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Y. KRASHANYTSYA, AMIR HOSHMANDI

National Aerospace University named after N. Ye. Zhukovsky "KhAI", Kharkov, Ukrane

TRIANGULATION METHOD OF BEARING SURFACES OF AIRCRAFT SYSTEMS

Modern ideology of computational approaches for solving initial value problems of continuum mechanics is based on the creation of an adequate mathematical models and computational methods of construction based on the geometric shape of the object. For the purpose of numerical implementation of the method of boundary integral equations developed algorithmic process coordinate surfaces perspective bearing systems of arbitrary spatial form in order to further their triangulation, ensuring the correct conduct of computer simulation to determine the distributed and the total aerodynamic characteristics.

Keywords: *load-bearing system of aircraft, boundary integral equation method of triangulation surfaces, geometric modeling, numerical implementation of decisions*

1. Introduction

Due to multi parameter nature and nonlinearity of the main tasks concerning continuum mechanics [1], the computational experiment along with the physical one obtained a considerable development. Currently, the development of computer technologies has reached such a level that it makes no sense any longer to demonstrate computer simulation or numerical experiment advantages in aerohydrodynamics compared to traditional physical modeling methods [2]. It should be emphasized that current research of problematic and sought continuum mechanics tasks and, in particular, aerodynamics, are based on advanced machines of functional and vector and tensor analysis [1], which is absolutely effective in operation, and contributes to the development of numerical methods for the solution of the entire spectrum concerning demanded mechanics tasks.

The aerodynamics of complex bearing surfaces (Fig. 1.1, 1.2) based on the systematic use of boundary integral equation method and numerical embodiment options the distributed and total nonlinear aerodynamic characteristics of bearing forms, planar and spatial ones are obtained, the processes that accompany the flow separation, the formation and stability of vortex formations are studied.

2. Problem formulation

Recently, the aircraft with additional airfoils (AAF) (see. Fig. 1.1, 1.2) is studied actively. These AAF prevent the overflow of the air flow and equalizes the pressure on the upper and lower wing surfaces, weakening a powerful end vortex by separating it into several vortices of smaller intensity.

Fig. 1.1. Bearing and control aerodynamic surfaces of modern aircraft

Fig. 1.2. Prospective aircraft with advanced aerodynamic mechanization systems

AAF application designed with the prediction of the necessary aerodynamic characteristics, allows to reduce the induced resistance of an aircraft, to increase an effective elongation of a wing and the lifting force at its end, to develop a course stability, to decrease the specific fuel consumption, to reduce the length of running start and run during an aircraft (AC) take-off and landing, that also has a considerable economic significance.

Currently a lot of AAF designs is known for different types of wings, mounted on the main AC differing by spatial forms, geometries and aerodynamic characteristics (see Fig. 1.1, 1.2).

The designing of AAF bearing and control elements is related taking into account the aerodynamic, energy, structural and geometrical, technological and mode characteristics that require the use of modern computer technology for the synthesis and the making of a required design decision.

The experience of recent years showed that along with the universal packages of application programs, the possibilities of which are often declared, you must continue to create, correct algorithms and software products from a mathematical point of view. The combination of numerical and analytical approaches based on the boundary integral equations in the calculations of aerohydrodynamic characteristics of aircraft, vehicles and their parts in different flight or movement modes, providing a sufficient economic benefit seems to be a very topical one. Now we are talking about the efficiency and the reliability of numerical simulation and numerical experiment improvement, because, despite all its advantages, it became apparent that a numerical experiment can not replace field tests completely for now. It is necessary to increase the speed, the volume and the accuracy of calculations. One way to improve the speed and accuracy of calculations is to increase the efficiency of geometric modeling in full compliance with certain differential-topological properties of curves and surfaces within the spaces of a given dimension.

