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RESEARCH ON THE OVERALL DESIGN OF A HIGH-SPEED MORPHING UAV

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Abstract

Due to its broad application prospects in the military and civilian fields, air-launch high-speed aircraft is an important direction for the development of high-speed aircraft in the future. However, air-launch supersonic vehicles face the characteristics of limited volume, small lift-to-drag ratio, difficult trimming, and poor handling characteristics. A supersonic vehicle with morphing wing can flexibly change its aerodynamic shape according to different flight environments, which can improve the weakness of supersonic flight. This paper takes the air-launch high-speed aircraft with the outer wing folded as the research object and carries out the overall design research according to the proposed task requirements. The tailless aerodynamic layout combined with the strake wing and the multi-section swept wing was proposed. Aiming at the difficult problem of longitudinal moment trimming, a combined analysis method of pressure center position and pressure map is proposed. The research results show that the aircraft designed in this study has good aerodynamic performance in different speed domains, and it can maintain the longitudinal moment trim at the cruise angle of attack(AOA).

Keywords: Air-launch, Morphing aircraft, Tailless aerodynamic layout, Longitudinal moment trim

1. Introduction

With the development of UAV technology, more flexible deployment mode, faster flight speed, longer flight distance, higher flight altitude, larger speed domain and airspace range have become the constant pursuit of aerospace science and technology workers[1]. Just as shown in Figure 1, Combined with the deployment form of air launch, the combat radius and combat flexibility of UAV are greatly increased, and the supersonic unmanned aerial vehicle is developing towards a wider speed domain and a wider airspace, which not only plays an important role in civil engineering, but also plays a very important role in military penetration, national defense and army construction[2]. However, the air-launch unmanned supersonic vehicle is faced with the characteristics of limited volume, small lift-to-drag ratio, difficult trimming, and poor stability and steering characteristics[3]. Besides, the overall design basing on single design points usually cannot meet the aircraft to achieve wide speed range, wide airspace mission requirements[4]. In this paper, a conceptual scheme of a high-speed aircraft for air-launch with the outer end of the wing folded into deformation is proposed, and an overall design study is carried out. The aircraft can be flexibly changed in aerodynamic shape according to the different flight environment after being carried by the carrier aircraft to high altitude, so that it has efficient aerodynamic performance both in the environment of low altitude, low speed and high altitude, high speed. At the same time, the folding of the outer wing segments can use shock wave compression to generate additional lift which can improve the lift-drag ratio of the aircraft when flying at high altitude and high Mach number[5].

Figure 1 The development of UAV technology

2. Overall parameter calculation

The overall design of the aircraft is a process of continuous iterative trade-off and gradual improvement, which requires a preliminary conception and estimation as the initial stage of the overall design iteration[6]. The overall design research of the aircraft in this paper starts with the estimation of the overall parameters, and guides the conceptual shape design of the aircraft through the overall parameters, and uses the concept sketch to guide the selection of the overall parameters.

The overall parameters of the aircraft include the estimation of the take-off gross weight and the selection of design points (thrust-weight ratio and wing load). In this study, the estimation strategy for the overall parameters is to use a low-precision model in the first round which the dynamic model, the aerodynamic model and the weight model are all obtained by empirical methods. The second round of estimation takes the estimated total weight of the first round as the reference input, uses a more accurate numerical model for estimation, and finally obtains relatively accurate overall parameters.

In addition, whether it is to design a new type of aircraft or to modify the existing aircraft, it requires clear and complete design requirements. Aircraft design starts with its requirements, which is the starting point and the most important basis for the overall design of the aircraft. The design requirements and performance indicators of the high-speed folding aircraft studied in this paper are shown in Table 1.

Table 1 UAV Design Specifications

Design Specifications	
Cruising Altitude	25Km
Cruising Speed	3.5Ma
Payload	500kg
Voyage	1000Km

The task profile is shown in Figure 2.

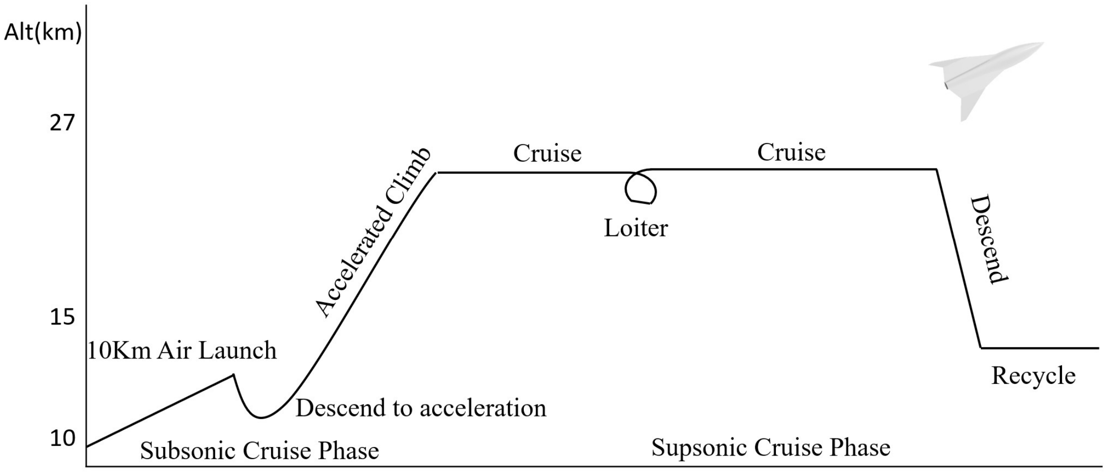


Figure 2 Mission Profile

2.1 Gross weight estimation

The gross take-off weight of unmanned aerial vehicles can be roughly divided into the following three categories[7]:

$$m_0 = m_{PL} + \left(\frac{m_F}{m_0}\right) \cdot m_0 + \left(\frac{m_E}{m_0}\right) \cdot m_0 \tag{1}$$

In the formula, $\frac{m_F}{m_0}$ is the fuel weight ratio; $\frac{m_E}{m_0}$ is the structure weight ratio, which can be calculated by the relevant empirical formula $\frac{m_E}{m_0} = Am_0^C K_{VS}$.

Deforming the formula (1) again, we can get:

$$m_0 = \frac{m_{Pl}}{1 - (m_F/m_0) - (m_E/m_0)} \tag{2}$$

Among them, m_{PL} has been known, and further calculation of the fuel weight ratio is required.

Firstly, the mission profile is roughly divided by the method of mission analysis, and its fuel weight variation coefficient is given in each mission segment. Since the aircraft studied in this paper is launched from space, there is no warm-up and take-off phase, which greatly reduces the amount of fuel required.

For the fuel mass ratio of the climb section, it can be calculated by the following empirical formula[8].

subsonic cruise phase:

$$\frac{m_i}{m_{i-1}} = 1.0065 - 0.0325Ma \tag{3}$$

supersonic cruise phase:

$$\frac{m_i}{m_{i-1}} = 0.991 - 0.007Ma - 0.01Ma^2 \tag{4}$$

The cruise and mission circling phases calculate their weight changes according to the Breguet formula,

$$\frac{m_i}{m_{i-1}} = \exp\left(-\frac{1000gRC}{V(L/D)}\right) \tag{5}$$

The fuel consumption rate C is given by the altitude-speed characteristics of the turbo-sub-combustion ramjet, and the lift-drag ratio L/D and the range R are calculated from the aerodynamic estimation model and the mission segment.

After calculating the fuel mass ratio of each mission profile, the fuel weight ratio can be obtained by multiplying, and the iterative calculation of the total weight can be carried out through the formula, the result are shown in the Table 2.

