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Temperature and velocity conditions in vertical channel of ventilated facade

Температурный и скоростной режимы в вертикальном канале вентилируемого фасада

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Ключевые слова: вентилируемые фасады; конвективные воздушные потоки; русты; скорость воздуха; температура воздуха; облицовочный слой; воздушный зазор

Abstract. The most economically viable and practicable method of moisture removal from the air gap with the help of free convective air flows are presented in the article. An experiment conducted on a laboratory bench simulating a hinged ventilated facade is described. The parameters and design features of a particular building envelope are determined. Also, the impact of technological gaps – grooved lines is described, which influence the air velocity in the ventilated channel, which in turn affects the temperature and humidity conditions of the building envelope. The experimental evaluation of air velocity and air temperature along the height of ventilated layer is provided in the article. The impact of grooved lines density and the method of hot plane heating on the distribution of air temperature and velocity. Optimal is the construction which is designed with the least number of rusts, from the technological point of view.

Аннотация. Был рассмотрен наиболее экономичный и практичный метод удаления влаги из воздушного зазора навесного вентилируемого фасада – с помощью свободноконвективных потоков воздуха. Описан эксперимент, проведенный на лабораторном стенде, имитирующем собой навесной вентилируемый фасад. Были определены параметры тепломассообмена и конструктивные особенности отдельно взятой ограждающей конструкции. Также было рассмотрено влияние технологических зазоров-рустов, воздействующих на скорость воздуха в вентилируемом канале, которая, в свою очередь, влияет на температурно-влажностный режим ограждающих конструкций. Приведена численная оценка скорости движения и температуры воздуха по высоте вентилируемой прослойки. Установлено влияние рустов и способа обогрева «горячей» стенки на распределение скорости и температуры воздушного потока. Оптимальной является конструкция с наименьшим, с технологической точки зрения, количеством рустов.

1. Introduction

Ventilated facade – is a facade with ventilated air gap aimed at climatic action protection and exterior development.

The system is constructed in the way, where air gap, which is located between insulation and outer cladding, provides free air movement. Free convective air flows occur in air gap because of volume force, which depends on density difference and which is justified by heat energy transfer due to temperature non-uniformity. Besides, there are technological gaps – grooved lines. From a physics perspective, a facade without grooved lines forms an ideal channel.

These constructive features influence air velocity in vertical channel. Air velocity affects temperature and humidity conditions of external envelope.

As can be seen from the above, natural air movement in a gap provides dryness of a wall and prevent condensate formation in insulation layer.

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At the present times suspended ventilated facades building is relevant to many Russian and foreign scientists. A great contribution to the study of free-convection flow in a vertical ventilated channel was made by Russian and foreign researchers. The article of V.G. Gagarin, V.V. Kozlov, D.V. Nemova, M.V. Petrochenko, E.B. Yevtushenko and many other specialists have been devoted to the determination of the thermophysical properties of ventilated air gaps and their influence on the temperature and humidity conditions of the enclosing structures [1–29].

The paper [1] studies physical processes of free convective current and determines the conditions of cool air filtration in the gap. There are a number of problems associated with the condensation of moisture in the structure in the operation of ventilated facade systems with air gap widely used today in construction [3–7].

The article [8] determines best hydraulic ventilated cavity of a suspended facade. The author of the article [10] estimates the average velocity of free-convective current dependence with different wall temperature.

The author of the article [11] gives the description of air-vent quarter division with different air motion modes. The research [15] determines experimentally and theoretically the average velocity and temperature profiles along the ventilated channel width.

The article [27] provides evaluation methods of thermal insulation with longitudinal air filtration of ventilated facade.

The article describes the impact of arrangement of assembling grooved lines and the heating methods of interior wall plan on air velocity and temperature in vertical ventilated air gap. That is especially important in the conditions of the temperature and climatic zone of St. Petersburg.

Research objective:

- determining the influence of grooved lines density and the method of hot plane heating on the distribution of air temperature and velocity in free convective flow.

Goal Setting:

- determining the average velocity and temperature of free convective flow in air gap in relation to grooved lines pitch with constant geometric parameters of the gap;
- determining of heat and mass transfer parameters for various degrees of hot surface heating.

