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EFFECT OF THE AERODYNAMIC STRUCTURE OF A FLOW ON THE HYDRAULIC CHARACTERISTICS OF THE DIFFUSER OF A FLAT-FLAME INJECTOR TORCH

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It is experimentally established that the admission of a twisted flow into a diffuser makes it possible to increase the expansion angle of the flow and reduce the dimensions of the torch.

Conical and plane diffusers with small divergence angles [1-3] are commonly used in various aerodynamic systems in the case of potential flow to smooth out the velocity profile and increase total pressure. Separated flows, arising at angles greater than 5-10°, place limitations on the degree of divergence of the diffuser. Such flows favor the formation of eddies and stagnant zones, which leads to dissipation of the flow energy and pressure loss. The main characteristic of the diffuser is the impact efficiency, which is determined experimentally for different divergence angles. This characteristic is inserted into a formula for determining the pressure loss from the difference in velocities in the inlet and outlet sections of the diffuser [2, 3]

$$\Delta P = \frac{(w_1 - w_2)^2}{2g} \varphi_{\text{dif}}. \quad (1)$$

The problem posed here was to obtain a flat flame 300 mm wide at the combustion front using a cylindrical mixing chamber 50 mm in diameter and having a minimum distance between the inlet and outlet sections of the diffuser. The chamber was chosen on the basis of the capacity of the torch, while the width of the flame was chosen on the basis of processing considerations connected with the area of application of the torch. The losses in the diffuser were limited by the excess gas pressure of 50 kPa and flow rate of 1 m^3/h (the maximum permissible quantity of vapor phase of the liquified gas taken from the 50-liter container).

The above problem cannot be solved with a diffuser with the recommended divergence angle of 5° [3], since the above dimensions for the mixing chamber and outlet section would give the diffuser a length of several dozen gauges. This would in turn increase friction losses of the kinetic energy of the flow and the dimensions of the torch.

A broad flame front could be obtained only by introducing a twisted flow into the diffuser cavity. It was suggested a priori that the more intensive development of such a flow [4] would ensure unseparated flow in a diffuser with a large divergence angle. Three diffusers with divergence angles of 45, 60, and 75° and curvilinear generatrices were studied on the basis of this proposal. The inlet sections of the diffusers were made circular, with a diameter equal to the diameter of the mixing chamber. The circle was made into an ellipse going away from the inlet, with the ellipse degenerating into a slit with the dimensions 300 × 6 mm at the diffuser outlet [5]. This optimum shape for the diffusers was chosen in accordance with the work [6], where the authors give preference to diffusers with a convex inlet section and a rectilinear continuation to a concave outlet section.

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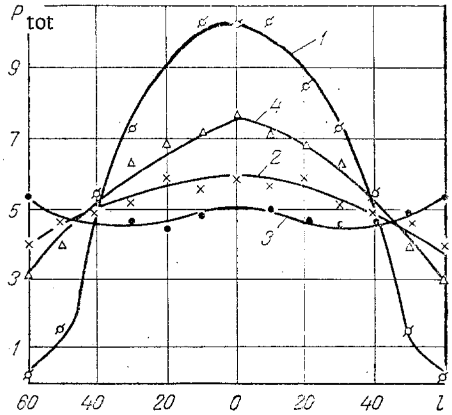

Fig. 1. Distribution of total pressure in the middle section of the diffuser with divergence angles of 45, 60, and 75°: 1) ε = 60°, n = 0; 2) 60 and 2; 3) 45 and 2; 4) 75 and 2. P_{tot}, mm H_2O; l, mm.

The character of flow in the middle sections of the diffuser was judged from the total pressure in the flow. The experimental results, shown in Fig. 1, permit us to conclude that, with a twisted flow, separated flow is seen when the diffuser has a divergence angle 75 = $\varepsilon > 60°$. With $\varepsilon \leqslant 60°$, flow separation from the wall does not occur and the diffuser length is four mixing-chamber gauges. For this diffuser, we measured the drop in static pressure in the inlet and outlet sections of the flow. This value turned out to be $\Delta P_{st} = 2.1$ mm H_2O. The mean flow velocity values $w_2 = 4.8$ m/sec at the outlet and $w_1 = 6.3$ m/sec at the inlet were used in conjunction with Eq. (1) to determine the impact efficiency $\varphi_{dif} = 0.18$. According to [3], the value of this coefficient corresponds to a diffuser divergence angle of 10° in the case of potential flow.

Thus, twisting of the flow in the mixing chamber, the size of which is determined in accordance with [7], ensures unseparated flow in the diffuser. This has a positive effect on drag in the torch as a whole. With a twist parameter n = 2 and optimum operating conditions (consumption of the gas—air mixture flowing through the diffuser 28.5 m^3/h), $\xi = 1.31$. According to the data in [8], the value of ξ fluctuates within the range 5.2-6.3 with n = 1.9-2.5 for torches and with a swirl vane. The value of ξ also increases with n. Thus, at n = 2.84, $\xi = 3.5$ for the design examined here. Further increase in the twist parameter causes the drag coefficient to approach an extreme value, which disrupts the injecting capacity of the torch and hurts its performance.

NOTATION

n, twist parameter of gas—air flow; ΔP, increment in total pressure in diffuser; φ_{dif}, impact efficiency; w_1, flow velocity at diffuser inlet; w_2, flow velocity at diffuser outlet; ε, diffuser divergence angle; ξ, drag coefficient.

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