Table 2 Estimated gross weight for the first round

Division of tasks	Fuel mass ratio	Estimated gross weight
Subsonic separation	0.8486	
Supersonic cruise	0.8971	
Mission Hovering	0.9112	6057.69kg
Supersonic cruise	0.89717	
Unpowered glide	0.9768	

Using the total weight calculated in the first round as input, an estimation of the weight in the second round is carried out. A more accurate numerical calculation model and a more detailed mission profile division were used in the second round of estimation. The dynamic model is obtained by numerical simulation of the turbo-sub-combustion ramjet, the aerodynamic model is obtained by vortex lattice method, and the weight model is obtained by the task analysis method. The second round of estimation results are as shown in Table 3.

Table 3 Estimated gross weight for the second round

Division of tasks	Fuel mass ratio	Estimated gross weight
Subsonic separation and accelerated to 0.6Ma	0.9996	
Dive acceleration to 1.5Ma	0.96	
Supersonic climb accelerated to 3Ma	0.9942	
Cruise acceleration to 3.5Ma	0.9973	4585.5136kg
maintain cruise	0.8971	
Mission Hovering	0.9112	
supersonic cruise	0.8971	
Descend and recover	0.9951	

After two rounds of weight estimation, the final estimated total weight is 4585.51kg.

2.2 Wing load and thrust-weight ratio selection

The determination of the wing load is directly related to the establishment of the aerodynamic layout of the aircraft, and the selection of the thrust-weight ratio is related to the selection of the engine. For the morphing aircraft, the selection of wing load needs to comprehensively consider different deformation forms, so that the appropriate aerodynamic performance can be maintained during the deformation process.

For the morphing aircraft studied in this paper, the appropriate thrust-to-weight ratio and wing load are obtained by empirical statistical methods. According to the different flight performances required for subsonic flight and supersonic flight, we select the wing load in the subsonic flight mode as 152kg/m^2, the wing load at cruising supersonic mode is 170kg/m^2, and the thrust-to-weight ratio is 0.53.Finally, the overall parameters estimated according to the design indicators are shown in Table 4.

Table 4 Estimate overall parameters

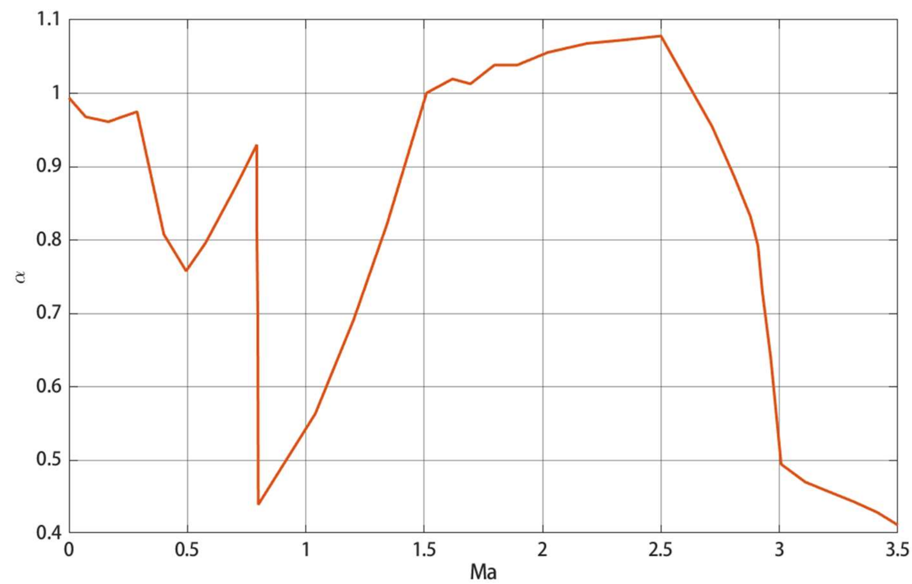
gross weight	Wing load (subsonic)	Wing load (supersonic)	Thrust to weight ratio
4585.5136Kg	152kg/m^2	170kg/m^2	0.53

3. Powerplant selection

Since the flight mission needs to cross multiple airspaces and multiple speed domains, the adaptability of the engine to work in different flight environments is relatively important. Engines with a single cycle mode often cannot meet the needs of flight from subsonic to 3.5Ma flight in near space.

Due to the thin atmosphere, the turbojet engine faces the problems of low working efficiency and low Reynolds number flow separation[9] of the compressor in the near space, and the thrust cannot be well generated at the speed of 3.5Ma. The ramjets used by some hypersonic vehicles also cannot work at low Mach numbers, and require the carrier aircraft to carry or booster rockets to accelerate to a certain speed to start. Therefore, the morphing aircraft studied in this paper selects the low boost ratio turbine/sub-combustion ramjet combined cycle engine (TBCC) designed in the literature[10].

When the maximum flight Mach number is in the range of 3.0~5.0, the low boost ratio turbo/sub-scramjet combined cycle engine is the best choice. According to its working altitude and working Mach number characteristics, combined with the flight conditions of the aircraft studied in this paper, the working process of the TBCC engine can be described as follows. when the aircraft is launched by the carrier aircraft at 0.8Ma and 11km, the turbine engine is first used to make aircraft to accelerate and climb within its optimal working range. when the aircraft accelerated to a speed of 2.5Ma and altitude of 16km, the sub-combustion ramjet reach its starting speed. Then the sub-combustion ramjet starts and work with the afterburning turbine engine, the morphing aircraft continues to accelerate and climb to the near space at speed of 3.0Ma. At this time, the turbine mode is closed and the air flow directly enters the ramjet combustion chamber from the outer duct. TBCC engine is converted into a single working mode of sub-combustion ramjet and the aircraft continues to accelerate the aircraft to the cruising speed of 3.5Ma, maintaining this speed and High altitude for cruise flight and mission turns, etc. The sea level thrust of the engine reaches 4561kg, and its performance[10] in flight missions changes as shown in Figure 3.



(a) Variation curve of thrust attenuation coefficient with Mach number

(b) Variation curve of fuel consumption rate with Mach number

Figure 3 Engine performance

4. Aerodynamic layout design

For morphing aircraft, the aerodynamic layout designed for a single design point often cannot meet the optimal performance of the entire flight stage, and certain trade-offs must be made. According to the task analysis in this study, the supersonic cruise stage is the main task stage of the aircraft, so that the supersonic cruise performance occupies a high proportion in the overall design trade-off of the aircraft. On the basis of supersonic performance, the subsonic flight performance is taken into account by changing the shape of aircraft.

4.1 Choice of Aerodynamic layout

Referring to the aerodynamic layout of the existing supersonic aircraft and hypersonic aircraft, the high Mach number aircraft designed in this paper adopts a tailless aerodynamic layout that combines large strake wing and multi-section swept wings[11]. Compared with the normal layout aircraft, The tailless layout has the advantages of low weight, good stealth characteristics, and low supersonic resistance[11]. Therefore, the tailless layout has become the mainstream layout for high-speed stealth unmanned combat aircraft.

In order to take into account the aerodynamic performance of different speed regions and reduce the spanwise space in air-launch, the wings of the aircraft are designed into the outer wing section and the inner wing section, hereinafter referred to as the outer wing and the inner wing respectively. It can be rotated and folded around the axis in the middle of the two wings, as shown in Figure 4. This deformation form can make the wing and the lower surface of the fuselage form a cavity[13], and use the compression effect of the shock wave to increase the pressure on the lower surface of the fuselage at supersonic speed, thereby generating additional compression lift and improving the lift-to-drag ratio. In addition, the outer wing folding also has the following characteristics[14] during supersonic flight:

(1) Make the wingtip function as a vertical stabilizer, which can increase the sailing stability of the aircraft.
(2) At supersonic speed, the dihedral effect can be canceled.
(3) Destroy part of the lift generated by the rear of the airfoil, avoid excessive rearward movement of the center of lift, and stabilize the aircraft.

(4) Taking into account the aerodynamic performance of high and low speeds, it meets the speed domain requirements of air-launch.

