Existing software for computational hydrodynamics with the application of network methods are ineffective since computing a construction with variable geometry is very prolonged. Consequently, the use of vortex methods with the application of models of the medium, which enables finding unsteady loads with an accuracy acceptable for engineering computations with relatively shorter computing time when solving the problems of hydroelasticity, is urgent.

The method of discrete vortices proposed in [1, 2] is applicable to the calculation of the stalling flow of single bodies oscillating both along and transversally to the flow, as well as in the case of the appearance and development of the self-oscillation mode. The method makes it possible to establish the width of the retraction zone and the amplitude-frequency characteristics of the mode. Using this model, a problem of the stalling flow of a multicomponent construction is considered, the solutions of which have distinctions in principle compared with the problem of a single body [3, 4].

This article is devoted to the development and implementation in a form of complexes of programs (in the MATLAB medium) of effective methods of modeling the flow of a viscous liquid or gas to investigate the aerohydrodynamic loads on the bodies performing arbitrary motions, including variation in shape, and to solve problems of the motion of bodies under the effect of aerodynamic forces. Using these programs, we performed numerical experiments, in which aerodynamic forces affecting the immobile elements of the city infrastructure (bridges, passages, pipe constructions, resilient station buildings) and calculated self-oscillations of constructions in a separated flow stream. Formulas for the calculation of hydrodynamic forces affecting the bodies with their arbitrary motion in a viscous fluid and the variation in shape are derived through the characteristics of the vortex field.

The joint solution of the set of equations, which describe the body oscillations and determine the corresponding hydrodynamic forces at each step of computation, made it possible to apply a modernized method of discrete vortices to calculate self-oscillations of constructions of various types.

To solve the boundary problem, a certain method is given, which combines the collocation method and the mirror reflection method. This method makes it possible to calculate the stalling flow from a cylindrical surface of an arbitrary cross section [3, 4].

Constructions in the air flow caused by the passage of the Sapsan high-speed train are subject to the effect of aerodynamic forces, which can be determined by numerical methods. In this case, vortices break away from badly streamlined structures and cause unsteady hydrodynamic forces on them. These forces, with little structure resistance, can cause vibrations that are dangerous for the structure and considerably increase drag and lift forces. We calculated the evaluation of a wind load affecting the immobile pedestrian bridge (Fig. 1) by the method of discrete vortices. It is shown in Fig. 2, where the Karman track coming from the bridge profile and the dependence of coefficients of hydrodynamic forces $C_x, C_y$ on dimensionless time $\tau$, respectively, are shown.

The application of modern program tools and high-performance computers in the ANSYS framework enables specialists to solve the stated problems with the necessary accuracy and reliability in a 3D formulation. In view of the extreme laboriousness of these computations and the impossibility of their application in the case of oscillations of the structure, or of varying its shape even when using multiprocessor computers, it is reasonable to use the extensive experience of analytical calculations and classical methods accumulated by the domestic scientific school.
Problems, which appear during the interaction of the vortex trace and the elastic structure, can be divided into two groups: self-oscillations of the structure caused by unsteady forces from the vortex trace and the aerodynamic instability of the elastic structure in the flow. The first group includes the problems of vibration in the gas flow of badly streamlined posts, various pipelines, ropes, tower facilities, chimneys, etc. The second group includes the problems of the stability of cantilevered cylindrical structures and chimneys with purifying facilities.

Torsion oscillations of the aerodynamic surface as a system with one degree of freedom are the result of the stalling flutter excited due to the nonlinear characteristics of the lifting force in the vicinity of the appearance of the flow stall, or in conditions of loss of the lifting force. This phenomenon is also observed in structures having wide surfaces, during flow around which the flow stalls depending on the attack angle of the incident flow. With a detailed investigation of the flutter, nonlinear aerodynamic effects manifest themselves in almost all cases. However, in some situations, it was possible to successfully solve the problem based on linear analytical approaches because precisely at the initial stage of the process, which can be considered as that one characterized by only small oscillation amplitudes, separation of the stable and unstable modes occurs [5]. This makes it possible to analyze the flutter based on the conventional consideration of the stability of linear elastic systems. Problems of pitching and stall flutter can be also solved using the method of discrete vortices [2, 3].

A modernized method of discrete vortices does not require the construction of networks, does not contain the empirical parameters, and makes it possible to attain a high resolution of the flow structure. The method reproduces these features of the processes which were not included in algorithms and models in an explicit form (for example, the distance between the Karman vortices along the horizontal and vertical, the intensity of the Karman vortex, etc.) [2, 3]. In the framework of a modernized method of discrete vortices, let us determine the aerodynamic forces affecting the mobile elements of the infrastructure (bridges, passages, pipe constructions, elastic station buildings) and calculate the self-oscillations of structures with the passage of high-speed trains in the 2D formulation. This calculation makes it possible in real time and clearly (animation) to represent the pattern of the stalling flow of the body of a complex configuration oscillating in a transverse air flow.

Let the cylinder oscillate perpendicularly to the flow under the effect of hydrodynamic forces. In this case, the motion of the cylinder can be described by the set of equations

\[
y'' + \delta y' + y = c_y m \frac{\pi}{\pi Sh_0^2}, \quad c_y = f (y, y', y'', \alpha), \quad (1)
\]

of which the second equation is nonlinear. Both equations are written in the dimensionless form, where \(y = y/R\) is the dimensionless motion of the cylinder; \(R\) is the cylinder radius; \(\delta\) is the logarithmic decrement of oscillations; \(\bar{m} = \pi \rho R^2/m\) is the ratio of the attached mass of fluid to the mass per unit length of

![Fig. 1. Pedestrian bridge across the railways.](image1)

![Fig. 2. Calculation of the pedestrian bridge by the method of discrete vortices: (a) distribution pattern of discrete vortices under the effect of the uniform flow on the profile with velocity \(U_c\) and (b) time dependence of coefficients of aerodynamic forces affecting the pedestrian bridge; (1) \(c_x\) and (2) \(c_y\).](image2)