EFFICIENCY OF HEAT SHIELDING OF A PLANE WALL DURING BLOWING OF AIR THROUGH A SLOT AT AN ANGLE TO THE SHIELDED SURFACE

E. P. Dyban, E. G. Popovich,
and V. M. Repukhov

UDC 536.244

Results are presented of an experimental study of the effect of the angle of secondary air injection on the efficiency of heat shielding of a plane surface at the turbulent surface layer.

Experimental data cited in the literature known to us [1-3] on the effect of the geometry of a slot on the efficiency of heat shielding of a wall

$$\eta \equiv \frac{T_1 - T_{a.w.}}{T_1 - T_2}$$

were either obtained in simultaneous measurement of several characteristic quantities (in particular, shape of slot channel, relative arrangement of slot edges, and angle of injection of the secondary current [1-2]) or [3] were presented in a form which does not allow one to fully evaluate the effect on η of the angle of the secondary current supply.

To obtain the indicated data experimental studies were conducted on the efficiency of heat shielding of a flat plate at a wide range of variation (from 0 to 90°) in the angle of injection of the secondary current while maintaining a fixed shape and degree of restriction of the channel for its supply.

The experiments were conducted on a low velocity wind tunnel with a working channel constructed in the form of a chute with cross section dimensions of 120 × 120 mm and length 750 mm. The lower wall of

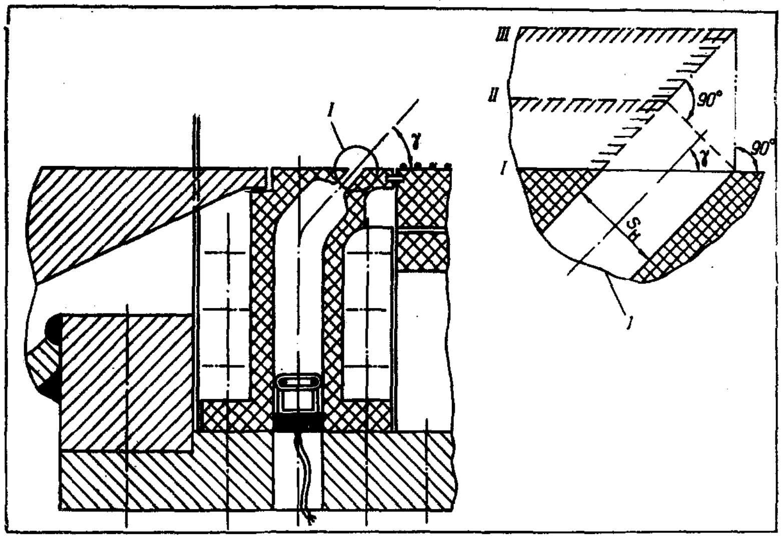

Fig. 1. Shape and location of slot for secondary air injection.

Institute of Technical Thermophysics, Academy of Sciences of the Ukrainian SSR, Kiev. Translated from Inzhenerno-Fizicheskii Zhurnal, Vo. 20, No. 2, pp. 294-298, February, 1971. Original article submitted February 4, 1970.

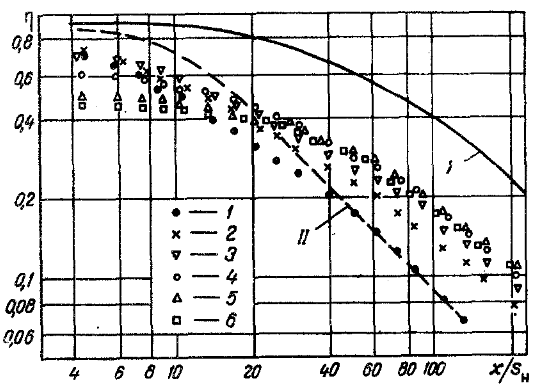

Fig. 2. Dependence of efficiency of heat shielding of a wall on dimensionless distance x/s_H for various injection coefficients m. $\gamma = 0°$: I) m = 1.0; II) 0.3. $\gamma = 90°$: 1) m = 0.3; 2) 0.5; 3) 0.8; 4) 1.0; 5) 1.2; 6) 1.6.

the chute served as a thermoinsulating measuring plate made from Textolite with a Chromel – Copel thermocouple surface. The secondary air is blown through individual plane slots distributed at the start of the working section in front of the measuring plate. Slots were used in the experiments with angles of inclination to the channel axis $\gamma = 0$, 45, 75, and 90° (Fig. 1). The nominal height of the slot, S_H measured in a plane perpendicular to the channel axis, was from 2.05 to 2.5 mm for slots with different angles γ. Slots with angles $\gamma = 0$ and 90° were made of Textolite, while the slots with angles $\gamma = 45$ and 75° were made of asbestos cement. In the latter case three variants of the position before and behind the chute were studied: flush with the measuring plate (I), perpendicular to the channel axis (II), and perpendicular to the shielded surface (III).