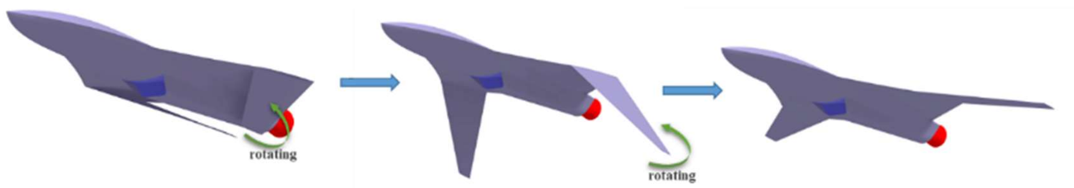


Figure 4 Outer wing folding

As shown in Figure 5, Pattern(a) is the mode when aircraft is mounted on the carrier before the launch. At this time, the outer wing segments of the aircraft are folded inward to minimize the spanwise space occupation, so that the carrier can load as much of the morphing aircraft as possible. The carrier aircraft in this study is a large civil transport aircraft, as shown in Figure 6, which has a take-off weight of 560 tons and a mounting position in the middle of the two fuselage, so it can mount three folded high-speed Aircraft.

Pattern(a) Pattern(b) Pattern(c)

Figure 5 Aerodynamic Layout

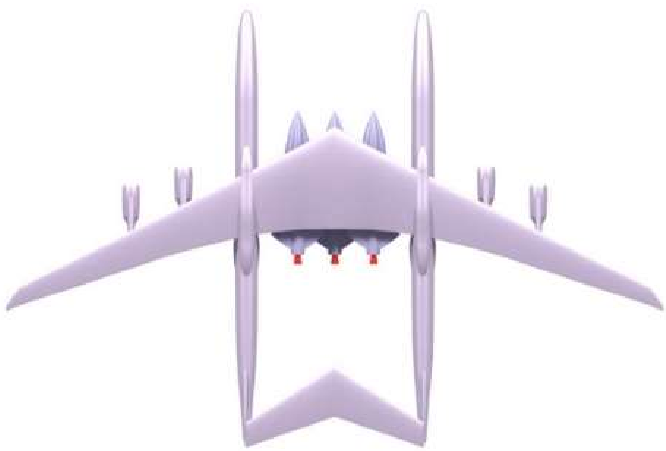


Figure 6 High-speed morphing aircraft carried by the parent aircraft

Pattern(b) is the fully deployed subsonic flight mode, which the aircraft can obtain the largest wing area and aspect ratio. When the aircraft is launched into the air at subsonic speed by the carrier aircraft, it can carry out subsonic cruise with better aerodynamic performance; When the aircraft starts to accelerate and climb, the outer wings begin to gradually fold inwards to adapt to the gradually increasing Mach number, weaken the influence of wave drag, and improve the lift-to-drag ratio; When the aircraft accelerates to a speed of 3.5Ma and an attitude of 25Km, the supersonic cruise flight begins. At this time, the aircraft deforms to pattern(c) to maintain the aerodynamic performance of supersonic cruise.

4.2 Airfoil selection

The airfoil that constitutes the wing is an important factor affecting the aerodynamic characteristics of the wing which not only has a great influence on the aerodynamic characteristics of the aircraft, but also affects the strength of the structure and the manufacturing process. The choice of airfoil is one of the first problems to be solved in the design of aircraft aerodynamic layout. A good airfoil selection can make the designed aircraft achieve the best aerodynamic performance under the design requirements. For supersonic aircraft, a symmetrical airfoil with a sharpened leading edge and a relatively small thickness is generally used. This airfoil can reduce the shock intensity of the leading edge and reduce the wave resistance as little as possible, thereby increasing the lift-to-drag ratio.

Referring to the airfoil design of SR-71[15], the high-speed morphing aircraft designed in this paper adopts a symmetrical thin airfoil with a relative thickness of 2.15%, just as shown in Figure 7. In order to solve the problem of difficult pitch trimming caused by the rearward lift center, airfoil parameterization is used to reduce the load on the trailing edge of the basic airfoil, which makes the trailing edge of the symmetrical airfoil is upturned by a certain angle to reduce the lift contribution caused by rear part of the airfoil. Since the moment arm from the trailing edge of the wing to the center of gravity is longer, this approach can obtain a larger head-up moment at a loss of less lift, which is beneficial to the realization of trim.

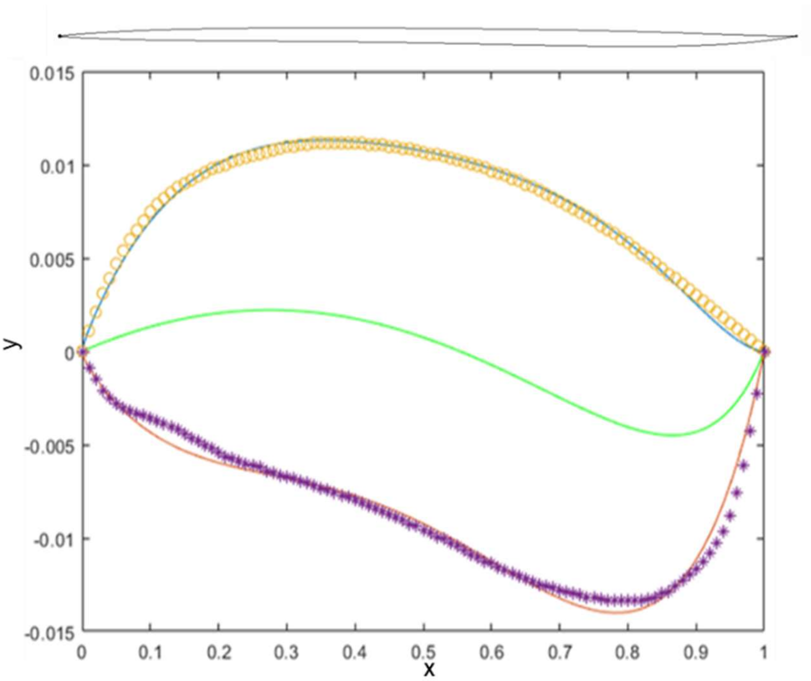


Figure 7 Airfoil selection

4.3 Fuselage and Air Intake Selection

In terms of the fuselage, for the airflow with a high Mach number, the fuselage resistance is smaller when the fuselage is a slender body, and the nose should be pointed to avoid the formation of bow shocks. Referring to the fuselage length of other similar aircraft, the length of the fuselage is initially selected to be 11m; for supersonic aircraft, the fuselage resistance is the smallest when the slenderness ratio is 12. Considering the requirements of fuselage loading and engine intake, the maximum width of the fuselage is 0.916m.

In terms of air intake, the air intake selected in this study is the belly air intake, and the gas passes through multiple shock waves and compression wave systems through the S-shaped elbow and enters the compressor turbine of the TBCC engine or directly fills into the ram combustion chamber, as shown in Figure 29. The wave system design of the supersonic inlet will not be discussed in this article.

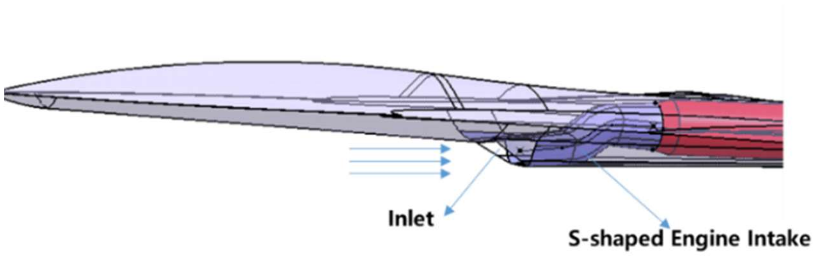


Figure 8 Belly air intake

4.4 Control Surface

The aerodynamic focus of the aircraft with no tail layout is often relatively backward, which will generate a large bowing moment, so the aircraft designed in this paper uses a large area of the trailing edge of the wing as ailerons and elevators. When the rudder surfaces on both sides rotate at the same time, it provides pitching moment, and when they rotate differentially, it provides rolling moment. The folded outer wing can be used as a vertical stabilizer to provide heading stability, and the rudder surface on it can provide yaw moment, just as shown in the Figure 9.

