EXPERIMENTAL RESEARCH OF MIXING AXISYMMETRICAL JET IN THE CHANNEL WITH PERMEABLE WALLS AND CLOSE ENDS

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Propagation of axisymmetric gas jet in the atmosphere bounded by the channel (tube) walls happens in technical devices where one uses the effects connected to the interaction of reactive mediums: appearance of gradients of pressure in the space round the jet, formation of zones of back flows (recirculation), growth (ejection) of co-current medium into the channel with further mixture of the flows. These effects are especially important being applied to the gas-burning devices and were experimentally studied before for the case when the jet was moving in the tube opened from two sides with non permeable walls [1, 2], where the pressure fields were studied according to the jet length, the fringe and size of recirculation zone, velocities profiles and concentration of gas mediums. A qualitative image of flows and quantitative dependences of localization of recirculation zones was done on account of the results obtained

At the present time one elaborated the technologies of studying new permeable porous and heat-resistant materials [3]. The items manufactured from these materials are used for producing irradiating (flameless) burning devices [4], having several advantages of existing fame burners. Elaboration of new methods of processes organizing is needed for effective and safe work of such devices.

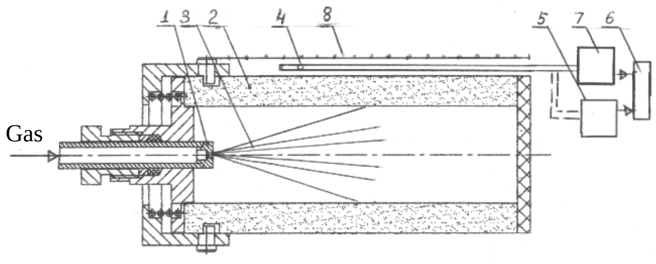
This work represents the results of experimental researches of effects accompanying the propagation of high-pressure gas jet in both-sides closed tube with permeable walls. The complex diagnostics included measuring the static pressures along the tube length, determining material jet concentration along the tube, and flows visualizations near the tube by the mean of smoke. While determining the static pressures and visualizing the flows air was injected inside the tube; for measuring concentrations carbon dioxide (imitating propane according to its density) was used being suitable for gas analysis of the mixture.

The experiment set scheme is represented in Fig. 1*a*. Gas (air) injection was done from the nozzle 1 to the tube 2 with length of 500mm, diameter 48 mm and wall thickness of 10mm. The tube is produced by the method of self-propagating high temperature synthesis (SHS) from intermetallides of the system NiAl with the size of pores 0,1–0,5 mm, providing good gas permeability through the wall. The jet 3 with conical shape formed during the injection causes the changes in the ambiance of static pressures (p),which were measured by the thin tube 4 with closed end wall and a hole on the side (analogue of Pitot tube) and connected to the sensor of pressure "Agava" 5, which signal was transmitted to the computer 6. During the measurements the tube 4 moved to the axial direction all over the tube 2 wall. Analogically, the same tube 4, connected to the gas-analyzer 7 "Test" one determined the fields of concentration of CO_2 mixed with air. Flow visualization with smoke was done by the mean of electrically heated nichrome wire 8 wet with dielectric oil. The wire was pulled above the tube 2 along the whole length of it.

During the experiments one changed the pressures of P gas injection (0,853 atm), nozzle hole diameter d_C (0,40.6 mm) and the distance from the tube cut till the nozzle l_C (6206 mm).

The smoke visualization showed interesting quality image of the flows outside the permeable tube (Fig. 1 *b*, *c*): at the initial part from the nozzle side smoke wisps are soaked inside the tube, at the other part of the tube the smoke is contrarily rejected aside by the air going out through the tube wall. There is a transition zone between these parts, where the smoke is not soaked and is not rejected; moreover, the position of this zone depends on l_c: the deeper is the nozzle in the tube the further is the zone from the beginning of the tube (in Fig. 1*b* – l_c = 56 mm, in Fig. 1*c* – l_c = 156 mm). In such a manner, the jet motion inside the permeable tube causes ejection of the surrounding air inside at the initial part and efflux of the medium outside at the rest of the part. Experimental values of static pressures measured outside the permeable tube are shown in Fig. 2*a*, where one selected typical modes demonstrating the influence of injection conditions of the gas (represented in the table).

Modes designation	P (atm)	d_c (mm)	l_c (mm)
1 – ×	3	0,4	6
2 – Δ	3	0,6	6
3 – ○	1	0,6	6
4 – □	3	0,6	56
5 – ◊	3	0,6	106