3. Geometric modeling results

According to developed tradition, the long period of preliminary design phase was associated with the need for successive stage implementation: the preparation of a project, the creation of a model, the testing in a wind tunnel and the drawing up of an adjusted project. The creation of a model is often the slowest and the most expensive stage of this process. The use of a well-established computer program according to the method of calculation aerodynamics allows the testing of alternative project series (e.g., with different geometric configuration) in a wide range of parameter value change, such as the Reynolds number, Mach number, the angle of flow deflection.

Based on the ideology of boundary integral equation method, an integrated computer technology seems to be especially promising. This method was the most effective one in the cases of internal and external problems concerning continuum mechanics for unbounded domains with compact internal borders and allows, in particular, to determine directly the distribution and total aerohydrodynamic characteristics of aircrafts and their parts.

During the study of these characteristics for aircraft carriers and their bearing and control systems on the basis of the boundary integral equation method with the help of computer technology with its correct numerical implementation the triangulation method of an object surface in orthogonal curvilinear coordinate system is used (Fig. 3.1, 3.2) [3]. In modern systems of geometric modeling objects are represented as the combination of simple elements (primitives).

The process of a complex configuration polygon area splitting in a set of triangles is called triangulation and performed, depending on a surface class - a plane, section surface, the surface given by an array of points and interpolating functions, etc.

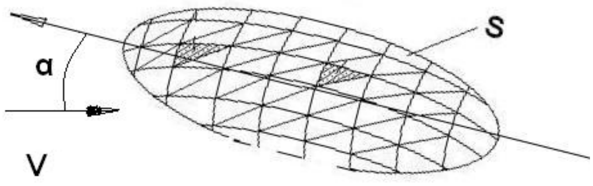

Fig. 3.1. Canonical triangulated surface in a natural coordinate system

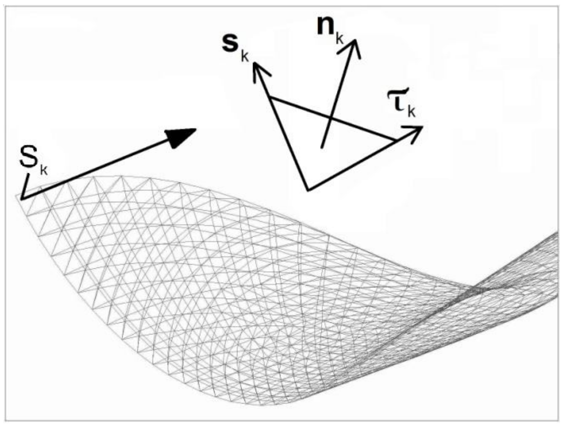

Fig. 3.2. The elements of triangulated bearing surface in a natural coordinate system

Also there are different subclasses of surfaces - conical, spherical, cylindrical, ellipsoidal, and others. During the analysis or the synthesis of complex surfaces they are approximated by the mesh of triangles, and subsequently they operate with simple polygonal regions, i.e. with each of the triangles.

Triangulation (from Latin triangulum - triangular) - was one of the methods for basic geodetic network development and currently it is a powerful method for three-dimensional object construction using software in computer graphics. Triangulation algorithm is applicable to a surface of any shape in a plane and in a spatial cases [4]. This approach, along with the subsequent quadrature-interpolation process of integral calculation like potentials leads to a linear system of algebraic equations for the desired kinematic and dynamic parameters of a task.

The development of computer graphics for the tasks of this class requires powerful hardware and intellectually provided algorithms for the purpose of coordinate system development based on three-dimensional models of an arbitrary spatial shape, followed by the decomposition of images into the simplest elements-triangles. This is explained by the following reasons:

- a triangle is the simplest polygon the vertices of which firmly determine a brink;
- any area which may be divided into triangles;
- the computational complexity of partition algorithms into triangles is substantially less than at the use of other polygons;
- it is easy to determine its three nearest neighbors with common faces for a triangle.