However, the lift generated by the elevator is in the downward direction, causing lift loss. At the same time, the lever arm is short, and the trim efficiency is not well. Moreover, for the aircraft with a large speed range, the aerodynamic focus will shift backward when it crosses from subsonic speed to supersonic speed, which makes it difficult to balance the different speed regions. Therefore, the high-speed morphing UAV designed in this paper adopts a large swept delta wing, and at the same time selects a multi-section swept wing with large strake wing to assist the longitudinal moment trim. The final aerodynamic layout is shown in Figure 10.

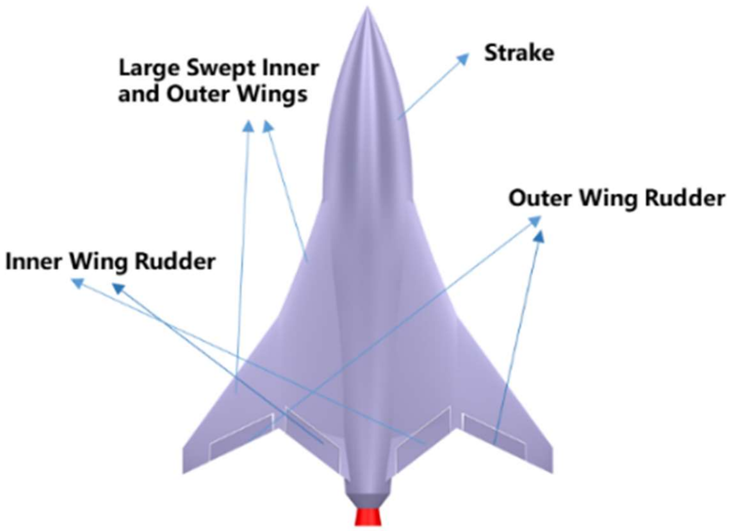


Figure 9 Control surface indication

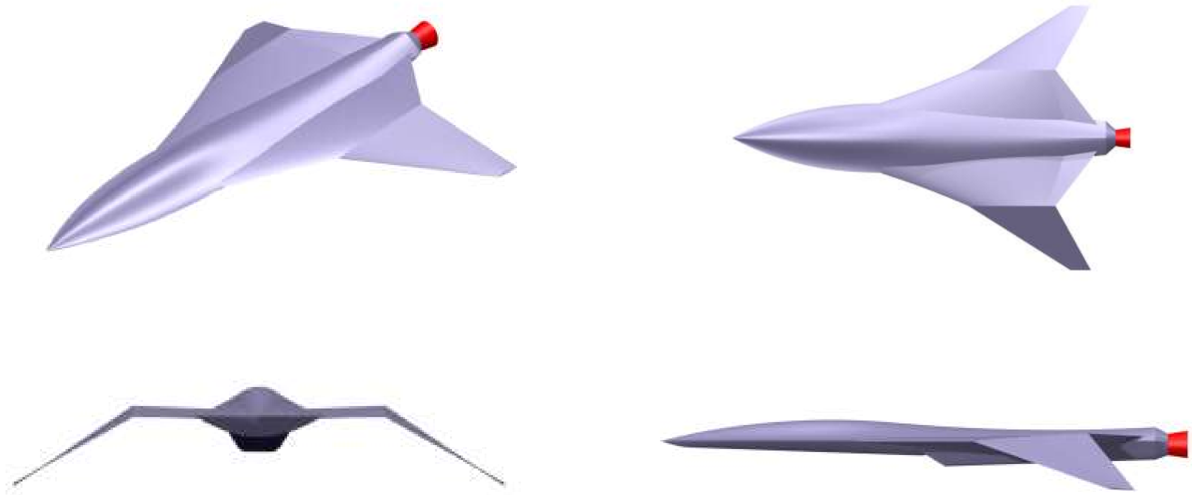


Figure 10 Pneumatic layout display

4.5 CFD Simulation and Verification

This study uses the RANS CFD calculation method which is commonly used in engineering. In the selection of turbulence model, the S-A model has been widely used in the aviation field, which has a good effect on wall-constrained flow (such as aircraft outflow) and good convergence for calculating high-speed outflow[16]. Therefore, this paper adopts the S-A turbulence model and the coupled energy equation for the CFD simulation of the high-speed morphing aircraft.

（1） Aerodynamic calculation of subsonic

The aerodynamic numerical simulation is carried out for the aircraft in the subsonic cruise state, and the calculation grid is shown in Figure 11.

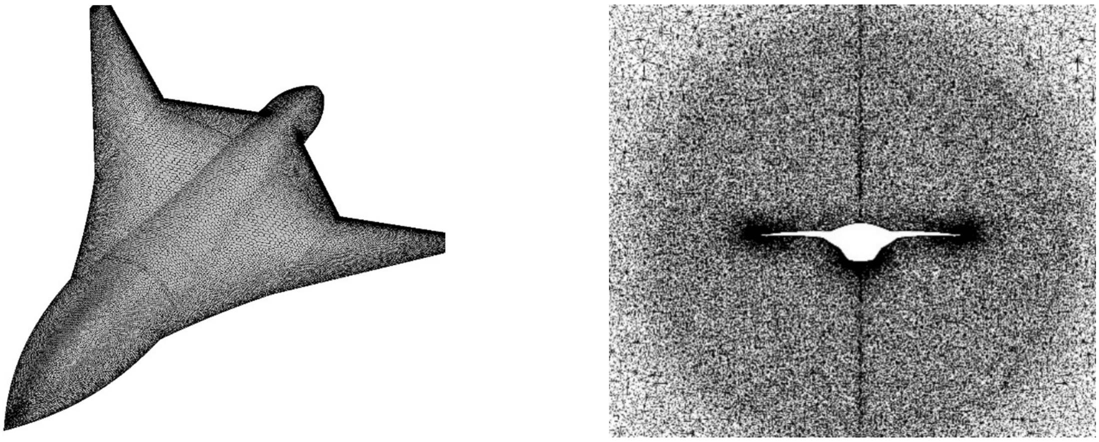
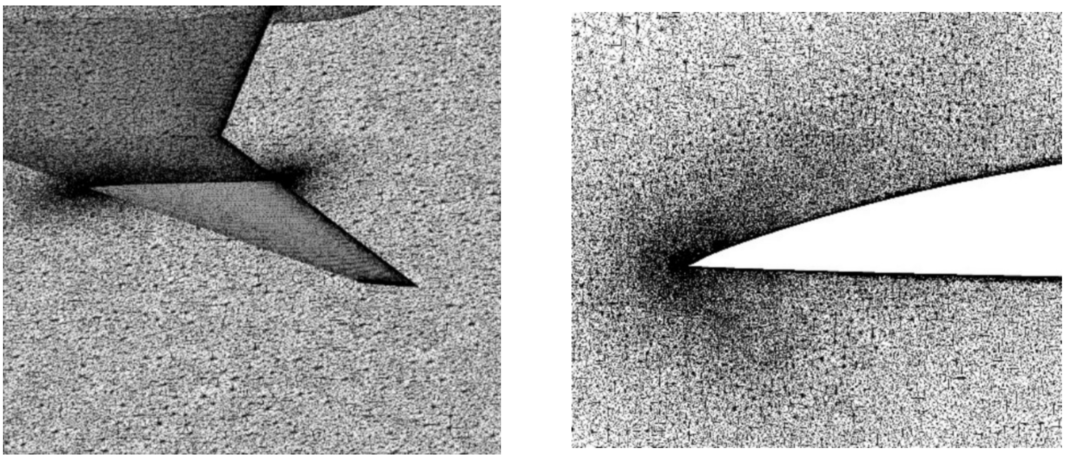


