# Computational study of bearing walls fire resistance tests efficiency using different combustion furnaces configurations

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**Abstract**. Imperfection of structure, metrological instruments and fuel and nozzle system control methods the conditions are created ensuring non-homogeneous distribution of temperatures throughout heated surfaces of tested structures and during their fire-resistance tests in combustion furnaces. The article contains results of numerical simulation of bearing walls fire resistance test performed using different configurations of combustion furnaces. Using computer-assisted gas and liquid flow simulating software temperature gradient for heated surfaces of bearing walls was created and temperature distribution for every minute of the computational experiment for each configuration was calculated. In temperature gradients 6000 to 7500 cells were located (depending on the particular configuration design), evenly distributed throughout the structure surfaces, containing temperature data in any moment during the computational experiment. As a result of processing of these data the value of temperature dispersion value was calculated. Difference between maximum and minimum temperatures on the surface of a reinforced concrete was also determined. Based on the curves representing temperature dispersion values at the surface of each of the simulated structures of the furnace chamber for every minute of the computational experiment the configuration with the most homogeneous temperature distribution throughout the heated surfaces of the bearing wall was defined, what allows reducing an error occurring due to temperature distribution non-homogeneity by heated surface structures during the fire resistance test.

## Problem statement

Whereas testing in combustion furnaces [1, 2] are carried out in the "standard" temperature mode, there arises a question concerning homogeneousness of a reinforced concrete structure heating depending on design and configuration of the combustion furnace used, since internal design of its chamber, layout of burners and combustion products exhausting holes affects homogeneousness of temperature distribution throughout the heated surface of vertical structures, in particular this refers to wall structures.

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## Analysis of recent achievements and publications

In works [3-5] a CFD FlowVision 2.5 software-assisted combustion furnace computer model creation and computational test process was described for a furnace used for real tests; during the process efficiency of heating process simulation for further use in studying of structural characteristics of combustion furnaces affect to their metrological characteristics is shown.

In accordance with the previous studies [3-5], imperfection of structure, metrological instruments and fuel and nozzle system control methods the conditions are created ensuring non-homogeneous distribution of temperatures throughout heated surfaces of tested structures and during their fire-resistance tests in combustion furnaces.

## Purpose

The existing scientific works contain no researches with regard to effect of non-homogeneous temperature distribution throughout heated surfaces of bearing walls on fire resistance test results adequacy.

Based on the aforesaid, it is supposed to use existing structures of vertical combustion furnaces and an experience in designing of such quipment [6] taking into consideration general requirements [1, 2] in order to carry out the research.

## Method

Using mathematical practice and models described in [3-4], and grounding on their adequacy, confirmed by [5], using computer-assisted modeling the article deals with a number of geometric configurations of vertical combustion furnaces (number and layout of burners and fume gases exhausting holes etc. were varied) and the way structural features of the stand can influence homogeneousness of the temperature distribution throughout heated surfaces of walls is shown. As a result, a configuration providing the most homogeneous temperature distribution throughout heated surfaces of a vertical structure was determined in course of the test.

## Consideration on methods and results

During the research several configurations and stands for combustion furnaces used in testing of vertical building structures were studied. Their structural features were described in previous works [3-4]. In order to analyze their effectiveness, were studied temperature distribution throughout heated surfaces of a structure at the 60$^{th}$ minute of the test, as well as temperature value dispersion at a surface of each simulated configuration of a furnace for every minute of the computational experiment and curves for their change over time were studied.

Every configuration was assigned a unique symbol. Figure 1 illustrates temperature distribution throughout the structure heated surfaces for every configuration at the 60$^{th}$ minute of the test.

We believe that main disadvantage of the configuration named “A” (Fig. 1-a) is, compared to other configurations, small volume of furnace chamber, inefficient layout of the sole hole for fume gases exhausting. Due to that the heated reinforced concrete structure is heated non-homogeneously. The structure is heated less in central part of the furnace and above the hole for combustion gases exhausting.

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After alternating of design of the furnace inner combustion chamber (Fig. 1-b) temperature distribution throughout the heated surfaces of the structure became even less homogeneous. However, more characteristic vertical distribution of temperatures is observed.

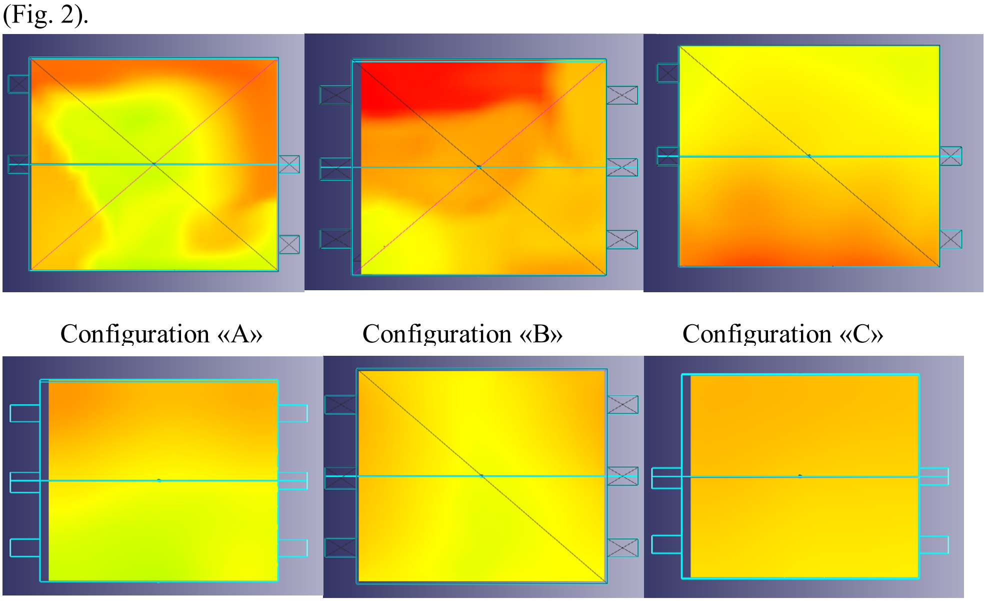
In "C" configuration (Fig. 1-c) more homogenous temperature distribution was achieved compared to "A" and "B" configurations, but due to location of combustion products exhaustion holes closely to burners, convection flows were directed towards these holes, too, and, as a result, this zone had higher temperature.

