UNIVERSAL THERMAL MICROSYSTEMS BASED ON SILICON CARBIDE

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Abstract: *The results of modeling the thermal characteristics of microsystems, evaluated mutual thermal influence of the elements depending on the type of construction.*
KEYWORDS*: Heat-loss anemometr, thermal microsystem, wide-band semiconductor, modeling thermal performance, pyrometry.*

1. Introduction

At present, there is a tendency for development of various types of flowmeters and sensors for measuring the characteristics of gas flows. In general, the changes themselves undergo the design of the probes themselves and select materials with characteristics that exceed traditional values. As shown by the analysis of literature sources, one of several best technologies for investigating the properties of gas flows remains thermal anemometry and the method of television pyrometry. The authors note the high sensitivity of the methods and the considerable accuracy, in comparison with the known methods for measuring the characteristics of gas flows. These methods arc widely used in industry, oil and gas, laboratories, military science, etc.

2. Problem discussion

Currently, scientific and production technologies involve the use of high-temperature operations to produce refractory high-strength materials, diagnostics of various technical systems under extreme conditions, etc. For such operations, various energy sources (in particular propane-butane in burners) and their effective use are required. To achieve maximum efficiency, you need to know the speed and temperature of the gas flow.. [1,5] At the same time, in the field of thermal anemometry, as has been shown by the analysis of literature data, a thermoanemometric method (TAM) is currently a fairly common method for measuring the volumetric flow rate of gases. As a sensitive element in a thermoanemometric probe, thin electrically conductive wires and films with low thermal inertia are often used. The known disadvantages of TAMs are: a decrease in sensitivity with an increase in the flow rate of the measured gas, low mechanical strength, impossibility of burning (selfcleaning), as well as a change in graduation due to aging and re-crystallization of the wire material due to dynamic loads and high heating temperature [1]. The listed disadvantages limit the use of TAM based on traditional probe designs under extreme operating conditions, including high temperatures of the measured gas flow, the presence of radiation, etc.

3.Objective and research methodologies

The paper presents the results of a study of two directions, the method of television pyrometry and the method of thermoanemometric analysis of the characteristics of gas flows.

3.1 Method of television pyrometry for measuring the velocity of a gas stream.

For the experimental study, a technique was developed for measuring the flow velocity from the angle of deviation of the pendulum from the vertical. The option of technical implementation is as follows:

a) The pendulum and the holder are mounted in the positioner, and the gas flame region is placed;
b) The camera connected to the computer registers the image of the pendulum;
c) With the help of special software installed on the computer, the flow velocity along the angle of the pendulum deviation from the vertical is calculated.

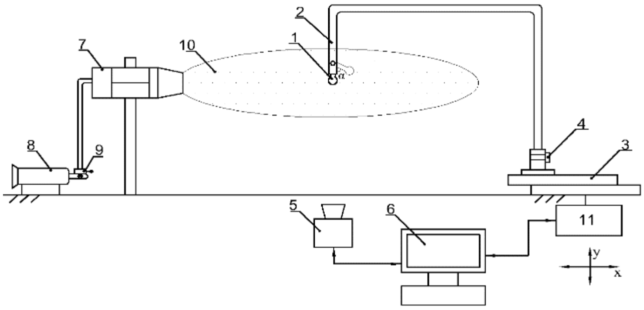

Figure 1 *- Schematic representation of the technical implementation of the flow velocity measurement technique:*
1 - The pendulum; 2 - Holder; 3 - Positioner; 4 - Adjustment device; 5 - Camera; 6 - Computer with special software; 7 - Nozzle; 8 - Gas source; 9 - Rotameter; 10 - Gas flow; 11 - Positioner controller.

To determine the velocity of the gas flame, it was required to obtain the dependence of the velocity of the gas flame on the angle of deviation of the pendulum from the vertical. For this purpose, a simplified physico- mathematical model was used. The obtained dependence is represented by the formula 1:

$$\upsilon = \sqrt{\frac{m \cdot g}{\rho \cdot S \cdot \cos(\alpha)} \cdot tg(\alpha)} \quad (1)$$

where m - is the mass of the pendulum, g;
g - acceleration of gravity, m/s^2;
ρ - is the density of the gas flame, kg/m^3;
α - angle of deviation of the pendulum from the vertical, deg
The specificity of the flame is such that it has a definite structure [1]:

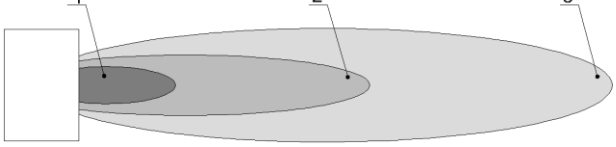

Figure 2 *- Structure of the flame: 1 - core; 2 - recovery area; 3 - area of the torch.*

