Accuracy Analysis of Aerodynamic Calculation of 2-Dimensional Trajectory Correction Projectile Based on DATCOM

Hanzhou Wu, Min Gao, Xieen Song, Jingqing Xu, Yi Wang, Jie Zhao

Abstract—**As an engineering software for calculating the aerodynamic parameters of aircraft, Missile DATCOM is widely used in the design and demonstration stage of aircraft research. In this paper, a 2-dimensional (2D) trajectory correction projectile is taken as the research object, and the DATCOM calculation accuracy is analyzed. The results show that in the software parameter setting, although method 1 describes the body is not accurate enough, its own geometry generators can accurately describe the body contour. The aerodynamic parameters calculated by this method are more accurate than method 2. The aerodynamic parameters of the 2D trajectory correction projectile calculated by DATCOM have a large system error compared with the wind tunnel test data. This paper proposes a system error compensation method (SECM) to compensate the calculated data, which can greatly reduce the system error. After the error compensation correction, the axial force coefficient (C_A) error is reduced to less than 3%, and the normal force coefficient (C_N) error and the pressure center position (XCP) error are generally reduced to within 10% and 5%, when the sideslip angle is 0°. When the sideslip angle is less than 4°, the C_A error is less than 5%, and when the sideslip angle (β) is less than 1°, the main data error of C_N is less than 15%, and the main data error of XCP is less than 25%. These errors meet the engineering calculation accuracy requirements. This method cannot completely replace wind tunnel tests and computational fluid dynamics (CFD) simulation calculations, but it can greatly reduce the number of wind tunnel tests and the CFD simulations, and has strong application value.**

Index Terms—**DATCOM, accuracy analysis, systematic error compensation, 2-dimensional trajectory correction projectile**

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I. Introduction

The proportion of precision guidance ammunition used in warfare continues to increase, but its high cost has led to a significant increase in the war cost, limiting its extensive equipment. The 2-dimensional (2D) trajectory correction projectile only transforms the traditional projectile fuze, the cost is relatively low. On the basis of realizing the traditional fuze function, the data measurement module and the canard control module are integrated on the fuze. After the projectile is launched, the trajectory correction is performed through the canard control system, and finally the projectile fly to the target point. This kind of projectile has the advantages of low manufacturing cost and high shooting accuracy, and largely solves the contradiction between the precise strike of the ammunition and the cost.

The aerodynamic shape of the correction component of the 2D trajectory correction projectile has a great influence on the trajectory characteristics of the projectile, such as flight stability, range, and impact point dispersion. Mastering the influence of different correction component shape on the aerodynamic characteristics and trajectory characteristics of the 2D trajectory correction projectile is the basis for the design of the aerodynamic scheme of the correction component [1].

At present, the main methods to obtain aerodynamic parameters are wind tunnel test, CFD simulation and engineering calculation. Wind tunnel test cycle is long, the cost is high, and it is not suitable for the early stage of aerodynamic scheme demonstration; the CFD simulation can get accurate aerodynamic parameters, but the software parameters are complicated, and the computer hardware requirements are high, which are mostly used for the improvement of the scheme and aerodynamic characteristics research [2-4]; currently, the commonly used method in the primary stage of aerodynamic scheme demonstration is engineering calculation. DATCOM, also known as Missile DATCOM, is called Missile Data Compendium, an aerodynamic engineering software developed by the US Air Force Research Laboratory. DATCOM is widely used in the aerodynamic calculation of aircraft plane, airships, projectiles, missiles and other aircraft. The software integrates the wind tunnel test data of the US Air Force in recent decades, with strong adaptability and high precision. With the development of technology and the accumulation of test data, the program has been continuously revised and supplemented [5].

Literature [6-10] performed aerodynamic calculations on

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individual wings, aircraft body and wing-body, and analyzed the aerodynamic characteristics of different wing and body shapes, which provided data reference for aircraft shape design. The aerodynamic calculations of the airship are carried out in [11] and [12]. The results show that DATCOM calculates the pitching moment coefficient with high precision, but there is a certain error in the drag coefficient. Similarly, the literature [13] and [14] pointed out that the error of calculating the longitudinal aerodynamic coefficient of the missile is large. In the aerodynamic analysis of unmanned aerial vehicles, by designing different aerodynamic shapes, the flight operability of the aerodynamic parameters analysis aircraft is calculated, which has greatly help to the design of the previous scheme [15-17]. Literature [18-22] used DATCOM to analyze the aerodynamic characteristics of a deformable wing or a swept-wing aircraft, which helped to analyze the crossover problem between multi-body motion and transient aerodynamics. Literature [23-26] combine DATCOM with Monte Carlo algorithm, particle swarm optimization algorithm, genetic algorithm, etc., with the shape parameters of the missile as the optimization target, and calculates the optimal aerodynamic shape of the missile, and achieves the ideal effect.

As an engineering calculation software, DATCOM calculation accuracy is not high. Some researchers have interpreted and developed the DATCOM software program, and replaced some of the theoretical formulas (and empirical or semi-empirical formulas) with poor calculation accuracy with the latest and more accurate theoretical calculation formulas [27-29]. The calculation accuracy has been improved to some extent, but there is still a large error compared with the wind tunnel test data. Some researchers compiled the wind tunnel test data of different aircraft, built a database, and then combined it with DATCOM software, which broadened the calculation range of DATCOM and improved the calculation accuracy [30-32]. For some models lacking wind tunnel test data, the researchers combined CFD simulation data with DATCOM to correct the calculation error, and the calculation accuracy is also improved [33, 34].

From the existing published literatures, the researchers obtained more accurate aerodynamic parameters through wind tunnel test and CFD software. There are few literatures using DATCOM to obtain accurate aerodynamic parameters of projectiles. The aerodynamic shape of the 2D trajectory correction projectile is quite different from traditional missiles, rockets, and mortar bombs. The canard of the trajectory correction projectile is limited to the diameter of the fuze head. The span of the canard cannot exceed the diameter of the projectile. The area of the canard is limited and the correction capability is limited. Therefore, accurate aerodynamic parameters of the trajectory correction projectile are required, and is of great significance for studying the aerodynamic characteristics of the projectile and formulating the projectile trajectory correction strategy. In this paper, DATCOM is used to calculate the aerodynamic parameters of a 2D trajectory correction projectile under different Mach, angles of attack (AOA) and sideslip angle (β). Based on the wind tunnel test data, the calculation accuracy of DATCOM is analyzed. The system error compensation method (SECM) is proposed to correct the system error of DATCOM calculation data, and obtain more accurate aerodynamic parameters. SECM can greatly improve the DATCOM calculation accuracy. SECM cannot completely replace wind tunnel tests and CFD simulation calculations, but it can greatly reduce the number of wind tunnel tests and CFD simulation tests, and save financial resources and time costs a lot.

