Separation simulation studies of large disturbance and high speed at low altitude

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Abstract. Based on the secondary development function of ADAMS/VIEW, a parameterized simulation model of aircraft separation simulation is established by the external Fortran subroutine. A five-dimensional aerodynamic matrix is established in the program. The four-dimensional interpolation algorithm is used to calculate the aerodynamic values of the six components in real time, and the time-varying six-component aerodynamic data is provided for the aircraft and the lower stage. Based on the preliminary simulation analysis, based on the fully parameterized dynamic model, the variables such as angle of attack, side slip angle, pitch angular velocity, yaw angular velocity, roll angular velocity, aerodynamic force, aerodynamic moment, mass, and moment of inertia, which plays a role in predicting separation.

1. Introduction
The separation simulation of the current aircraft mostly uses high-level language programming to establish dynamic equations. There are two main methods for separating and simulating the current engineering applications: one is to perform collision analysis with ADAMS after MATLAB, and the other is dynamic simulation of separation process by ADAMS. The first type of fusion of MATLAB calculations with ADAMS is cumbersome. The second operation is relatively simple, but it is not possible to accurately simulate aerodynamics in real time. In this paper, the second method is used to simultaneously simulate real-time aerodynamics to simulate the separation process. Using numerical methods for simulation analysis, the modelling process is complex and cannot guarantee accuracy and stability. For engineers, too complex variables and combinations of deviations are not conducive to the understanding and application of engineering personnel [1]. For an aircraft with a low-altitude, high-speed and large-interference environment, the separation body is affected by various deviation factors during the separation process. The influence of different deviation factors on the separation process is mutually coupled, so the level must be interfered with by random factors. The simulation process was carried out during the separation process, and the statistical results of the separation simulation were obtained. In this paper, the highly parametric dynamics modelling is realized by the ADAMS secondary development function. The real-time multi-dimensional interpolation calculation of aerodynamics is realized by the joint simulation of the external FORTRAN subroutine and the ADAMS software. The deviation analysis is carried out, which is suitable for low-altitude high-speed A method for predicting the separation of interference separation systems. In this paper, the FORTRAN programming makes a linear difference between the aerodynamic database based on the angle of attack, the side slip angle and the relative distance, and considers the influence of the initial
attitude deviation, aerodynamic deviation, quality characteristic deviation and other deviation factors on the separation result, and makes a separation prediction.

2. Meaning of the ADAMS secondary development technology
In the ADAMS dynamics simulation, the inherent characteristics of each component (moment of inertia and centroid position, etc.) are the key parameters of the simulation input [1]. Apply ADAMS secondary development technology to establish a system that can quickly generate model parameters and dynamic simulation. By inputting the parameters such as centroid coordinates, mass, moment of inertia, stiffness and damping characteristics of each component, the system can establish the dynamic model of the corresponding characteristics and obtain the corresponding simulation results [2]. Separation analysis is usually performed using the mechanical system dynamics analysis software ADAMS [3].

In order to improve the efficiency of modelling and post-processing of the original software, and considering the similarity of the structural form, support form and separation order of the different tasks, it is necessary to carry out secondary software development based on ADAMS [4]. ADAMS/Solver has powerful secondary development capabilities, using Fortran to write custom functions, and compiling with ADAMS/View. Compiled functions can be used in ADAMS/View expressions, and connecting custom process models to ADAMS does not affect the computational efficiency and speed of the prototype [5].

3. Overview of the Fortran model
After loading the database of aerodynamic forces with angle of attack, side slip angle and relative distance into the Fortran model, the parameters of the aerodynamics are read by the ADAMS, and the aerodynamic force is interpolated by the interpolation function. The ADAMS/View is compiled by Fortran through the Solver libraries call. Dynamic link library, the resulting aerodynamic force is loaded into the corresponding position of the ADAMS dynamic model [5].

4. Modelling of separation system
A rigid body model is established based on the cold structure layout and specific dimensions of the aircraft. Taking the actual apex of the aircraft as the origin, the origin points to the tail along the axis of the aircraft, and the X-axis is positive. The origin is perpendicular to the X-axis and points in the positive direction of the Y-axis of the back of the aircraft. The coordinate system is determined by the right-handed spiral rule, and the structure of the aircraft is shown in Figure 1. The unit settings of the model are shown in Table 1.

![Figure 1. Aircraft structure model.](image)

**Table 1. Model unit list.**

| Physical Quantities | Length | Mass | Force | Time | Angle | Frequency |
|---------------------|--------|------|-------|------|-------|-----------|
| unit                | mm     | kg   | N     | ms   | deg   | Hz        |

4.1. Rigid model
The model is imported into ADAMS, and attributes such as quality characteristics are attached to the model. The imported model is shown in Figure 2. The quality of the model, the moment of inertia and the position of the centroid are respectively assigned to the upper and lower levels of the aircraft, and
embedded into the ADAMS through the dialog box, which can quickly modify and reset the parameters.

**Figure 2.** ADAMS initial rigid body model.

4.2. Force model

The force model includes separation pulses, contact impact forces, splitting and pulling forces, as well as the upper aerodynamic and lower aerodynamic forces of the aircraft. The pulses and the insertion and removal forces are separated separately, different forces are parameterized at corresponding positions of the rigid body model, and the separated collision forces are added to the model in the form of contact models, and the time of failure is added to the model. Set the collision force according to the time series.

