AVIATION IN THE XXI-ST CENTURY

NATIONAL ACADEMY OF SCIENCES OF UKRAINE
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PROCEEDINGS

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

"Safety in Aviation and Space Technologies"

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1.5. Engines and Power Installations

1.6. Methods and facilities of technical and medical diagnostics

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Research of exhaust-screen devices for jet-engine

The article addresses scientific issues of design of exhaust screens as most common and reliable method of protecting aircraft from guided infrared homing head missiles and surface-to-air missile systems. Array of experiments was conducted for different types of jet engines, all of which achieve forward thrust from the principle of jet propulsion: turbojet, turbofan, turboprop and ramjet. Using non-axial flow turbines result in a drop of thrust power. For purposes of reducing energy loss and achieving less field flow fractionation static exhaust blades should be used.

At present the most perspective and commonly used way of planes, helicopter and other air objects protection form target engagement by missiles with infrared homing and also from man-portable air-defense system (MANPADS) is the use of ejectors in exhaust screen devices [1-3].

Using of MANPADS by terrorist groups is extremely exacerbated the problem of civil aircraft and helicopter flight safety and also made this issue on of the most acute and actual in the modern world. Therefore, the new direction of aviation facilities, flight safety is a creation of aircraft protection system from potential destruction.

According to the data [4] decreasing of exhaust gas temperature from engines on 30% leads to decreasing the length of the capture range by opto-electronic systems on 43% and reducing temperature to 50% decrease the length of the capture range on 67%. Consequently, the use of ejectors in GTE exhaust screen devices is appropriate and necessary in many cases.

Theoretical investigation improving of the experimental data those allow to describe with the help of some equations gas flows and gas mixes. By the methods of applied mathematics developed efficient ways to solve these equations on a computer.

Experimental data give an opportunity to define the necessary values of physical and chemical characteristics, which are common to the investigation environment or process. A lot of tasks before scientists, caused by the development of modern technology, currently, can’t be solved by calculation-theoretical methods. In these cases there are widely used gas-dynamic experiments, conducted in wind tunnels and special gas dynamic facilities.

During providing gas-dynamic calculations are commonly used simplified theoretical understandings about average gas flow parameters along the cross section of desired object channel using main patterns of the flow that are found by experiment.

During providing calculation of GTE compressors and turbines, nozzles and diffusers, rocket engines, wind tunnels, ejectors, gas pipes and other technical facilities used characteristics obtained from generalization from theoretical and experimental studies.

For the definition of a gas flow feature in present conditions, provide complex of different shapes axial subsonic gas ejectors experimental investigation with flow turning from 0 to 90°. Experimental investigation produced on model facilities, general view gives on fig.1 *a, b*.

a) *b)* *c)*

Fig. 1. Wind tunnel with nozzle part

The installation looks like an open wind tunnel and includes lines of compressed air supply, receiver, transitional section, and knot for installation of different type of nozzles, chamber of mixing and diffusers and instrumentation. Air from environment supply to installation with the help of two consistently connected superchargers (fig. 2 *c*).

Main constructive features of operation parts were taken according to the recommendation [5]. In order to provide a uniform velocity and pressure field in the wind tunnel was designed honeycomb and anti-turbulence netting. Geometrical dimensions of calming chamber correspond to ГОСТ 10921-74.

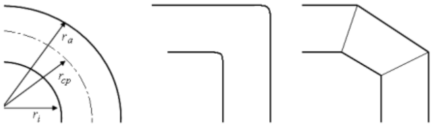
During the research process was obtained capacity characteristics of receiver cross section that narrows the profile of which was close to the Witoszynskyj curve. In this cause exhaust diameter was equal to 105 mm. Along with nozzles have been tested mixing chambers. Diameter of an initial cross section of mixing chamber changes according to ejection coefficient n=0.01; 0.05; 0.1. The length of the mixing chamber was 350 mm. For the cylindrical part of the chamber was mounted tapered expanding section (subsonic diffuser) with half cone -4°.

Nozzle models, mixing chambers and diffusers were installed in compressed air supplying manifold after the transitional cross section of the receiver. One of the variants of experimental model nozzle part of active gas flow and experimental model of axial subsonic ejector present at fig. 3.

Fig. 3. Experimental model nozzle tips and model axial subsonic ejector

In all cases, design of the gas ejector model allows to change the ejection rate by the changing of cross-section area of the passive air ringing type nozzle. Irrespective of the form of the channel cross section turning of a flow provided by a right angle or along the curved channel contour of which consisted of straight segments.