2. Methods

Imperfection of building constructions leads to excess humidification. That is why it is necessary to focus on water storage capacity of materials. Most methods of insulation layer moisture control aimed at reducing moisture inflow to the air gap.

Moisture removal with the help of free convective air-flows is the most economically viable and practicable method, since the energy source is the heat flow from the hot wall to air. No other external energy sources (ventilators) are needed. Free convection in gravity field is justified by the existence of negative air density gradient, which is associated with temperature gradient. If the surface temperature is higher than the ambient temperature, the air flow in the surface runs hot, becomes lighter and ascends. In this case, less denser air layers replace the ascended layers.

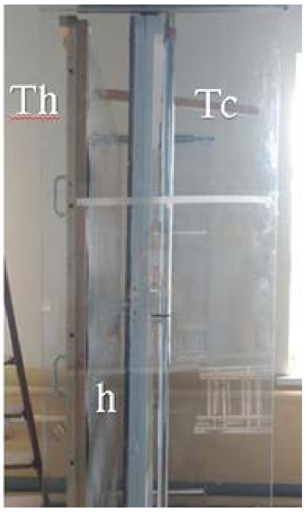
When considering moisture removal, significant attention should be paid to grooved lines, which perform thermal compensator function. Cladding grooved lines provide hydraulic connection with outdoor air. All mentioned factors are prevailing when designing and engineering air cavities. All results of the research were obtained experimentally. Schematic view of a ventilated gap (Fig. 2), which is located between the “hot” plane $y = 0$ (with the temperature $T_h = 67$) and the cold plane $\mathbf{y} = h$ (with the temperature $T_c = 22$). Pressure at level $z = 0$ equals p_0, pressure at level $z = h$ equals p_1, while $p_0 > p_1$. It is required to estimate average velocity and temperature through free-convective flow. To measure the speed are used a thermo-anemometer Testo 435-2, with a resolution of 1 cm/s, it allows to measure the velocity with an error of 0.5 cm/s, air temperature - with an error of 0.1 °C

Required control volume comes over the air-vent and spreads out from zero level to $z = L$ plane, which lays above the outlet air-vent cut in still air. It is taken, that outdoor air penetrates air cavity through lower air holes. Outdoor air ascends along the air-vent and passes through upper air holes [16].

Heating is provided by three vertical fastened thermal elementary units. For equal heat distribution the elementary units are fastened to the tin sheet with high thermal conductivity. Consequently, T_h = const. Model height equals L = 2040 mm, while $L >> h$. When manufacturing the facade model, we should take into consideration the difference in the temperatures of outer and inner layers, which is justified by the heating systems operation. The model considers heating of the wall and heat inflow to the air cavity. For this experiment different combinations of thermal elements are used: lower-middle, lower-upper. Upper-middle combination is not used, since the lower installation section is not heated and there is no air heating in channel inlet. The temperature in this section stays homothermal, consequently, there is no active air movement and the flow is inefficient.

Velocity depends on the air supply method, internal parameters of the gap and the method of hot plane heating. In the experiments the gap width /h/ was set at h = 80 mm = const. In the experiments grooved lines pitch with different fixed activation methods of heating elements was determined. For this purpose, the average velocity and temperature of air in central part of the low were measured.

Figure 1.Thermal anemometer



Figures 2,3. Installation scheme

3. Results and Discussion

Within the scope of the given measurements, the following charts were obtained, fig. 4-12. Figures 4-5 show air and velocity dependence on height with different grooved lines pitch and constant heating along the height. Based on the obtained dependencies it was identified that air flow temperature increases when grooved lines pitch increases (with constant heat flow density along the heated channel height). The most significant reason is the decrease of high-density air inflow to the channel. The velocity is maximum in the ideal channel (grooved lines are fully closed).

