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Research on Optimization of Mass Center Balance Fuel Supply Strategy for Aircraft in Straight Flight

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Abstract

During the flight of the aircraft, with the increase of fuel consumption, the distribution of residual fuel in each fuel tank of the aircraft will change, so the centroid of the aircraft will change. In this paper, according to the mass and shape of the aircraft and the fuel tank, as well as the mass and shape of the fuel contained, the mathematical expressions of the centroid position when only the net weight of the aircraft and the centroid position of each fuel tank are obtained. The weighted average of the centroid position when the net weight of the aircraft and the centroid position of each fuel tank are calculated, and the weight is set to their respective weight, The expression of centroid position of aircraft (including fuel tank) is obtained. By constructing the mathematical model satisfying the relevant constraints and solving it with particle swarm optimization algorithm, we get the best fuel supply strategy for the aircraft in straight flight.

Keywords

Aircraft Centroid; Fuel Supply Strategy Optimization; Particle Swarm Optimization.

1. Introduction

During aircraft flight, the change of aircraft center of gravity has an important impact on aircraft stability and maneuverability [1-2]. With the change of flight attitude and fuel consumption, the change of aircraft fuel system center of gravity has become one of the important factors affecting the change of aircraft center of gravity [3-5]. Therefore, whether the change of aircraft center of gravity is within the allowable range of aircraft, It has become an important basis for judging the feasibility of aircraft fuel system design scheme. The key to the calculation of the center of gravity of the aircraft fuel system is to quickly and accurately determine the liquid level position of the remaining fuel in the fuel tank according to the specific oil level angle and remaining fuel volume [6].

At present, the commonly used method to determine the fuel level position is to establish the fuel quality characteristic database by slicing the fuel solid model through digital fuel sensor or CATIA secondary development technology, and then obtain the fuel level position under specific conditions and its corresponding fuel system center of gravity by linear interpolation based on the database [7-10].

Aircraft fuel centroid is of great significance to determine the feasibility of aircraft fuel system design scheme, improve flight quality and ensure flight safety. In the scheme design stage of the aircraft fuel system, whether the center of gravity of the fuel system is within the allowable range can be determined by calculating the fuel quality characteristics, which is an important basis for judging the feasibility of fuel system design scheme. During aircraft flight, the determination of aircraft fuel centroid is conducive to the comprehensive management of the fuel system and ensures that the aircraft center of gravity is maintained within the allowable range, to improve flight quality and ensure flight safety [11-13].

Due to the complexity of aircraft fuel tank structure and shape, the centroid position of aircraft fuel is a multivariate nonlinear function of oil level height, fuel tank shape, flight attitude, and

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other information, and an accurate analytical formula cannot be found [14]. Therefore, the interpolation method based on the fuel quality characteristic database is usually used to calculate the fuel centroid position in engineering. Firstly, the fuel quality characteristic database of a specific model is established through slicing, and then the fuel level angle is calculated according to the oil level height, flight attitude angle, acceleration, and other data provided by various sensors during aircraft flight. Finally, the fuel particle position is calculated by interpolating the fuel quality characteristic database [15].

During the flight, the aircraft with multiple fuel tanks can supply fuel through the joint fuel of several fuel tanks to meet the flight mission requirements and engine working requirements. In the process of mission execution, the change of aircraft centroid has an important impact on aircraft control. The distribution of oil in each tank and oil supply strategy will lead to the change of aircraft centroid, and then affect the control of aircraft. Therefore, formulating the fuel supply strategy of each fuel tank is an important task of this kind of aircraft control. In this paper, the fuel supply strategy of the aircraft fuel tank can be described by the speed of fuel supply to the engine or other fuel tanks.

2. Description of Centroid Change of Aircraft in Straight Flight

With the continuous flight process, a certain amount of fuel will be consumed, which will lead to the dynamic change of onboard fuel. At the same time, the aircraft will produce different flight postures such as straight flight and pitch flight, to form different pitch angles. Therefore, under the conditions of different pitch angles of the aircraft and different fuel volumes in each fuel tank, the liquid in the fuel tank will have a variety of different shapes, and the centroid position will change accordingly. Therefore, the key fuel supply strategy for the aircraft fuel tank is to solve the problem of the centroid position of aircraft and its fuel tank during flight.

