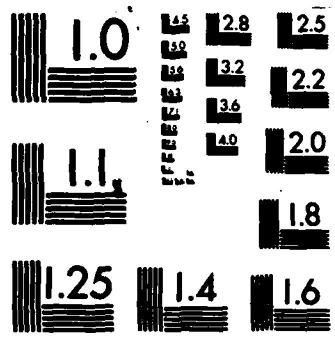
AD-A137 585 THE PRESENT CALCULATION METHOD OF ADHERING LAYERS ON AIRCRAFT WINGS(U) FOREIGN TECHNOLOGY DIV WRIGHT-PATTERSON AFB OH H BAO 13 JAN 84 1/1

UNCLASSIFIED FTD-ID(RS)T-1692-83 F/G 20/4 NL

END
FILMED
3-84
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

FTD-ID(RS)T-1692-83

AD A137585

FOREIGN TECHNOLOGY DIVISION

AIR FORCE SYSTEMS COMMAND

THE PRESENT CALCULATION METHOD OF ADHERING LAYERS ON AIRCRAFT WINGS

by

Bao Hanling

FOREIGN TECHNOLOGY DIVISION

DTIC
ELECTE
FEB 7 1984
S D
B

Approved for public release;
distribution unlimited.

DTIC FILE COPY

84 02 07 098

EDITED TRANSLATION

FTD-ID(RS)T-1692-83 13 January 1984

MICROFICHE NR: FTD-84-C-000025

THE PRESENT CALCULATION METHOD OF ADHERING LAYERS ON AIRCRAFT WINGS

By: Bao Hanling

English pages: 10

Source: Guoji Hangkong, Nr. 5, 1983, pp. 23-25

Country of origin: China
Translated by: LEO KANNER ASSOCIATES
F33657-81-D-0264
Requester: FTD/TQTA
Approved for public release; distribution unlimited.

PREPARED BY:

TRANSLATION DIVISION
FOREIGN TECHNOLOGY DIVISION
WP-AFB, OHIO.

GRAPHICS DISCLAIMER

All figures, graphics, tables, equations, etc. merged into this translation were extracted from the best quality copy available.

Accession For	
NTIS GRA&I	☑
DTIC TAB	☐
Unannounced	☐
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	

THE PRESENT CALCULATION METHOD OF ADHERING LAYERS ON AIRCRAFT WINGS

Bao Hanling

With smaller and smaller tolerances in aircraft design, there are higher and higher requirements projected for aircraft performance. Like the wind tunnel, computers are also expected to be an experimental tool in quantitatively forecasting aircraft performance. Thus, it becomes more and more urgent to calculate analytically the viscous adhering layer and its interference effect on non-viscous flow. Since the 1970s, considerable efforts have been given in solving three-dimensional adhering layers. It is considered that methods of adhering layers and successive substitution of potential flow can be used to obtain the numerical solution of the adherance problem to satisfy engineering accuracy. In the aeronautical field, first of all the calculation of three-dimensional aircraft wings must be solved. Since 1975, almost all aircraft corporations in advanced countries have developed their own computer programs for calculation of the three-dimensional adhering layer of aircraft wings. However, since the engineering simulation of turbulent flow is still not accurate enough, and there are insufficient data from wind tunnel and flight certification, considerable gaps exist for the application requirements. Up to now, development toward perfection is still underway.

At present, considerable emphasis is still given to the development of adhering layer calculation internationally. Since the first Turbulent Flow Adhering Layer International Conference was convened at Stanford

University in 1968, similar activities have taken place several times. Every few years, the United States Air Force and West Germany convene an adhering layer technical exchange conference. In Europe, a permanent organization, the Viscosity Committee, has been founded to promote and conduct the evaluation of the calculation method of shearing flow.

As is well known, the primary problem of calculating the turbulent flow adhering layer is to make models for turbulent flow phenomena. At present, there are two major categories of methods used: field simulation and total volume simulation. Field simulation is called the differential method, and total volume simulation is called the integration method. In either method, considerable experience should be related on to completely solve the equations.