Near the lower wall of the chute the current flow was close in its characteristics to the flow along a flat plate and the dynamics of the boundary layer were turbulent. A detailed description of the experimental apparatus, characteristics of the working section, and methods of conducting and working out the experiment were given in [4, 5].

Air at low velocities and temperatures ($u_1 \leq 25$ m/sec; T_1 and $T_2 \leq 380°K$) was used for the primary and secondary currents in all the experiments, where the temperature of the secondary current was ~50° higher than the temperature of the main current. In order to achieve maximum uniformity of the temperature field at the entrance to the working section, the temperature of the primary current was chosen equal to room temperature. The system of temperature stabilization of the primary and secondary currents assured a maximum error in the measurement of the efficiency at $\eta > 0.1$ not exceeding ± 10% (relatively). In the experiments whose results are presented below the quantities characterizing the operation of the apparatus remained stable and were equal to

$$\mathrm{Re}_1 \equiv \frac{\rho_1 u_1 s_H}{\mu_1} = 0.25 \cdot 10^4; \quad \overline{T}_{aT} \equiv \frac{T_{aT}}{T_1} = 1.0; \quad \theta \equiv \frac{T_2}{T_1} = 1.17.$$

For each slot geometry the coefficients of injection m were varied over a range from 0.3 to 1.5.

The results of experimental studies with slots in which the edges of the outlet were perpendicular to the axis are given in a logarithmic coordinate system in the form of the dependence of heat shielding efficiency η of the dimensionless distance from the slot x/s_H.

Thus, data are presented in Fig. 2 for two limiting cases of injection: curves I and II correspond to tangential injection ($\gamma = 0°$) with injection coefficient m = 1.0 (I) and m = 0.3 (II) [6], while the experimental points refer to injection through a slot with $\gamma = 90°$ [5].

The efficiency for a slot with $\gamma = 0°$, at all profiles x/s_H = const grows with an increase in the injection coefficient from 0 to m = 1.0, while the shape of the curves remains almost unchanged [6]. At the same time the shape of the efficiency curves for a slot with $\gamma = 90°$ is strongly dependent on the injection coefficient (Fig. 2), where the nature of the change in efficiency differs for different sections. At a distance from the slot ($x/s_H > 40$) the change in efficiency takes place just as in the case of a tangential slot, while close to the point of injection ($x/s_H < 10$) η decreases with an increase in the injection coefficient. Thus, for example, for a slot with angle $\gamma = 90°$ at an injection coefficient m = 1.6 there is a decrease of 50% in the efficiency close to the slot in comparison with the efficiency for a tangential slot ($\gamma = 0°$). Here if we consider the minimum allowable value of the efficiency to be $\eta = 0.4$, the extent of shielding of the plate surface from the effect of the primary current is reduced by five times in comparison with a tangential injection of the secondary air supply. An analogous picture is found in a comparison of the experimental data for slots with $\gamma = 45°$ on the one hand and $\gamma = 75°$ on the other.

A correlation of all the experimental data on the efficiency of heat shielding of a plane wall behind slots ($\gamma = 0$, 45, 75, and 90°) with fixed values of the injection coefficient is presented in Fig. 3. As seen