At fig. 4 present three types of turning knees and marked inside radius r_i, external r_a and average r_{av} radiuses of the curve.



a) *b)* *c)*

Fig. 4. Type of knees: a - curvilinear; b - rectangular; c - broken

To rebuild the model conditions at the active gas nozzle input were used turning knees with flow turning to 90°.

Research of the gas ejector with mixing chamber and flow turning, which had several stages of passive gas, conducted on the prototype, that is presented on fig. 5.

Fig. 5. Multistage mixing chamber

Visualization of the flow was provided with the help of gluing hair strands on the surface of the mixing chamber, which is reflected in fig. 6.

Complex of research experiments involved studying construction of gas ejectors with the intensification of the mixing process:

- gas ejectors with nozzles of active gas, that divided on to the several flows;
- gas ejectors with nozzles of active gas, with had part of transition cylindrical in to the flat;
- gas ejector with petal active gas nozzle;
- gas ejector with the combined nozzle of active gas and supplying of passive gas into the center of mixing chamber.

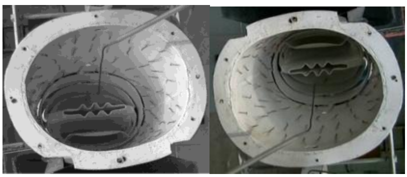


Fig.6. Flow visualization at experimental model of ejector

Results of experimental investigations

In ejectors with petals at the inlet to the mixing chamber (fig. 7) alignment of the velocity field is more intense. At low velocities unevenness of velocity field produce useful effect, that obtained by further aligning at mixing chamber, doesn't compensate the value of hydraulic losses which increased.

Fig.7. Prototype of ejector with petals at the inlet to mixing chamber

Consequently, there is a finite optimal length of mixing chamber. Experimentally this is defined by the presence of a maximum static pressure of the mixture at some finite distance from the inlet to the mixing chamber.

This is caused by the necessity to turn the hot gases behind the mixing chamber up regarding the helicopter to reduce the length of its capture by missile of «ground-to-air» type.

Flow turn leads to additional energy losses and as a result, in reducing of power turbine power.

In order to reduce energy losses and providing uniform velocity field advisable to use profiled or non-profiled plates and guide vanes that installed at the corner [6].

Provide research of experimental prototypes of ejector type exhaust screen devices of the flow turning with guide vanes at the outlet of the mixing chamber (diffuser).

At fig.8 shows an experimental prototype of ejector type exhaust screen devices with guide vanes at the outlet from mixing chamber. Research has approved that the using of guide vanes at the outlet from exhaust screen devices and reduced direct "visibility of hot gases" gas ejector active nozzle. This, in turn, reduces range of helicopter capture by "air-land" missile type with infrared homing heads.

The length of the mixing chamber of exhaust screen devices restricted by permissible dimensions of the helicopter, so the mixing process intensification depends from the length of mixing chamber and become more actual.

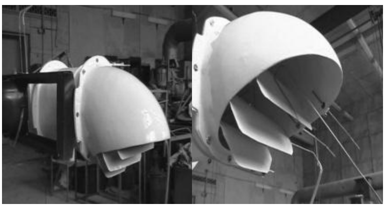


Fig.8. Experimental type of exhaust screen devices with guide vanes

Important direction of intensifying the mixing process is the using flow spin, separation of the active gases into the several jets, applying a petal type of mixers and other.

The analysis of work on the subject of research where the results of experiments and theoretical knowledge leads to the conclusion that the satisfactory results of theoretical researches is available only for the causes of insignificant flow spinning and absence of reverse gas flow. Nowadays, significant characteristics for the subsonic gas ejectors with intensification of the mixing process can be determined only by experiment.

Conclusions

Substantiated a scientific and technical problem of development exhaust screen devices device as one of the most common and effective means of aircraft protection, helicopters and other air objects from destroying with infrared homing heads and portable MANPADS.

In determining the characteristics of gas flow in real conditions performed complex of experimental studies of various forms axial subsonic gas ejectors with flow turning from 0 to 90°. Visualization of the flow in the mixing chamber performed by using a carbon black mixture and horsehair stickers.

Studied the structures of gas ejectors with active gas nozzles that divided into several flows; gas ejector with nozzles of active gas that had transition parts from cylindrical to flat; gas ejector with combined nozzles of active gas and supplying of passive gas inside the mixing chamber.

Revealed that flow turning leads to additional energy losses and thus to reducing of the power turbine. In order to reduce energy loss and providing uniform velocity field appropriate to use profiled of non-profiled plates of guide vanes.

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