Differential Method

Generally, the differential method solves the partial differential equations based on the adhering layer equations including the appropriate Reynolds stress hypothesis. According to different hypotheses, the equations can be divided into two types: (1) one or more differential equations to directly represent the hyperbola type of stresses, and (2) the parabola type with the use of vortex viscosity to represent stress. The degree of complexity of the second type of equations is determined by the description modes of characteristic length and characteristic velocity of vortex motion. If algebraic means are used to describe the characteristic length and velocity, this is called the model of zero equations. If only the characteristic velocity is described with differential equations, this is called the single equation model. If both the characteristic length and the characteristic velocity are described by differential equations, this is called the double equation model. Of course, it is feasible to develop a multi-equation model but the greater calculation time required cannot be compensated by accuracy; therefore, it is seldom used. In the method of vortex viscosity, the zero equation model is extensively used at present, because from the study of the two-dimensional adhering layer, accuracy using the single equation model has no significant improvement, while the double equation model is too complicated (in the region nearing the separating flow, the double equation model can often give more rational results). In the aerodynamic field, the zero equation model with wide applications includes the Cebeci-Smith model and Mitchell model. The former model is the dual-layer model: the damping factors of longitudinal direction pressure gradient and wall surface mass jetting effect are included in calculation of the internal adhering layer. In the external layer, consideration is given that the vortex viscosity is proportional to the displacement thickness of the two-dimensional form, and also the influence of alternating turbulent flows. The Mitchell model is a single layer model composed of a single hyperbola tangent function with multiplication of a simple Von-Trest damping factor. The Cebeci-Smith model is more rational because more factors are considered; however, this model is more complicated than the Mitchell model. Whatever the type of algebraic model, it is only determined by the local gas stream parameter; i.e., the "upper stream historical effect" of the turbulent flow is not considered. The upper-stream effect can only be revealed by using differential equations to describe the turbulent flow regime.

Quite a few researchers often introduce the isotropic hypothesis of the vortex when using the vortex viscosity model in the three-dimensional state. In other words, values of vortex viscosities in various directions are the same. Actually, as early as 1974 East's experiments indicated that this hypothesis is actually without rational basis. Not long ago, papers written by Tassa et al. revealed that the non-isotropism of vortex viscosity has an influence that cannot be neglected in calculating the adhering layers.

Integration Method

Generally, the integration method integrates the main equations in advance along the thickness direction of the adhering layers. Thus, the original parabola type equation with three variables becomes a hyperbola equation with only two variables. After integration, the Reynolds stress term becomes the coefficient of friction. This equation is called the moment integration equation of the adhering layer. As proved by considerable practice, a good integration method should be coordinated with appropriate differential type auxiliary equations. The blending equation is a relatively good auxiliary equation currently used for three-dimensional calculation. The method of using this equation is called the blending method.

The rational behind the blending method can be explained in the following: the reason the energy of the adhering layer of the turbulent flow is not dissipated is that the energy formation process of the turbulent flow (just the opposite of the dissipation process) occurs in the adhering layer; this is the so-called abrupt phenomenon of turbulent flow. The energy required in the formation process is provided by the interaction of free flow and turbulent flow; i.e., the fluid of the non-turbulent flow (of the free flow) at the boundary of the adhering layers is continuously rolled into the adhering layers; this process is called blending. The momentum is transmitted into the fluid of the turbulent flow of the adhering layer by collision between fluid masses. Therefore the fluid mass entering the adhering layer during the blending process can more or less reveal the total volume characteristic of the turbulent flow phenomenon in the adhering layer.

The blending coefficient C_E is the most important parameter in the blending method; the coefficient represents the dimensionless flow rate of the net input into a controlled cross-sectional area of the adhering layer. For different derivation methods of C_E, there are three branches of the blending method: 1. the Smith method: C_E is the algebraic form obtained empirically; 2. The Cousteix method: C_E is the algebraic form obtained through similar solutions; and 3. The Stock method: C_E is derived by an empirical differential equation (thus, consideration is given to the "upper-stream historical effect" of the blending process).

In the integration method, only the total volume parameters of the adhering layer are given, such as the coefficient of friction at the wall surface. The flow details of the flow field are not provided. Since the fundamental basis of the integration method is not as sound as it should be, the integration method is inferior to the differential method in adapting to different types of flow. At the present stage, however, the integration method is as good as the differential method with fast calculation speed, quite high cost effectiveness, and is more adaptable for application in calculations requiring repeated and successive substitution for the adhering layer and the potential flow. Therefore, in many countries research and development are still stressed on this type of method.

Table 1 lists methods and types for calculating the three-dimensional adhering layers of an aircraft wing.

Table 1.