II. DATCOM Overview

A. DATCOM introduction

DATCOM was first released in 1960, and in 1978 it formed a more complete version through continuous expansion of functions. DATCOM contains wind tunnel test data from the US Air Force for decades, and integrates many theoretical formulas, empirical formulas and semi-empirical formulas for calculating the aerodynamic parameters of aircraft, and is written in Fortran language. It adopts the modular calculation method. Firstly, the aerodynamic parameters of each shape component of the aircraft are calculated separately. Considering the interaction effect between components, the aerodynamic parameters of the aircraft are calculated by the component combination method. The specific use flow of DATCOM is, first input parameters describing the aircraft shapes and flight environment, click on the main function to run DATCOM, the software finds the wind tunnel test data and the theoretical calculation formula similar to the input parameters, and calculates the aerodynamic coefficient by fitting the difference method. DATCOM has a wide range of calculations, strong robustness and easy operation. It can calculate input conditions quickly, and is often used in the initial stage of aircraft development to screen different shape schemes.

B. DATCOM's running process

DATCOM consists of a main program and several subroutines. The subroutines consist of a data input module, a data storage module, three output modules and several other models relate to aerodynamic calculation functions. The main program calls other subroutines according to the calculation requirements of the data input module, and completes the aerodynamic calculation according to flight conditions and environmental setting requirements. The software has the function of checking errors. For problems that do not meet the parameter setting requirements or input format errors, the program can not run, DATCOM can automatically check the positioning and classify the errors. For an error input that does not affect the calculation logic, DATCOM chooses to automatically ignore the input error and continue to run. The output file of DATCOM calculation result are files in "DAT" format, so the software can also be used together with other software, such as MATLAB, C language, etc., to facilitate the analysis of calculation results and flight modeling. The program running process is shown in Fig. 1.

III. Calculation Precision Analysis of the Description Method of Projectile Body

The DATCOM program sets up two methods for describing the body of an aircraft. In the first method, the aircraft geometry is divided into nose, centerbody, and aft body sections [35]. The contour of the nose can be selected from five types: cone type, pointed arch shape, exponential type, Haack and von Karman. The centerbody is a cylinder or elliptical cylinder with a constant radius. The aft body can be described as a contraction type, or external expansion type. Method 2 uses the head of the aircraft as the starting coordinate and defines the radius of the body at different positions pointing in the direction of the tail. This method can accurately describe the shape of the body. In the aerodynamic calculation, DATCOM developers recommend using method 1, but the reasons are not specified. In this paper, a calculation example is used to analyze the two methods based on the calculation accuracy of the aerodynamic coefficient.

A. Projectile model

The calculation model selected in this paper is a type of 2D trajectory correction projectile. As shown in Fig. 2(a), the projectile correction actuator is the four piece of canard on the projectile head. The details of the projectile fuze head are shown in Fig. 2(b). The shape of the four piece of canard is identical. The canard angles of No. 1 and No. 3 are +4 °, which provides the fuze with a rolling moment relative to the reverse rotation of the projectile during flight. The canard angles of No. 2 and No. 4 are opposite, with 4 ° and -4 ° respectively, providing trajectory correction force and moment for the projectile during flight. It can be seen from Fig. 2(a) that the contour of the trajectory nose is not a continuous arc or straight line, but a cylinder is added to the head of the fuse. The cylindrical section integrates components related to the projectile trajectory correction system, mainly including motor modules, attitude measuring modules et al. This shape design of the projectile nose can not be fully described in method 1 in DATCOM, and can only be approximated from the optional five shape descriptions. This paper describes it as a conical shape. When using Method 2 to describe the shape of the projectile, it is only necessary to describe the radius of the projectile at the position of the node where the diameter of the projectile changes significantly along the direction of the projectile axis. For arc segment bodies, the description accuracy can be improved by increasing the node density. Method 2 can basically describe the shape of the body.

B. Calculation accuracy analysis of two kinds of body description methods

The DATCOM calculation data was compared with the aerodynamic parameters obtained from the wind tunnel test. In order to reduce the error caused by the model difference, in this paper, the model used for DATCOM calculation is exactly the same with the shape and size of the projectile in the wind tunnel test, which is the 1:2 reduced model. At AOA of 0 °, the axial force coefficient (C_A) and normal force coefficient (C_N) of the projectile corresponding to different Mach numbers are shown in Fig. 3. In the legend of Fig. 3, "WT" is an abbreviation for wind tunnel, which is wind tunnel test data, and "W1" and "W2" represent method 1 and method 2. It can be seen from Fig. 3 that the C_A error and the C_N error calculated by DATCOM are both large. On the whole, the relative error of C_A is smaller than that of C_N. The error of C_A and C_N calculated by method 1 is smaller than the data obtained by method 2.

The C_A and C_N of the projectile at different AOA are shown in Fig. 4 to Fig. 6. It can be seen from Fig. 4 that at the subsonic speed, the C_A error calculated by method 1 at large AOA is larger than that of method 2. At the negative AOA, the C_N error calculated by method 1 is smaller than that of method 2, while at the positive AOA, the error law of C_N are all opposite calculated by the two methods. It can be seen from Fig. 5 that at the transonic speed, the C_A errors calculated by the two methods are both large. The error of the C_N calculated by the method 1 is greater than that of method 2 at the negative AOA, and the error law is opposite at the positive AOA. It can be seen from Fig. 6 that at the supersonic speed, C_A error calculated by method 1 is significantly smaller than that of the method 2, and C_N error calculated by method 1 is slightly smaller than that of method 2.

