UDC 629.735.03(02)

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Reducing of energy losses at the turbine outlet by means of application of diffuser-ejector systems

Analyzed ways of increasing of power and operation efficiency of GTU with application of diffusers in the systems of exhaust pipelines for pressure reducing after turbine machine last stage. Ways of increasing of technical and economic characteristics by application of diffuser-ejector systems are proposed

Traditional ways of GTU power and efficiency increasing

The problem of increasing the efficiency of gas turbine plants is currently being solved by increasing the aerodynamic improvement of the main equipment of these plants and by improving their thermal schemes, as well as by changing cycle parameters (the temperature in front of the gas turbine has the greatest influence).

Traditional ways of increasing the efficiency and reliability of the flow parts of power gas turbines have practically exhausted themselves. The efficiency of their flow parts reaches 91-92%, which brought the specified values closer to the theoretically possible values.

An increase in temperature gives a gain in economy. This trend is observed at all the created gas turbines and reaches values of 1350-1400ºC. New samples with a temperature of 1600°C are being created.

The use of such temperatures led to the need to use expensive heat-resistant materials and developing complex systems for cooling the flow part of gas turbines.

In this regard, the most promising from the point of view of increasing the internal relative efficiency of the gas turbine and its power are developments related to the reduction of irreversible losses of kinetic energy of the flow of working bodies that leave the last stages of these turbines. Absolute gas velocities at the exit from the last stage of some gas turbines of medium and low power are 150-350 m/s.

Diffusers in the system of removal of working media from gas turbines as a natural way to increase their efficiency and power

In gas turbines, the amount of kinetic energy losses after the last stage reaches 7-8% of the useful power of the gas turbine installation. So, for example, in the Siemens SGT5-4000F GTU with the gas consumption through the last stage equal to G = 656 kg / s and the axial speed after the last stage C_{2z} = 250 m / s (M_z = 0.3). the equivalent power of the output flow reaches 18 MW (9% of the useful power of the gas turbine power plant) [1].

All turbo-building companies in the world pay special attention to the problem of reducing these energy losses, trying to use the kinetic energy of the output flow to create a high diffusion effect at the last stage.

As a result of the use of annular diffusers in the exhaust pipes of gas turbines, it was possible to convert up to 50% of the kinetic energy of the flow leaving the last stages of these turbines into potential energy.

The power increase in the turbine when using such a ring diffuser can be estimated by the well-known ratio:

$$\Delta N_{0i} = G\frac{c_z^2}{2}(\zeta_{\Pi} - \zeta_{\Pi}^{Д})\eta_{0i},$$

where G is the consumption of the working fluid according to the last degree of GTU; c_z^2 - speed of output of the working body from the last stage in absolute motion; ζ_{Π} - coefficient of total losses without diffuser nozzle; $\zeta_{\Pi}^{Д}$ - coefficient of total losses of a nozzle with a diffuser; η_{0i} - internal, relative efficiency coefficient of the flow part.

When installing a diffuser with an opening angle α = 7º and a degree of expansion f = 2, losses are reduced by 50%, and when the degree of expansion is increased to f = (3-4), they fall by (70-75)%. The length of the diffuser, in this case, is commensurate with the length of the gas turbine itself - (5-7) meters. Therefore, diffusers with a large degree of expansion and moderate opening angles (up to 10º) have not found practical use. Limiting the angle of the diffuser in order to increase its degree of expansion and decrease its length is associated with an increase in pulsations at its input, as well as with separation of the flow from the walls in the diffuser

To increase the power on helicopter GTE can be used:

1) a diffuser, the installation of which allows you to lower the static pressure after the free turbine;
2) an ejector, which allows not only to lower the static pressure behind the free turbine, but also to reduce the temperature of the combustion products due to the mixing of air from the environment. On helicopters, ejectors are used to cool the space under the hood, reduce the temperature of gases and its removal, this is especially important in the hovering and back-and-forth flight modes.

Numerical modeling

The numerical study was performed in the universal built-in CAD system Catia5-CFD package/program FloEFD Mentor Graphics Corp. The calculations were performed for the take-off mode of operation of the gas turbine engine.

The purpose of the research was to determine the quality of the flow, the absence of secondary flows in the exhaust pipe of the engine under the same boundary conditions using an ejection blade.

The results of the calculations showed that the numerical simulation of the flow of exhaust gases in the exhaust device used in the composition of the TV3-117 engine in the CAD system Catia5-CFD package/program FloEFD Mentor Graphics Corp can be used not only to estimate the total pressure, but also to optimize the geometry of designed exhaust devices.

The effect of non-uniformity of the flow in the exhaust nozzle is shown. The equalization of the flow in the exhaust nozzle with the help of an installed vane resulted in a reduction of total pressure loss by more than 1%.

Fig. 1 shows the flow lines in the standard nozzle and the nozzle with the ejection blade installed. The nature of the flow has a complex spatial structure with a small number of vortex zones, which are concentrated in the area of flow turns.

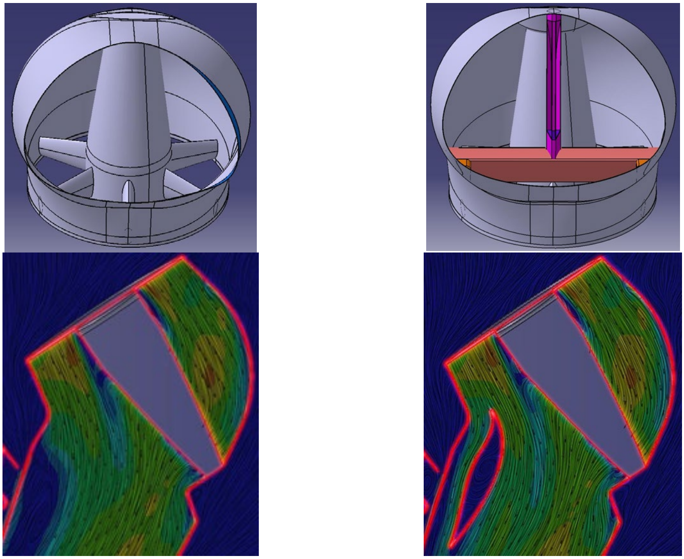

Figure 1 - Flow lines in a regular nozzle and a nozzle with an ejection blade.

Further calculation and experimental studies should be carried out with the aim of:

- reducing the unevenness of the flow from the exhaust nozzle of the helicopter engine;
- verification of the results of a numerical study by comparison with the results of further experimental studies and field tests in the conditions of a helicopter flight.

References

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