For aerodynamics, it is impossible to implement the calculation and solution process by relying solely on ADAMS itself. This function needs to be implemented by an external FORTRAN subroutine. First, establish the GFORCE force in the FORTRAN at the action point of the aircraft (the GFORCE force is the calling function between the FORTRAN program and the ADAMS), and input the reference point ID number required for calculating the aerodynamic force in the parameter field (the ID number is the corresponding object in the ADAMS). The number, such as the upper level of the aircraft number is 8), and finally fill in the FORTRAN program name and the compiled link file name "mysub::GFOSUB" ("mysub::GFOSUB" is the entry format for the ADAMS call FORTRAN program), as shown in Figure 3. Complete the setup to invoke the aerodynamic data in the software and simulate the simulation in real time.

**Figure 3.** Dialog box for setting mass and moment of inertia.
4.3. Constraint model
FIXED JOINTS is used to securely connect aircraft components. The upper and lower stages of the aircraft are fixed by four FIXED JOINTS connections and the CONTACT constraint is added to the four FIXED JOINTS. FIXED JOINTS is invalidated after a certain period of time by the simulation script (the simulation script is briefly introduced below) to achieve the purpose of simulating the unlocking process.

4.4. Measurement model
Angle, angular velocity, separation distance and angle of attack and side slip angle are set in the software. Taking the elevation angle as an example, the Euler angle measurement method is adopted in ADAMS. The specific statements are as follows:

AX (MARKER_CM_Feixingqi, MARKER_Measure_origin).

The measurements that need to be output are summarized in the same dialog box, as shown in Figure 4. You can click on the desired measurement to view the relevant results.

![Figure 4. Dialog box for call measurement model.](image)

4.5. Simulation script
“SIMULATION SCRIPT” is a way to control the simulation process of the simulation process in ADAMS. It can set different conditions by setting different SENSOR (SENSOR is a measurement, which can be called by ADAMS internal function) to make different conditions, and make The force or connection is valid or invalid, enabling simulation of the entire separation process.

5. Variance influence analysis
The main parameter deviations include: angle of attack, side slip angle, pitch angle, yaw angle, rolling call, pitch angular velocity, yaw angular velocity, rolling speed, mass characteristic deviation, aerodynamic deviation. The causes of the deviation are machining errors, test errors, simulation errors, etc. Use the “Design Evaluation” tool of ADAMS/View to analyse the degree of influence of the variation of various variables on the simulation results.

Taking the angle of attack deviation as an example, the angle of attack is equally divided into 5 (-3, -2, -1, 0, 1) within the deviation range, and the simulation is designed using Design Study. As shown in Figure 5, the process of separating the upper and lower areas of the aircraft. In Figure 3, a is the attitude of the whole aircraft at the initial moment of separation, b is the relative attitude of the upper and lower stages of the aircraft when separated for 100ms, and c is the relative attitude of the upper and lower stages of the aircraft when the last seconds (500ms) are separated. After the pitch angle is selected as the key factor, you can get the curve consisting of 5 pitch angular velocity curves, as
shown in Figure 6, the abscissa is the time axis (in milliseconds), the ordinate is the pitch angular velocity (in degrees per millisecond), trial_1, trial_2, trial_3, trial_4, trial_5 indicates that the angle of attack is -3, -2, -1, 0, 1, respectively. According to the simulation report, it can be known that the initial angle of attack increases within the range of deviation to reduce the pitch angle velocity.

![Figure 6. Curves of pitch angle velocity.](image)

Due to the limitations of the length of the paper, this paper only gives the calculation curve by taking the angle of attack as an example. In this way, the influence of the parameter deviation on the post-separation attitude can be obtained, and the purpose of predicting the attitude of the aircraft at the time of separation has been reached.

By using the same method to analyze different deviation factors, a set of deviations that have the worst influence on the pitch angular velocity can be obtained, that is, the measured slip angle increases within a certain range, the moment of inertia decreases within a certain range, and the head receives the aerodynamic force. Increasing the moment will increase the pitch angular velocity, as shown in
Table 2. According to the combination of the deviations, a set of starting conditions with the maximum pitch angular velocity can be obtained. As shown in Table 3, the control system can judge whether the controller can meet the control requirements according to the starting control conditions. In this way, it can play a predictive role.

**Table 2. Severe deviations list.**

| Physical Quantities | Attack Angle (°) | Sideslip Angle (°) | Mass and Moment of Inertia (%) | Aerodynamic Force (%) | Aerodynamic Torque (%) |
|---------------------|------------------|--------------------|--------------------------------|-----------------------|------------------------|
| Deviation Value     | -3               | 2                  | 110                            | 110                   | 120                    |

**Table 3. Starting conditions list.**

| Physical Quantities | Roll Angle (°) | Yaw Angle (°) | Pitch Angle (°) | Roll Angle Velocity (°/s) | Yaw Angle Velocity (°/s) | Pitch Angle Velocity (°/s) |
|---------------------|----------------|--------------|----------------|---------------------------|--------------------------|---------------------------|
| Deviation Value     | 2              | 1            | 1              | 80                        | 30                       | 67                        |

6. **Results of separation predicted**

In this paper, Adams secondary development language is used to generate a parametric modelling tool for dynamic simulation. Using this tool, a parametric simulation model of a certain aircraft separation simulation is established. The method of external subroutine is used to realize multi-dimensional linear aerodynamics. Interpolation, and the influence of the main parameter deviation on the simulation results is studied, and a set of control conditions under severe deviation is obtained (severe deviation refers to the worst change of attitude at the end of simulation). In this way, the attitude of the aircraft at the time of separation can be predicted. According to the simulation results, the initial angle of attack increases within the deviation range. The initial measured slip angle decreases within a certain range, the initial moment of inertia increases within a certain range, and the initial aerodynamic force and torque received by the upper stage decrease, which makes the posture after separation better. And the predictive results obtained in this way have been tested by wind tunnel test and control rate algorithm, and will be tested in subsequent studies.

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