

Research on the overall parameter design based on the optimization of the aircraft model

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Abstract. With the rapid development of the economy and the continuous improvement of aerospace technology, Aircraft play an important role in various neighborhoods. This paper analyzes and optimizes the aerodynamics and drag of the aircraft, and then the minimum drag model corresponding to the aircraft is obtained through genetic algorithm. The results show that the minimum drag model of the aircraft is affected by the shape of the fuselage, wings, cabin, tail and other models, it is necessary to calculate the minimum drag of the aircraft through genetic algorithm is 5411884N. It is hoped that this research can promote the development of aircraft optimization in the aviation field.

Keywords: Genetic algorithms, Optimize, Aerocraft.

1. Introduction

In the field of aerospace, with the maturity of aerospace technology, the research on the shape optimization of aircraft has also become the focus. The aircraft mainly relies on the static buoyancy of the air or the aerodynamic force generated by the relative motion of the air to fly into the air. We establish target optimization through genetic algorithm [1, 2], take the minimum drag as the optimization goal, and solve the optimal solution by editing and solving the problem by taking multiple variables such as the aircraft body, wing model, and aircraft cabin as constraints, so that the aircraft is subjected to the least resistance, and the optimization of the aircraft shape is a very important basic science problem in the field of aerospace [3].

At present, the fastest flying aircraft is the X-43 test aircraft developed by NASA with a height of Mach 9.8, and the coupling between aerodynamics, propulsion systems, structures and other disciplines in the study of the aircraft has been greatly enhanced, and the design difficulty has also increased, making the relevant research difficult. Zhang Zhenming et al. [4] studied the parametric modeling method based on class function/shape function for the lift body and waverider fuselage, and calculated the aerodynamic characteristics and optimized the shape to solve various complex problems in practical engineering [5,6]. For the domestic research and discussion on aerodynamic shape design, combined with foreign related research results, the aerodynamic design and the research methods involved are studied [7,8]

Based on the existing problems in the current research, this paper proposes a genetic algorithm optimization algorithm model and a study on the aerodynamics of the aircraft during flight, which is expected to provide a reference and reference value for the best design of the aircraft in the aerospace field by optimizing the design of the aircraft shape [9~10].

2. The basic fundamental of Genetic algorithms

2.1. The structure of Genetic algorithm optimization

Genetic algorithms are a family of search algorithms inspired by the theory of natural evolution. It has the characteristics of parallel search, robustness, adaptability, etc. The process consists of coding, initializing the population, appropriately evaluating the population individuals, selecting cross-variation, decoding, and outputting the optimal solution. The optimal solution is obtained by discussing the obtained data, and the flow chart is shown in Figure 1.