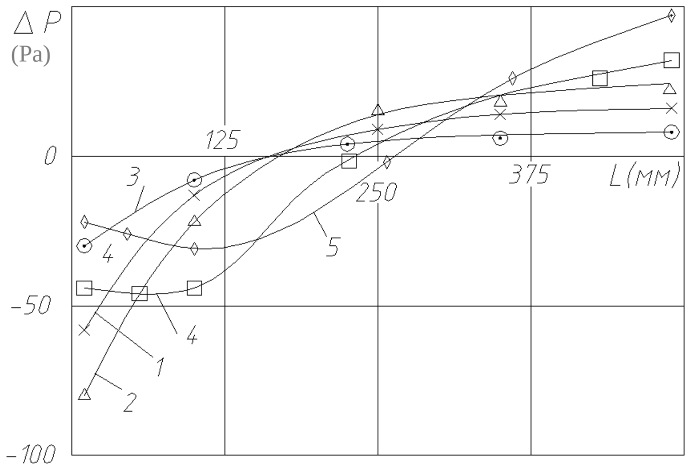
a

b

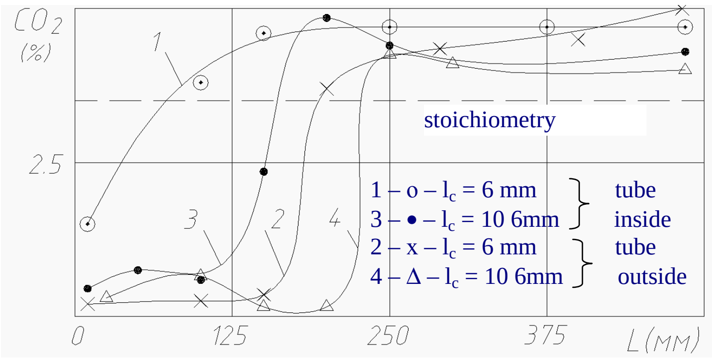
c

Fig. 1. The experiment set scheme (*a*) and smoke visualization results (*b*, *c*)

All 5 represented modes have similar properties: statistic pressures have negative values (relative to the atmospheric pressure) at the initial part of the tube near the external wall, which causes absorption of ambience into the tube. Moving away from the initial part of the tube the values of p increases up to zero and higher marking the zone of effusion from the tube till its end. The influence of the nozzle diameter is seen by comparing two curves 1 and 2 (0,4 and 0,6 mm): increasing of d_c results by more important medium discharge ant the initial part (jet ejection capacity) and great values P ant the rest of part Influence of injection pressure is observed by comparing the curves 2 and 3: when P grows (from 1 up to 3 atm) medium ejection increases, therefore the intensity of the mixture effusion from the tube is increased too. The modes mentioned were done at l_c = 6 mm, when the nozzle was at the beginning of the tube, in such a case the length of the ejection zone up to P = 0 was similar – 145 mm (see Fig. 2*a*). When the nozzle is moved to the tube for 56 mm the appearance of the curve P(L) is qualitatively changed, the ejection zone is enhanced, and the curve of pressure 4 is more sloping. Large penetration of the nozzle l_c =106 mm (curve 5) elongates more the ejection zone and, the zone of effusion if accordingly contracted. In such a manner the change of d_c, P and l_c can be controlled by the pressure and the absorption area into the permeable tube and the intensity and the effusion area of gas mixture from the tube. In connection with the application of present researches of jet mixer for the burner while injecting the fuel jet (propane, for example) by varying the conditions of the injection it is possible to control the quality of mixing the fuel and the oxidizer. It was shown by the experiments of injecting carbon dioxide and measuring the concentration of CO_2 mixed with air inside and outside the permeable medium at different values of P and l_c. Figure 2*b* represents the data obtained at certain modes (P = 1,7 atm, l_c = 6 and 106 mm showing that the concentrations of CO_2 inside the tube at the injection area differs manyfold (curves 1 and 3) to the n-th degree, marking the area of unsteady stream and mixture of two mediums called the area of recirculation [1]. The concentrations of CO_2 are practically constant both inside the tube and outside of it further from that zone downstream.



a)



b)

Fig. 2. Statis pressures (*a*) and CO_2 concentrations (*b*) profiles along tube length (*L*)

Though the absolute values of CO_2 are close for calculated one for propane stoichiometric concentration, what is important for organizing burning on the surface of the permeable tube, where one can obtain given fuel-oxidizer correlations in dependence of the conditions of fuel jet injection.

The results described considering the data obtained in [1] on interaction of the jet with concurrent in the open tube with impermeable wall are represented as the following scheme of flows inside; outside and through the wall of impermeable porous tube with closed sidewalls (Fig. 3).

When the gas is injected from the nozzle 1 to the tube 2 the formed jet 3 causes the pressure gradients in longitudinal and transverse direction. Under its action the surrounding medium moves: at the initial part the outdoor air goes through the tube wall inside (ejection), where it is carried into the downstream flow. The jet getting to the inside tube wall is roughly broken causing the appearance of positive pressure gradient with appearance of the reverse flow and forming the zone of recirculation 4. In this zone 4 the materials of the jet and concurrent flow are mixed, after that the mixture if pressed through the tube wall outside by over-pressure (in comparison with the atmospheric) in the tube parts below the recirculation zone. The

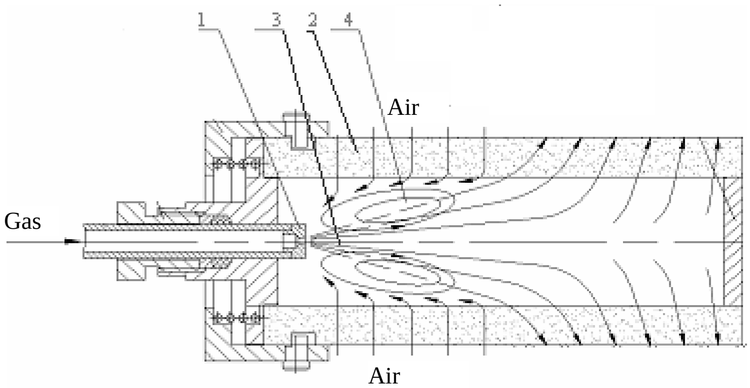


Fig. 3. The scheme of flows causing by moving jet

following scheme admits regulation of recirculation, ejection and effusion zones size, as well as the mix-composition by changing the conditions of jet injection and is a base for designing jet mixer for performing burning on the surface of permeable porous material done in radiation burners. As distinct from the existing burners operating with inflammable mixture prepared before in special mixers; the mixture inside the device described is prepared directly inside the burner, that assures safety from such phenomenon as the flame flash-back into the mixer.

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