2.1. Problem Description

It is assumed that this kind of aircraft has a total of 6 fuel tanks, and the fuel supply diagram of each fuel tank is shown in Figure 1.

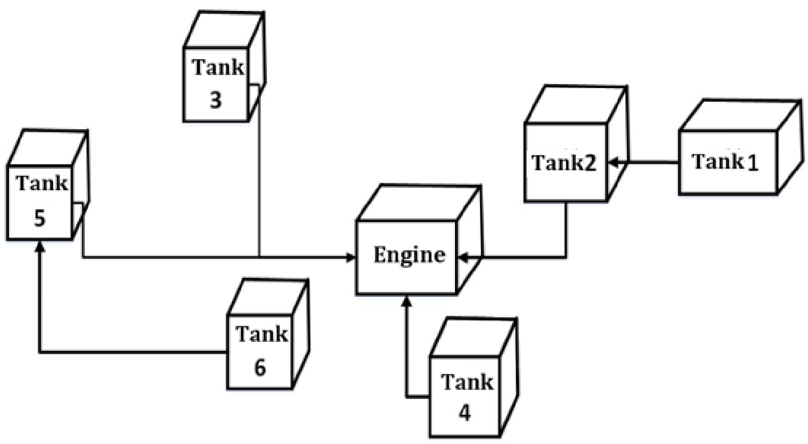

Figure 1. Fuel supply diagram of the aircraft fuel tank

The structure of aircraft (such as the position, shape, size, fuel supply relationship, fuel supply speed limit, etc.) affects the fuel supply strategy of the fuel tank and the change of aircraft centroid. To simplify the problem, the structure of the aircraft and its related fuel supply constraints are described as follows:

(1) The tank is cuboid and fixed inside the aircraft (as shown in Figure 1). The length, width, and height of the tank i are a_i, b_i and c_i, i=1,2,⋯,6. The three directions of length, width, and height are parallel to the X, Y, and Z axes of the aircraft coordinate system.

(2) In the aircraft coordinate system (see the appendix for the description of the coordinate system), the centroid of the aircraft (without oil) is $\vec{c}_0$ (0, 0, 0), the center position of the ith empty oil tank is $\vec{P}_i$, i=1,2,⋯,6. The total weight of the aircraft (without oil) is m.

(3) The upper limit of oil supply speed of the ith oil tank is U_i (U_i>0), i=1,2,⋯,6. The duration of one oil supply for each oil tank shall not be less than 60 seconds.

(4) Main oil tanks 2, 3, 4 and 5 can directly supply oil to the engine. Oil tank 1 and oil tank 6 are used as backup oil tanks to supply oil to oil tank 2 and oil tank 5 respectively. They cannot supply oil to the engine directly.

(5) Due to the limitation of aircraft structure, up to 2 oil tanks can supply oil to the engine at the same time, and up to 3 oil tanks can supply oil at the same time.

(6) During the mission of the aircraft, the total amount of joint fuel supply of each fuel tank shall at least meet the needs of the engine for fuel consumption.

2.2. Problem Analysis

According to the mass and shape of the aircraft and the fuel tank, as well as the mass and shape of the fuel loaded, the mathematical expressions of the centroid position when only the net weight of the aircraft and the centroid position of the fuel in each fuel tank are obtained. Among them, the centroid position of each fuel tank changes with different oil level heights and different fuel shapes in the fuel tank formed by different flight attitudes of the aircraft. Calculate the weighted average of the centroid position of the aircraft net weight and the centroid position of the fuel in each tank, and set the weight to their respective weight, that is, the weight of the centroid position of the aircraft net weight is the aircraft net weight M, and the weight of the centroid position of the fuel in each tank is the fuel remaining in the tank at a specific time m_i^t, the expression of the centroid position of the aircraft (including fuel tank) is obtained after the weighted average of the two.

According to the fuel supply speed of each fuel tank of the aircraft in the mission, combined with the previously obtained formula of the centroid position of the aircraft (including the fuel tank), calculate the centroid position of the aircraft per second in the aircraft coordinate system, process the data in the table with MATLAB software, and combine the obtained centroid coordinate data of each fuel tank with the mass of the fuel tank and the mass and centroid of the aircraft when it is empty, Thus, the three-dimensional coordinate representation of the aircraft centroid is obtained, and the centroid position change curve of the aircraft during the mission is obtained.