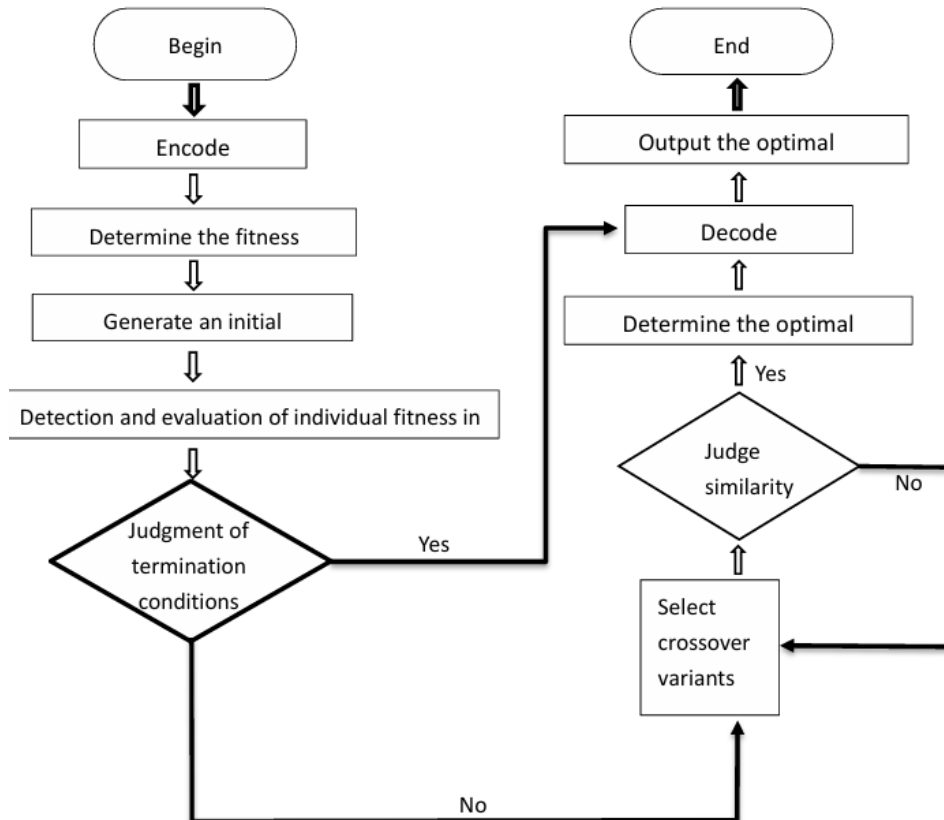


Figure 1. Block diagram of genetic algorithm.

(1) Heredity: Generating new populations by duplicating individuals in a population, often using genomes and chromosomes to represent solutions in solution space. Chromosomes are usually binary encoded and represent the properties and characteristics of the solution.

(2) Variation: To introduce a new solution, variation is achieved by changing certain bits of the chromosome. This approach upsets the balance of populations and increases the diversity of search spaces, which in turn helps to find better solutions.

(3) Selection: The probability that an individual is selected for breeding is proportional to its fitness. The probability that the i th individual will be selected p_i expressed as:

$$p_i = \frac{f(x_i)}{\sum_{j=1}^N f(x_j)} \quad (1)$$

Where: $f(x_i)$ is the fitness of the i th individual; N is the total number of individuals in the population

(4) Crossover: Generate a new individual by randomly pairing two individuals to cross. In the search process, cross-operation helps to generate new solutions and expand the search space.

(5) Encoding: Representation of solutions in the problem space through genetic manipulation. The choice depends on the needs of the question and the nature of the search space.

2.2. Consideration of the model based on various factors

(1) Aerodynamic analysis and optimization of aircraft

The characterization of the aerodynamic moment and aerodynamic force that the aircraft receives when it moves in the air is called the aerodynamic performance of the aircraft. In order to improve the performance of the aircraft and meet the design requirements, the aerodynamic performance of the aircraft is analyzed and optimized.

The analysis of aircraft aerodynamic performance mainly includes two aspects: flow field analysis and aerodynamic coefficient. Flow field analysis is an analysis of the state of air flow around an aircraft through experimental methods and numerical simulations. Aerodynamic coefficient analysis is to calculate and analyze the aerodynamic coefficient of the aircraft to evaluate the performance of the aircraft.

Wing type, flaps, tail, fuselage shape, etc. are the main factors affecting the aerodynamic performance of the aircraft. Figure 2 shows the effect of wing length on drag.

The aerodynamic performance of the aircraft can be improved by means of aircraft structure optimization, aircraft wake control, and aircraft surface finish improvement. And by installing wake plates, edge jet devices, etc., the aircraft can improve the control of the wake of the aircraft and reduce the impact of the wake on the subsequent aircraft.

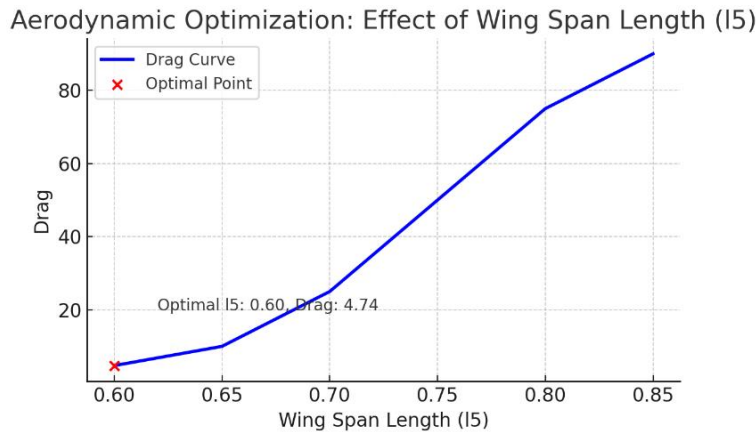


Fig 2. Effect of wing length on drag.