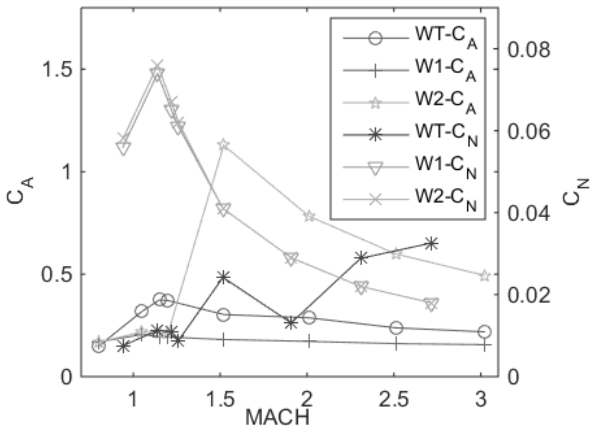


Fig. 3. Curves of C_A-Mach and C_N-Mach

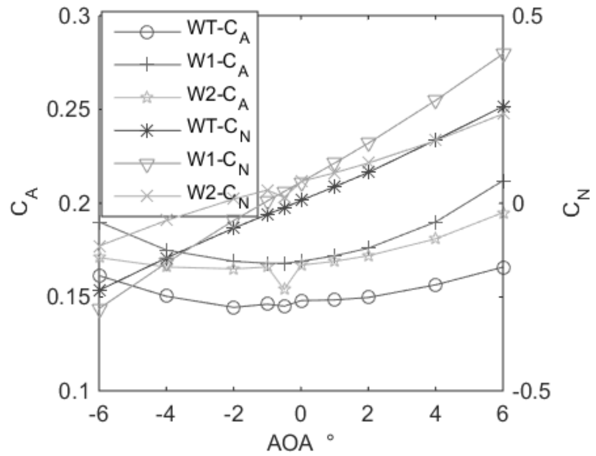


Fig. 4. C_A-AOA & CN-AOA at 0.8 Mach

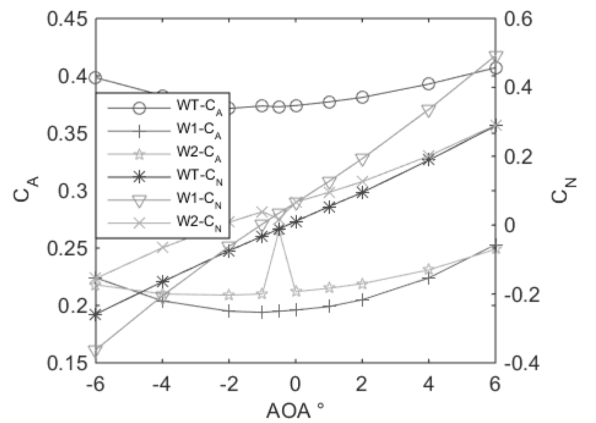


Fig. 5. C_A-AOA & CN-AOA at 1.15 Mach

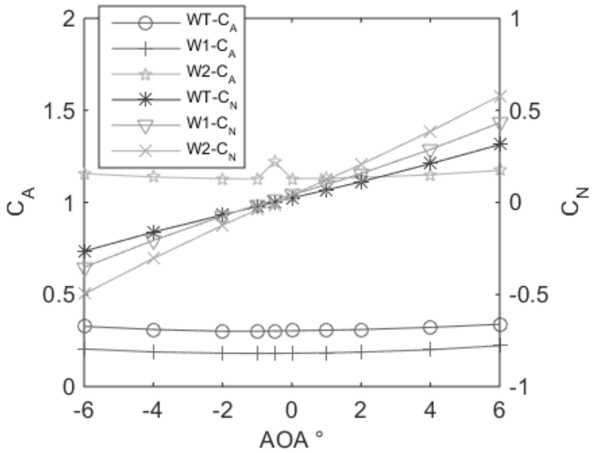


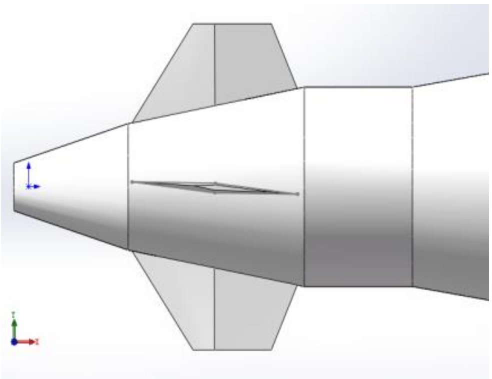
Fig. 6. C_A-AOA & CN-AOA at 1.52 Mach

Above analysis shows that the C_A and C_N of the 2D trajectory correction projectile calculated by method 1 are more accurate than method 2. This also confirms the DATCOM instructions, "it is highly recommended to use Method 1 to describe the aircraft body as much as possible. The program automatically calculates the body contour based upon the segment shapes using geometry generators. Hence, more accurate calculations are possible." [35] In the following analysis, this paper describes the projectile body based on Method 1, and further analyzes the accuracy of DATCOM's calculation of aerodynamic parameters.

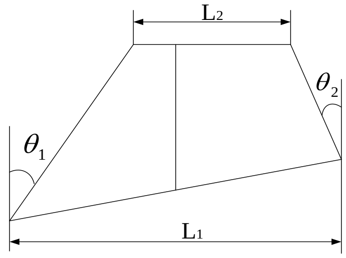
IV. DATCOM Calculation Accuracy Analysis

A. *Research object introduction*

For the 2D trajectory correction projectile, the aerodynamic characteristics at flight are directly related to the shape of the trajectory correction actuator—the canard. Different canard shapes correspond to different aerodynamic coefficients of the projectile. This section mainly analyzes the accuracy of the aerodynamic coefficients of DATCOM's calculation of different canard shape schemes of projectiles. The two canard shape schemes selected in this paper are shown in Fig. 7 and Fig. 8. The canard leading edge sweep angle of scheme 1 is larger than that of scheme 2, and the trailing edge sweep angles of the two canard are the same. The two canard have the same length, span, and position parameters. Therefore, the total canard area of scheme 1 is smaller than that of scheme 2.

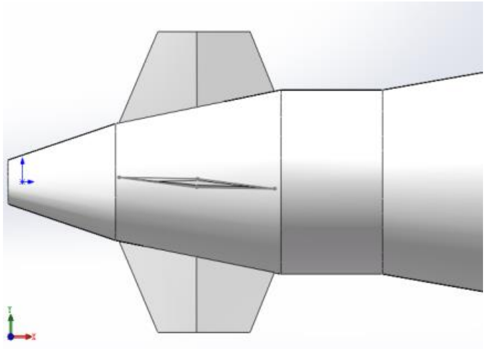


(a) Canard model of scheme 1

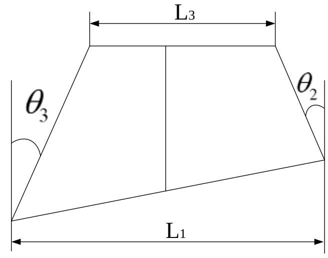


(b) Canard shape parameters of scheme 1

Fig. 7 Canard shape of scheme 1



(a) Canard model of scheme 2



(b) Canard shape parameters of scheme 2

Fig. 8 Canard shape of scheme 2

B. *Accuracy analysis of* C_A

Enter the same parameters as the wind tunnel test environment in the DATCOM parameter input file. Based on the wind tunnel test data, the error analysis of DATCOM calculation results of C_A was performed. The error varies with the Mach as shown in Fig. 9. The error varies with the AOA as shown in Fig. 10.

