Exploration and study of fluid thrust vector nozzle

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Abstract. A fluid thrust vectoring nozzle model was established, and the numerical simulation was used to study the model and flow. When the control slot was closed at the same time, the control slot did not work and the main direction was in the central region. When the control slot opens at the same time, due to the influence of the mainstream low pressure, the outer air flow flows into the mainstream from the upper and lower air inlets respectively, and the mainstream flow increases slightly. The main flow will not deflect when the upper and lower air inlets are opened or closed at the same time, thus verifying the accuracy of the calculation model. When one side of the air inlet is opened and the other side of the air inlet is closed at the same time, the external gas flows into the mainstream from the open side of the air inlet and impacts the mainstream. As the mainstream is impacted asymmetrically, it deflects to the closed side of the entrance. Fluid thrust vectoring nozzle has the advantages of simple structure and high control efficiency.

1. Introduction
Thrust vector technology is an important way to improve the high maneuverability of aircraft. It is one of the key technologies for future fighters. The thrust vector is deflected by the thrust vectoring nozzle, and the required control torque is obtained. At present, the thrust vectoring nozzles are mainly composed of mechanical controlled nozzles and fluid controlled nozzles.

The thrust vectoring nozzle used in practice is mainly controlled by machinery. After the mechanical thrust vectoring nozzle is used in aircraft, many characteristics have been improved to varying degrees and great engineering benefits have been obtained. However, there are several unfavorable problems in the mechanical thrust vectoring nozzle: the structure is complex: the mechanical thrust vectoring nozzle depends on a large number of actuating components to drive the tail nozzle to change its exit direction. To change the thrust direction, many actuators make the tail control mechanism of the nozzle very complex. The quality is heavy: the tail nozzle is in the high temperature environment when it works. The mechanical thrust vectorial nozzle is not only resistant to high temperature but also the mechanical strength is high. It causes the heavy weight of the engine tail nozzle, usually can make the engine weight increase 20%-30%, the reliability is poor, the nozzle life is short: the mechanical thrust vectoring nozzle has complex structure. Due to the large number of actuators, its reliability is greatly reduced and its service life is relatively short, usually only 200-300 hours. Engine thrust loss is serious: thrust loss of mechanical thrust vectoring nozzle can reach more than 10% when the nozzle deflects, and thrust loss is serious.
Due to the many shortcomings of the mechanical thrust vectoring nozzle, it is difficult to meet the requirements of future fighters with low reflectivity, light weight, low cost and high reliability. The thrust vectoring nozzle in the form of fluid does not need complex moving parts. It only needs a simple gas source and ventilation pipe, and the weight of the mechanical type is lighter and the reliability will be greatly improved. The technology of fluid thrust vector control will be the new direction of the development of thrust vector technology. Therefore, it is an urgent task to study the mechanism of jet thrust vector control and to master the technology of jet thrust vector control. The thrust vector deflector of the thrust vectoring nozzle in the form of fluid is mainly controlled by shock wave, inclined throat, reverse flow control and co flow control. A new type of nozzle is designed, its structure is novel; the nozzle can carry on the control of thrust vector deflection with gas source and gas source; it is similar to the same direction flow, which is different mainly in the control of the air source; the main flow velocity of the nozzle can reach the supersonic speed, which is similar to the actual condition; to the main stream, the main stream is similar to the actual condition. The deflection control can basically achieve continuous deflection control.

2. Model Introduction
The shape of the nozzle section is classical, and there is a control port on the top and bottom of the nozzle expansion section. The nozzle model and grid are shown in Figure 1. The grid of the mainstream part of the model is structured grid, and the grid of the control part is an unstructured mesh. The plane in the graph is the section of the model, which shows the grid of the section.

![Figure 1. Model description](image)

3. State Description
3 typical states are simulated by numerical calculation. The specific parameters of each state are shown below.

| state   | Pressure inlet | Up airflow entrance | Down airflow entrance |
|---------|----------------|---------------------|-----------------------|
| state 1 | 5000Pa         | off                 | off                   |
| state 2 | 5000Pa         | on                  | off                   |
| state 3 | 5000Pa         | on                  | on                    |
4. Calculation Results

4.1. The Upper and Lower Control Seams Do Not Open
The pressure of the pressure inlet is 5000Pa; the upper and lower control joints are set on the surface of the material, and the air flow can not pass through.
Fig. 2 Streamlines of Y-direction velocity and flow field on the centrosymmetric plane under this condition.

![Figure 2. Velocity and streamline diagram of state 1](image)

Figure 2. Velocity and streamline diagram of state 1

Figure 3 shows the static pressure cloud on the symmetrical surface.

![Figure 3. Static pressure diagram of state 1](image)

Figure 3. Static pressure diagram of state 1

4.2. The Upper Control Seam and the Lower Control Seam Cannot Be Opened.
The pressure at the pressure inlet is 5000Pa; the inlet of the upper control slot is completely open and connected with the atmosphere; the inlet of the lower control slot is set on the surface of the object, and the airflow can not pass through.
Fig. 4 is a streamline diagram of the Y-direction velocity and flow field on the centrosymmetric plane under this condition.
4.3. Upper and Lower Control Seam Opening
The pressure at the pressure inlet is 5000Pa; the upper and lower control joints are fully open and connected to the atmosphere.

Fig. 6 is a streamline diagram of the Y-direction velocity and flow field on the centrosymmetric plane in this state.

Figure 4. Velocity and streamline diagram of state 2

Figure 5. Static pressure diagram of state 2

Figure 6. Velocity and streamline diagram of state 3
5. Conclusion

Fluid thrust vectoring nozzle can control the direction of the mainstream well and has a good application prospect. When the control joints are not opened on both sides, the flow field is symmetrical. When only one side of the control joints is opened, the gas flows from the control joints to the mainstream under the influence of the mainstream low pressure, and the mainstream is deflected by the impact of the fluid in the control joints. The control effect is similar to that of mechanical vectoring nozzle, but it is obvious that the fluid thrust vectoring nozzle is simple in structure, does not need additional aircraft weight, and has high efficiency.

The next step is to refine the parameters of the model, further explore the control mechanism, achieve the accurate control effect of the mainstream position as far as possible, and improve the control efficiency.

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