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DISCRETE VORTEX METHOD CAPABILITY TO PREDICT AEROELASTIC RESPONSE OF BRIDGE DECKS

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The research deals with the capability of the discrete vortex method to model interaction between a fluid stream and a solid body immersed in it. In general the phenomenon can be met in many technical problems. This paper focuses on an aeroelastic response of bridge decks i.e. it considers a building structure and wind interaction. Engineering practice shows that all cable-stayed and suspension bridges (Fig.1) should be examined to determine the risk of flutter that can develop in their central parts under a wind attack.

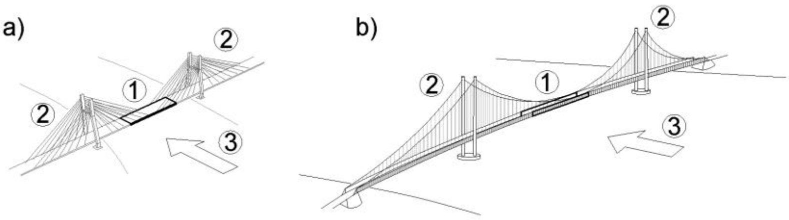

Fig. 1: Types of bridges at risk of flutter: a) cable-stayed, b) suspension bridge
1 central part prone to flutter, 2 outer parts, 3 wind attack

Due to the complexity of the phenomenon sectional model tests in wind tunnels (Fig.2a) have been treated as the most reliable so far. Analytical and numerical methods meet the difficulty of proper modeling of turbulence and a boundary layer. Discrete Vortex Method (DVM) has been recognized as one of the most promising computer methods that are able to manage the problems (Larsen, Walter, 1997).

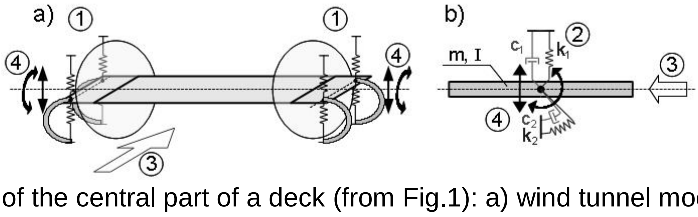

Fig. 2: Models of the central part of a deck (from Fig.1): a) wind tunnel model, b) 2D computer model; 1 elastic suspension, 2 suspension reduced to its characteristics, 3 air stream, 4 degrees of freedom

DVM is a numerical method developed for solving the Navier-Stokes equation based on the Lagrangian model of particle tracing (Koumoustakos, Cottet, 2000; Lewis, 2005). In DVM the equation is solved by a direct simulation of the physical phenomenon. A finite mesh associated with the finite volume or finite element method is not used in DVM. Moreover there is no need to employ artificial models of turbulence such as k-ε, k-ω or LES.

Assuming a homogeneous fluid we can write the Navier-Stokes equation in the form:

$$\frac{\partial \mathbf{u}}{\partial t} + (\mathbf{u} \cdot \nabla)\mathbf{u} = -\nabla p + \frac{1}{Re}\Delta \mathbf{u} \qquad (1)$$

where: $\mathbf{u}$ -velocity field, p -pressure field, Re –Reynolds number, t-time. The equation is decomposed by calculation the rotation of the vector **u**, which gives the vorticity transport equation that is composed with two parts: advection (2) and diffusion (3):

$$\frac{\partial \boldsymbol{\omega}}{\partial t} + (\mathbf{u} \cdot \nabla)\boldsymbol{\omega} = 0 \qquad (2)$$

$$\frac{\partial \boldsymbol{\omega}}{\partial t} = \frac{1}{Re}\Delta \boldsymbol{\omega} \qquad (3)$$

where: $\boldsymbol{\omega} = \nabla \times \mathbf{u}$ is a vorticity field of the flow. The separation lets us treat the flow as two simultaneous phenomena: advection and diffusion. This is the core idea for computer simulations of fluid flow in DVM.

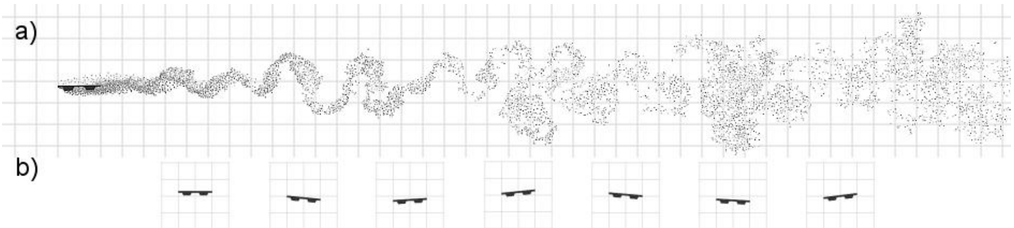

Fig. 3: DVM computer simulation of an air flow around a bridge deck model: a) snapshot of a vortex street created by the deck, b) motion of the deck during the simulation

Computer code based on DVM algorithm has been developed by the author and numerical simulations were carried out (Fig.3). 2D counterparts of wind tunnel sectional models (Fig.2) were considered in 4 cross-section configurations (Fig.4a-d). Computer simulation output (Fig.4) is compared with experimental data (Nowicki, Flaga, 2011).

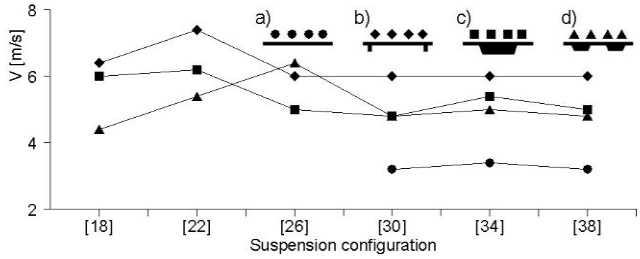

Fig. 4: Onset flutter velocity against suspension configuration for different shapes of cross-section of decks, a) – d) schematic view of applied cross sections

This abstract is supplemented with visualization available at: www.tomasznowicki.eu/kkmp

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