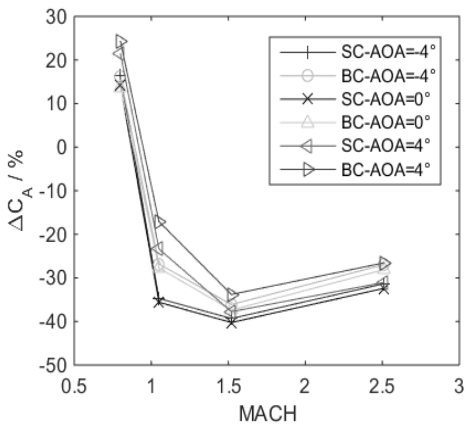


Fig. 9 Error of C_A varies with the Mach

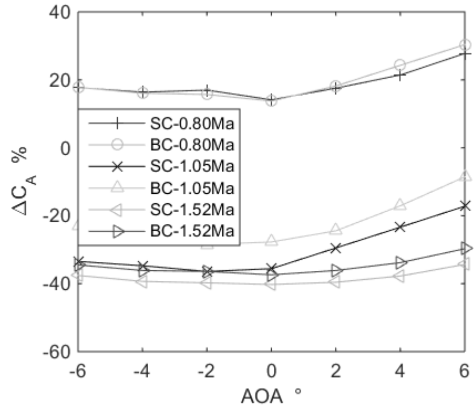


Fig. 10 Error of C_A varies with the AOA

In the legend of Fig. 9 and Fig. 10, "SC" and "BC" respectively indicate "projectile with small canard" and "projectile with big canard".

It can be seen from Fig. 9 that the C_A calculated by DATCOM of the two kind of projectiles all have large system errors, and the deviation varies with the Mach. At the same AOA, C_A errors of the two projectiles varies with the Mach. It can be seen from Fig. 10 that, under the same Mach, although the system errors of C_A of two projectiles calculated by DATCOM is not the same, the two system errors are substantially parallel to each other at different AOA. In the actual application, the similarity of the system error can be utilized, and the system error compensation is performed on the DATCOM calculation data with similar shape, and the accurate aerodynamic data can be obtained. It is assumed that the wind tunnel test was carried out on the projectile with scheme 1 canard (small canard projectile) at different Mach and AOA. The C_A of projectile with scheme 2 canard (big canard projectile) is obtained under the requirement of minimizing the number of wind tunnel tests. It is only necessary to carry out a wind tunnel test at different Mach for the big canard projectile at a certain AOA. The specific implementation steps are as follows:

1. The C_A of the small canard projectile at different AOA and Mach was obtained by wind tunnel test. The C_A of the small canard projectile at different AOA and Mach is calculated by DATCOM. The DATCOM data system error of small canard projectile is calculated with wind tunnel test data.

2. For the big canard projectile, the wind tunnel test with different Mach is performed to obtain the C_A at a fixed AOA of α_1. The C_A of the big canard projectile at different AOA and Mach is calculated by DATCOM. Based on the wind tunnel test data of big canard projectile, the C_A system error of the DATCOM data at α_1 AOA is calculated.

3. Using DATCOM data system error of big canard projectile at α_1 AOA minus small canard projectile system error that of the same AOA, and getting their difference $\Delta e_{\alpha 1}$.

4. Add the DATCOM system error of small canard projectile at other AOA and the $\Delta e_{\alpha 1}$ to DATCOM data of big canard projectile at other AOA, and the C_A of big canard projectile with system error compensation is obtained.

The implementation process of the system error compensation method (SECM) is shown as Fig. 11. To simplify the presentation, the projectile 1 in Figure 11 refers to the small canard projectile and the projectile 2 refers to the big canard projectile. The system error compensation correction of other aerodynamic coefficients calculated by DFATCOM is also based on above step.

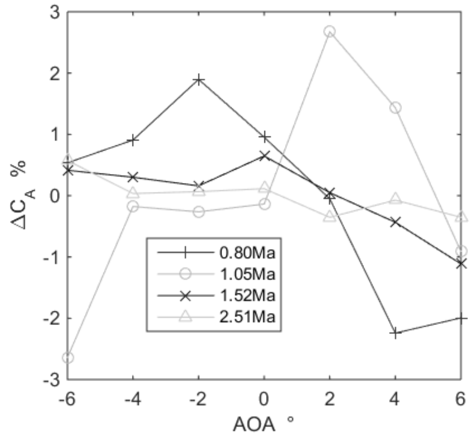


Fig. 12 C_A error of big canard projectile after compensation correction

Based on the SECM, the DATCOM data of the big canard projectile was corrected using the wind tunnel test data and the DATCOM data of small canard projectile and the wind tunnel test data of different Mach at AOA of 0 °of big canard projectile. The C_A error of the corrected data relative to the wind tunnel test data is shown in Fig. 12. It can be seen from Fig. 12 that the C_A error of the big canard projectile is greatly reduced after the compensation correction, and the error is basically within 3%, which fully satisfies the accuracy requirement.

C. Accuracy analysis of C_N

Based on the wind tunnel test data, the error analysis of the DATCOM calculation results of C_N was performed. The error varies with different Mach as shown in Fig. 13. The error varies with the AOA as shown in Fig. 14.

It can be seen from Fig. 13 that at the subsonic and transonic speeds, the C_N error calculated by DATCOM is large at 0 °AOA of two kind of projectile. The variation of the C_N error of the two kind of projectiles is basically the same at different Mach. It can be seen from Fig. 14 that when the absolute value of the AOA of the projectile is less than 1 °, the error of the C_N calculated by DATCOM is large at the subsonic and transonic speeds. The C_N error of the two projectiles is basically the same at different AOA.

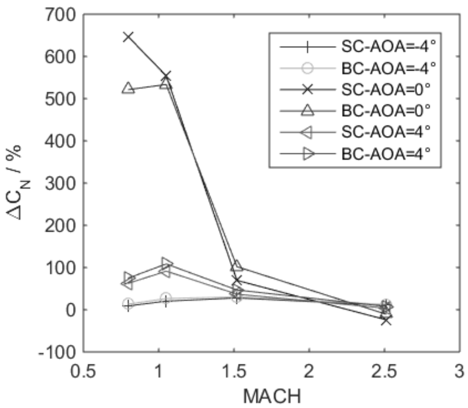


Fig. 13 Error of C_N varies with the Mach

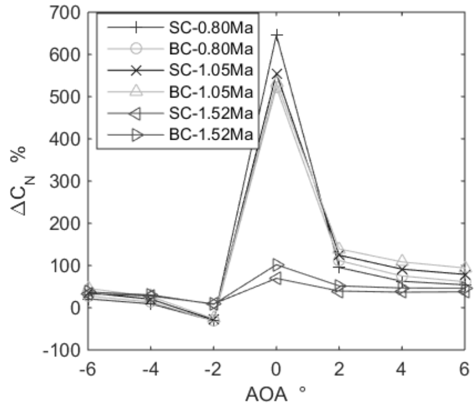


Fig. 14 Error of C_N varies with the AOA

According to the SECM proposed in section 4.2 of this paper, the DATCOM data and wind tunnel test data of Small canard projectile and the wind tunnel test data of different Mach at the AOA of -6 °of the big canard projectile are used to compensate for the C_N of the big canard projectile calculated by DATCOM. Fig. 15 shows the C_N error of the big canard projectile after compensation.

