Study of Changes in the Aerodynamic Characteristics of the Axisymmetric Supersonic Vehicle in Case of Gas Blowing from the Lateral Surface

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Abstract. We consider the flow around the axisymmetric supersonic vehicle with the use of gas jet blowing from the lateral surface. The blowing is made in series of points at different distances from the nose fairing. The aim of the work was to determine the changes in aerodynamic forces and the formation of the moment, when jet of gas blowing in different parts of the supersonic vehicle. The study was conducted by numerical modeling of different cases of injection. As a result, data were obtained which showed the degree of influence not only jet thrust from the jet flow, but same the impact of the redistribution of the flow by body surface on the formation of aerodynamic forces and moments.

Introduction

The main methods of modern flight control of supersonic vehicle in the Earth's atmosphere is a deviation of the aerodynamic control surfaces or thrust vector deflection of a jet engine [1]. The injection of the gas jets from the lateral surface of the supersonic vehicle is considered to be "untraditional" flight management issues. The use of jets to control, primarily, eliminates the spending of constantly aerodynamic resistance existing controls. The blowing system control provides a sufficiently high efficiency at low dynamic pressure (i.e., at low speeds or at high altitudes). These systems have a high performance (very little time inclusion and disconnection), which is essential for high-speed maneuvering of supersonic vehicle. However, the impact of the jet on the lateral flow over the surface at supersonic speeds still is a complex and poorly understood phenomenon, that makes it difficult to use blowing of systems management in practice [2]. Also, need study usefulness such a system at a relatively high dynamic pressure.

Formulation of the Problem

The flow was simulated around the axisymmetric supersonic vehicle with the air flow parameters of the respective flight at a height of H = 1,6 km at number Mach 3. The nose part has a conical shape with a cone angle $\varphi = 20^\circ$. The prolongation of all body of $L / D = 25,33$. The stabilizer consist of the six wings.

For the simulation were selected 5 holes of injection, as shown in Figure 1. The holes have a circular cross-section of the diameter $d / D = 0,1$. Injection at the location along the length of the studied body were at a distance from the nose $L / Lp = 0,12; 0.32; 0.52; 0.72$ and $0.93$. As the working gas, we use to create the jet air was supplied at $Mi = 2$, the stagnation pressure $Pi = 1.47$ bar and a temperature of stagnation $Ti = 300$ K. The simulation was performed for various cases, the location of the injection holes relative to the wings tail stabilizers. As a result, it was found that such a factor does not significantly affect the results obtained, except location immediately before
stabilizer. Therefore, in this paper we consider the placement of holes blowing in the plane between the two lobes of the tail stabilizer.

Results

After turning the system blowing a jet of gas expansion area creates an obstacle to the main stream. There are similarities between the injection jet and a solid obstacle. In [3, 4, 5] it was used analytical methods for considered the issue. In fact, the pattern formed in the case of the injection jet is similar to the flow pattern in the case of installation of the flow path blunt axially symmetric rigid body. As a result of the emergence of additional obstacles in the form of flow jet aerodynamic drag force axisymmetric supersonic vehicle streamlined at a zero angle of attack is changed to 2 - 4%. In the first blowing system creates reactive force jet along the axis Y. After this there is the effect of redistribution of pressure associated with a change in flow. Figure 2 shows the total value of the lateral force depending on the position of the jet blown, as indicated by the thrust force and by redistributing pressure.

![Figure 2. Is a cross forces at various positions exhaled jets.](image)

where - the impact of jet thrust, - redistribution effect of pressure on the surface, - net effect

It can be seen that the influence of the pressure redistribution effect can be about 4 times greater than the jet thrust. Since these forces are directed in different directions, the total net force exceeds the thrust only 3 times. In any case, the total net force directed toward the reverse thrust, which is contrary to the conventional idea of the effect on blowing with the lateral surface. When location the blown towards in the stern of the reduced impact area of the jet to the surface supersonic vehicle and, consequently, decreases the magnitude of the net force created. As a last resort to consider the situation of the jet thrust of the jet and the force of the pressure redistribution same direction, so the total net force changes direction toward the force of traction.

![Figure 3. Moments at different positions blowing jets.](image)

where - the impact of jet thrust, - redistribution effect of pressure on the surface, - net effect

Figure 3 shows the value of the total pitching moment about the center of gravity depending on the position of the blown jet along the length of the supersonic vehicle. It also shows the total moments the terms of this - from the effects impactofjetthrust and redistribution effect of pressure

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on the surface. It can be seen that the moment due to the thrust of the jet blown decreases when moving the hole of blowing the tail of the rocket and becomes negative when passing through the center of gravity. At the same time the induced moment of reallocation pressure increases as we move to the hole of blowing the tail of the rocket and \( L / L_p = 0.7 \) exceeds the moment of traction approximately 2.5 times. As a last hole of the considered position of the jet blowing moments of the same sign and the total moment exceeds the maximum moment from the impact of jet thrust in 4.3 times.

During the simulation of blowing gas jet from the side surface of the axisymmetric supersonic vehicle, it was noticed a dramatic change both the direction and magnitude of lifting force coupled with a change in flow, during the injection of the jet in the region of the tail fin. Clearly, the wings affect the pressure redistribution. We have conducted simulations of the axisymmetric flow blowing from an supersonic vehicle at a distance from the nose \( x / L = 0.12 \). Around the injection holes are positioned wings, the angle between the wings composes 60° (a). As the variant without wings (b). We were also examined: the configuration (c), with six wings on warhead, with an angle of between 60° and the hole of blowing on distance from nose \( x / L = 0.046 \) (before stabilizing wings) and the configuration (g), with four wings on warhead, with an angle of between 90° and the hole of blowing away from the nose \( x / L = 0.067 \) (in the middle of stabilizing wings).

![Configuration supersonic vehicles](image1)

**Figure 4. We viewed configuration supersonic vehicles.**

![Distribution of the total pressure on the surface of supersonic vehicle.](image2)

**Figure 5. Distribution of the total pressure on the surface of supersonic vehicle.**

Figure 5 shows the pressure distribution on the surface of supersonic vehicle. It is not difficult to notice that the configuration does not affect the overall picture of the formation of different pressure zones on the surface of the supersonic vehicle during gas jetblowing. One of the pressure zone, formed as a result appearance the vortex in shape horseshoe. The figure shows that in the presence near the hole of gas injection stabilizing wings, legs horseshoe shaped vortex fall on those wings. The wings can increase the area of exposure, which increases system efficiency. It can be seen from Figures 6 and 7.
Changing the direction of the lift force by placing the stabilizing wings near the hole of injection of the gas jet, can significantly increase the resulting moment (when compared to the cases (a) and (b), the increase was 6 times).

Conclusion

The results of numerical simulation of the axisymmetric flow supersonic vehicle with transverse blowing gas jet indicated that blowing jet leads to a redistribution of surface pressure, whereby there is a net force in the opposite direction from the direction of the reaction thrust jet stream and more than thrust force in 4 times. The point of application of transverse forces does not coincide with the point of application of reaction jets, causing additional induced pitching moment.

By moving the hole of blowing a jet along the length of the body pitching moment induced increases and $L / L_p = 0.7$ exceeds the maximum moment of the thrust force of about 1.7 times. When blowing jets in the aft body lateral force of the pressure redistribution coincides with the direction of the reaction jet, and the total net force exceeds the thrust of the jet 2.5. In this case, the total pitching moment exceeds the maximum moment of thrust approximately 4.3 times. This is due to the fact that the tail surface stabilizers are utilized in connection with which there is an increase of efficiency at blowing.

References