Any surface may be approximated with a desired accuracy by a grid of triangles. The approximation accuracy is determined by the number of triangles and the method of their choice. A high-quality object imaging that is close to an observation point, requires to take into account much more triangles than in the situation when the same object is located at a distance. Even a fairly coarse mesh is useful in practice, since the smoothing methods used in the display process may significantly improve a surface curvature image.

Triangulation, the splitting of a surface into simple elements makes it possible to control the accuracy during the calculation of aerodynamic characteristics. Depending on the requirements of a task and a computer configuration a number of triangles is selected in order to clarify the convergence of computing process and achieve an acceptable accuracy.

4. Mathematical model

The algorithm of such an approach implementation is developed in the case of an integral representation concerning the problem solutions in respect of flowing around an arbitrary spatial bearing system of by a real fluid flow [5]:

$$V = \oiint_{(S+\Sigma)} \left\{ \left(\left(\left(\frac{\partial V}{\partial n} + \left[n, [\nabla, V] \right] \right), \Gamma \right) \right) - \right.$$
$$\left. - \left(V, \left(\frac{\partial \Gamma}{\partial n} + \left[n, [\nabla, \Gamma] \right] \right) \right) \right\} dS \qquad (4.1)$$

of the fundamental boundary value problem of hydrodynamics as a conservative form of momentum conservation law in the simplest case of a steady motion concerning an incompressible viscous fluid taking into account the natural boundary conditions of the bearing system S flowing inside the control area Σ:

$$\left(\nabla, \left[V \otimes V + I \frac{p}{\rho} - \nu \nabla V \right] \right) = 0, \qquad (4.2)$$

where the tensor Γ is the fundamental solution of vector analysis basic problem [1]: $\nabla(\nabla, \Gamma) = I\delta(|x - y|)$,

$\otimes$ - the symbol of the tensor product, and I is a single tensor.

In order to calculate the aerodynamic characteristics of an object under study on the basis of the established system of boundary integral equations equivalent to set boundary value problem (4.1), using a graphical triangulation process, followed by an analytical calculation of the necessary integrals of potential type on flat triangular surface elements, the algorithm of this system transformation into the system of linear algebraic equations is created with a single guaranteed solution.

The procedure of illustration concerning the flow of three-dimensional bearing system or its component with the use of computer graphics to determine the aerodynamic characteristics, the programming interface is applied with an open graphics library OpenGL (Open Graphics Library) with the C ++ programming language and other software, confirmed by relevant documents, is presented on Fig. 4.1.

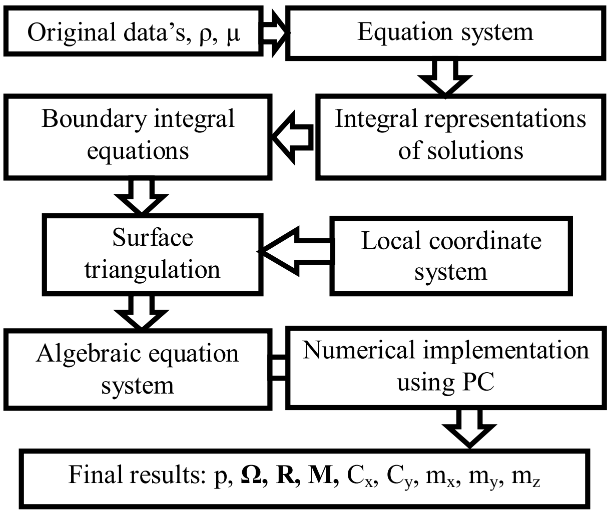

Fig. 4.1. Calculation procedure of total distributed aerohydrodynamic characteristics

Conclusion

Currently, the most promising method to solve a wide range of boundary value problems concerning continuum mechanics is the method of boundary integral equations, which allows:

- to reduce the dimension of a problem and consider more complex classes of problems than those that are solved by other methods;
- to determine unknown values on the boundaries of an area; the solutions in the interior points of an area are obtained by integration;

- nonlinear boundary problems for the systems of differential equations concerning basic conservation laws of mechanics lead to the system of linear boundary integral equations concerning unknown boundary values of the sought problem parameters or its wanted features;

- to perform the correct algorithms and implement some computational process to determine the kinematic and dynamic characteristics of the environment and a streamlined object interaction.

