Physical and Theoretical Models of Heat Pollution Applied to Cramped Conditions Welding Taking into Account the Different Types of Heat

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Abstract. The standard k-epsilon turbulence model, adapted for welding workshops, equipped with fixed workstations with sources of pollution took into account only the convective component of heat transfer, which is quite reasonable for large-volume rooms (with low density distribution of sources of pollution) especially the results of model calculations taking into account only the convective component correlated well with experimental data. For the purposes of this study, when we are dealing with a small confined space where necessary to take account of the body heated to a high temperature (for welding), located next to each other as additional sources of heat, it can no longer be neglected radiative heat exchange. In the task - to experimentally investigate the various types of heat transfer in a limited closed space for welding and behavior of a mathematical model, describing the contribution of the various components of the heat exchange, including radiation, influencing the formation of fields of concentration, temperature, air movement and thermal stress in the test environment. Conducted field experiments to model cubic body, allowing you to configure and debug the model of heat and mass transfer processes with the help of the developed approaches, comparing the measurement results of air flow velocity and temperature with the calculated data showed qualitative and quantitative agreement between process parameters, that is an indicator of the adequacy of heat and mass transfer model.

1. Introduction

Design and development of systems and means of protection of welder operator is detailed in the mathematical description unsteady heat and mass transfer processes of pollutants and excess heat from sources of pollution [1,2]. For one of studied objects of research include welding in the construction of pipelines. Welding ring pipe joints are carried out within the special devices (booths, tents) in order to prevent environmental influences (gusts of wind, rainfall, inflow of cold air) in the weld zone, i.e. processes take place in closed ventilated spaces.

2. Statement of research problem

Previously considered transient three-dimensional mathematical model of heat and mass transfer and heat of harmful impurities in the production environment with actively ventilated and sources of pollution and heat, which takes into account the turbulence of air-gas flows [3]. The standard k-epsilon turbulence model, adapted for welding workshops, equipped with fixed workplaces with sources of pollution, took into account only the convective component of heat transfer, which is quite reasonable for large-volume space (with low density distribution of pollution sources), especially since the results of model calculations taking into account only the convective component correlated well with experimental data.

3. The purpose and objectives of the study

However, for the purposes of this study, when we are dealing with a small confined space, where it is necessary to take into account the body heated to a high temperature (for welding), which are adjacent to each other as additional sources of heat, cannot be neglected radiative heat exchange. Therefore, it is reasonable to set purpose - experimental study of different types of heat transfer in a closed space is limited in welding and the behavior of a mathematical model describing the contribution of the various components of the heat exchange, including radiation, field influencing the formation of concentrations, temperatures, and air thermal stress mobility in the medium under study [4].

4. The results of experimental studies on physical models and discussing

This has been specially designed experimental setup and pick up the equipment for the purpose of studying the processes of heat diffusion in a fluid metering of heat in solids and radiant. To this end, it has been selected and assembled model object in the form of a ventilated cube with a simple geometric shape with an internal heat source (500W incandescent lamp) placed inside and the ability to create it in the ventilation air flows (carried outlet tube with a built-in fan). Field investigations of heat transfer processes carried out in the research laboratory of the department "BZhiZOS" DSTU.

The experimental setup is, in fact, the device is ventilated cube. The very size of the cube 0.5x0.5x0.5m was made of removable sheets of black metal thickness of 1 mm. Inside the cube in the center was secured incandescent lamp - a source of heat. On the front side (panel) cube holes were made for thermocouples through which the measurement of the air temperature inside the cube in its various locations. On the side of the cube in the middle there is a hole with a diameter of 50 mm, which is built into a plastic tube with a built-in fan it "ERA-5", providing extract hot air from the bottom. Fan through the adapter 250 mm was connected to a plastic tube with a diameter of 50 mm. When the fan is running, then the opposite wall cube is removed, providing a predetermined air capacity. General view of the installation shown in Figure 1.