3. Determination Strategy of Centroid Position of Aircraft in Straight Flight

3.1. Model Assumptions

(1) The attitude of the aircraft may change during flight, mainly the up and down pitch or left and right deflection of the flight course. To simplify the model, this paper only considers the change of centroid position of aircraft in straight flight.

(2) Assuming that the inertial force of the aircraft in the straight flight attitude is not considered, the fuel level remains horizontal without shaking;

(3) It is assumed that there will be no failure and no operation irrelevant to the mission during the execution of the mission;

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(4) It is assumed that the inner wall of each fuel tank of the aircraft is smooth, regardless of the friction between fuel and the inner wall of the fuel tank;
(5) It is assumed that the material and density of fuel contained in each fuel tank of the aircraft are the same, forming a balanced and uniform distribution state;

3.2. Symbol Description

To simplify the solution of the problem and the processing of numbers and formulas, in this paper, we will use the following symbols to represent variables. The symbols of the main variables are shown in Table 1.

Table 1. Symbol description of main variables

Symbol	symbol description
Pi	The initial center position of the ith empty tank
x_i^t	Does the fuel tank i supply oil at time t
$\overline{o}_i(t)$	Centroid position of fuel contained in tank i at time t
$\overline{l_i^t}$	Coordinates of the centroid of the fuel contained in tank i in the x-axis direction at time t
$\overline{w_i^t}$	Coordinates of the centroid of the fuel contained in tank i in the y-axis direction at time t
$\overline{h_i^t}$	Coordinates of the centroid of the fuel contained in tank i in the z-axis direction at time t
$\overline{m}_i^0$	Initial oil volume of tank i
$\overline{m}_i^t$	Remaining oil quantity of oil tank i at time t
m_i^t	The fuel supply of tank i at time t
V_i^t	The volume of oil tank i at time t
Q_t	The amount of oil consumed by the engine at time t
h_i^t	The height of the oil level of the fuel tank i at time t

3.3. Centroid Formula

The aircraft system in this paper consists of six fuel tanks, where M is the net mass of the aircraft, that is, the total mass of the aircraft system at no-load, $\vec{c}_0$ (0, 0, 0) is the initial centroid position of the aircraft, P_i, $i = 1,2,\ldots,5,6$. The initial center position of the ith empty tank. Suppose the centroid position of the oil in the ith tank is $\overline{o}_i = (\bar{l}_i, \bar{w}_i, \bar{h}_i)$, we take one of the oil tanks as an example, and its initial oil volume is m_i^0, then with the change of time, the mass of the oil volume in the oil tank at time t is:

$$\bar{m}_i^t = m_i^0 - \sum_{t=1}^{n} m_i^t \tag{1}$$

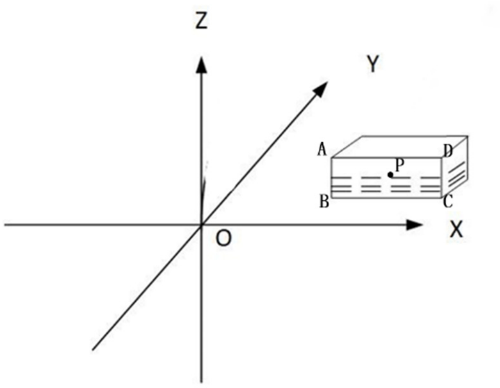

Figure 2. The state of the oil in the fuel tank when the aircraft is flying straight

Where $\bar{m}_i^t$ represents the remaining oil quantity of oil tank i at time t, m_i^t is the amount of oil delivered by tank i at time t.

When the aircraft flies straight, the distribution state of oil in each tank i is a uniform rectangular shape, as shown in Figure 2. It is known that the center position of each tank i is $P_i=(l_i, w_i, h_i)$

Then the bottom area of the oil in tank i is:

$$S_i^t = a_i b_i \tag{2}$$

The height of the oil is:

$$H_i^t = \frac{V_i^t}{S_i^t} \tag{3}$$

Therefore, it can be calculated that the centroid position of each fuel tank when the aircraft flies straight is:

$$\bar{P}_i^t = (\bar{l}_i^t, \bar{w}_i^t, \bar{h}_i^t) = (l_i, w_i, h_i - \frac{c_i}{2} + \frac{H_i^t}{2}) \tag{4}$$

It is known that the length, width, and height of each fuel tank are parallel to the X, Y and Z axes of the aircraft coordinates, and the central position of fuel tank i is known, then the central position of fuel tank i has not changed relative to the aircraft during the mission. That is, the coordinates of point B are $\left(l_i - \frac{a_i}{2}, w_i - \frac{b_i}{2}, h_i - \frac{c_i}{2}\right)$.