When calculating the flame velocity, it must be taken into account that it consists of zones with different viscosities and temperatures. The values of temperature and viscosity in different zones of the flame are shown in Table 1:
Table 1 – gas flame characteristics

	Core flame	Flame retarding zone	Flame torch area
Temperature, °C	300-500	1200-1500	700-1000
Viscosity, $10^6\ m^2/s$	48-79	233-280	115-177

With the help of Matchcad 15, mathematical modeling was performed to obtain the range of possible velocities in different areas of the gas flame:

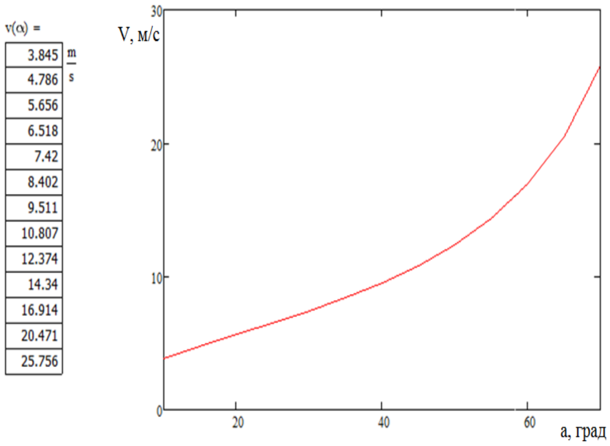

Figure 3 *– Velocity range and graph of velocity versus sensor deflection angle at ρ (500°C) = 0.456 kg/m*^{3}

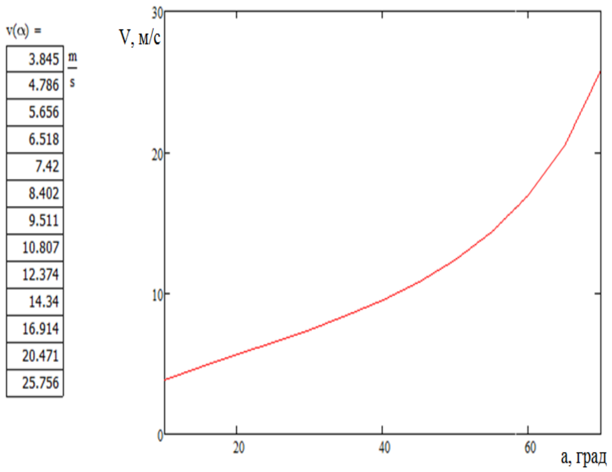

Figure 4 *– The speed range at the velocity versus the sensor deflection angle at ρ (900°C) = 0.301 kg/m*^{3}

3.2 Method of thermoanemometric analysis of the characteristics of gas flow.

The method involves determining the flow rate by changing the temperature of a thermistor probe heated by electricity placed in a controlled gas flow. The cooling of the thermistor probe depends on the flow rate, the physical properties of the gas (thermal conductivity, temperature and density) and the temperature difference between the thermistor probe and the gas.

As shown by the analysis of literature data, the thermoanemometric method (TAM) is currently a widely used method for measuring the volumetric flow rate of gases. As a sensitive element in a thermoanemometric probe, thin electrically conductive wires and films with low thermal inertia are often used. The known disadvantages of TAMs are: a decrease in sensitivity with an increase in the flow rate of the measured gas, low mechanical strength, impossibility of burning (self-cleaning), as well as a change in graduation due to aging and re-crystallization of the wire material due to dynamic loads and high heating temperature [1]. The above disadvantages limit the use of TAM based on traditional probe designs under extreme operating conditions, including high temperatures of the measured gas flow, the presence of radiation, etc.

The purpose of this work is to develop methods that allow the creation of a thermal microsystem with improved characteristics for measuring the velocity (flow rate) and temperature of gas streams, including under conditions of abrasive particles and radiation.

For the first time in work, the thermal micro-system layout in the thermistor probe of the anemometer and the temperature sensor in the form of a Schottky barrier made from a polytypic compound-silicon carbide is theoretically justified. It is shown that the use of single-crystal silicon carbide of certain polytype composition provides the following advantages of TAM:

1) A wide range of measured costs and high sensitivity (due to a controlled change in the electrophysical characteristics of the material);

2) High stability and reproducibility of the operating characteristics of the microsystem under extreme conditions (due to monocrystallinity, high Debye temperature and hardness, wide bandgap and erosion profiling capabilities);

3) The possibility of self-cleaning (due to high chemical and thermal resistance values). It is also worth mentioning that a patent for the invention of a thermal microsystem has been obtained.