Figure 1 – The experimental setup for the study of different types of heat transfer

As a source of heat than an incandescent lamp of 500 W was chosen randomly, since almost all supplied to the lamp energy is converted into radiant light. The losses due to conduction and convection are small. Such power lamp provides a high enough temperature to the glass bulb according to the source [5] 200-300 ˚C.
In addition, specially selected small internal volume of a cube V = 0,125 m^3 thermal stress within the object of the study was $Q= N / V = 500/0.125=4\ kW/m^3$, which is significantly higher hygiene standards for workplaces. As the driving force of air flow fan of the brand has been involved "ERA-5" with a maximum of 20 W, providing a predetermined maximum air flow 143 m^3 / h and discharge pressure 42.5 Pa.

The dynamics of the air temperature in the inner section of a closed cube with a device that simulates the propagation of heat welding gases from the heat source capacity of 0.5 kW.
Experiment 1. The ambient temperature in the room where he was set closed cube was T ambient air = 23.7 ˚C. Total test time was - 16 minutes. The initial temperature in the cube to turn on the lamp was 24 ˚C. The experimental results are shown in Fig. 3-4 and in Table 1.

As can be seen from the graphs in Figure 3 heat source heating mode, there is separation of temperature fields in the test section. If the maximum temperature near the source was 156 ˚C (measuring point 5) then measuring points remote from the source (point 1,3,6,8,9) it was in the range 45-60 ˚C. Furthermore, temperature measurements were performed on the cube of its faces surfaces cooled by ambient air. The table 1 shows the results of measuring the temperature in the cooling mode, the cube is not ventilated.

Table 1 – The surface temperature of the cube faces, ˚C

	Upper	Rear	Lateral (right)	Lateral (left)	Centre
Centre	59	56	59	50	56
Corner	48	48	48	42	48

In the second phase of the study used a vented cubic meters with an internal source of heat (fig. 2).