(2) Aerodynamics

The principle of reversibility: air can only be generated when the air moves relative to the object. Whether it is air motion against an object or an object motion against air, aerodynamic force is generated. In aerodynamics, it is called the "principle of reversibility".

For common natural phenomena and aerodynamic problems associated with model airplanes, air can be considered incompressible, i.e., the density of the air remains the same due to the small speed of air movement, as shown in Figure 3. The two cross-sections of the front and rear in the air passage shown in the figure are F_1 and F_2 can be obtained by using the above formula:

$$\rho_1 * V_1 * F_1 = \rho_2 * V_2 * F_2 \tag{2}$$

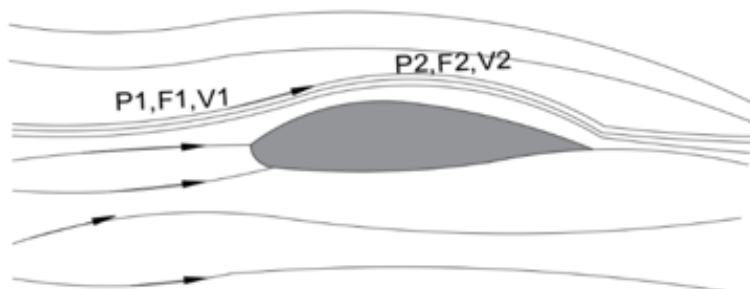


Fig 3. Schematic diagram of air velocity.

Bernoulli's theorem: where the velocity is greater, the pressure of the air flow is smaller; the lower the velocity of the flow, the pressure of the airflow

In a flowing air stream, there is both dynamic and static pressure, and the sum of the two is called the total pressure (or simply total pressure). If it is expressed in a formula, it is:

Static pressure + dynamic pressure = total pressure (constant)

$$\text{Namely: } P + \frac{1}{2} \rho V^2 = \text{constant} \quad (3)$$

By substituting the data of the cross-sectional F_1 and F_2 of two different airflow channels into the above equation, considering that air is an incompressible gas, $\rho_1 = \rho_2 = \rho$, Available:

$$P_1 + \frac{1}{2} \rho V_1^2 = P_2 + \frac{1}{2} \rho V_2^2 \quad (4)$$

(3) Research on drag reduction measures and optimization

The airfoil is an important part of the aircraft, and its shape and geometry have a significant impact on the generation of drag. Through CFD simulation and numerical analysis, combined with optimization algorithms such as genetic algorithm, the airfoil can be optimized to reduce its resistance.

Wingtip vortex control: The wingtip vortex is the rotating airflow generated by the aircraft during flight, which has a significant impact on the generation of drag. By controlling the generation and propagation of wingtip vortices, the drag of the aircraft can be reduced.

Frictional resistance: Because the air is viscous and causes the air to flow through the surface of the aircraft when the object moves in the air, it will have a frictional effect and produce frictional force, which plays the role of preventing the aircraft from flying, so this frictional force is also called frictional resistance. The frictional resistance is actually the sum of the viscous frictional forces of the air within the boundary layer.

Differential pressure resistance: Differential pressure resistance is caused by the pressure difference between the front and back of the object when the object is moving relative to the air. Differential pressure resistance is related to factors such as the shape of the object, its posture in the air current, and the maximum windward area.