It can be seen from Fig. 15 that the error of the C_N of the big canard projectile calculated by DATCOM is greatly reduced after the compensation correction, except that the AOA is 0 ° at subsonic. The C_N error at other Mach and AOA is less than 30%, and most of the error is less than 10%, the error size satisfy the requirement of engineering calculation accuracy.

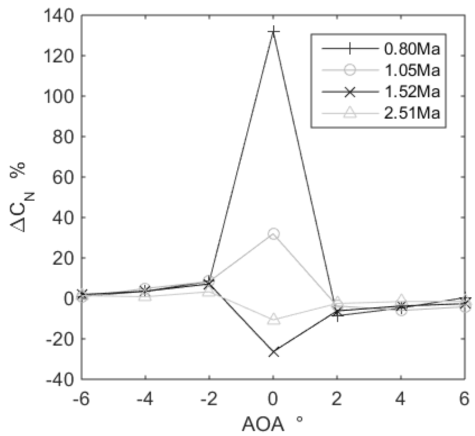


Fig. 15 C_N error of big canard projectile after compensation correction

D. Accuracy analysis of pressure center position

Based on the wind tunnel test data, the error analysis of the DATCOM calculation results of pressure center position (XCP) was performed. The error varies with different Mach as shown in Fig. 16. The error varies with the AOA as shown in Fig. 17.

As can be seen from Fig. 16, the XCP calculated by DATCOM of the two projectiles have a large error. When the absolute value of AOA is less than 4 °, the XCP error law of the two projectiles is comparatively consistent at different Mach, and the error value is also close. At 0 ° of AOA, the XCP error law of the two projectiles are comparatively consistent, but errors of the absolute value of the two projectiles are different. It can be seen from Fig. 17 that for the DATCOM data of different speed intervals, the XCP error law of the two projectiles are comparatively consistent at different AOA. At different AOA, the XCP error values of the two projectiles are also substantially equal. Therefore, we can continue to use the SECM to perform system compensation correction on DATCOM data.

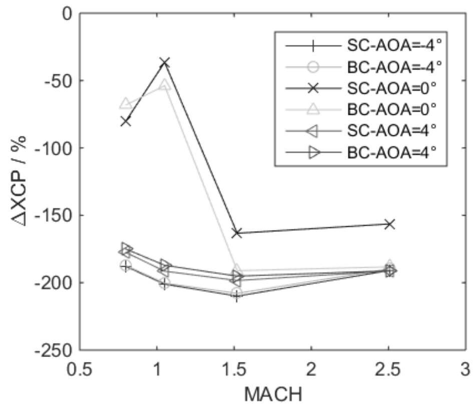


Fig. 16 Error of XCP varies with the Mach

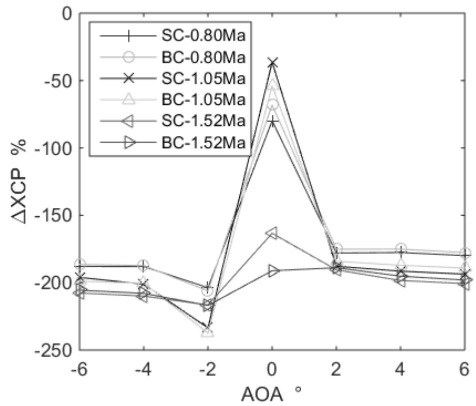


Fig. 17 Error of XCP varies with the AOA

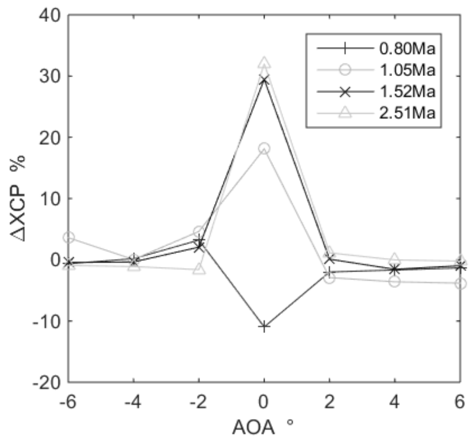


Fig. 18 XCP error of big canard projectile after compensation correction

Calculate the XCP system error of DATCOM of small canard projectile and DATCOM system error of big canard projectile at different Mach numbers at 2 ° AOA. The big canard projectile XCP data at the other AOA is compensated and corrected by using above system error. The DATCOM data error of big canard projectile after compensation correction changes with the AOA is shown in Fig. 18. As can be seen from Fig. 18, except for the maximum error of 30% when the AOA is 0 ° at 2.51 Mach and 1.52 Mach, the data error of other AOA is not more than 10%.

V. Sideslip Angle Influence On Calculation Accuracy

In the projectile flight, the angle between the axis and the speed direction is mainly composed of AOA and the sideslip angle (β). Generally, the AOA is larger and the β is smaller. The aerodynamic coefficients of projectiles are different at different β. This section mainly analyses the accuracy of DATCOM in calculating C_A, C_N and XCP when there are different β in projectile flight.

A. β influence on C_A calculation accuracy

Based on the wind tunnel test data, the error of DATCOM in calculating the C_A of projectile at different β is analyzed. The variation of error with β is shown in Fig. 19, and the variation of error with Mach number is shown in Fig. 20.