No matter how the aircraft pitch changes, the fuel oil in the fuel tank is evenly distributed, so the ordinate of the fuel centroid is always on the same horizontal line as the ordinate of the center position of the fuel tank when it is empty. Therefore, we convert this 3D model into a 2D model with $X(t)$ as the abscissa and $Z(t)$ as the ordinate, as shown in Figure 3.

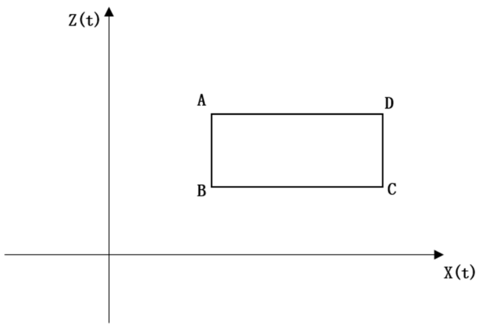

Figure 3. The coordinate system of the bottom area of the oil in the fuel tank after dimensionality reduction

The coordinates of point B in this plane can be expressed as $(l_i - \frac{a_i}{2}, h_i - \frac{c_i}{2})$.

Finally, use the center of mass position of each fuel tank i at each moment $\overline{o}_i(t) = (\bar{l}_i^t, \bar{w}_i^t, \bar{h}_i^t)$ and the position of the center of mass of the aircraft at the initial moment, that is, the no-load time $\vec{c}_0=(0,0,0)$, we can find the centroid position of the aircraft at each moment as:

$$\vec{c}_1(t) = \frac{M \times \vec{c}_0 + \sum_{i=1}^{6} \left[\overline{m}_i^t \times \overline{o}_i(t)\right]}{M + \sum_{i=1}^{6} \overline{m}_i^t} \tag{5}$$

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3.4. Model Construction

In this paper, the mathematical model of the centroid position change of an aircraft in straight flight is set up as follows:

Objective function:

$$\min \max_{t} ||\vec{c}_1(t) - \vec{c}_2(t)||_2 \tag{6}$$

Constraints:

$$m_i^t \le U_i, i = 1,2,\cdots,6, t = 0,1,2,\cdots,7200 \tag{7}$$

$$60 - (t_F - t_0) \le N\left[2 - \left(x_i^{t_0+1} - x_i^{t_0}\right) + \left(x_i^{t_F+1} - x_i^{t_F}\right)\right], t_0,\ t_F \in [0,7200)\ and\ t_0 < t_F, i = 1,2,\cdots,6 \tag{8}$$

$$1 \le x_2^t + x_3^t + x_4^t + x_5^t \le 2, t = 0,1,2,\cdots,7200 \tag{9}$$

$$\sum_{i=1}^{6} x_i^t \le 3, t = 0,1,2,\cdots,7200 \tag{10}$$

$$m_i^t \le \overline{m}_i^t, i = 1,2,\cdots,6, t = 0,1,2,\cdots,7200 \tag{11}$$

$$\sum_{t=0}^{t_M} m_i^t \le \overline{m}_i^0, i = 1,3,4,6 \tag{12}$$

$$\sum_{t=0}^{t_M} m_2^t \le \overline{m}_1^0 + \overline{m}_2^0 \tag{13}$$

$$\sum_{t=0}^{t_M} m_5^t \le \overline{m}_5^0 + \overline{m}_6^0 \tag{14}$$

$$m_2^t + m_3^t + m_4^t + m_5^t \ge Q_t, t = 0,1,2,\cdots,7200 \tag{15}$$

$$\overline{m}_i^T = \overline{m}_i^0 - \sum_{t=0}^{T} m_i^t, i = 1,2,\cdots,6 \tag{16}$$