Figure 11 Subsonic Computing Grid

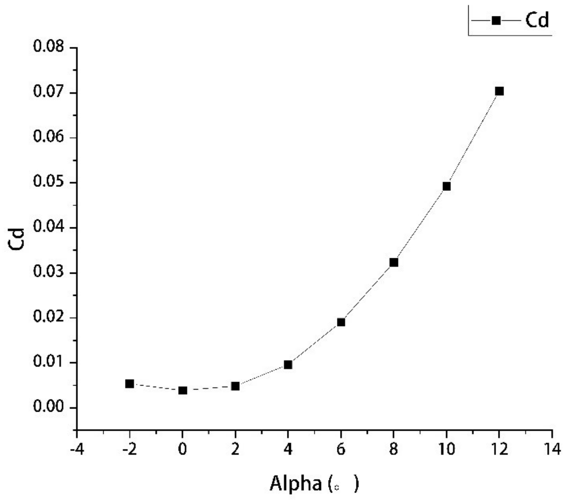
The calculation model uses the blocking cone to process the intake port to avoid the influence of the intake port on the resistance. The grid type adopts unstructured grid, so that it is convenient to write corresponding script files for automatic grid division of aircraft of different configurations. Both the wall surface and the flow field adopt the polyhedral mesh type and the prism layer mesh generates the boundary layer. The key parts such as the leading and trailing edges of the wing and the wing tip are densified, as shown in Figure 12. In addition, 50 times the characteristic length of the flow field is calculated and the final number of grid calculations is about 6 million. The selected state for calculation is: H=10km,V_∞=0.8Ma,α=-4°~12°,Δα=2°, the center of gravity is at 56% of the fuselage.



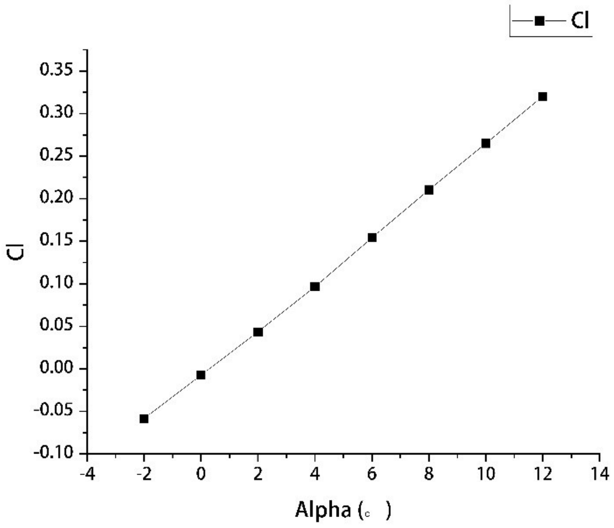
（a）mesh refinement （b）Boundary layer grid

Figure 12 Mesh details

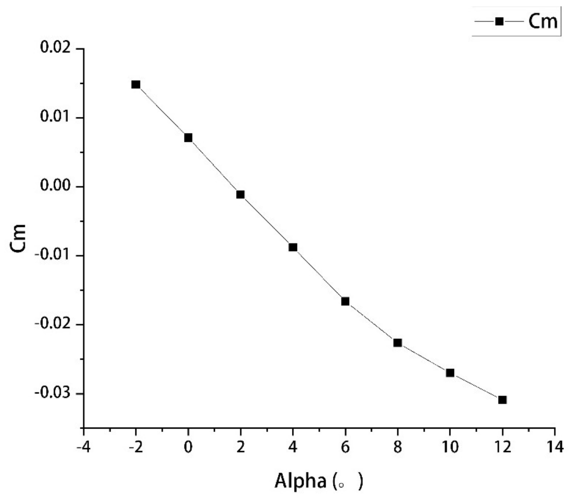
As shown in Figure 13, it is the calculation result of subsonic longitudinal aerodynamic data. From the AOA-lift coefficient curve, it can be seen that the lift coefficient is relatively linear in the range of large AOA, and it is not easy to stall at high AOA. The lift-drag ratio curve shows that the maximum lift-drag ratio is 10 when the AOA is 4°, which meets the flight performance requirements. The moment-AOA curve shows that it has longitudinal static stability. When the AOA is greater than 8°, the longitudinal static stability is weakened, but it tends to be stable overall. However, the longitudinal moment curve shows that it has a large bowing moment, and it is difficult to trim when cruising.



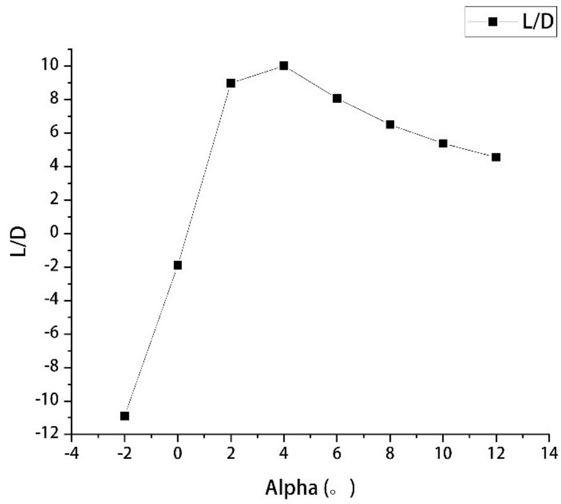
（a）Drag Coefficient-AOA



（b）Lift coefficient - AOA



（c）Longitudinal moment coefficient - AOA



(d) Lift-to-drag ratio - AOA

Figure 13 Subsonic longitudinal aerodynamic calculation results

（2） Supersonic cruise calculation

Compared with the subsonic calculation, the supersonic state calculation needs to use a denser grid to deal with the pressure and temperature steps brought by the shock wave. The calculation grid is shown in Figure 14.

The supersonic calculation selection state is: $H=25km, V_\infty=3.5Ma, \alpha=-4°\sim12°, \Delta\alpha=2°$, the center of gravity is at 56% of the fuselage.