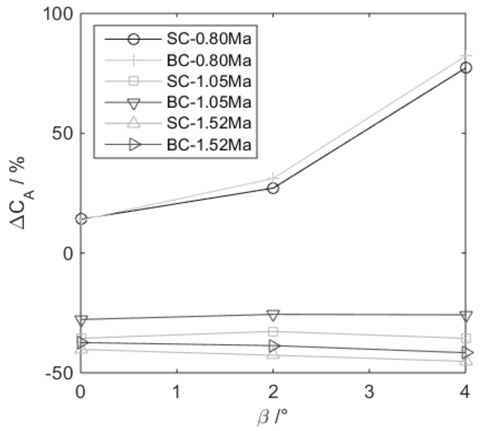


Fig. 19 Variation of C_A error with β at different Mach Numbers

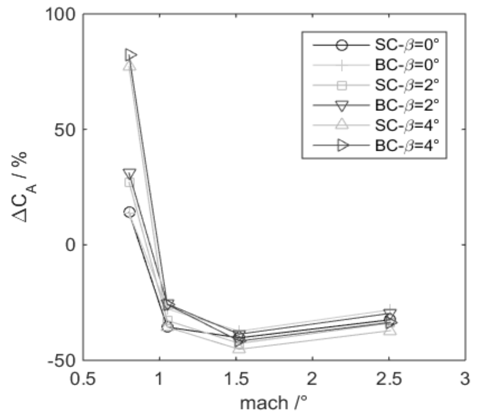


Fig. 20 Variation of C_A error with Mach numbers at different β

As can be seen from Fig. 19, the C_A error of two canard scheme projectiles calculated by DATCOM is different at Mach number, and the difference between the two errors is also different at different Mach numbers. However, the amplitudes of these two errors are basically the same with the change of β. It can be seen from Fig. 20 that the C_A error curve of the two canard scheme projectiles do not show a good parallel relationship with the Mach number at the same β in the transonic range. This shows that the difference of the errors in calculating the C_A of two projectiles by DATCOM varies with the change of Mach number.

Based on the SECM, the C_A of big canard projectile at different β and Mach numbers are compensated by using the small canard projectile C_A errors at different Mach numbers and β, and the C_A of big canard projectile at β of 0 ° and different Mach numbers calculated by DATCOM. After compensation correction, the variation of C_A error with β at different Mach numbers is shown in Fig. 21. It can be seen from Fig. 21 that the C_A error of big canard projectile decreases obviously after error correction. When the β is less than 4 degrees, the C_A error of the is less than 5%, which has high accuracy.

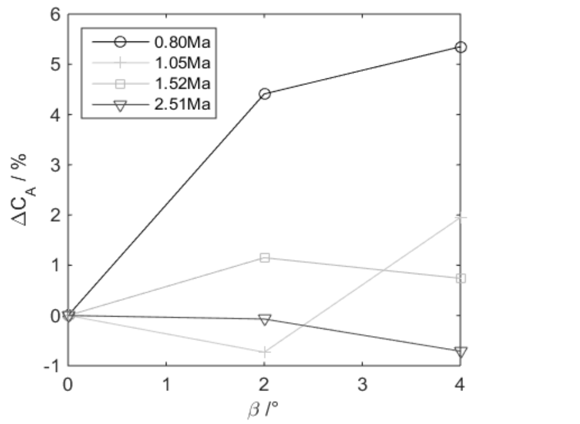


Fig. 21. The variation of C_A error with the β after compensation correction

B. β influence on C_N calculation accuracy

Based on the wind tunnel test data, the C_N errors of two kind of canard projectiles at different β calculated by DATCOM are analyzed. The variation of error with β is shown in Fig. 22, and the variation of error with Mach number is shown in Fig. 23.

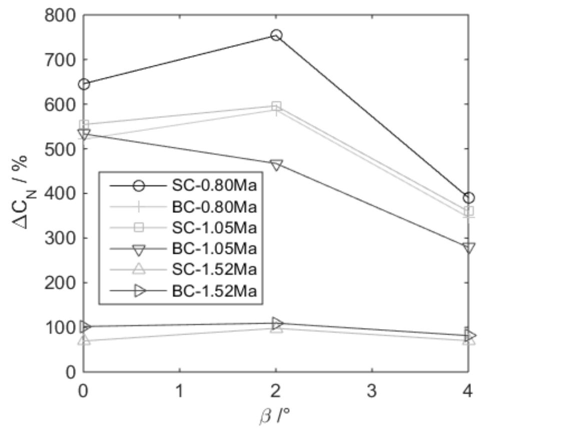


Fig. 22 Variation of C_N error with β at different Mach Numbers

It can be seen from Figs. 22 and 23 that the errors of C_N calculated by DATCOM at different β are larger, while at large β and high Mach numbers is small. From Figure 22, it can be seen that the C_N errors of two canard projectiles calculated by DATCOM have the same trend with the change of β, but the variation amplitude is different at different β, and the difference between the two errors is also different under different Mach numbers. It can be seen from Fig. 23

that the C_N error curves of the two canard scheme projectile are not parallel with the Mach number at the same β, and there is a cross between them.

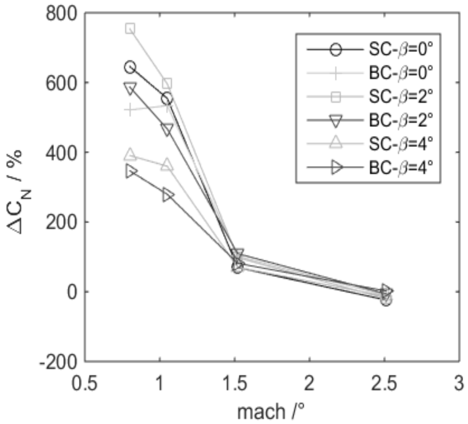


Fig. 23 Variation of C_N error with Mach numbers at different β

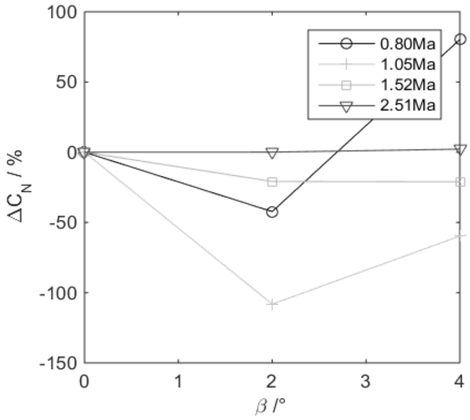


Fig. 24. The variation of C_N error with the β after compensation correction

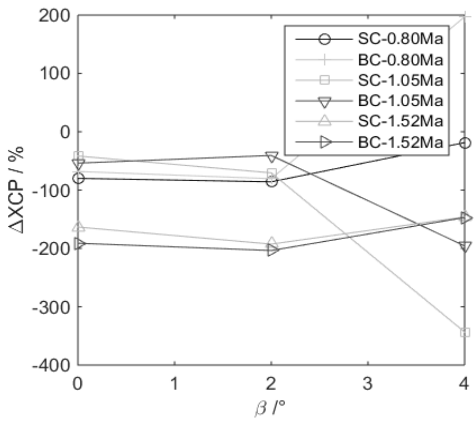


Fig. 25 Variation of XCP error with β at different Mach Numbers

Based on the SECM, the C_N of the projectile with big canard scheme calculated by DATCOM at other β are compensated by the method of C_A correction in the previous section. After compensation correction, the C_N error varies with the β at different Mach numbers as shown in Fig. 24. It can be seen from Fig. 24 that the C_N error is greatly reduced after compensation correction at high Mach number, which basically meets the accuracy requirement. In transonic region, the maximum error is 105% after compensation correction due to the weak regularity of DATCOM calculation error. When the β does not exceed 1 degree, the maximum error of C_N is not more than 50%, and most data errors are less than 15% after compensation correction, which basically meets the accuracy requirements.

