Proper Orthogonal Decomposition of the Unsteady Flow Field in a Butterfly Valve

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Abstract. The current work presents a methodology developed for the analysis of the unsteady flow field induced by a butterfly valve. The methodology carried out includes three parts: (i) numerical simulation of the flow field; (ii) validation of numerical results against experimental data and (iii) analysis of the unsteady flow field with the POD method. The CFD simulations are performed using OpenFOAM v2112 while the POD analysis is carried out as a post-processing step using Modred Python Library. The eigenvalues and eigenmodes of the unsteady flow field are extracted to identify the coherent flow structures associated with several valve-disk opening angles. The main flow features (stagnation point, jet flow, separated flow, vortex structures) corresponding to different opening angles (0°, 15°, 30°, 45° and 60°) of the valve-disk are identified. Numerical investigations provide an in-depth analysis of the unsteady flow field to support the development of various butterfly valve control strategies.

1. Introduction

The flexible operation of hydropower units leads to the new challenges in safe service and lifetime assessment of the hydropower fleet [1]. The valves are the key safety elements to shut off the flow in the shortest time possible while respecting the maximum admissible pressure in the penstock. The type of valve (e.g. butterfly, spherical) and its operating parameters (closing time, closing law) are selected according to the configuration and requirements of each hydropower plant. Improper selection of valve operating parameters can lead to catastrophic events. A catastrophic accident was reported at Oigawa hydropower plant due to the sudden closing of a butterfly valve. The main source of the accidents identified by Bonin [2] was the lack of a secure adjustment of the butterfly valve. Several extensive investigations have been conducted to improve the main performances (i.e. hydraulic losses, volumetric leakage) of the butterfly valves. However, the safe operation of hydroelectric plants under the imposed conditions requires a deeper understanding of the unsteady phenomena induced by the operation of butterfly valves, especially in transient regimes. The purpose of the investigations carried out in the manuscript is to identify and evaluate the hydrodynamic phenomena developed in the operation of the butterfly valves [3]. In order to achieve this goal we started with 2D numerical simulations of the turbulent flow in the cross section of the 3D disc shaped butterfly valve, Section 2. The cross section view of the 3D butterfly valve-disk has the shape of the biconvex arc similar to the investigations conducted by Morris and Dutton [6]. Therefore, the numerical results obtained on the flap for several opening angles in Section 3 were validated against experimental data [6]. Both the force and moment