2.3. The establishment of simulation model

The other parameters of the coupling structure are set as follows: the l_6 is fixed to 143cm, and the fixed wing half-span length is 1000cm (a total of 8 ribs are evenly distributed, so that the 6 ribs in the middle are 0-1 discrete variables, where 1 means that there are ribs arranged here, and 0 means that the ribs are not arranged). Cl_6 show whether the logical value of the wing rib 2 is arranged at the 6 positions of the wing, $i=1, \dots, 6$), the fuselage half-span length is fixed at 500cm, the l_2 takes the fixed value of 120cm, the d_1 takes the fixed value of 250cm, the d_2 takes the fixed value of 350cm, and the d_4 takes the fixed value of 150cm.

Establishment of the objective function:

According to the formula for calculating the resistance of the liquid, the formula for calculating the air resistance can be obtained, according to which the objective function can be established:

$$M \inf(x) = F_d = 0.5 * C * P * S * V^2 \quad (5)$$

Where F_d is the air resistance, c_d is the drag coefficient of the object, ρ is the density of the air, v is the velocity of the object relative to the air, and s is the cross-sectional area of the object in the air.

Model constraints:

(1) Aircraft host model constraints. During the flight, the main body of the aircraft is the main part affected by the air resistance factor, and the reasonable design of the main body model makes the aircraft suffer the least resistance.

- (2) Aircraft wing model constraints.
- (3) Aircraft cabin model constraints.

(4) Constraints on skeletal structure design variables. According to the value range of the given structural parameters of the aircraft, the optimal value is obtained so that the drag of the aircraft is minimized.

The design variables for the aircraft cabin structure are as follows:

$$\left\{ \begin{array}{l} 0 \leq c_{16}^i \leq 1 \text{ (Discrete variables of 0 or 1)} \\ 270 \leq l_1 \leq 290 \\ 0.1 \leq l_3 \leq 0.35 \\ 0.45 \leq l_4 \leq 0.55 \\ 0.65 \leq l_5 \leq 0.9 \end{array} \right. \quad (6)$$

(5) Cabin structure design variable constraints. Similarly, according to the value range of the given parameters, the optimal value is obtained so that the drag on the aircraft is minimized.

The design variables of the aircraft cabin structure are as follows:

$$\left\{ \begin{array}{l} 65 \leq R_1 \leq 90 \\ 75 \leq R_2 \leq 100 \\ 20 \leq R_3 \leq 30 \\ 8 \leq t_5 \leq 15 \\ 8 \leq t_6 \leq 15 \\ 8 \leq t_7 \leq 15 \\ 350 \leq G_c \leq 450 \end{array} \right. \quad (7)$$

As has been noted, the constraint function conditions of the model when the variables are changed, and the genetic algorithm is used to solve the problem.

The four different aircraft shapes were calculated separately, and the average resistance per unit area of the four shapes was compared to further determine the shape of the optimal aircraft.

Considering the four conic curves shown in Figure 4 respectively, and taking the four curves of circle, ellipse, parabola and hyperbola as the shape of the aircraft, the four different aircraft shapes are calculated separately by genetic algorithm, and the calculation formulas of the four conic curves are shown in Table 1. The average resistance per unit area of the four shapes was compared to further determine the shape of the optimal aircraft.

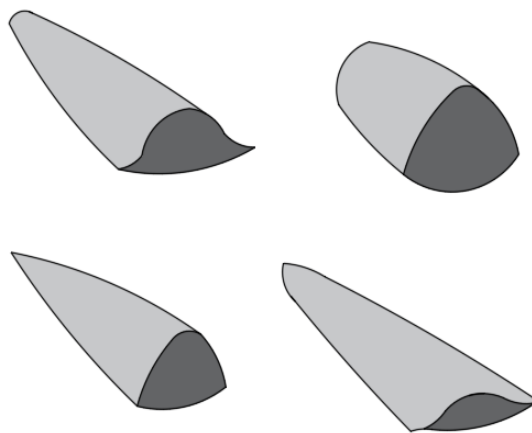


Fig 4. Schematic diagram of the four types of conic curves.

Table 1. Four conic curve surface area and volume formulas.

