APPLICATION OF DISCRETE VORTEX SINGULARITIES METHOD TO THE AEROELASTIC PROBLEMS IN PARACHUTE CONSTRUCTING

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Summary In the present work authors consider the complex mathematical model for the calculation of a form and aerodynamics characteristics of a parachute. Authors use the discrete vortex method for the aerodynamics calculation. The form of a canopy is précised with respect to the calculated press on the surface. General description of the mathematical model is given and calculating examples for actual problems provided.

INTRODUCTION

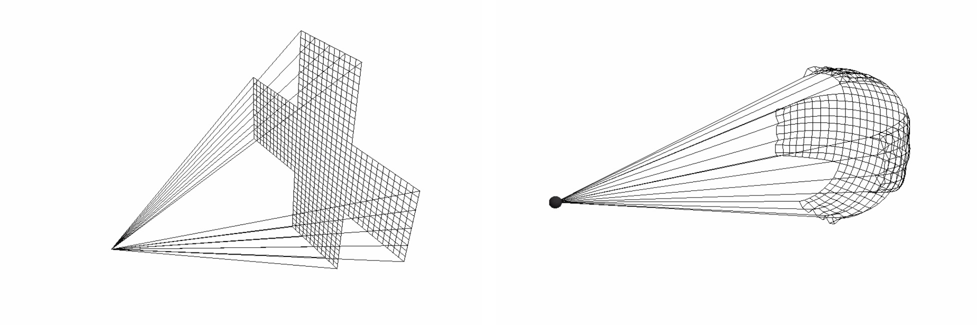
In the parachute design process modeling of its future shape is closely connected to its aerodynamic characteristics. Specifics of the construction process is that one needs to find the initial cutting form of fabric which will take the shape assuring attainment of the required summary aerodynamic characteristics affected by the interaction of unknown aerodynamic forces and elastic forces of fabric and power straps. That is why the problem of software development for modeling aeroelastic interaction process with purpose of simultaneous calculation of filled shape of cupola and its aerodynamic characteristics for known cutting form is of great interest at present.

MATHEMATICAL MODEL

Author presents the software complex for computer simulation of general process of fluid flow past parachute and simultaneous calculation of its shape at small subsonic velocities with consideration for vortex wake evolution, tense-strained state of parachute, aerodynamic loads and aerodynamic coefficients and moments affecting parachute.
The mathematical model of software is based on collaborate use of the method of lumped mass and method of vortex cells. The main modules of software are the program for calculating the filled form and tense-strained state of parachute and program for modeling unsteady separated flow past parachute.
In the described model at first the filled form of parachute for predefined uniform pressure fall is calculated with the method of lumped mass. Then calculation of flow past parachute with the help of vortex method is done in the course of which the iteration precision of cupola shape and tense-strained state of it based on pressure fall distribution got from aerodynamic calculation takes place.
In accordance with the method of lumped mass parachute is represented as a set of point masses distributed in a domain. These masses are concentrated in calculation points and freely connected to each other by zero-weight elastic pivots (threads) which are only stretching. So a grid appear which model the elastic characteristics of the construction. With this two independent grids are created - one for power frame with straps and one for fabric. General numerical scheme of parachute is created by superposing these two grids. Masses of coinciding grid nodes and stiffness of incoming to the nodes zero-weight elastic pivot are summed. Aerodynamic loads at parachute surfaces are approximated with a group of forces applied to calculating points. To find the initial shape of cupola and to precise the shape during calculations the system of equations is solved that describe the dynamics of calculation points motion for defined aerodynamic forces with respect to appearing elastic forces.
For the purpose of mathematical modeling of air flow past parachutes the method of vortex cells is used [1-3]. The unsteady problem for the ideal incompressible fluid should be solved. The essence of the method is based on modeling the surfaces of bodies and vortex wakes following them with vortex sheets and approximation of the vortex sheets with set of discrete vortex frames. In the solution of the problem the unknown intensities of vortex frames at body surface are finding from the system of algebraic linear equations approximating non-penetration condition. The intensities of vortex frames in the flow and the shape of vortex wake can be found in accordance to the theorem of vortex motion along the trajectories of fluid particles in flow and theorem of constant velocity circulation over any contour moving together with flow.
During calculations at each discrete moment of time the following unknowns need to be found: the positions of vortex frames modeling the vortex wake, intensities of vortex frames at the body surface, aerodynamic loads at cupola surface. Cupola form precision can be found from the calculated aerodynamic loads.

EXAMPLES

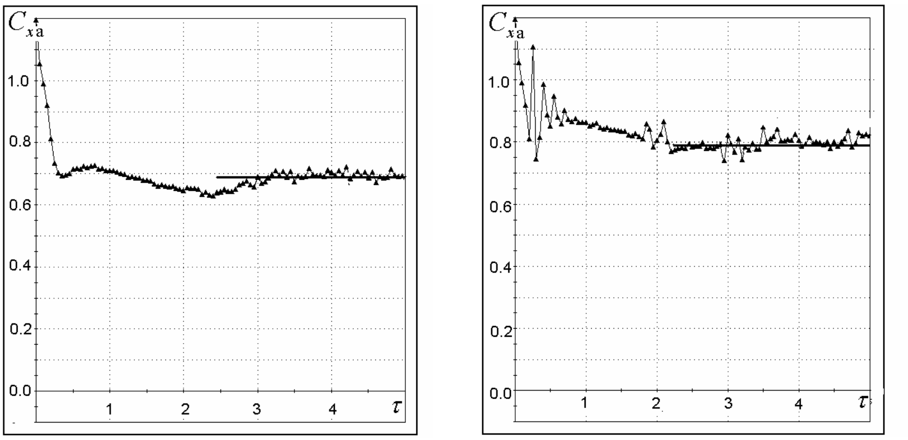
To show the capabilities of the developed software author places the example of numerical modeling of the aerodynamic characteristics of crest parachute. In Fig. 1 the initial power scheme of parachute cupola and parachute shape got after the pilot calculation with predefined constant pressure fall are shown. This pilot shape becomes initial shape to aerodynamics calculation.



Initial scheme Pilot filled shape

Fig.1. Discretisation of vortex structures

Fig. 2 shows the dependencies of the cupola drag coefficient from measureless time. Drag coefficient C_{xa} and measureless time τ are defined by formulas $C_{xa} = \dfrac{X}{\rho V_\infty^2 S}$, $\tau = \dfrac{tV_\infty}{b}$, where X - drag power, ρ - air density, V_∞ - velocity of undisturbed flow in infinity, S - square of cutting form of parachute, b - characteristic dimension chosen as scale of cutting form of parachute.



a) Calculation with fixed shape of cupola b) Calculation with cupola precision

Fig.2. Drag coefficient dependency from time

So the calculation model using collaborate process of flow modeling and shape precision provide better results than the calculations with fixed shape of cupola.

References

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