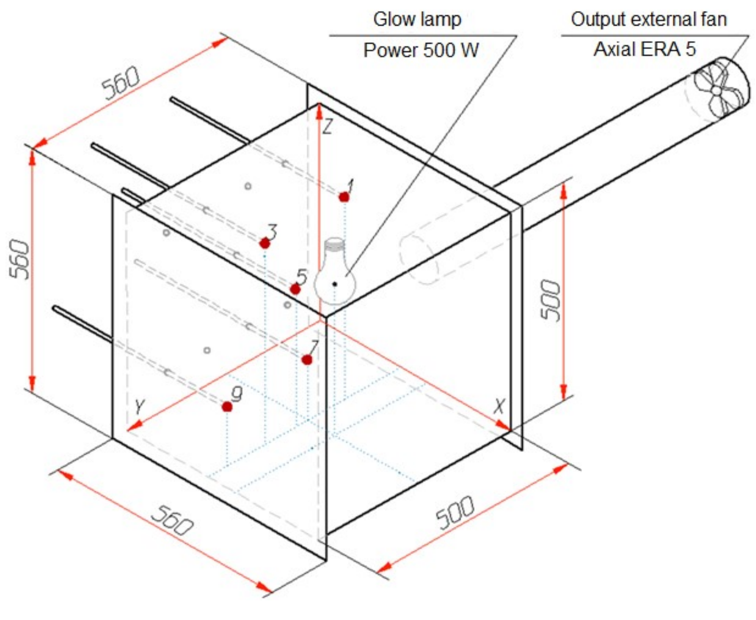

Figure 2 – Location of measuring points in a cube

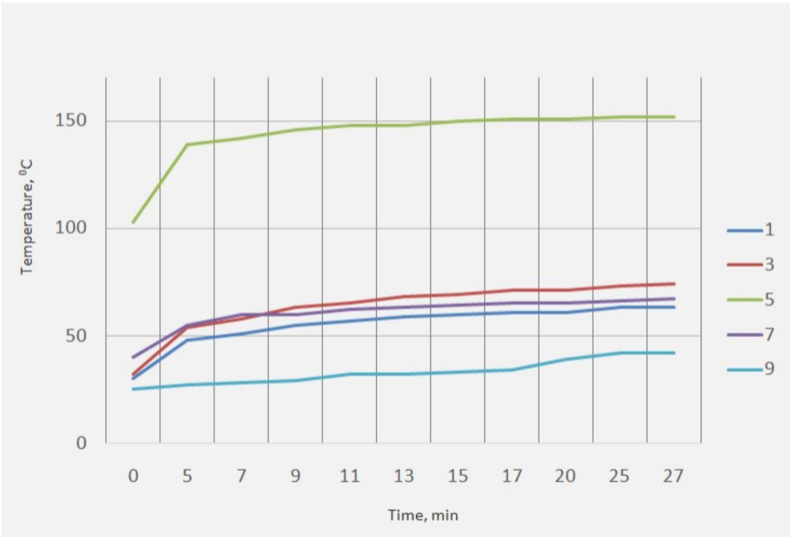

Figure 3 – Changes in air temperature in the measurement points within the closed not ventilated cube

Experiment 2. Turn on the fan. Ambient air temperature is 23.7 ˚C. Air velocity in the pipe was 2.9 m/s. Using differential manometer Testo 521 using a Pitot tube air velocity of air from the fan side was measured v = 3.8 m/s at a temperature 29.5 ˚C, same air velocity at the entrance to the pipe v = 4.5 m/s, 30 ˚C temperature, air flow rate Q = 127m^3/h. For a given fan performance opposite side of the cube has been removed.

The experimental results are shown in Figure 4. It is seen from experiments that after the creation of conditions of aeration cube, the temperature in all points of the cross section of heat source decreases to 40-50 ˚C, and the difference between the maximum temperature at the point 5 and the minimum temperatures at 9 becomes further smaller than in the first experiment, about 60 ˚C.

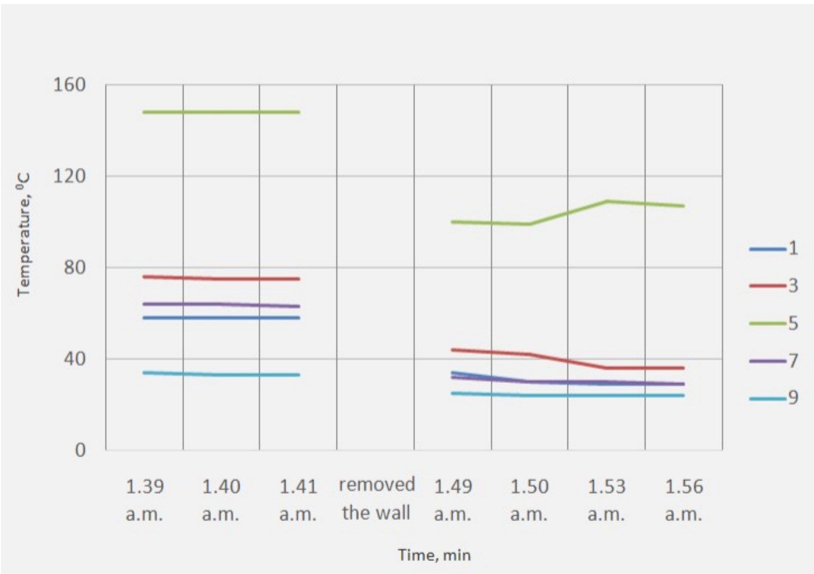

Figure 4 – Changes in air temperature in the measurement points within the closed ventilated cube

Experiment 3. In order to clarify the boundary conditions for the mathematical model of heat and mass transfer were carried out additional studies of the temperature field on the glass bulb incandescent 500 W. Temperature measurement results at five points of heat source are presented in Figure 5.