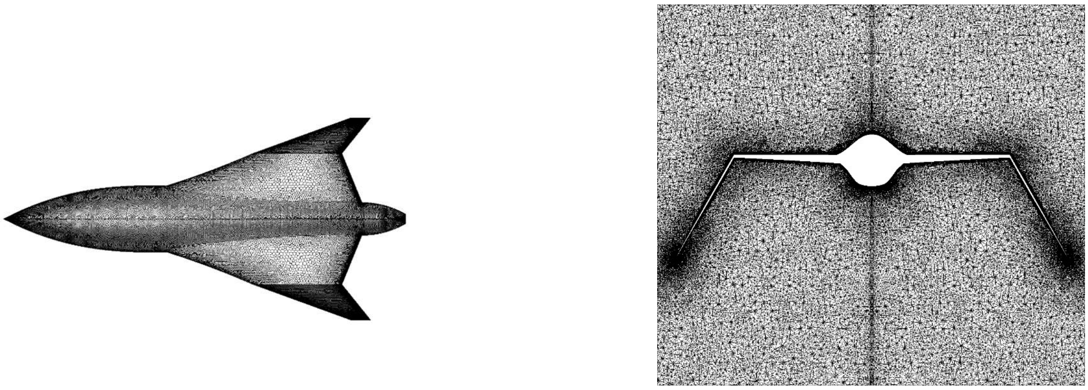
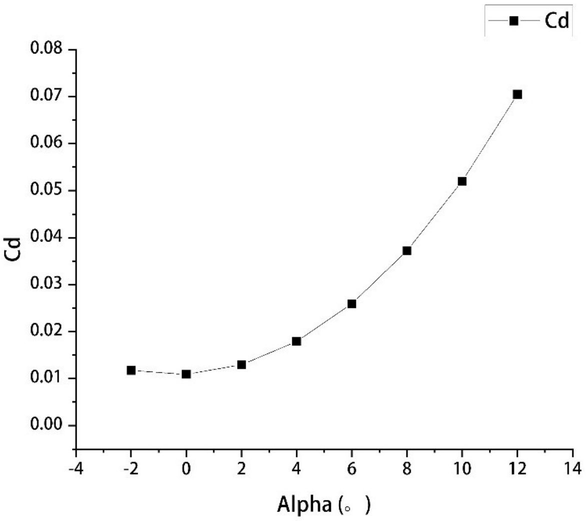
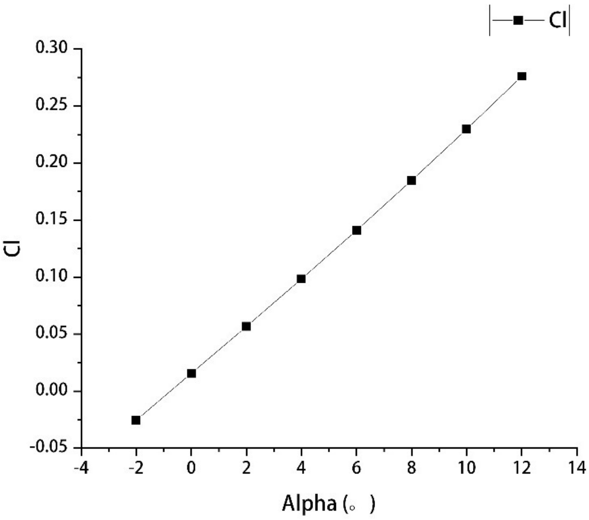


Figure 14 Supersonic Computing Grid

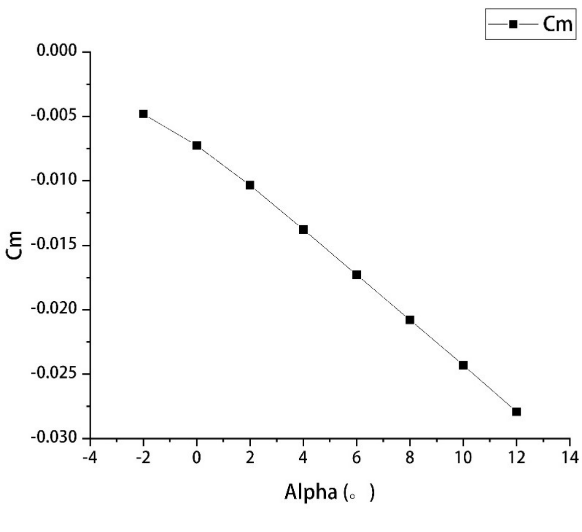
The calculation results in the supersonic state are shown in Figure 15. It can be seen that the lift shows a linear relationship within the range of the calculated angle of attack, and the maximum lift-drag ratio is 5.5. The Longitudinal moment shows that the aircraft has a large static stability margin during supersonic cruise, but it still shows that it has a large bowing moment and it is difficult to trim.

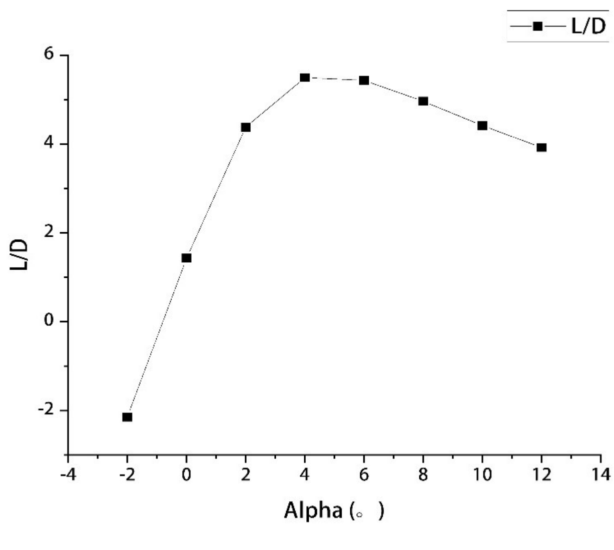


(a) Drag Coefficient-AOA



(b) Lift coefficient - AOA





(c) Longitudinal moment coefficient - AOA (d) Lift-to-drag ratio - AOA

Figure 15 Supersonic longitudinal aerodynamic calculation results

After calculating the aerodynamic layout designed in this study, it can be concluded that the tailless layout with large-area strake wing and multi-section swept wings has good aerodynamic performance, and it can cruise at a speed of 3.5Ma at a height of 25Km.

5. Pneumatic layout adjustment for longitudinal trim

From the above aerodynamic calculations, it can be seen that the longitudinal moment is difficult to balance during cruise in both supersonic and subsonic states, and it is necessary to adjust the aerodynamic layout of the fuselage through certain analysis. The method of combining pressure center change analysis and pressure map analysis is proposed below to make the longitudinal moments of the morphing aircraft in the supersonic and subsonic as balanced as possible.

Firstly, the change of the pressure center is analyzed within the range of calculating the AOA. As shown in Figure 17, taking the direction pointed by the nose as the front, the center of pressure is always behind the center of gravity within the range of the calculated AOA. When the center of gravity is moved to the longitudinal neutral and stable position, as shown in Figure 16, it can be found that the longitudinal moment at this time is still the head-down moment, which means that under the premise of longitudinal static stability, moving the center of gravity all the time cannot make the aircraft trim longitudinally. Moving the center of gravity beyond the aerodynamic center may leads to static instability instead.

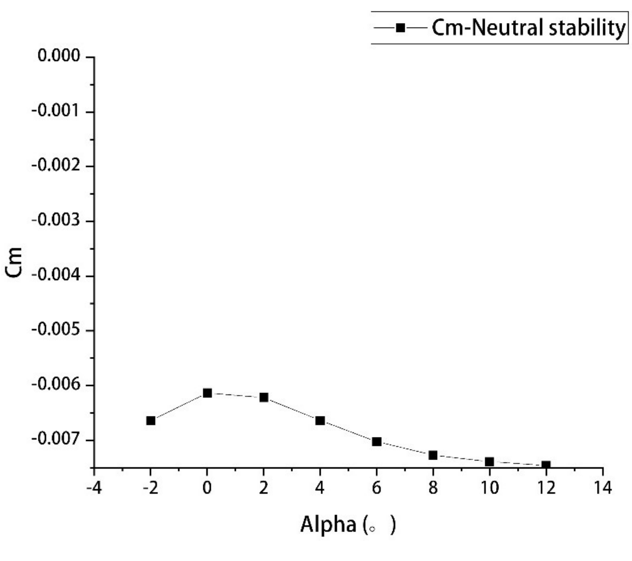


Figure 16 Longitudinal moment curve at neutral stability

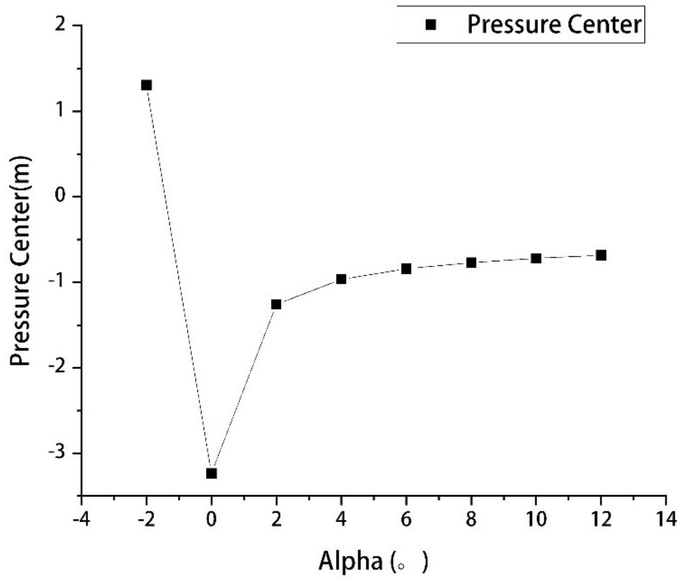


Figure 17 The distance between the center of pressure and the 66.6% center of gravity

