Large Scale Systems Control

Condition Diagnostics of Russian Railways Infrastructure Constructions under Aerodynamic Loads from High-Speed Trains


*Blagonravov Institute for Machine Sciences, Russian Academy of Sciences, Moscow, Russia
**Science and Research Center StaDyO, Moscow, Russia
***Moscow State University of Civil Engineering, Moscow, Russia

e-mail: kaplunov@imash.ru, nvalles@imash.ru, 97dis@mail.ru, stadyo@stadyo.ru, sergdubpodlipki@mail.ru

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Abstract—Aim of the present research is realization of a complex procedure on the basis of the combined approach for modeling aerodynamic loads on elements of the infrastructure (station constructions and designs, pedestrian crossings, bridges and tunnels) at high speed trains passage. Work is devoted to powerful methods of viscous gas currents modeling programs development and realization for research of aerodynamic loads on bodies making various movements, including shape variation, and to problems of bodies movement under aerodynamic forces solution.

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1. INTRODUCTION

SJC “Russian Railways” has initiated the development of a technological platform “High-Speed Smart Railway Transport” whose main objective is to develop a system of technical regulations and national standards that would take into account worldwide experience of design, construction, and maintenance of high-speed railway transport that would allow to transport traffic according to the best world practices.

2. METHODS FOR SOLVING THE PROBLEMS

The main project objective is to model and estimate aerodynamical loads on infrastructure elements when high-speed trains pass by; by infrastructure elements, we mean buildings on stations, pedestrian passes, bridges, and tunnels.

In the project we propose to use a combined approach based on the joint application of two methods. The first is one of the most powerful and modern software for hydrosdynamydodynamic computations, ANSYS CFD, which implements the method of finite volumes to solve three dimensional Navier–Stokes equations with a wide spectrum of turbulence models and settings (LES, DES, SAS SST, RANS, and URANS); it has been successfully verified by the developers on a wide range of problems for which we have test results in wind tunnels and prototype measurements [1, 3–8].

The actual aerodynamic computations were done with the software unit ANSYS CFX (called CFX in what follows). The CFX unit lets the user model laminar and turbulent flows, compressible and incompressible liquid, related heat exchange problems, multiphase flows, processes of boiling, burning, condensation, filtering, chemical reactions and so on. The unit supports more than twenty different turbulence models. The CFX unit does not include grid generators but rather lets one import grids prepared by other programs, in particular, by the ANSYS preprocessor with ANSYS APDL parameterized macros.
The second method is an original and effective Modernized Discrete Vortex Method (creation of IMASH RAS) that lets one quickly solve a wide range of flow problems for rigid and elastic bodies of various shape for a given range of Reynolds numbers in the numerical experiment; it was approved with known experimental data. Using this method, we find aero-dynamical forces acting on moving elements and multicomponent systems in infrastructure constructions (bridges, pedestrian passes, pipe constructions, elastic station constructions) and also compute self-oscillations of the constructions as high-speed trains pass by in the 2D setting [2, 9–12].

The main idea and innovativeness of the proposed method is to use a combination of these two approaches Using modern software and a lot of computational power, the first method lets us to solve the proposed problem with the necessary accuracy and reliability in the 3D setting. Due to very high computational load of these computations, even with a multicore computer it makes sense to use the extensive experience in analytic computations and classical methods collected by the Russian scientific school (the second method).

3. MAIN RESULTS

Existing software suites for computational hydrodynamics that use grid methods turn out to be inefficient in computations for constructions with changeable geometry. The computations in this case are prolonged. Therefore, it is a good idea to use vortex method with environmental models which allow to find non-stationary loads in hydroelasticity problems with sufficient for engineering computations precision and significantly smaller computational time expenditures.

The modernized discrete vortex method does not require grids construction, does not contain empirical parameters, and allows to achieve high definition of flow structure. The method has low scheme viscosity, and the numerical scheme is stable (there are no interruptions due to unbounded growth of variables). The developed method also significantly extends the capabilities of numerical studies for the vortex formation mechanism and structure of non-stationary separated flow for arbitrary motion and shape changing of the flowed bodies; it is also useful in such problems as the optimal choice of parameters for the cross section configuration.

The proposed modernized discrete vortex method can be applied to compute flow separation of single body that oscillates both along and across the flow, as well as in case of self-oscillations initiation and development. Method allows to define the width of the synchronization zone and amplitude-frequency characteristics of regime. This model also allows to consider the separation flow problem for a multicomponent construction, solutions of this problem, conceptually differ from single body problem solution (Figs. 1 and 2).

Modeling experience with the discrete vortex method has shown that the resulting model has the following advantages. On a unified mathematical and computational foundation, one can construct an entire hierarchy of software that is suitable for a wide range of applications. Based on this software, together with a physical experiment we obtain important material which extends our understanding and limits of applicability of these schemes and models are defined. Thus, we pass from single problems to complex problems solution on system base.

Many years of experience in the development and application of the discrete vortex method has shown that it has important advantages. Firstly, it has unique capabilities in constructing vortex traces and jets. Secondly, it contains an explicit stochastic mechanism (deterministic chaos) which is important to model turbulence. Thirdly, the problem dimension is significantly reduced because we only need to watch track vortices on body surface and in trace but not in entire space.

For the first time we have obtained a formula to find aerodynamic forces acting upon an arbitrary profile via instantaneous velocities of discrete vortexes in separated flow. Body may self-oscillate in the separated flow (Fig. 3).