Section shape	area	volume
Circle	$s = 4\pi r^2$	$V = \frac{4}{3}\pi r^3$
Elliptic	$s = \frac{4}{3}\pi ab$	$V = \frac{4}{3}\pi abc$
Hyperbola	$s = \frac{2h}{3}(2\pi b + 4a - 4b)$	$V = \frac{4}{3}\pi ab^3$
Parabola	$s = \frac{4}{3}\pi ab$	$V = \frac{4}{3}\pi abc$

Considering multiple factors such as aircraft area, skeleton structure and cabin area, the constraints on the objective function are established:

$$\left. \begin{aligned}
 L_1 &= \int_{-w}^w \sqrt{1 + \frac{4l_3^2 x^2}{w^4}} dx \\
 L_2 &= \int_{-w}^w \sqrt{1 + \frac{4(l_5 - l_3)^2 x^2}{w^4}} dx \\
 C_1 &= \int_{-w}^w (-\frac{l_3}{w^2} x^2 + l_3) dx \\
 C_2 &= \int_{-w}^w (-\frac{l_5 - l_3}{w^2} x^2 + l_5 - l_3) dx
 \end{aligned} \right\} \quad (8)$$

Skeletal structure constraints
 Cabin structure constraints

Under the analysis of four different conic curves as the shape of the aircraft, Genetic algorithm models can be used to solve problems, and consider how to design the optimal shape of the aircraft under multiple constraints (aircraft main body model, wing model, aircraft cabin model) so that the drag is minimized. We need to establish an objective optimization model, with the minimum resistance as the optimization goal, the skeleton structure design variables and cabin structure design variables are used as constraints, and solve the optimal solution of the problem by editing.

3. Results

3.1. Establishment of the model

Based on the genetic algorithm, the optimal model of the aircraft is solved by establishing the objective function and constraints. Under these conditions, the four curves of circle, ellipse, parabola and hyperbola are taken as the shape of the aircraft, and the four conic curves are studied and compared to find out the minimum resistance corresponding to the optimal curve model.

3.2. Analysis of experimental results

Based on this condition, establish objective functions and determine constraints, the minimum drag model of the aircraft was obtained by genetic algorithm. The results obtained by genetic algorithm are analyzed to obtain the corresponding data in Table 2, the values of the skeletal structure and cabin structure variables in the table are within the corresponding constraint ranges. This is shown in Figure 5.

Table 2. Aircraft optimization parameters.

l3	l4	l5	R1	R2	R3	t5	t6	t7	Gc
0.157	0.504	0.731	78.8	75	20	14.58	10.3	12.06	416.5

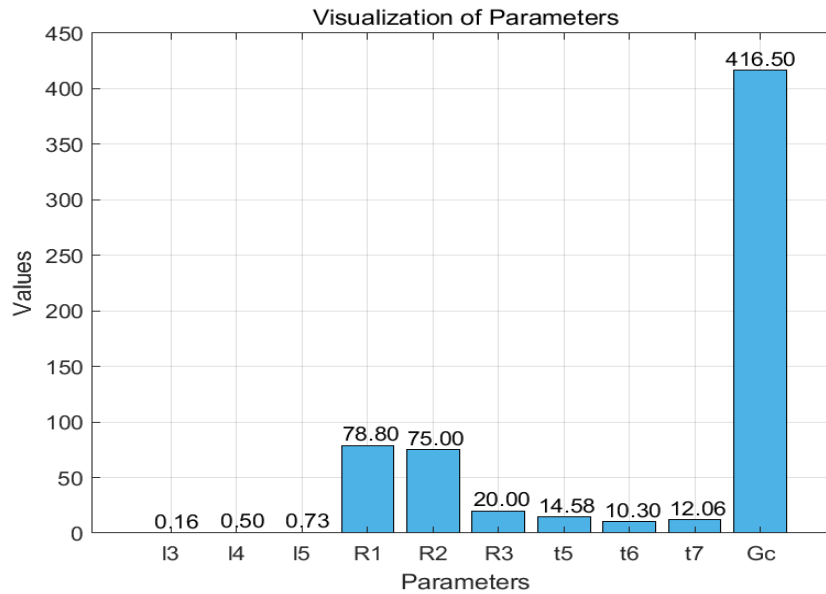


Fig 5. Optimal aircraft model parameters.