As it is shown in Fig. 1-d the hole in central part of the furnace leads to higher degree of temperature homogeneousness during heating of the structure compared to "C" configuration. That's why it was decided to continue research with regard to determination of the most homogeneous heating of a structure.

The following configurations of furnace in our temperature distribution research were "F" (Fig. 1-f) and "E" (Fig. 1-e) configurations. Advantage of the "F" configuration is the fact that heating is carried out using 4 burners, but their layout is altered compared to the initial configuration (Fig. 1).

The following stage of the research was determination of temperature dispersion value at surfaces of all simulated furnace chamber design for every minute of the computational experiment followed by building of time-dependent graph for change of this value.

Using computer-assisted gas and liquid flow simulating software, CFD FlowVision 2.5, temperature gradient for heated surfaces of bearing walls was created and temperature distribution for every minute of the computational experiment for each configuration was calculated [7]. In temperature gradients 6000 to 7500 cells were located (depending on the particular configuration design), evenly distributed throughout the structure surfaces, containing temperature data in any moment during the computational experiment. As a result of processing of these data the value of temperature dispersion value was calculated (Fig. 2).



Configuration «A» Configuration «B» Configuration «C»

Configuration «D» Configuration «E» Configuration «F»

**Fig. 1.** Temperature gradient at the heated surface of the simulated structures configurations from A to F.

The graphs have one particular characteristic feature: most of curves, representing numerical value of temperature dispersion, have an extreme point. After the initial phase, increase of dispersion value begins to decrease continuously. It can be explained by reviewing of standard temperature curve of a fire event [1]. It is characterized by a drastic increase of temperature inside combustion chamber of the furnace during first minutes of an experiment and further decrease of difference between extreme points of maximum and minimum. Therefore, the experiment was limited by calculation of the 60th minute (Fig. 2).

Another discovered characteristic feature is the fact that the less such extreme point value is, the earlier it is reached referred to a temporal curve.
After thorough reviewing of the created configurations it becomes obvious that the least dispersion values during the whole time period of interest are observed in "E" and "F" configurations. The highest value of temperature dispersion in "F" configuration is observed at the 40th minute of the experiment, and for "E" configuration maximum point of this parameter is reached at 41st minute. At the same time, configurations "A" and "B" have reached the maximum almost at the 60th minute.

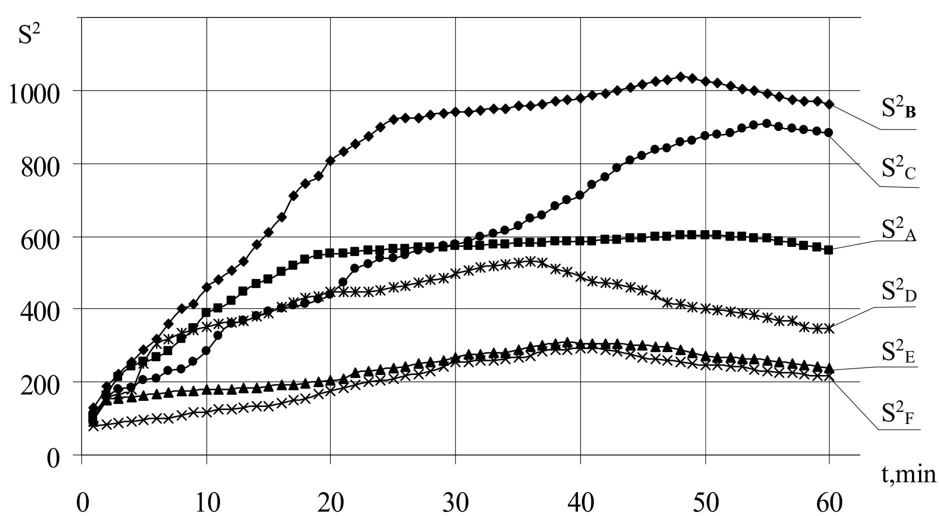



**Fig. 2.** Dispersion of the temperature of the heated surface of the bearing wall in the computational experiment. $S^2_{A-F}$ - The dispersion of the temperature of the heated surface of the bearing wall in the computational experiment in the configuration of the fire furnace, which corresponds to this index ("A-F" configurations).

Having reviewed all created configurations, one can say that average time value of the extreme point reach is 45th to 50th minute of the experiment, when allowable differential between maximum and minimum temperature in the furnace chamber decreases [1].

Thus, a conclusion can be drawn based on the obtained results.

## Conclusions

This work shows results of the computational simulation of a range of computer configurations of stands for testing of bearing walls. Based on the curves representing temperature dispersion values at the surface of each of the simulated structures of the furnace chamber for every minute of the computational experiment (Fig. 2) the configuration with the most homogeneous temperature distribution throughout the heated surfaces of the bearing wall was defined, what allows reducing an error occurring due to temperature distribution non-homogeneity by heated surface structures during the fire resistance test.

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