AVIATION IN THE XXI-ST CENTURY

INTERNATIONAL CIVIL AVIATION ORGANIZATION
NATIONAL ACADEMY OF SCIENCES OF UKRAINE
MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
NATIONAL AVIATION UNIVERSITY

PROCEEDINGS

THE SIXTH WORLD CONGRESS "AVIATION IN THE XXI-st CENTURY"

"Safety in Aviation and Space Technologies"

Volume 1

September 23-25, 2014
Kyiv, Ukraine

INTERNATIONAL CIVIL AVIATION ORGANIZATION
NATIONAL ACADEMY OF SCIENCES OF UKRAINE
MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
NATIONAL AVIATION UNIVERSITY

PROCEEDINGS

THE SIXTH WORLD CONGRESS
"AVIATION IN THE XXI-st CENTURY"

“Safety in Aviation
and Space Technologies”

September 23-25, 2014

Volume 1

KYIV 2014

UDC 621.694.2:629.3082.3(045)

K.I. Kapitanchuk., PhD. Sc. Science,
P.I. Grekov, PhD. Sc. Science,
N.M. Andriyishyn, M. Y. Bogdanov
(National Aviation University, Ukraine)

INTEGRAL METHOD OF GAS EJECTORS CALCULATING IN MIXING CHAMBER WITH UNEVEN FLOW BY SECTIONS

The possibility of using the integral method of calculating of the gas ejector considering uneven flow along the mixing chamber.

Increase in requirements to efficiency of power plants, the desire to get the most power and provide the least resistance to external integration of glider of aircraft have led to the need for deep research of gas dynamics flow in the output devices, which are the most important elements of power plants.

Use of ejector jet nozzle (output devices) of various applications creates additional problems relating to issues of optimal aerodynamic design to improve the efficiency of their use with minimal loss of energy and decreasing cost of the life cycle.

A variety in gas-dynamic and geometric parameters of turbulent three-dimensional flow that determine the type, scheme and the laws regulating jet ejector nozzle (output devices) do not allow, nowadays, theoretically solve all problems that arise in practice in development of array of nozzles for modern and future aircraft. [1]

In all sections of the mixing chamber of the finite ejector length there is uneven distribution of gas flow parameters. Therefore, the calculations of the ejector at input and output cross-sections, where flows are considered consistant are insificient.

Most unreasoned is an introduction of idialized model of the mixing chamber and the assumption of complete mixing of flows. Mixing chamber has a length comparable to its diameter.

Therefore, the velocity profile of the initial flow in output cross-section of mixing chamber is inconsistant. Strict length of mixing chamber leads to flow pressure rates decrease in ejector.

Moreover, the inconsistance of the flow due to incomplete mixing reduces efficiency of the diffuser and increase the pressure therein. In general, change among the parameters of the jet flow is faster than in the ideal case, and mixture of cold air appears to be less intense.

Calculation of the flow mixing process in the mixing chamber of the ejector is one of the applications to the theory of a free jet. Two streams of different initial speed, temperature, molecular weight and chemical composure will mix in ejector mixing chamber to gradualy reduce all uneveness of parameters to form a consistant flow.

Fig. 1 shows a diagram of the flow in the mixing chamber and the process of formation of the velocity field in the cross section of mixing chamber [2-4]. Universality of fields in different cross-sections allows the calculation of flow parameters in any cross-section point of mixing chamber via certain integral dependencies.

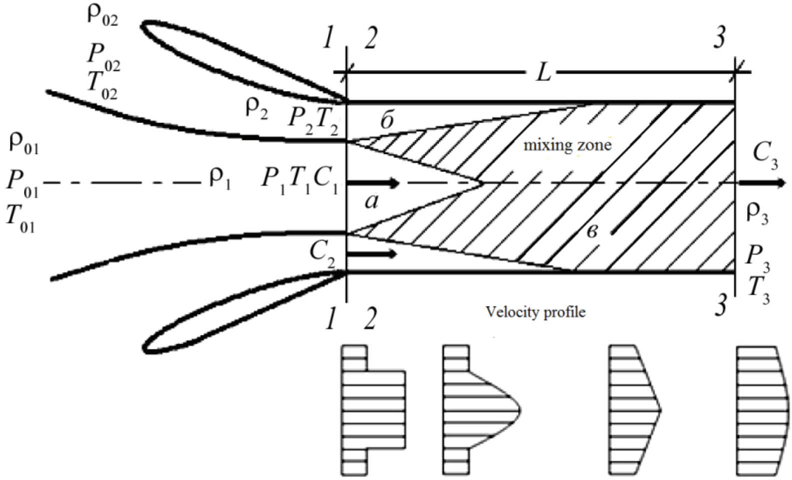

Fig. 1. Scheme of the flow in the mixing chamber of a gas ejector:
$\tilde{a}$ the potential core of active gas, $\tilde{b}$ a potential core passive gas;
$\tilde{c}$ mixing zone

To calculate the pressure in the short ejector one needs to know the total momentum in section *3-3*, that depends on the velocity profile.

Lets use the property of self-similarity profile in a turbulent mixing layer, as described in works of Abramovich [5] and Schlichting [6]:

$$c_1(x,r) = \frac{c_1(x)+c_2(x)}{2} + \frac{c_2(x)-c_1(x)}{2} f(z),$$

where $z = \dfrac{r - r_1(x)}{b(x)}$, $f(z)$ – universal function (at constant pressure of flow in cross-section).

To calculate the $f(z)$ formula $f(z) = (3z - z^2)/2$ can be used.