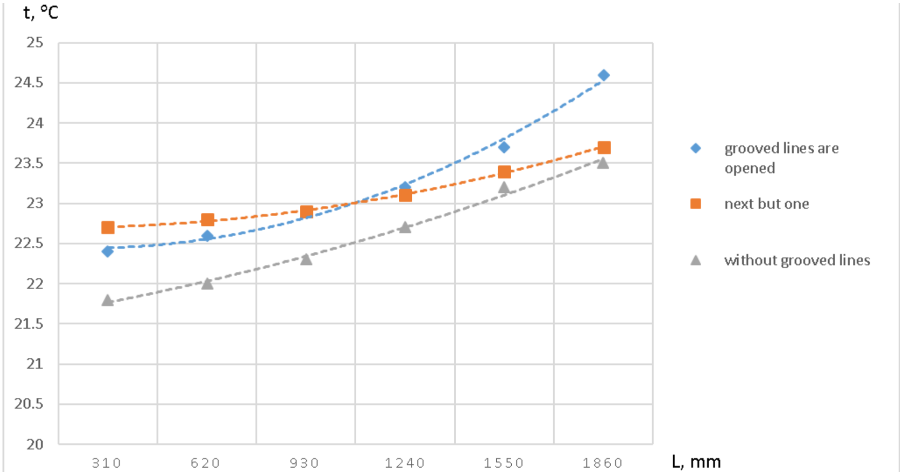


Figure 4. Temperature distribution along the channel height in relation to grooved lines pitch with constant height heating

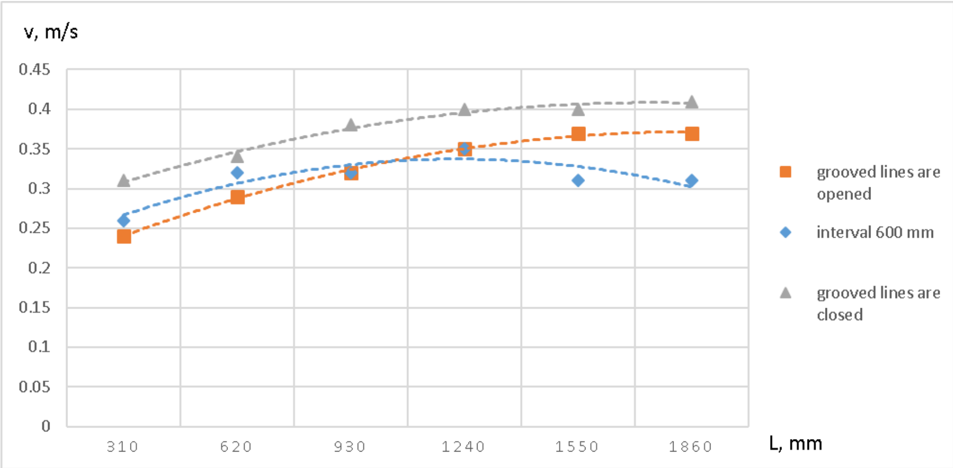


Figure 5. Velocity distribution along the channel height in relation to grooved lines pitch with constant height heating

Figures 6-7 show the velocity-temperature to height relations with different grooved lines pitch and activated central and lower heat sources. While lower and central installation sections heating, the temperature of the top section does not change significantly. As may be supposed, air flow temperature increase occurs due to blowing-out through the upper grooved lines. In the top unheated section of the channel, the velocities converge and have no relations to the grooved lines pitch.