The necessity of step-by-step solution of the problems of designing the SiC-thermal microsystem is pointed out, which, for example, is due, not to the study of the influence of conductive bonds, abrasive and radiation fluxes on the electrical properties of the elements of the microsystem.

4. The results of the study and their discussions

The study of the thermal regime of the microsystem, in which the thermal bonds between the elements are determined mainly by the conduction process, the properties of the material and the design features, is a model analysis of the distribution of the temperature field from a strongly heated element to a slightly heated one.. For comparison, 2 variants of the design and the thermal model of the microsystem, presented in Figure. 5, are proposed.

According to the obtained data, curves for the dependence of the electric current on the temperature of the model under study at two point (1), and the coldest point (2) itself, shown in the Fig.7, are plotted. Figure 7 shows that the thermal model this the though hole is preferable, in consequence of the fact that the temperature of the thermo – anemometer in working conditions has less effect on the thermometer located on the foot on the microsystem. In this case, the inverse thermal effect is excluded from the calculation since the working temperature of the thermometer is assumed to be equal to the temperature of medium being measure.

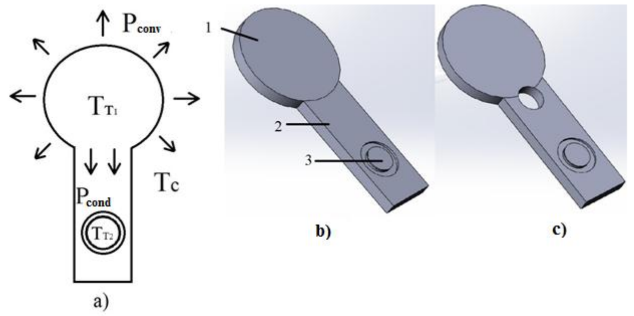

***Figure.* 5** *- Thermal model of microsystem (a), microsystem design without hole (b), microsystem design with hole (c). 1 - the site of the heat-loss anemometer; 2 - the leg; 3 - the site of the thermometer.*

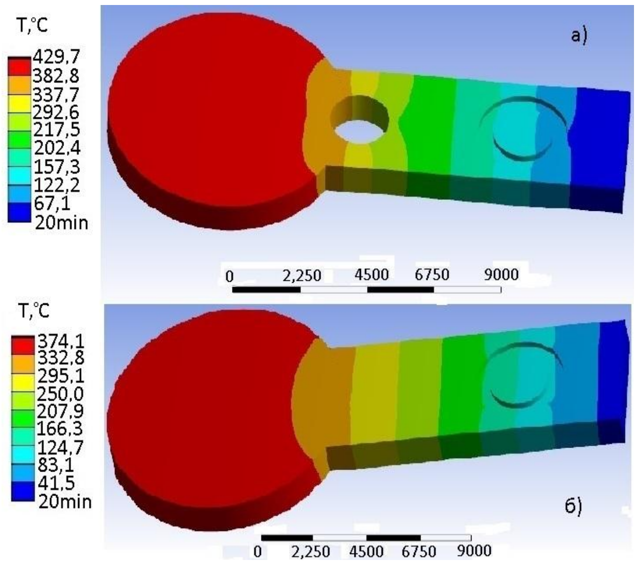

Figure 6 *– Temperature field in the microsystem.*

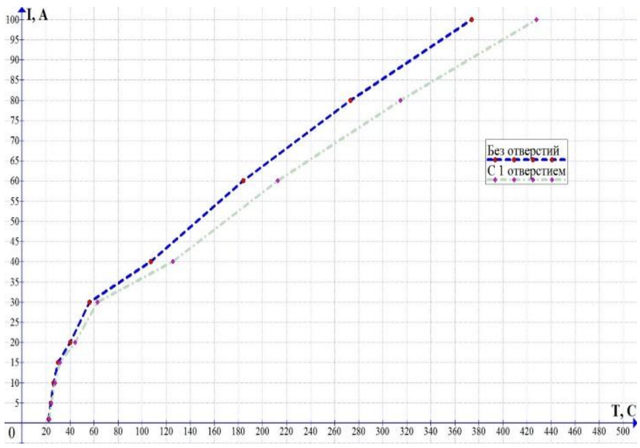

Figure 7 *- Graph of the temperature dependence of the microsystem at the "hot spot" itself on the magnitude of the electric current.*

5. Conclusion

In the course of the study, a method for calculating the micro-system was proposed, showing the mutual thermal effect of the elements. According to the data of the study, curves for the dependence of the electric current on temperature are plotted, as shown in Fig. 7.Based on the results of the simulation, it can be judged that the tested versions of the microsystem designs have significant temperature differences >50 ℃ in the presence of small design solutions

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