During the study of these aircraft characteristics on the basis of boundary integral equation method using the modern software products and computer technologies the author developed an object surface triangulation method in a curvilinear orthogonal coordinate system. Triangulation algorithm is applicable to the surfaces of any shape in a plane and in a spatial cases. The article shows the results of geometric modeling with the subsequent triangulation of an aircraft wing surface with additional aerodynamic surfaces, which allow to reduce the induced resistance of an aircraft, increase an effective extension of a wing and the lifting force at its end, to improve the course stability, reduce specific fuel consumption, reduce the length of running start and run during an aircraft takeoff and landing, which has also a significant economic effect.

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Рецензент: д-р техн. наук, проф., профессор кафедры А. В. Амброжевич, Национальный аэрокосмический университет им. Н. Е. Жуковского «ХАИ», Харьков.

МЕТОД ТРИАНГУЛЯЦИИ ПОВЕРХНОСТЕЙ НЕСУЩИХ СИСТЕМ ЛЕТАТЕЛЬНЫХ АППАРАТОВ

Ю. А. Крашаница, Амир Хошманди

Современная идеология построения вычислительных подходов решения начально-краевых задач механики сплошных сред базируется на создании адекватной математической модели и построении расчётных методов исходя из геометрической формы объекта. С целью численной реализации метода граничных интегральных уравнений развит алгоритмический процесс координирования поверхностей перспективных несущих систем произвольной пространственной формы с целью дальнейшей их триангуляции, что обеспечивает проведение корректного вычислительного эксперимента с целью определения распределённых и суммарных аэродинамических характеристик.

Ключевые слова: несущие системы летательных аппаратов, граничные интегральные уравнения, геометрическое моделирование, метод триангуляции поверхностей, численная реализация решений

МЕТОД ТРІАНГУЛЯЦІЇ ПОВЕРХОНЬ НЕСУЧИХ СИСТЕМ ЛІТАЛЬНИХ АПАРАТІВ

Ю. О. Крашаниця, Амір Хошманді

Сучасна ідеологія побудови обчислювальних підходів щодо вирішення початково-крайових задач механіки суцільних середовищ базується на створенні адекватної математичної моделі і побудові розрахункових методів виходячи з геометричної форми об’єкта. З метою числової реалізації методу граничних інтегральних рівнянь розвинений алгоритмічний процес координування поверхонь перспективних несучих систем довільної просторової форми з метою подальшої їх тріангуляцією, що забезпечує проведення коректного обчислювального експерименту визначення розподілених та сумарних аеродинамічних характеристик.

Ключові слова: несучі системи літальних апаратів, граничні інтегральні рівняння, геометричне моделювання, метод тріангуляції поверхонь, числова реалізація розв’язків

Крашаница Юрий Александрович – д-р техн. наук, проф., профессор кафедры аэрогидродинамики, Национальный аэрокосмический университет им. Н. Е. Жуковского «Харьковский авиационный институт», Харьков, Украина, e-mail: u.krashanitsa@khai.edu.

Хошманди Амир – аспирант кафедры аэрогидродинамики, Национальный аэрокосмический университет им. Н. Е. Жуковского «Харьковский авиационный институт», Харьков, Украина.

Krashanytsya Yurii – Doctor of Technical Sciences, Professor of the Department of Aerodynamics, National Aerospace University named after N. Ye. Zhukovsky “KhAI”, Kharkov, Ukrane, e-mail: u.krashanitsa@khai.edu.

Hoshmandi Amir – PhD Student the Department of Aerodynamics, National Aerospace University named after N. Ye. Zhukovsky “KhAI”, Kharkov, Ukrane.