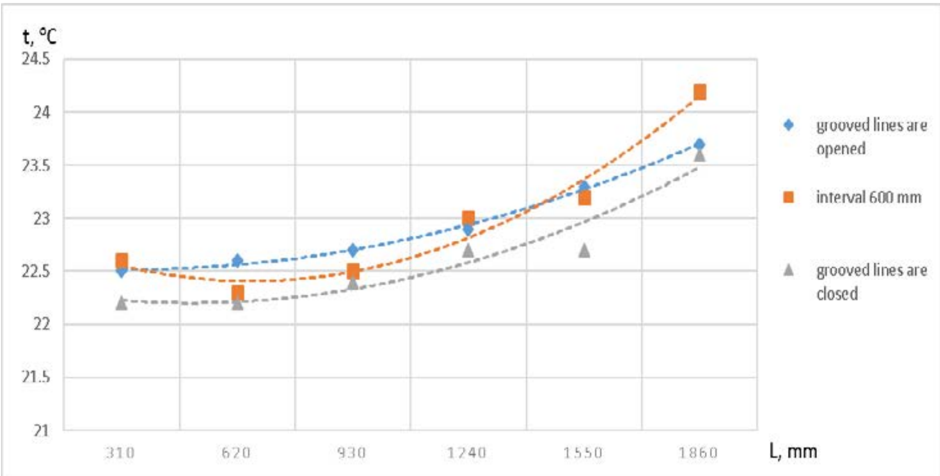


Figure 6. Temperature distribution along the channel height in relation to grooved lines arrangement with activated central and lower heat sources

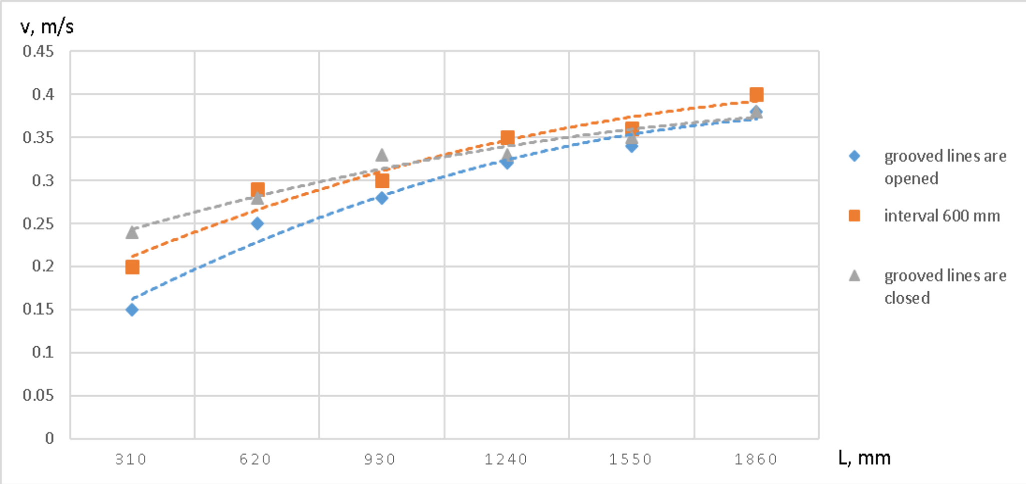


Figure 7. Velocity distribution along the channel height in relation to grooved lines arrangement with activated central and lower heat source

Figures 8-9 show the velocity-temperature to height relations with different grooved lines pitch and activated central and lower heat source. Based on the results it is concluded that temperature and velocity distribution in relation to grooved lines pitch corresponds the above given charts, while heating of channel inlet and outlet, and central section adiabatization. There is minimal fibration of experimental data in central unheated section.

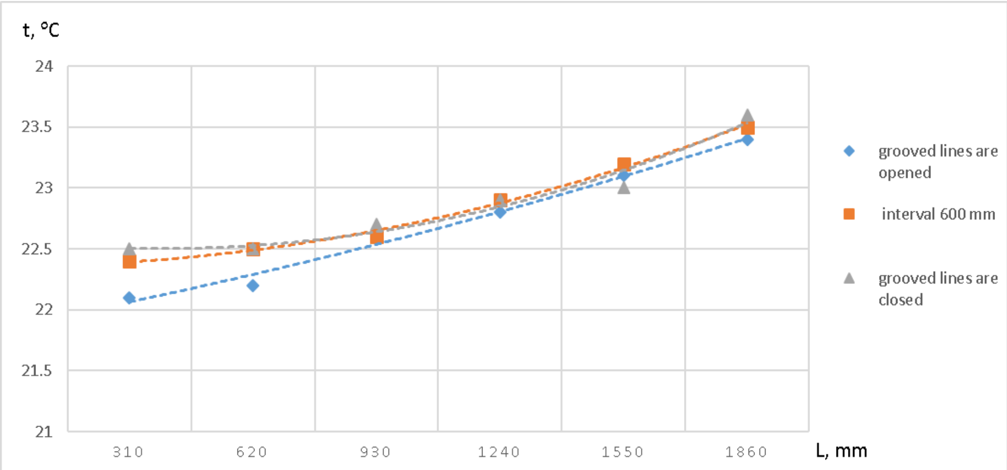


Figure 8. Temperature distribution along the channel height in relation to grooved lines arrangement with activated central and lower heat sources

