Linear Global Stability Analysis of Vortex Shedding Dynamics Around a Bullet-Shaped Bluff Body

R Mitruț[1,ON1], D M Bucur[1,ON2,*], G Dunca[1,ON3] and M J Cervantes[2,ON4]
[1]Department of Hydraulics, Hydraulic Machinery and Environmental Engineering, University Politehnica of Bucharest, Bucharest, Romania
[2]Division of Fluid and Experimental Mechanics, Luleå University of Technology, Luleå, Sweden
ORCID numbers: ON1: 0000-0003-3403-2900, ON2: 0000-0003-4771-5292, ON3: 0000-0003-2517-2610, ON4: 0000-0001-7599-0895

[*]Corresponding author: diana.bucur@upb.com

Abstract. The paper presents the numerical simulations of the flow around a bullet-shaped bluff body at low Reynolds number, Re = 500. The bluff body is fixed and aligned with the free-flow direction, with a diameter D = 10 mm and a length-to-diameter ratio L/D = 2. The numerical investigations are carried out in two steps. Firstly, unsteady three-dimensional (3D) direct numerical simulations (DNS) are performed until the vortex shedding behind the bluff body occurs and becomes periodical. The flow is compared to experimental data available in the literature. Secondly, a two-dimensional (2D) linear stability analysis is performed on a 2D plane obtained by intersecting the 3D geometry with a meridional plane. using the time-averaged flow. The frequency of the most unstable eigenmode associated with the vortex shedding is found to be in good agreement with the 3D results.

1. Introduction

During the last decades, only few renewable energy sources (RES) managed to leave the prototype idea and stepped up for mass energy production, such as wind and solar sources. Still, these green energy sources suffer from a lack of continuity in the production and storage capacity. In this context, the hydropower is used to balance the energy grid due it its capability of storing the raw energy of water in artificial lakes and due to the fast response time of hydraulic turbines. The power demand on the energy market varies so the hydraulic turbines are nowadays often used in off-design operating conditions which lead to the apparition of large pressure fluctuations that originates from the cavitation vortex flow, inducing in some conditions a rotating vortex rope (RVR) [1,2]. Not only that the cavitation induces erosion to the turbine components, but in extreme cases the frequency of the RVR could match the frequency of the entire power plant which leads to the resonance [3]. Due to the costs associated to the investigations, limited and difficult access into the hydraulic turbine draft tube and its complexity, the RVR is studied in several research in simplified geometries in order to understand its physics [4-6]. Recent work interprets the RVR as the result of an unstable eigenmode of a self-sustained instability which develops in space and time [7,8]. The eigenmode represents the spatial structure of an instability and its growth rate and frequency could be determined by performing a linear stability analysis (LSA) of the flow. LSA results may also be used to represent sensitivity maps which are used to localize the most receptive zone to an external force. According to the literature, these zones could be used to modify the base flow dynamics by active or passive techniques in order to manipulate and stabilize the flow [9-11]. These techniques may firstly be tested and