It can be concluded that the optimal aircraft structure can minimize the drag on the aircraft at this time, and the minimum drag at this time is 5411884.

By constructing four different conic surfaces, the values and minimum resistance corresponding to each curve are obtained by analyzing the drag of the aircraft shape corresponding to the four curves, as shown in Figure 6. Table 3 shows the parameters of the four aircraft models.

Table 3. Parameters of the four types of conic curves.

Section shape	l_3	l_4	l_5	R_1	R_2	R_3	t_5	t_6	t_7	G_c
Circle	0.128	0.524	0.762	86.81	75	20	13.4	14	10.81	366
Elliptic	0.348	0.457	0.65	80.48	75	20	13.39	12.10	12.53	400
Parabola	0.165	0.550	0.664	85.48	75	20	10.36	8.931	14.56	400
Hyperbola	0.301	0.531	0.697	84.92	75	20	9.07	10.51	9.48	400

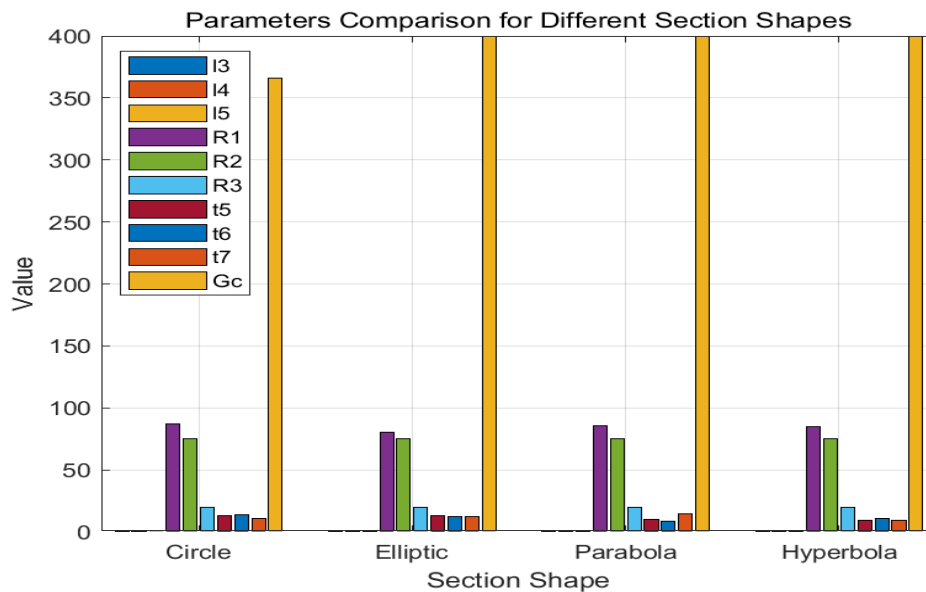


Fig 6. Four conic curve parameters.

Based on the data obtained in the above table, the objective function and constraints optimized based on the minimum drag model are obtained, and the minimum drag of the four aircraft shapes of circle, parabola, ellipse and hyperbola are calculated by using genetic algorithm, which are 5367705, 5262518, 5723401 and 5140245.

4. Conclusion

The optimization of aircraft is of vital importance to the development of today's aerospace technology. As can be seen from these results, wings and cabin of the aircraft, the objective function is established by taking the design variables of the skeleton structure and the design variables of the cabin structure as constraints, even the optimal model of the aircraft, that is the minimum drag model of the aircraft, by genetic algorithm is it calculated. And by optimizing the four conic curves as the wing, the best model of the wing is obtained as hyperbola. Its minimum drag coefficient is 5140245. The study of the model in this paper enhances the aerodynamic performance of the aircraft, reduces the drag, and improves the flight efficiency of the aircraft.

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