Other variables determined by the following algorithm:

– unperturbed velocity in the potential flow fields $c_1(x)$ and $c_2(x)$ defined by the values of static pressure from Bernoulli equation;

– half-width of the mixing layer $b(x)$ calculated with step-by-step integration of equation

$$db(x) = C' \frac{c_1(x)-c_2(x)}{c_1(x)+c_2(x)},$$ where – dimensionless constant [7];

– center of the mixing layer $r_1(x)$ calculated from the equation of conservation of mass in integral form;

– pressure $p(x)$ calculated with step by step integration of pulses equation

$$dp(x) = -\frac{dM}{A(x)}, \text{ where } M(x) = \int \rho C^2 dA .$$

Usually, integration of the equations to calculate $b(x)$ and $p(x)$ isn't difficult. Function $c_1(x)$ and $c_2(x)$ are the function of pressure (Bernoulli's law), and conversely, the pressure is a function of $c_1(x)$ and $c_2(x)$.

All variables in the right-hand side of equations must be defined from the previous step before iteration (Fig. 2). At the end of the jet potential Bernoulli equation is not applicable. Therefore, the value $c_1(x)$ calculated from the equation of conservation of mass and value of $r_1(x)$ considered equal to $b(x)$.

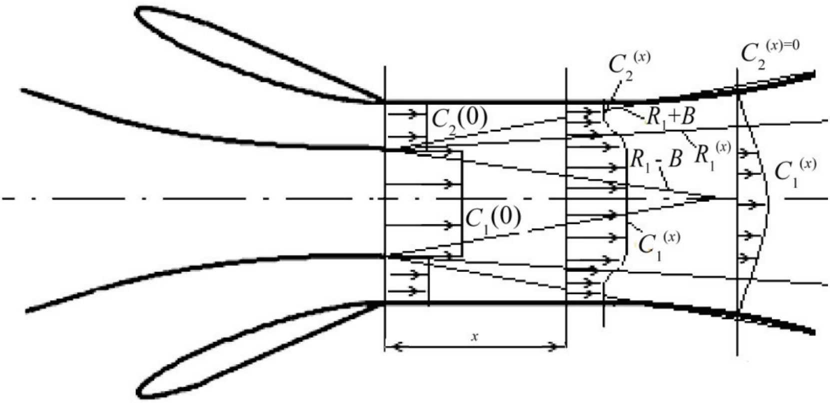

Fig. 2. Mixing chamber design model

The region of outer potential ends where the pressure is increased to value corresponding

$p(x) > p(0) + \rho c_2^2(0)/2$, in other words, at $c_2^2(x) < 0$.

This section describes cross-section, in which the mixing layer boundaries $(r_1 + b)$ does not reach the walls. If the mixing layer boundaries reaches the wall of the chamber, the Bernoulli equation must be replaced by another equation where $c_2(x) = 0$.

This based on an assumption of continuity $c_2(x)$. Its admission should be confirmed by comparing the calculation results with experimental data. In contrast to the approximate model of ideal mixing, used integral method can only be applied to axially symmetric ejectors. As the leafed nozzle significantly improves short ejectors output it's important to calculate the parameters for increasing ejection without using cumbersome three-dimensional applications.

Nozzle of arbitrary cross-sectional shape has axisymmetric equivalent of the same area, they differ from each other only by perimeter value.

Perimeter of leafed nozzle is greater than the perimeter of equivalent nozzle in K times [7], by value $K = P_r / (2\sqrt{\pi A_1})$.

It can be shown that axisymmetric approximation allows to simulate three-dimensional flow by changing dimensionless constant C' in the half-width mixing layer equation with $C' = KC'$.

In the case non-axisymmetric nozzle $K > 1$, corresponding thickness of the mixing layer grows faster than round nozzle case, mixing will be more intense and pressure grows at a short distance. However, in this case there is a problem determining static pressure at the mixing chamber inlet.

Conclusions

In all sections of the finite length ejector mixing chamber there is uneven distribution of gas flow parameters.

Therefore, the calculations of the ejector at input and output cross-sections, where flows are considered inconsistant, and in many cases are insufficient.

Thus, the idea of using the integral method for calculating the gas ejector considering uneven flow along the mixing chamber is put forward.

References

1. *Лаврухин Г.Н.* Аэрогазодинамика реактивных сопел // Внутренние характеристики сопел. — М.: Физматлит, 2003. — 376 с.
2. *Авиационные* эжекторные усилители тяги / В. Г. Ененков, А. Л. Клячкин, В. С. Коротков, В. М. Супрун; под ред. А. Л. Клячкина. – М. : Машиностроение, 1980. – 135 с.
3. *Дослідження* методів зменшення теплової помітності літальних апаратів / М. С. Кулик, П. І., Греков К. І. Капітанчук, О. Г. Ластівка // Промислова гідравліка і пневматика, 2008. – №1 (19). – С. 46–50.
4. *Греков П.І., Капітанчук К.І., Козлов В.В.* Pick up the question of definition gas-dynamic parameters of subsonic ejectors // The Fifth World Congress «Aviation in the XXI-st Century Safety in Aviation And Space Technologies». – Kyiv. : NAU, 2012. – V.1. – P. 1.13.15 –1.13.19.
5. *Абрамович Г. Н.* Теория турбулентных струй / Г. Н. Абрамович. – М. : ЭКОЛИТ, 1960. – 720 с.
6. *Шлихтинг Г.* Теория пограничного слоя / Г. Шлихтинг. – М. : Наука, 1974. – 711 с.
7. *Гогиш А.В.* Теория двумерных отрывных течений / А. В. Гогиш, В. Я. Нейланд, Г. Ю. Степанов // Итоги науки и техники. Гидромеханика. – М. : Наука, 1975. – С. 5–73.