	-	+	-	-
4	-	-	+	+	-	-	+
5	+	+	-	+	-	-	-
6	-	+	-	-	+	-	+
7	+	-	-	-	-	+	+
8	-	-	-	+	+	+	-

Using a computer model, the values of temperatures from the thermal effects of fire on neighboring buildings in wind conditions were calculated, which are shown in table 3.

Table 3

Estimated values of the temperature of thermal impact on neighboring buildings under the influence of wind

Distance from the source of thermal radiation, m	Estimated value of the temperature of the thermal impact of the fire on neighboring buildings in conditions of wind exposure according to table 2							
	1	2	3	4	5	6	7	8
18	206	118	148	24	42	24	38	22
15	232	171	206	27	64	29	51	26
10	251	203	230	51	76	40	72	29
8	296	218	252	74	83	63	80	41
6	303	241	281	101	98	87	96	69
4	367	328	342	205	196	191	206	90
2	518	426	501	381	268	208	292	152

The criterion for estimating the thermal impact of a fire torch on a neighboring object is the distance at which the thermal impact reaches the values of autoignition of materials (in this case, pine wood). The values of such distances are given in table 4.

Table 4

Distances from the thermal radiation cell obtained in the conditions of a complete factorial experiment according to the accepted planning matrix

Experiment number	1	2	3	4	5	6	7	8
Distance from the source of thermal radiation	18,7	9,9	15,2	4,1	3,8	2,5	4,1	1

The constants of the numerical regression equation (1) can be determined using formulas (2) given in [4,17]:

$$b_0 = \frac{1}{N}\sum_{i=1}^{N} y_i;\ b_1 = \frac{1}{N}\sum_{i=1}^{N} x_1 y_i;$$

$$b_2 = \frac{1}{N}\sum_{i=1}^{N} x_2 y_i;$$

$$b_3 = \frac{1}{N}\sum_{i=1}^{N} x_3 y_i;$$

$$b_4 = \frac{1}{N}\sum_{i=1}^{N} x_1 x_2 y_i;$$

$$b_5 = \frac{1}{N}\sum_{i=1}^{N} x_1 x_3 y_i;$$

$$b_6 = \frac{1}{N}\sum_{i=1}^{N} x_2 x_3 y_i;$$

$$b_7 = \frac{1}{N}\sum_{i=1}^{N} x_1 x_2 x_3 y_i,$$

where N = 8 - the number of experimental situations according to the experimental plan; x_i is the value of the parameter according to the plan matrix, y_i - the value of the specified heat flux

According to the results of the calculations, the obtained constants of the numerical regression equation are given in tables 5.

Table 5

Constants of the numerical regression equation.

Coefficient	b_0,	b_1,	b_2,	b_3,	b_4	b_5	b_6	b_7
Value	7,41	3,1	1,31	4,6	-0,51	1,94	1,1	-0,06

Based on the results of the calculations, a data table was developed for further calculations of the impact of fire on neighboring buildings in the conditions of wind exposure, which is shown in table 6.

Table 6

Data of distances at which thermal influence reaches values of temperature of spontaneous combustion of materials

The value of the fire load q, MJ / m^2	Estimated distance, (m) depending on the duration of thermal irradiation (t, min.) And wind speed (v,m/s)					
	5 m/s			10 m/s		
	t, min.					
	>10	10÷60	>60	>10	10÷60	>60
to 100	27	28	32	28	29	34
from100 to 400	29	30	35	30	31	38
from 400 to 1500	32	35	40	33	36	45
from 1500	34	37	45	34	38	49

Obtaining the coefficient of thermal impact of fire on neighboring buildings in wind conditions is possible as the ratio of the data in table 6 to the data without wind exposure. The obtained coefficients for each experiment are shown in table 7.

Table 7

The coefficient of wind influence on the heat transfer process between the fire torch and the neighboring object.

The value of the fire load q, MJ / m^2	Coefficient of wind influence					
	5 m/s			10 m/s		
	t, min					
	>10	10÷60	>60	>10	10÷60	>60
to 100	1,06	1,04	1,02	1,1	1,08	1,08
from100 to 400	1,08	1,06	1,07	1,2	1,09	1,2
from 400 to 1500	1,07	1,07	1,03	1,1	1,1	1,2
from 1500	1,08	1,08	1,08	1,08	1,2	1,2

From the ratio of the determined coefficients we calculate the average value, which is α = 1.1.

Conclusion

According to the results of a numerical experiment using mathematical models of computational gas hydrodynamics, the dependence of the time of fire in a neighboring building on wind speed, distance between buildings and fire load, when the building irradiated with a fire torch is located on the windward side relative to the fire view:

$$y = 7{,}41 + 3{,}1x_1 + 1{,}31x_2 + 4{,}6x_3 - 0{,}51x_1x_2 + 1{,}94x_1x_3 + 1{,}1x_2x_3 - 0{,}06x_1x_2x_3$$

So, on the basis of the revealed regularities the influence of fire on the neighboring buildings taking into account wind is established that can be described in the form of the correction factor considering influence of wind which value makes $\alpha = 1{,}1$.

Proposals for improving the regulatory framework for the requirements and calculation method for forecasting the thermal impact of fire on neighboring buildings, taking into account the wind, namely amendments to DSTU 9058: 2020 "Fire safety. Determination of fire distances between objects by calculation methods. Substantive provisions".

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АНАЛИЗ ДИНАМИЧЕСКИХ ПАРАМЕТРОВ ПРИВОДОВ ПОДАЧИ СТАНКОВ С ЧПУ

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ANALYSIS OF DYNAMIC PARAMETERS OF FEED DRIVES FOR CNC MACHINES

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