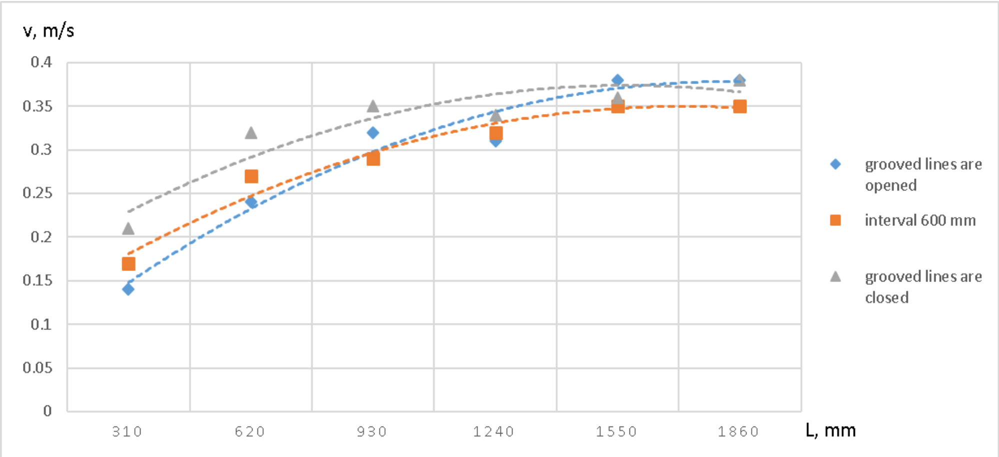


Figure 9. Velocity distribution along the channel height in relation to grooved lines arrangement with activated central and lower heat sources

Figures 10-12 show the velocity to height relation with different variations of heat flow distribution. It was identified that velocity increases in heated areas. From Figures 11, 12 it is observed that the velocity growth rate is maximal in the ideal channel.

This can be explained by inability of high-density air to penetrate the channel, and by change absence of air flow movement with hermetic sealing of grooved lines.

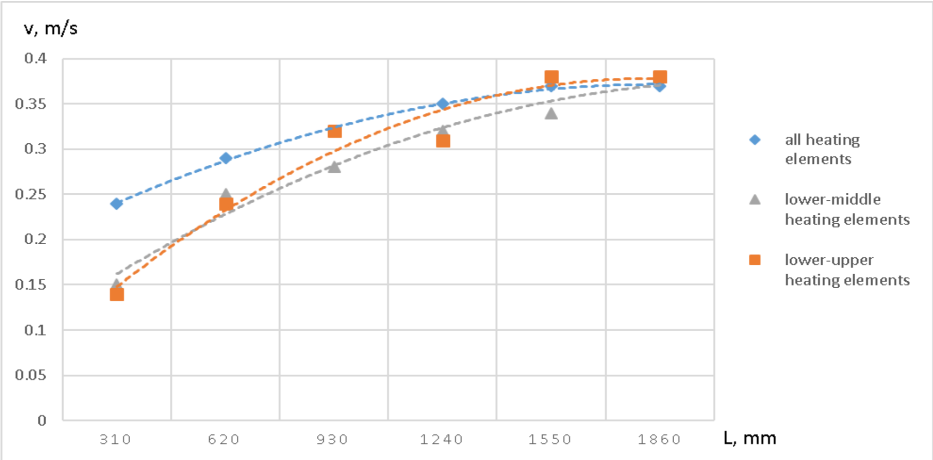


Figure 10. Velocity distribution along the channel height in relation to variations of heat flow with opened grooved lines