$$m_i^t \le N \times x_i^t, i = 1,2,\cdots,6, t = 0,1,2,\cdots,7200 \tag{17}$$

$$x_i^t \le N \times m_i^t, i = 1,2,\cdots,6, t = 0,1,2,\cdots,7200 \tag{18}$$

$$\overline{l_i^t} = l_i, i = 1,2,\cdots,6 \tag{19}$$

$$\overline{w_i^t} = w_i, i = 1,2,\cdots,6 \tag{20}$$

$$\overline{h_i^t} = \frac{1}{2}\left(h_i - \frac{c_i}{2} + \frac{\frac{\overline{m}_i^t}{\rho}}{a_i \times b_i}\right), i = 1,2,\cdots,6, t = 0,1,2,\cdots,7200 \tag{21}$$

$$\vec{c}_1(t) = \frac{M \times \vec{c}_0 + \sum_{i=1}^{6}\left[\overline{m}_i^t \times \overline{o}_i(t)\right]}{M + \sum_{i=1}^{6} \overline{m}_i^t}(16), t = 0,1,2,\cdots,7200 \tag{22}$$

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The objective function (6) is to find the minimum value of the maximum of all Euclidean distances formed by the instantaneous centroid and the ideal centroid of the aircraft during mission execution.

Firstly,restrictions related to fuel supply speed and duration:

Constraint condition (7) upper limit of oil supply speed of each oil tank. Constraint (8) the minimum duration of continuous oil supply of each tank is limited. With x_{it} is expressed as a 0-1 variable, which represents whether the oil tank i supplies oil at time t, when x_{it} = 0, it means that the oil tank i does not supply oil in the t second, when $x_{it} = 1$, it means that the oil tank i supplies oil in the t second. t_0 is the starting point of oil supply of an oil tank, t_F is the fuel supply termination point of an oil tank, t_0<t_F. The duration of each oil supply of each oil tank shall not be less than 60 seconds.

Secondly,restrictions related to the number of oil supply tanks:

Constraint (9) represents the maximum number of fuel tanks that can be supplied at the same time. Due to certain restrictions on the oil supply objects of the four main oil tanks and the two backup oil tanks, the four main oil tanks 2, 3, 4, and 5 can directly supply oil to the engine, and the two backup oil tanks 1 and 6 can not directly supply oil to the engine, but supply oil to oil tank 2 and 5 respectively. Constraint (10) represents a limit on the number of main tanks that supply oil to the engine. Due to the limitation of aircraft structure, up to 2 tanks can supply oil to the engine at the same time, and up to 3 tanks can supply oil at the same time. The constraint (11) is the limit on the amount of oil supplied by all oil tanks (main oil tank and backup oil tank).

Thirdly,restriction conditions related to fuel supply:

The constraint condition (12) is the maximum constraint on the amount of fuel that can be supplied by each tank. During the mission of the aircraft, the amount of oil in each tank will be reduced, so the amount of oil that can be provided by each tank will not exceed the amount of oil remaining in its storage. The constraints (13) and (14) are the respective minimum fuel supply limit and the total minimum fuel supply limit of each oil tank. It is known that four main oil tanks 2, 3, 4, and 5 directly supply oil to the engine, backup oil tank 1 supplies oil to oil tank 2, and backup oil tank 6 supplies oil to oil tank 5. Therefore, the amount of oil that can be provided by oil tanks 1, 3, 4, and 6 will not be more than the initial amount of oil it carries, the amount of oil that can be provided by oil tank 2 will not be more than the initial amount of oil it carries and the initial amount of oil that can be supplied by oil tank 1, and the amount of oil that can be provided by oil tank 5 will not be more than the initial amount of oil it carries and the initial amount of oil that can be supplied by oil tank 6. The constraint condition (15) represents the minimum limit constraint of the total fuel supply of each tank at any time. The constraint condition (16) is the constraint condition of the remaining oil amount of the oil tank i at time t.

Fourthly,relationship connection constraints:

Constraints (17) and (18) are relational connection constraints. It is intended that m_i^t and x_i^t connects two variables, where N is a positive number of infinity.