C. β influence on XCP calculation accuracy

Based on the wind tunnel test data, the XCP errors of two kind of canard projectiles at different β calculated by DATCOM are analyzed. The variation of error with β is shown in Fig. 25, and the variation of error with Mach number is shown in Fig. 26.

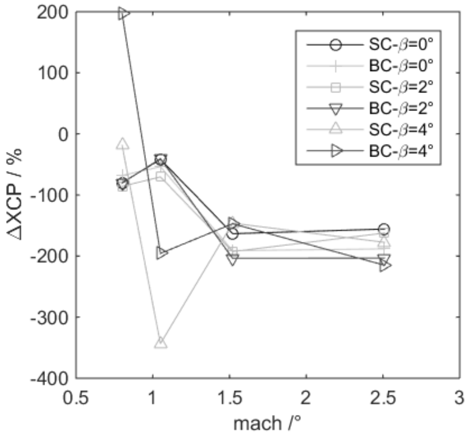


Fig. 26 Variation of XCP error with Mach numbers at different β

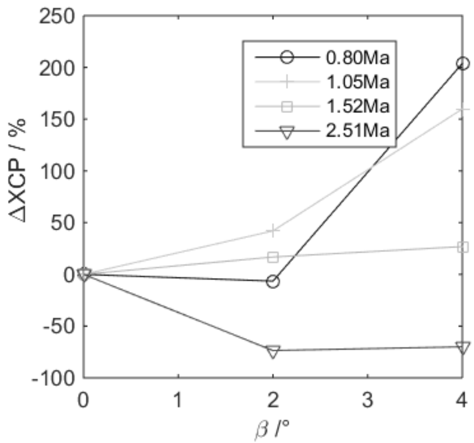


Fig. 27 Variation of XCP error with Mach numbers at different β

It can be seen from Fig. 25 that at different Mach numbers, the XCP errors of the two canard schemes projectiles calculated by DATCOM vary with the variation of β. The variation trends of the two errors are the same, but the variation amplitudes are different. Especially in the subsonic and transonic regions, with the increase of the β, the variation amplitudes of the two errors are quite different. It can be seen from Fig. 26 that at the same β, the XCP error curves of the two projectiles have the same trend with Mach number varies, but the variation amplitude is different, and the variation law of the two projectiles is not obvious.

Based on the SECM, the XCP of the projectile with big canard scheme calculated by DATCOM at other β are compensated by the method of C_A correction in the previous section. After compensation correction, the XCP error varies with the β at different Mach numbers as shown in Fig. 27. It can be seen from Fig. 27 that after error compensation correction, the projectile XCP error calculated by DATCOM is obviously reduced, but there is still a large deviation when the β is larger. When the β is less than 1 °, the error is less than 35%, and most of the errors are less than 25%. This error basically meets the accuracy requirements.

VI. Conclusion

In this paper, a 2D trajectory correction projectile is taken as the research object, and the DATCOM calculation accuracy of the aerodynamic parameters is analyzed. The calculation accuracy of two methods for describing aircraft body in DATCOM software is analyzed. The DATCOM data of the two kind of projectiles with different correction canard are compared and analyzed. The following conclusions can be drawn from the analysis results.

1. Although the parameter options in DATCOM used to describe the nose of the aircraft are few and the description method is not completely accurate in method 1, the DATCOM internal shape generation program automatically calculates the accurate aircraft shape based on all the parameters entered. Method 1 calculated C_A and C_N of the projectile are more accurate than Method 2.

2. The aerodynamic parameters of the two projectiles calculated by DATCOM all have larger systematic errors than the wind tunnel test data. At different Mach numbers, DATCOM calculates the aerodynamic parameters of the two projectiles with different errors. However, the error law of the aerodynamic parameters are consistent as the AOA changed.

3. SECM proposed in this paper can effectively correct the DATCOM data of big canard projectile at different AOA by using the wind tunnel test data of small canard projectile and DATCOM data as well as the wind tunnel test data of projectile 2 at a certain angle of attack.

4. The results show that, when the β is 0 °, the C_A error of big canard projectile does not exceed 3%, the C_N error generally does not exceed 10%, and the XCP error generally not exceeds 5%. When the β is less than 4 degrees, the C_A error is less than 5%, when β is less than 1°, the main data error of C_N is less than 15%, and the main data error of XCP is less than 25%. This precision meets the engineering calculation needs and can be used for the demonstration analysis of the aircraft shape scheme in the early stage.

5. SECM can greatly reduce the number of wind tunnel tests and CFD simulation calculations, greatly reduce time and financial costs, and has strong practical application value.