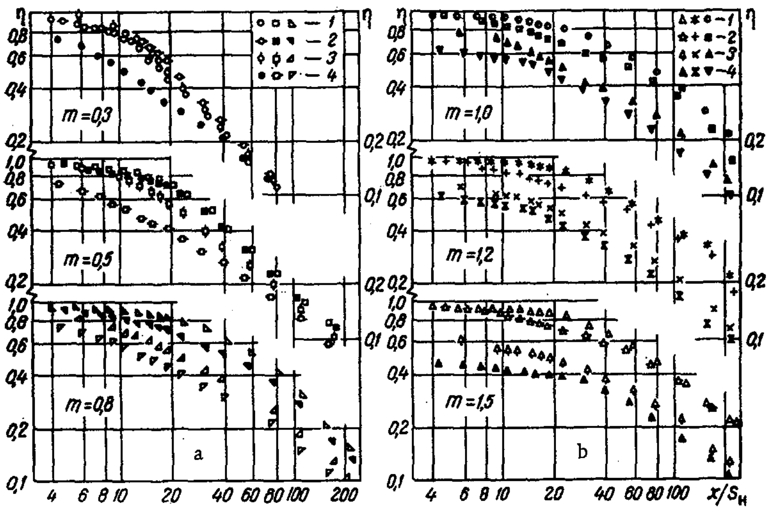

Fig. 3. Dependence of efficiency of heat shielding of a wall on the dimensionless distance x/s_H for three fixed values of the injection coefficient m = 0.3, 0.5, and 0.8 (a) and m = 1.0, 1.2, and 1.5 (b) and different angles of secondary air injection γ: 1) $\gamma = 0°$; 2) 45°; 3) 75°; 4) 90°.

from the figure, with an increase in the secondary air injection angle the efficiency on the whole decreases along the whole length of the measuring plate for all values of the injection coefficient. Vibration in the values of the efficiency at all profiles x/s_H = const can essentially be ignored at small injection coefficients $m \leq 0.3$ for slots with $\gamma \leq 75°$, and at $m \leq 0.5$ for slots with $\gamma \leq 45°$. At large values of the injection coefficient ($0.5 < m < 1.6$) the maximum reduction in efficiency for a slot with $\gamma = 45°$ does not exceed 0.15 in comparison with a tangential slot. As seen from Fig. 3, with an increase in the dimensionless distance from the slot x/s_H at small injection coefficients ($m \leq 0.8$) the efficiency curves have a tendency to draw together.

For slots with $\gamma = 45°$ the relative configuration of the outlet edges (see Fig. 1) has practically no influence on the efficiency of thermal shielding of the wall, while at the same time for slots with $\gamma = 75°$ the greatest efficiency is found when the edges are set perpendicular to the slot axis (II).

The configuration of edges flush with the shielded surface (I) leads to a negligible reduction in efficiency in comparison with the case given above (II) [7].

On the basis of the experiments conducted an increase in the angle of secondary air injection in relation to the shielded plate surface leads both to a reduction in the efficiency of heat shielding of the wall in comparison with tangential injection, and to a change in the nature of the dependence of efficiency on the injection coefficient in the immediate vicinity of the slot; the relative arrangement of the outlet edges of the slots with $\gamma \leq 45°$ has practically no influence on the efficiency, and at angles $\gamma > 45°$ one can recommend an arrangement of the edges flush with the shielded surface.

NOTATION

$\eta \equiv (T_1 - T_{a.w.})/(T_1 - T_2)$	is the efficiency of heat shielding of a wall;
$T_{a.w.}$	is the adiabatic wall temperature;
T_1 and T_2	are the temperatures of the primary and secondary currents, respectively;
T_{aT}	is the temperature of the surrounding medium;
Re_1	is Reynold's number, calculated from the parameters of the primary current and the slot height s_H;
$m \equiv \rho_2 u_2/\rho_1 u_1$	is the injection coefficient;
$\rho_1 u_1$ and $\rho_2 u_2$	are the mass velocities of the primary and secondary currents;
u_2	is the projection of the secondary current velocity on the axis of the slot channel;
u_1	is the primary current velocity;
x	is the distance along the measuring plate from the rear edge of the slot (with the current).

LITERATURE CITED

1. B. A. Zhestkov, V. V. Glazkov, and M. D. Guseva, Tr. In-ta im. Baranova, No. 267 (1955).
2. E. R. C. Eckert and R. C. Birkebak, Heat Transfer, Thermodynamics and Education, Boelter Anniversary Volume, New York (1964).
3. G. Reddy and J. Rama Subba, Inst. Engrs. (India) Mech. Engng. Div., 47, Part 3, No. 5, 158 (1967).
4. K. A. Bogakhuk-Kozakhuk, E. G. Popovich, and V. M. Repukhov, Heat Exchange in Energetic Devices [in Russian], Naukova Dumka, Kiev (1967).
5. V. M. Repukhov, E. G. Popovich, and V. M. Danileiko, Thermophysics and Heat Technology [in Russian], No. 15, Naukova Dumka, Kiev (1969).
6. V. M. Repukhov and E. G. Popovich, Dopovidi Akad. Nauk UkrRSR, Seriya A, No. 1 (1967).
7. E. G. Popovich, Technical Problems in Thermophysics [in Russian], No. 2, Naukova Dumka, Kiev (1969).