Fifthly,constraints related to centroid position coordinates:

The constraint conditions (19), (20), and (21) are based on the characteristics that the liquid in the oil tank is evenly distributed, combined with the mathematical expressions of the center of gravity and centroid coordinates of the multilateral body, to obtain the mathematical relationship between the centroid coordinates of the fuel contained in each oil tank and the length, width, and height of the fuel. The constraint condition (22) calculates the weighted average of the centroid position of the aircraft at the net weight and the centroid position of the fuel in each fuel tank, to obtain the three-dimensional centroid coordinates of the aircraft as a whole in the aircraft coordinate system.

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4. Model Solving

4.1. Particle Swarm Optimization Algorithm Solution

Particle swarm optimization algorithm is an evolutionary algorithm proposed by J. Kennedy and R. C. Eberhart in 1995 to simulate the foraging behavior of birds. It uses the individual information sharing in the population to move the whole population produce an evolutionary process from disorder to order in the problem-solving space, to obtain the optimal solution.

Particle swarm optimization (PSO) is a parallel algorithm, which finds the global optimum by following the current optimal value. This algorithm has attracted the attention of academic circles because of its advantages of easy implementation, high precision, and fast convergence, and shows its advantages in solving practical problems, which is suitable for the solution of the model constructed in this paper.

4.1.1. Particle Swarm Optimization Design

Particle swarm optimization (PSO) simulates the foraging behavior of birds in a flock by designing the speed and position of particles. Suppose there are n particles in a d-dimensional problem search space, and the current position of particle i in space is expressed as $X_i = \{x_{i1}, x_{i2}, \dots, x_{id}, \dots, x_{iD}\}$, and the flight speed is expressed as $V_i = \{v_{i1}, v_{i2}, \dots, v_{id}, \dots, v_{iD}\}, i = 1,2,\dots,n, d = 1,2,\dots,D$. Particle swarm optimization (PSO) simulates the information sharing of birds through two extremum solutions: one extremum is the optimal solution found by the whole group, which is called group optimal solution $gBest$; Another extreme value is the optimal solution found by particle i, which is called an individual optimal solution $pBest_i$. During iteration, particles update their speed and position by tracking these two extreme values, to move closer to the optimal solution. The update formula of the velocity and position of particle i in iteration $t+1$ is as follows:

Speed update formula: $v_{id}^{t+1} = \omega v_{id}^{t} + c_1 r_1 (pBest_i - x_{id}^{t}) + c_2 r_2 (gBest - x_{id}^{t})$

Location update formula: $x_{id}^{t+1} = x_{id}^{t} + v_{id}^{t+1}$

The velocity update formula consists of three parts: the first part is called the memory term, which represents the original motion inertia of the particle; the second part is called the self-cognition term, which means that the particle tends to approach its optimal position; the third part is called group cognition term, which means that particles tend to approach the optimal position of the group. Particles determine their next movement through their own experience and group experience. Among them, ω It is a dynamic weight. The typical dynamic weight is the linear decreasing weight proposed by Shi and Eberhart in 1998. It usually decreases linearly from 0.9 to 0.4 to obtain better optimization results. r_1 and r_2 is a random number in the range of (0,1). c_1 and c_2 is the learning factor, usually c_1=c_2=2.

4.1.2. Particle Swarm Optimization Process

Step 1: Initializing a group of particles (group size n), including random position and velocity;

Step 2: Evaluate the fitness of each particle;

Step 3: For each particle, its fitness value is compared with its best position $pBest$. If it is better, it is regarded as the current best position $pBest$;

Step 4: For each particle, its fitness value is compared with its best position $gBest$. If it is better, it is regarded as the current best position $gBest$;

Step 5: Adjust the particle speed and position according to formulas (2) and (3);

Step 6: If the end condition is not reached, go to step 2). According to the specific problem, the iteration termination condition is generally selected as the maximum number of iterations Gk or (and) the optimal position searched by the particle swarm so far meets the predetermined minimum adaptation threshold.

4.2. Description of Model Solving Parameters

It is known that the mass center coordinate of the aircraft (without oil) is (0, 0, 0), the fuel density is 850 kg/m^3, and the net mass of the aircraft is 3000 kg. The structural parameters of the aircraft and fuel tank are shown in Table 2 below.