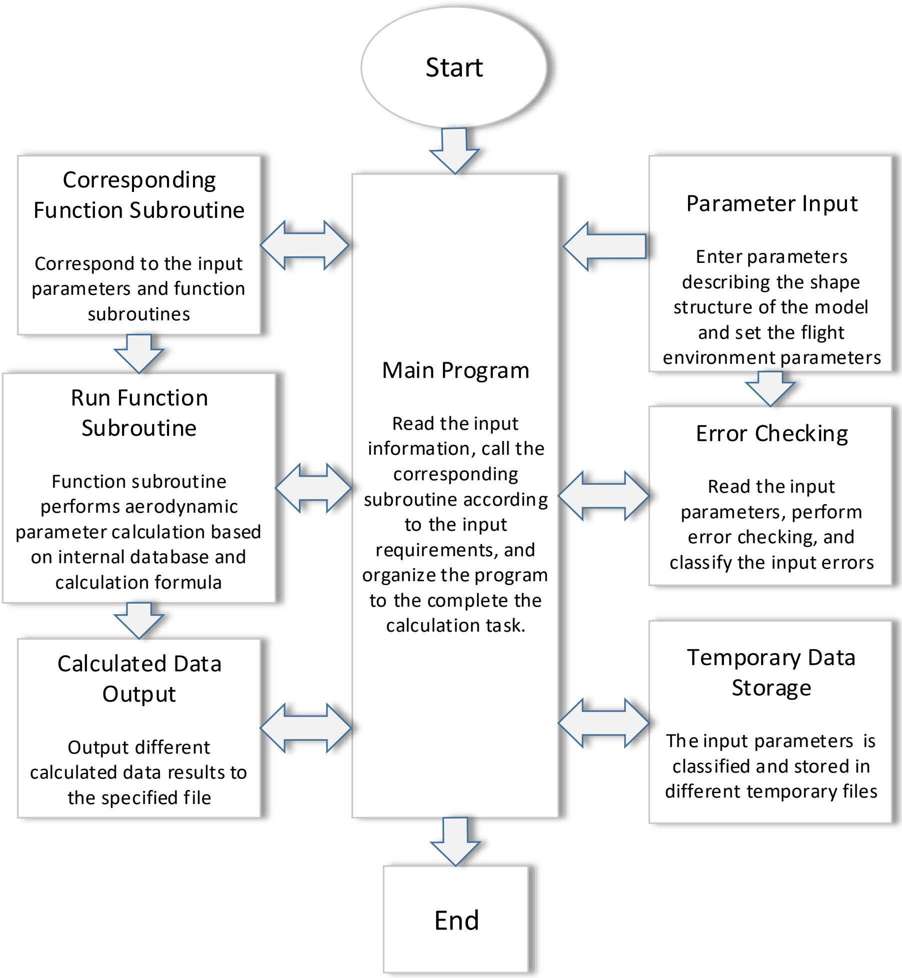
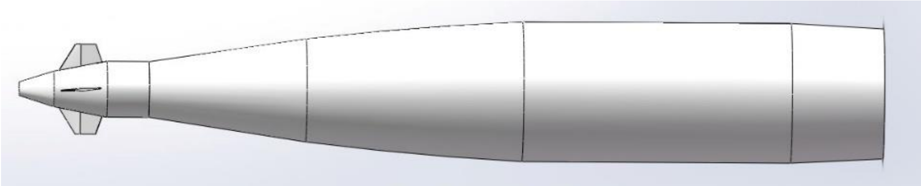
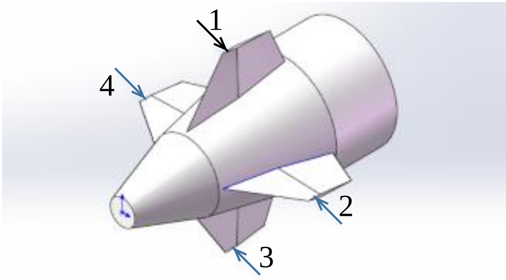


Fig. 1. DATCOM running process



（a） Projectile shape



（b） Head shape of the projectile fuze

Fig. 2 Projectile model

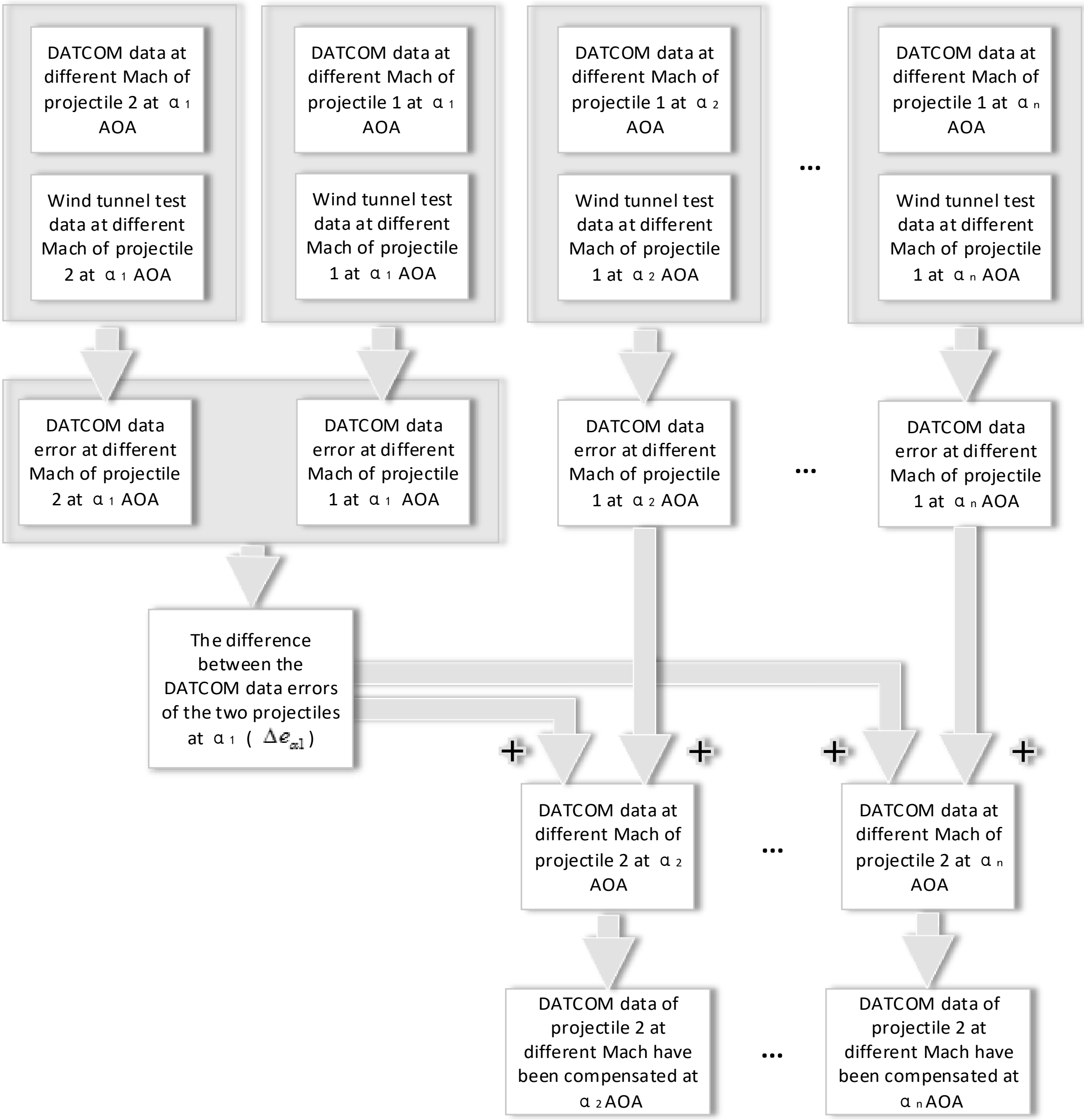


Fig. 11. Implementation process of the SECM

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