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OF FLIGHT VEHICLES AND THEIR ENGINES

Analysis of a Coaxial Gas Ejector
V. A. Sychenkov, V. I. Panchenko, and R. R. Khaliulin

Tupolev Kazan National Research Technical University, ul. Karla Marksa 10, Kazan, 420111 Tatarstan, Russia
e-mail: vsychenkov@mail.ru, panchenkonl@rambler.ru

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Abstract—In this paper, the results of investigating a coaxial gas ejector without increase of passive
flow pressure are presented. A technique for calculation of coaxial ejectors has been developed. This
investigation has resulted in the optimal structure of ejector with a high value of ejection coefficient.

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Ejector devices have found wide use in aeronautical engineering for augmentation of engine thrust,
reduction of exhaust gas temperature and noise, etc.

Ejector is a device for movement of fluids, gases, and other mediums; the working principle of which
consists in transferring the mechanical energy from one medium moving with the higher speed to another
one. Irrespective of its function, the ejector consists of the following structural elements (Fig. 1): (1) nozzle
of active (ejecting) flow; (2) nozzle of low-pressure flow (being ejected); (3) mixing chamber; (4) diffuser.

In the majority of cases, ejectors are equipped with a cylindrical or isobaric mixing chamber. In order
to attain a proper mixing of flows, it is necessary to provide a correct mixing chamber length
(approximately 6–8 diameters of its inlet section). In [1, 2], the techniques for decreasing the mixing
chamber length (ejector dimensions) by dividing the flow into several jets are presented. With this
method, the ejection coefficient is similar to that in the conventional structure (Fig. 1).

In order to increase this coefficient and decrease the mixing chamber length, we propose another
technique that consists in changing the ejector design.

With this aim in view, the ejector mounted downstream of the gas turbine engine is analyzed in an
try to decrease the value of $\text{exh}^*$ and decrease thereby the ejector dimensions. A distinctive feature of
this ejector consists in the zero pressure increase of the flow being ejected. Efficiency of the ejector
operation was estimated by the ejection coefficient value:

$$n = \frac{G_{\text{act}}}{G_{\text{act}}},$$  (1)

In order to choose the optimal geometrical characteristics for this ejector, the investigations have been
carried out using the following models: the mixing chamber diameter is $D = 0.06–0.42$ m; the inlet
The temperature of combustion products is \( T = 360 \) and \( 450 \) °C; the velocity is \( w = 30, 40, 50 \) m/s; the Reynolds number is \( \text{Re} = \frac{wL}{\nu} = 7720; 31100; 50500 \) (\( w \) is the velocity of active flow (combustion products); \( L \) is the characteristic linear size (the equivalent diameter \( d_{eq} \) or hydraulic diameter \( d_h \), and \( \nu \) is the kinematic viscosity coefficient of the gas of the active flow).

The ejection coefficient was determined by the formula obtained from the energy balance equation:

\[
\frac{\Delta p}{\Delta \rho} = \frac{G_{\text{act}}}{G_{\text{mix}}} = \frac{c_{\text{act}, T^*} - c_{\text{mix}, T_{\text{mix}}}}{c_{\text{act}, T^*} - c_{\text{mix}, T_{\text{mix}}}},
\]

where \( c_p \) is the thermal capacity at constant pressure; \( T^* \) is the stagnation temperature (the following subscripts are used: \( \text{act} \)—active flow of gas, \( \text{mix} \)—mixture at the ejector outlet, \( ej \)—air being ejected).

Figure 2 presents a schematic diagram of the experimental setup. On leaving the nozzle, the GTE combustion products enter the ejector (inlet section) being examined. The flowrate of active flow and air mixture with the combustion products is determined by measuring the excess total pressures \( \Delta p_{1}^{*} \) and \( \Delta p_{2}^{*} \) by the Pitot tube (Fig. 2).

The temperature of combustion products and the air being ejected is measured with the use of thermocouples mounted at the ejector inlet section (section 1–1 in Figs. 2 and 3). The temperature of the air–combustion products mixture is measured at the diffuser exit (section 2–2 in Figs. 2 and 3). In our experiments, use was made of the chromel-coppel thermocouples.

The temperature values are the averages over the flowrate. The ejection coefficient was determined using formula (2). This method was used to study the different ejector models.

In the first step, we studied the influence of active flow nozzle scheme on the ejection coefficient (Fig. 4). This distribution of velocity \( (C_\alpha) \) in the active flow jet was first proposed in [3].

Installation of the active flow nozzle with free-vortex jet permits us to increase the ejection coefficient value by a factor of 1.6 due to increasing the velocity at the jet boundary with a larger curvature (Fig. 5).

In this case, the basic geometrical parameter is \( \alpha = \frac{F_1}{F_2} = 0.5; 0.33 \)

The influence of characteristic dimensions of the cylindrical (diameter \( D \)) and annular (\( H \)) mixing chambers on forming the temperature field profile at the ejector outlet (Fig. 6) was investigated.

As is seen from the graph (Fig. 7), the core heated up to \( 320 \) °C is observed in the model of ejector without the centre body, while on the diffuser walls, it attains \( 50 \) °C. It is indicative of the fact that the flow of combustion products fails to mix with the air being ejected. As to the ejector model with the