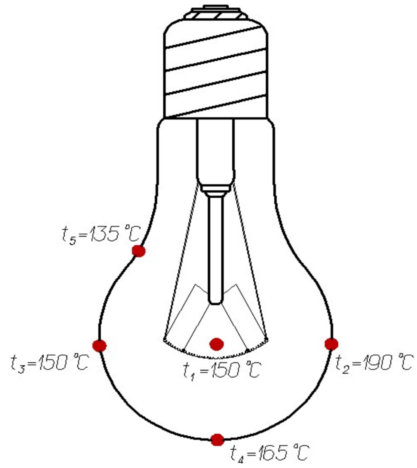

Figure 5 – The temperature field in the glass bulb heat source

5. The results of theoretical research. Mathematical model.

In the numerical solution of the problem is carried out in a CAD-CAE Solid Works package, to this end, developed a method of construction in a software environment CAE model package ventilated cube with different power heat sources. Conducted field experiments to model cubic body and modeling of heat and mass transfer processes with the help of the developed approaches, comparison of air flow velocity and temperature measurement results with the calculated data showed qualitative and quantitative agreement between process parameters, that is an indicator of the adequacy of heat and mass transfer model.

The software for semi-enclosed and confined spaces where there is a welder working in cramped conditions, considering contamination and discharge of heat during the welding process, which allows to calculate the concentration of harmful substances field, temperature, air flow and thermal stress. The problems of convergence calculations and selection of a finite element mesh. Using software developed by the calculations of, possible to determine the optimum operating parameters of the mobile complex ventilation [6], ensuring safe sanitary conditions of work welders at work in cramped conditions and confined spaces [7-10].

Conclusions

Developed and tested for adequacy physical and theoretical models of heat and mass transfer of pollutants in confined confined space taking into account active ventilation. The proposed mathematical model allows you to determine with a sufficient degree of accuracy values of temperatures, air mobility, and also concentrations and heat stresses in the medium under study. The model describes the contribution of various components of heat transfer, including radiation, influencing the formation of the investigated parameters in the working zone of welding. The obtained results allow us to proceed to the studies of heat and mass transfer of pollutants both in terrestrial ventilated chambers during construction of main gas and oil pipelines, and in the protective chambers when welding under water.

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References

[1] Grishagin V.M. *Svarochny aerosol: obrazovaniye, issledovaniye, localizaciya, primineniya: monografiya* [Welding fumes: education, research, localization, use: monograph] / V.M. Grishagin. - Yurga Institute of Technology. - Tomsk: Publishing house of Tomsk Polytechnic University, 2011. - 213 p.

[2] Rykalin N.N. *Raschyoty teplovih processov pri svarke* [Calculations of thermal processes in welding] / N.N. Rykalin. M.: Engineering, 1951 296 p.

[3] Final element modeling of mass transfer of impurities in the production environment taking into account the turbulence of air flow / B.Ch. Meskhi [and others] // Don Herald. state. tehn. Univ. 2012 Vol. 12, №6 (67). p.10-16

[4] The methodology and principles to find solutions and safety of welders work in cramped conditions and on hard objects / D.A. Koronchik [and others] // Don Herald. state. tehn. Univ. 2016 Vol. 12, 3 (86). p.141-147.

[5] Taubkin S.I. Fire and explosion, especially their expertise. M.: 1999. 600 p.

[6] *Ventilyacionniy complex: patent 2600717 MPK: F24F7/00* [Vent Complex: Patent 2600717 IPC: F24F7 / 00 / B.Ch. Meskhi, Y.II. Bulygin, A.L. Gaidenko, D.A. Koronchik, O.V. Denisov, D.V. Rogozin, A.N. Sitnikov 2015 130 241/12; appl. 07/22/2015; 27.10.2016 bull. 30.

[7] Levchenko O.G., Metlitski V.A., *Sovremennie sredstva zashchity svarshchikov* [Modern protective remedies of welders] / O.G. Levchenko, V.A. Metlitski. K .: Ecotehnologiya, 2001. 84 p.

[8] Flow Simulation 2012 Technical Reference.

[9] http://www.solidworks.ru/

[10] G. Plymouth AB. *Chistiy svezhiy vozduh: Katalog.* [Clean fresh air: Catalogue. - Malmo (Sweden), 1988 30 p.