

Nonlinear dynamics of plates and shallow shells interacting with moving fluid

Konstantin Avramov, Helena Strel'nikova

A.N. Podgorny Institute for Mechanical Engineering Problems, Kharkov, Ukraine

Summary. Self-sustained vibrations of plates at two-sided interaction with moving fluid are considered. Fluid-structure interaction is described by a hyper singular integral equation, which is solved by Galerkin method. The plate performs geometrical nonlinear vibrations, which is described by finite-degree-of-freedom nonlinear dynamical system. Nonlinear modes are developed to analyze the self-sustained vibrations.

Introduction

Interaction of thin-walled structures with a moving fluid or gas takes place in marine engineering, energetic and aerospace engineering. Therefore, many efforts were made to analyze this problem [1]. Periodic and chaotic self-sustained vibrations, which are generated by airflow moving from one side of the plate, are analyzed in [2-4]. The number of modes for appropriate description of plate self-sustained vibrations in airflow is investigated in [5]. It is shown that six modes are enough for adequate description of vibrations. The Lyapunov values are calculated to analyze qualitative behavior of periodic motions in flutter instability region by Librescu, Chiochia, Marzocca [6]. Incompressible potential flow about two and three-dimension bodies is considered in [7]. The surface-source method, which describes fluid-structure interaction, is treated. This method is reduced to the hyper singular integral equation. 3D potential flow is used to describe pressure acting on vibrating plate by Novichkov [8]. The results are compared with the data obtained by piston theory. Tang, Dowell [9] are analyzed the plate in subsonic potential flow. Vortex lattice method is used to describe fluid-structure interaction. Aeroelastic instability of plates in subsonic flow is analyzed in the paper [10]. 2D incompressible flow is considered: the pressure acting on the plate is described by linear hyper singular integral equation. Liu, Dowell [11] described the vibrations of aerodynamic surface by two-degrees-of-freedom model. The action of incompressible flow on vibrating surface is reduced to lifting force and moments. Dynamics of the system is described by two nonlinear integro-differential equations.

Double-side interaction of a fluid flow with a plate is considered in this paper. Self-sustained vibrations of the plate are analyzed. The surface-source method is used to describe fluid-structure interaction. This method is reduced to hyper singular integral equation, which is solved by Galerkin technique. The vibrations of the plate are described by finite-degrees-of-freedom nonlinear dynamical system. Variant of Shaw-Pierre nonlinear modes is suggested to analyze the self-sustained vibrations. Using this approach, the flutter of the plate is analyzed. The analysis of complex chaotic vibrations is presented too.

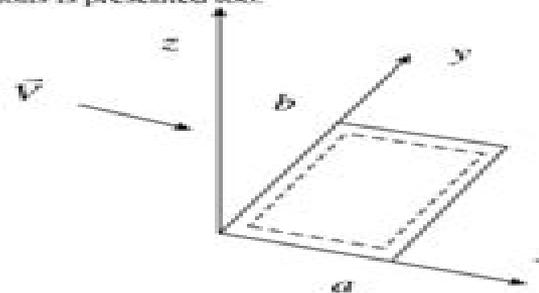


Fig.1. Sketch of the mechanical system

Problem formulation

Dynamics of simply supported plate in the flow of incompressible potential fluid is considered. The flow at a distance from the plate has constant velocity V (Fig.1). 3D flow is considered. The fluid dynamics is described by the velocity potential $\varphi(x, y, z, t)$. The lateral displacements of the plate is denoted by $w(x, y, t)$. It is assumed, that the normal component of the plate velocities is equal to the normal component of the fluid velocities, which is described by the following equations:

$$\left. \frac{\partial \varphi}{\partial z} \right|_{z=w} = V \frac{\partial w}{\partial x} + \frac{\partial w}{\partial t}; \quad \left. \frac{\partial \varphi}{\partial z} \right|_{z=-w} = V \frac{\partial w}{\partial x} + \frac{\partial w}{\partial t}. \quad (1)$$

The pressure acting on the plate is obtained from the Bernoulli's equation, which has the following form:

Nonlinear Dynamics Of Shells Plates

Katrin Zwirgmaier



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