Table 2. Structural parameters of the aircraft and fuel tank

Tank	Center position of fuel tank (unit: m)			Fuel tank size (unit: m)			Initial oil volume (m^3)
	x	y	z	Long (x axis)	Width (y axis)	High (z sxia)	
Tank 1	8.9130435	1.20652174	0.61669004	1.5	0.9	0.3	0.3
Tank 2	6.9130435	-1.39347826	0.21669004	2.2	0.8	1.1	1.5
Tank 3	-1.686957	1.20652174	-0.28330996	2.4	1.1	0.9	2.1
Tank 4	3.1130435	0.60652174	-0.18330996	1.7	1.3	1.2	1.9
Tank 5	-5.286957	-0.29347826	0.41669004	2.4	1.2	1	2.6
Tank 6	-2.086957	-1.49347826	0.21669004	2.4	1	0.5	0.8

Table 3. Shows the upper limit of oil delivery and the connection relationship of each oil tank

Output part	Input parts	The upper limit of oil delivery (kg/s)
Tank1	Tank 2	1.1
Tank 2	Engine	1.8
Tank 3	Engine	1.7
Tank 4	Engine	1.5
Tank 5	Engine	1.6
Tank 6	Tank 5	1.1

4.3. Model Solution Result Display

According to the planned fuel consumption speed data of the aircraft in a mission and the ideal centroid position data of the aircraft in the aircraft coordinate system, through the programming of particle swarm optimization algorithm with visual studio 2015, we obtained the fuel supply speed data of six fuel tanks of the aircraft during the execution of this mission, which is displayed in a group per second. The table 4 is the example results.

Table 4. The fuel supply speed data of six fuel tanks during the straight flight of aircraft

Time(s)	Fuel supply speed of tank 1 (kg/s)	Fuel supply speed of tank 2 (kg/s)	Fuel supply speed of tank 3 (kg/s)	Fuel supply speed of tank 4 (kg/s)	Fuel supply speed of tank 5 (kg/s)	Fuel supply speed of tank 6 (kg/s)
1	0	8.16E-12	0	0	0	0
2	0	0	0	0.006132	0.007163	0
3	0	0.014127	0	0	0.011045	0
4	0	0.045555	0	0	0	0.001683
5	0	0	0	0	0.078837	0.002977
6	0	0.058315	0	0	0.072056	0
7	0	0.206157	0	0	0	0.004107
8	0	0.138819	0	0	0.172833	0
9	0	0	0	0.201323	0.249094	0
10	1.1	1.8	0	0	0	0
11	1.1	0.821907	0	0	0	0
12	0	0.463595	0	0.574227	0	0

13	0.131654	1.252791	0	0	0	0
14	0	0.644891	0	0.800851	0	0
15	0	0	0.094997	1.5	0	1.1
16	1.1	1.8	0	0	0	0
17	0	1.8	0	0	0	1.1
18	0	1.8	0	0	0	1.1
19	0	1.8	0	0	0	0
20	0	1.8	0	0	0	0
21	0	1.8	0	0	0	0
22	0	1.8	0	0	0	0
23	0	0.803785	0	0	0.417622	0
24	0	0	0	0.837	0.180404	0
25	0	1.8	0	0	0	0
26	0	0.745866	0	0	0	0
27	0	0.516438	0	0	0	0
28	0	0	0	0.200967	0.245499	0
29	0	0.198026	0	0	0.241984	0
30	0	0.324387	0	0.173607	0	0

According to the fuel supply speed data of six fuel tanks when the aircraft flies straight, the maximum distance between the instantaneous centroid and the ideal centroid of the aircraft is 0.872cm, and the total fuel supply of the four main fuel tanks is 8.282m^3.

5. Conclusion

Aiming at the optimization of aircraft centroid balance fuel supply strategy, this paper considers that in the mission planning process in which the aircraft always maintains level flight (pitch angle is 0), the optimization goal is to minimize the maximum value of the Euclidean distance formed by the Euclidean distance between the instantaneous centroid and the ideal centroid at every second during the mission execution, and comprehensively considers multiple constraints, The mathematical model including the fuel centroid formula is established, which has a reliable mathematical basis, increases the accuracy of the algorithm to obtain the optimal solution, and makes the model have good universality and generalization.

However, the model constructed in this paper contains more variables, which leads to the increase of problem-solving dimension. When the problem data is so complex, it brings a lot of problems to our algorithm. Therefore, the subsequent model construction will consider reducing the variable dimension and reducing the difficulty of the algorithm.

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