(a) 序号	作 (b) 者	(c) 方法类型	(d) 文献出处
1	A.Tassa等 (e)	旋涡粘度代数模型 (f)	AIAA-82-0224
2	J.F.Nash等 (e)	雷诺应力方程方法（显式）(g)	NASA CR-132335等 (e)
3	J.F.Nash等 (e)	雷诺应力方程方法（隐式）(h)	Lockheed Rep. LG76ER0199
4	T.Cebeci等 (e)	旋涡粘度代数模型 (f)	NASA CR-2777 等 (e)
5	J.D.McLean	旋涡粘度代数模型 (f)	AIAA77-3
6	J.P.F.Lindhout等 (e)	雷诺应力方程方法（不可压）	NLR TR74159U 等 (e)
7	J.Cousteix等 (e)	掺混方法 (k) (j)	ONERA TR NO1975-43 等 (e)
8	W.Kordulla	旋涡粘度代数模型 (f)	AIAA-77-209等 (e)
9	A.K.Rastogi等	旋涡粘度双方程模型 (l)	AIAA J.Vol16 No2
10	P.D.Smith (e)	掺混方法 (k)	ARC R&M 3739
11	H.W.Stock	掺混方法 (k)	Dornier GMBH77/51B 等 (e)
12	D.B.Spalding	旋涡粘度双方程模型 (i)（不可压）	Computer Method in Applied Mechanics and Engineering Vol3. N2

Key: (a) Sequential number; (b) Authors; (c) Type of methods; (d) Source of papers; (e) et al.; (f) Algebraic model of vortex viscosity; (g) Reynolds stress equation method (exposed type); (h) Reynolds stress equation method (concealed type); (i) Double equation model of vortex viscosity (incompressible); (k) Blending method; (l) Double equation model of vortex viscosity ; (j) Reynolds stress equation method (incompressible).

Coordinate System

One of the important techniques in calculating three-dimensional adhering layers is the selection of a coordinate system. A good coordinate system should adapt to a random plane shape of an aircraft wing and simplify calculation as much as possible. Generally, these two requirements are contradictory. In the rectangular coordinate system, the expression mode of equations is simple but inconvenient in usage. Most researchers using the differential method are accustomed to the non-orthogonal curvilinear coordinate system adhering onto a surface of substance: the surface of an aircraft wing is divided into lattices by percentage ratios of chord length and span length into coordinates of x and z directions; the direction perpendicular to the surface of the aircraft wing is the y coordinate with standardization treatment in order to reduce variations on the thickness of the adhering layer and variation of flow variables between two adjacent wing cross-sections, so that the step length of the difference can be relatively long. The integration method used abroad adopts a random curve coordinate system without restricting the plane shape of the aircraft wing, but the method has very long calculation formulas. In China, a blending method program adaptable to calculation of the adhering layer of a random plane shape has been used. In this method, equations are written in the rectangular external streamline coordinate system. When equations are being solved, the equations are converted into the equal percentage ratio chord coordinates; thus, the method becomes relatively simple.

Difference Format

In both the differential and integration method, in the last stage difference method solving for differential equations is required. In solving parabola type equations in the differential method, customarily a three-point or two-point (with second stage accuracy) box type concealed type difference format is adopted along the directions of the chord and thickness; in the span direction, the exposed type difference format is adopted. Then, in selecting difference elements, the concept of the related region should be considered. In the region where the span direction flow has its direction changed, in some methods there is only first stage accuracy along the span direction. In some other methods, along the thickness direction of the adhering layer and the span direction, there are alternately adopted the exposed and concealed types; this is called the ADI method. In this method, a faster convergence is obtained. For example, on a VAX11/780 computer, the average calculation time of each lattice point is only $6.6x10^{-2}$ second in CPU.

Both the Reynolds stress equation and blending methods are of the hyperbola type. When the equations are being solved, both the exposed and the concealed types can be used. Since a long time ago, it was considered that the efficiency of the exposed type is relatively low; however, as revealed in calculations recently, the overall cost effectiveness of the exposed type method is better than the concealed type method because it avoids the time-consuming successive substitution process though with a relatively short step length.

Comparison of Methods

Although many calculation methods relating to the adhering layer of an aircraft wing were developed over many years, up to now we still cannot say which calculation method and code have sufficient accuracy through sufficient operation conditions of flow along aircraft wings. It ..is published at AIAA (1980), the results of four calculation methods for three different plane shapes of aircraft wings (2, 3, 4, and 5 in Table 1) used by three major aircraft corporations in the United States (Lockheed, Douglas and Boeing). Calculations were conducted on CDC 7600 computers. Refer to Table 2 for the calculation time used on the number of dividing lattices and the lattice nodal points on the surface of each aircraft wing.

As revealed by calculation results, there are considerable differences between various methods, especially between the exposed and concealed type methods. This reveals that the solution of adhering layer equations not only is very sensitive to different mechanical models, but also to different mathematical processing methods. The conclusion of the report is that it is urgently required to have reliable experimental results to further clarify which methods are the better ones. Besides, the report also considers that for aircraft wings of some plane shapes, sometimes the difficulty of non-co verger in successive substitution may occur in the calculation process of wo algebraic model methods.