Combined with the longitudinal moment curve, it can be obtained that to make the aircraft trim at the cruise AOA, the center of pressure of the whole aircraft should be located before the center of gravity before the cruise AOA in order to provide the head-up moment. When the AOA increases, the center of pressure of the whole aircraft moves backward. To the rear of the center of gravity, the bow moment is provided. For the aircraft in this study, the moment contributions of the wings and the fuselage are shown in Figure 18. It can be seen that the fuselage lift contribution before the cruise AOA needs to be increased. Besides, by combining the aerodynamic characteristics of the fuselage and the wing at different angles of attack, it can be seen that the -4° mounting angle of the wing can make the aircraft longitudinally trimmed at the 5.3° AOA. However, considering that the mounting angle of -4° is not conducive to the aerodynamic performance of the aircraft during subsonic flight and aerodynamic layout, it is a better choice to use the wing tip twist.

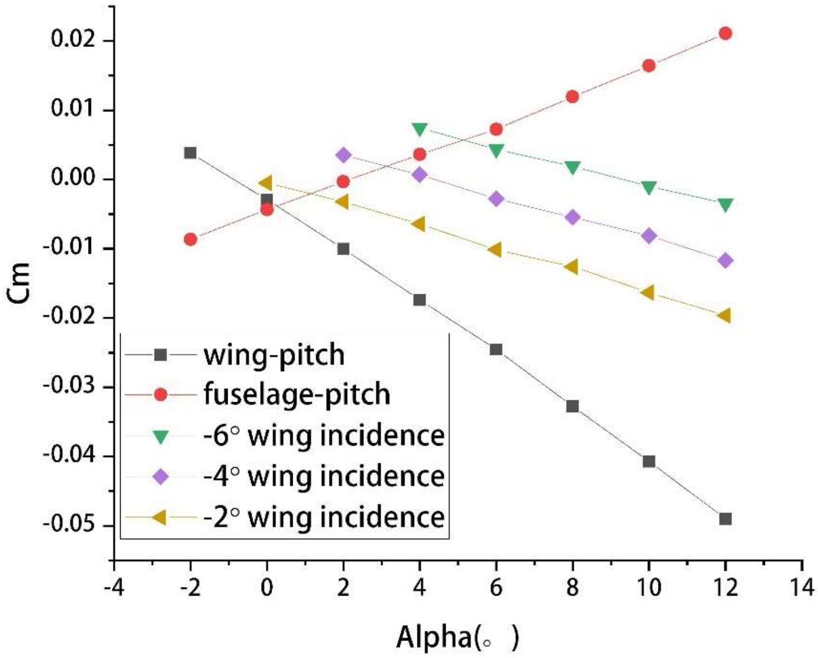
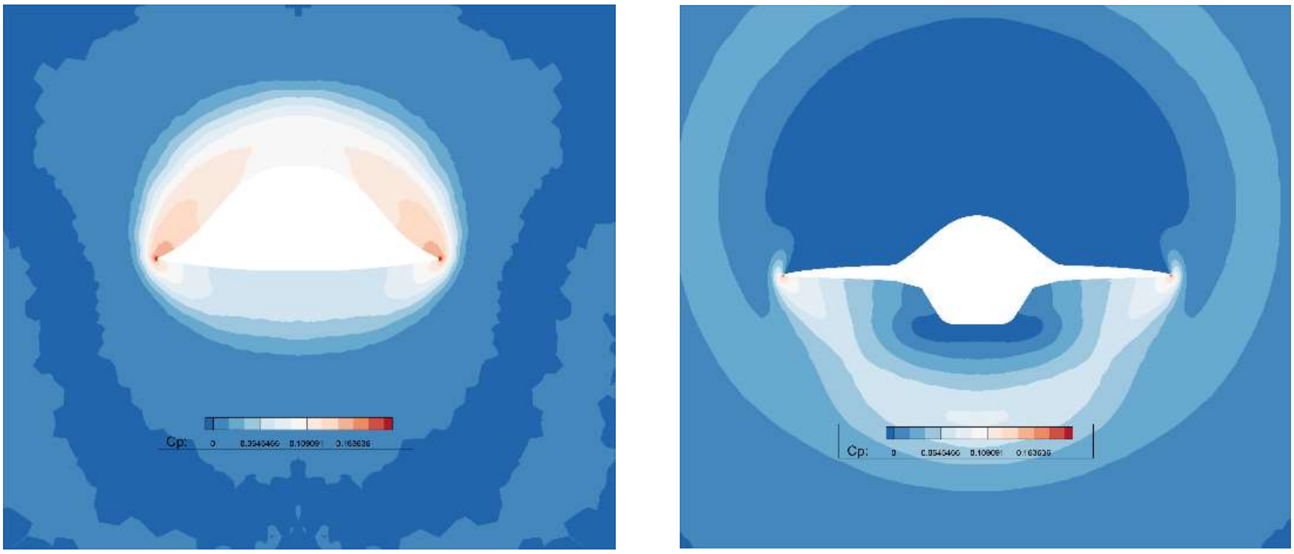


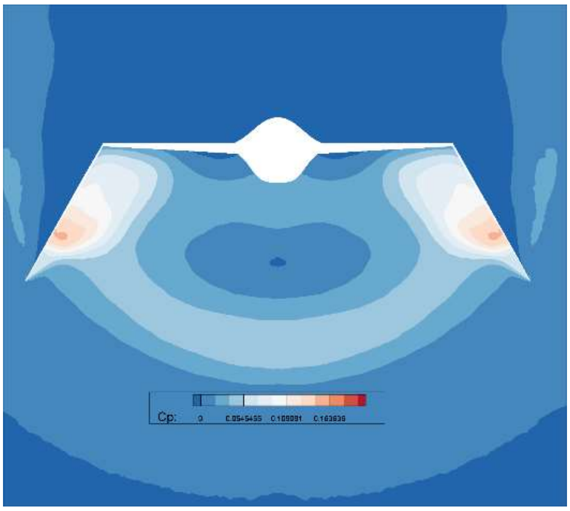
Figure 18 Longitudinal moment curves at different mounting angles

Combined with the pressure map for analysis, Figure 19(a) and Figure 20 shows the pressure distribution in the front of the fuselage. It can be seen that there is a high pressure area on the upper surface of the fuselage head, causing a certain bowing moment. In the Figure 19(c), when the outer wing is folded, the compression effect of the shock wave here creates a large-scale high-pressure area, so the pressure center of the whole aircraft is relatively backward, resulting in a large bowing moment.