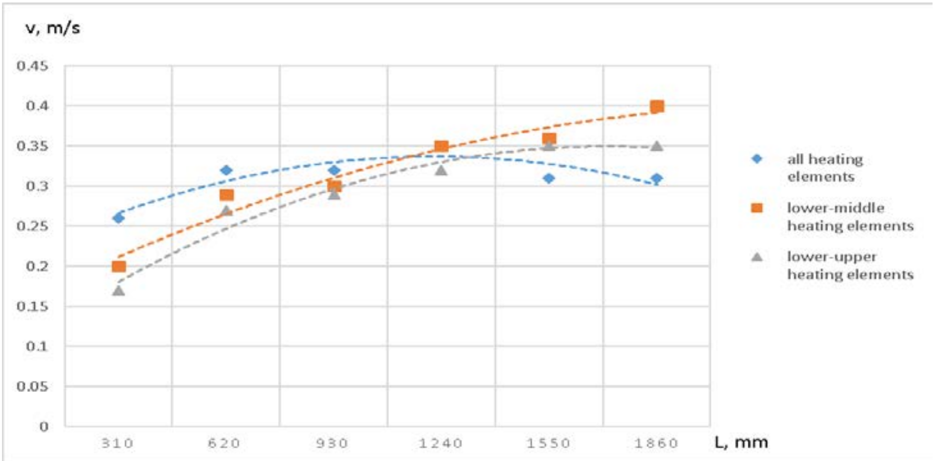


Figure 11. Velocity distribution along the channel height in dependence with heat flow variations with groove line pitch of one meter

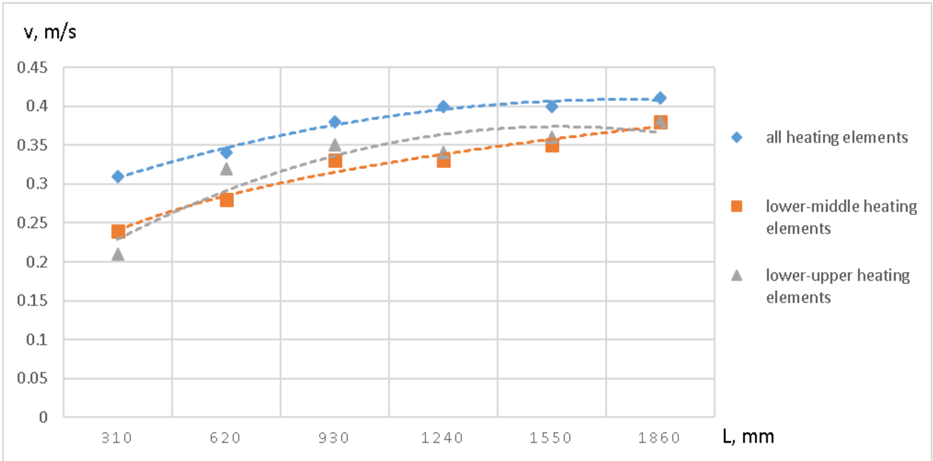


Figure 12. Velocity distribution along the channel height in dependence with heat flow variations in the ideal channel

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The main goal of this article is to study the mechanisms of the method of heating the wall on the heat and mass transfer parameters of the facade along its height. The article focuses on the experimental determination of temperature and airflow velocity dependences from combinations of heat sources in the ventilated channel of the facade and the width of the facing layers panels.

In articles by other authors on the same topic are described the heated enclosing structure with a constant temperature and averaged height parameters of the air in the channel [1, 4, 8–9], but the contribution of technological gaps – grooved lines is not taken into account. In this researching examines the influence of the variable position of heat sources and various combinations of grooved lines on the efficiency of the entire system.

4. Conclusions

Based on the results the following conclusions can be summarized:

1. A series of experimental studies was carried out and the result of which it was found that the facade is sensitive to changes in grooved lines number and heating method change.

2. The maximum velocity – around 0.37 m/s – is observed with hermetically-sealed grooved lines (the ideal channel), but at the present time such system is technologically impracticable. Minimum number of grooved lines is optimal (in this case interval is 600 mm).

3. For thermal energy saving purposes, heating of the middle section of the channel can be neglected. When heating of the middle section is neglected, the average velocity undergoes minor changes.

4. Temperature variation rate in different heating areas changes in dependence with grooved lines spacing. The fibration of experimental data in unheated sections is minimal.

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