Table 2.

(a) 代码 \ 机翼 (b)	A	B	C	t (秒) (c)
纳什显式 (d)	-----	7 × 81 × 20	7 × 81 × 21	0.023
纳什隐式 (e)	1 × 30 × 21	7 × 13 × 21	7 × 31 × 21	0.15
麦克林 (f)	39 × 42 × 30 39 × 50 × 30 30 × 15 × 30	-----	39 × 42 × 30 39 × 50 × 30 30 × 15 × 30	0.077 0.083 0.095
塞比西 (g)	25 × 25 × 30	7 × 13 × 30	7 × 27 × 30	0.04

Total number of nodal points = span direction x chord direction x normal direction.
Number of nodal points (at the surface lattice of the aircraft wing) N_p = span direction x chord direction.
Total CPU time = $t \times N_p$.

Key: (a) Code; (b) Aircraft wing; (c) Second; (d) Nash exposed type; (e) Nash concealed type; (f) McLean; (g) Cebeci.

In 1981, a shearing flow calculation method evaluation team of the European Viscous Flow Committee used a 35° sweptback aircraft wing and flow M number 0.5 in a calculation example to conduct unified evaluation on eight established calculation methods for the adhering layer of turbulent flow in European countries. Seven of the eight calculation methods used methods 5 through 11 given in Table 1; another method is the Brest method of two-dimensional stress equations. The evaluation results of the calculation methods are similar to the aforementioned conclusions, in that the differential method is no better than the integration method with higher accuracy. Therefore, considerable work should be conducted to reach the practical degree for calculating the three-dimensional adhering layers of aircraft wings.

In 1982, Tassa et al. in the United States published a relatively encouraging calculation result; his method is similar to the Cebeci method except the calculation on the influence of isotropism in vortex viscosity and adoption of the ADI technique. In other words, the Tassa method utilizes all the good points of the currently available differential method. As revealed in results, the calculation moment thickness and chord direction displacement thickness match the experimental results quite well; however, the result of the span direction displacement thickness is not as good and the calculation examples are only limited to the flow field of the central region of the half wing-span. Further checking is required on the accuracy of the entire aircraft wing.

Several Viewpoints

1. In the calculation result affecting the three-dimensional adhering layer (especially the result of lateral-direction parameters), one of the most outstanding problems in accuracy is the realization of the direction field of Reynolds stress or the non-isotropism of turbulent flow. At present, in some methods the non-isotropic hypothesis used is still far from perfect, as it is without theoretical basis.

2. The integration method has an advantageous aspect because it only solves for the total volume and avoids the difficult problem of the stress direction field. However, it is difficult to process the lateral-direction velocity cross-sectional state, and similarly there is considerable difficulty in accurate simulation of lateral-direction parameters. There will be greater difficulties when reversal of lateral flow occurs in some regions of the aircraft wing.

3. When the flow is nearing separation, the calculation becomes very difficult due to the singularity of the adhering layer equation itself. Therefore, frequently a cutoff calculation is required at a certain position before separation. This requires a criterion of determining three-dimensional separation. This is also one of the important problems worth stressing in present and future studies.

4. Since the input data are quite sensitive in calculating the corresponding potential flow of the adhering layer, it is necessary to develop a

high accuracy calculation method in developing the potential flow for mutual successive substitution of adhering layer flow and potential flow.

5. The greatest obstacle hampering the theoretical development of a three-dimensional adhering layer is the lack of experimental data used in certification. Since the interference effects of the wind tunnel wall, fulcrum and probes still cannot be sufficiently eliminated, at present considerable technical difficulties still exist in measuring the adhering layers, especially in a high air speed wind tunnel.

6. Studies in the 1970s on the large scale vortex phenomena and the abruptly occurring phenomenon of turbulent flow at the laminar bottom layer of the adhering layers can be said to be a historical discovery in studies of turbulent flow. In the 1970s, the so-called sub-scale lattice method appeared; in the method, the three-dimensional scale used is considerably smaller than the largest vortex scale, but the three-dimensional scale is still considerably greater than the smallest vortex scale. Therefore, the influence of large scale vortexes can be revealed. Although the sub-scale lattice method is still at the initial stage, this method shows a new direction in studies of turbulent flow.

7. Before the 1970s, the calculation of three-dimensional adhering layers of an aircraft wing was almost a blank. In this short span of ten years, more than 10 methods have appeared. Although these methods are not entirely satisfactory, it can be said that the mathematical difficulties of solving the equations are nearing a complete solution. Only in mechanics are there still many unknown factors waiting for researchers' creative explorations in continued studies.

FILM

3-8