(a) Front of the fuselage

(b) Center of the fuselage



(c) Rear fuselage (outer wing folded position)
Figure 19 Aircraft lateral pressure map

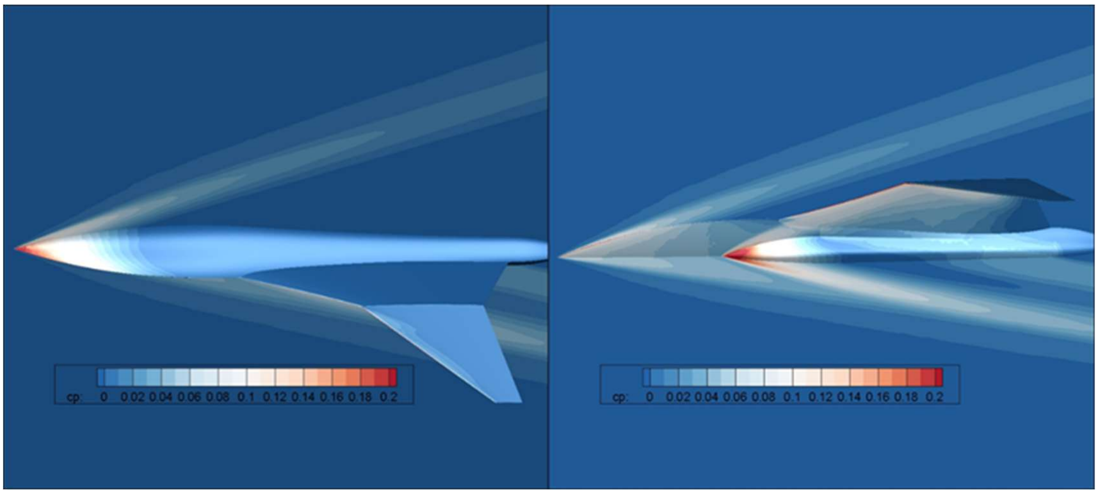
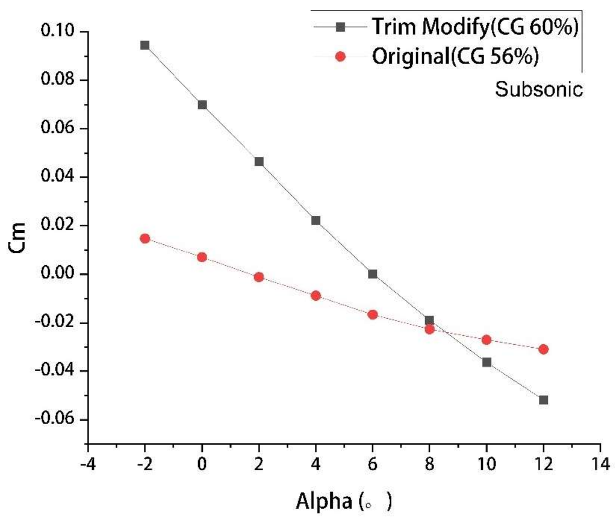


Figure 20 Longitudinal pressure map of aircraft

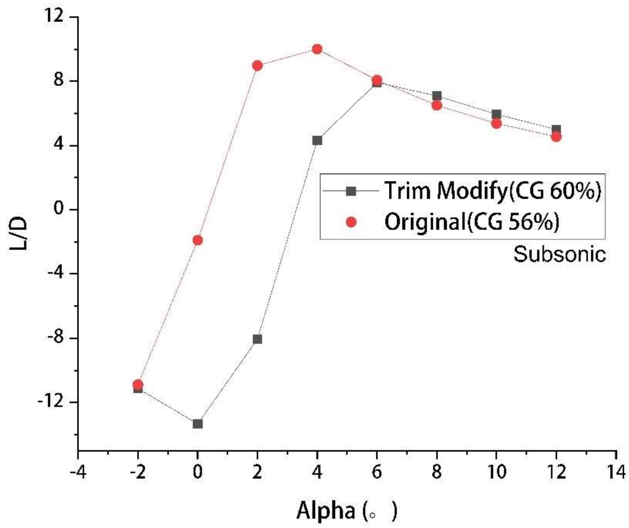
Based on the above analysis, the following adjustments are made to the aerodynamic layout of the aircraft involved in this paper:

a) The inner wing tip is twisted by -4° to reduce the lift contribution of the wing when the whole aircraft is at a small AOA.
b) The outer wing tip is twisted by 4°, which improves the aerodynamic performance during subsonic flight to a certain extent.
c) The front part of the fuselage is tilted up, which makes it generate greater lift at a small AOA.
d) Change the shape of the front of the fuselage to make its surface pressure distribution more reasonable.
e) Increase the area of the side bars of the fuselage to improve the lift of the fuselage.

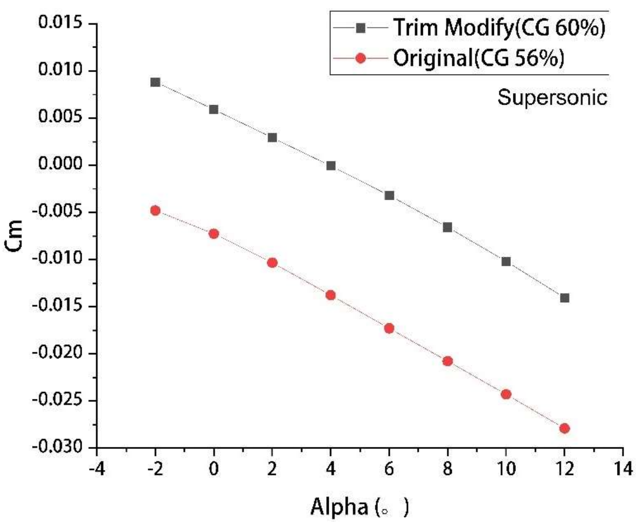
After the above adjustments, the CFD simulation verification was carried out again, and compared with the unadjusted supersonic calculation results, as shown in Figure 21.



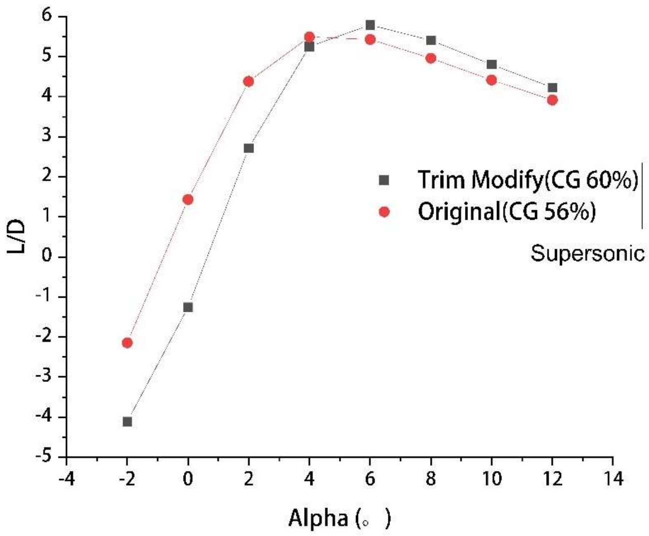
(a) Subsonic longitudinal moment coefficient - AOA



(b) Subsonic lift-drag ratio-AOA



(c) Supersonic longitudinal moment coefficient - AOA



(d) Supersonic lift-drag ratio-AOA

Figure 21 Comparison of aerodynamic characteristics before and after trim

It can be seen that after the adjustment, the longitudinal moment can reach the trim state at the appropriate AOA whether in the supersonic or the subsonic. The morphing aircraft maintain a high lift-drag characteristic at the trim AOA, showing a good cruise characteristics.

6. Conclusions

This paper takes the air-launch high-speed aircraft with the morphing wing as the research object, carries out the overall design research according to the proposed task requirements, forms the calculation method of the overall parameters of the high-speed morphing aircraft, and the aerodynamic layout form and longitudinal moment trim adjustment analysis method are proposed.

The research shows that the total take-off weight can be estimated by the combination of low-fidelity and high-fidelity models. CFD simulations show that the tailless aerodynamic layout with large strake wing in front fuselage and multi-section swept wings has good supersonic aerodynamic characteristics. The variable configuration method of folding the outer section of the wing can not only make the aircraft maintain good aerodynamic performance in different speed regions and air regions, but also increase the lift by using shock wave compression.

The research shows that the proposed method combining pressure center analysis and pressure map is an effective method to solve the longitudinal trim of this kind of aircraft. By adjusting the shape of the fuselage to change its moment characteristics, the high-speed morphing aircraft can achieve the effect of trimming.

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8. Copyright Statement

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