Influence of swirl ratio on the onset of columnar vortices in the mixing part of swirl generator

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Abstract. The study presents analysis of conditions for the onset of columnar vortices in the mixing part of swirl generator. The simplified geometry, used for this analysis, is based on the physical model of the bladeless swirl generator developed by the research group from Brno University of Technology. This swirl generator was previously used for several studies of the spiral vortex structures generated in the diffuser part. The main aim for the current study is the mixing mechanism, which is realized in the part where the axial inflow meets the tangential one. Since there are no guide vanes or other driving geometry features, the mixing mechanism is realized randomly, is strongly time-dependent and its behavior is linked to the swirl ratio between the axial and tangential inflows. From previous studies, the appearance of vortical structures with columnar-like shape was identified. For the better understanding of this mixing mechanism, which may influence the flow downstream and consequently the generated vortex, the several swirl ratios of axial and tangential inflow were studied. The dynamic of vortices are extracted using A-f analysis and proper orthogonal decomposition. The results are based on the CFD simulation employing a hybrid RANS+LES turbulence models.

1. Introduction

The flow interaction between stationary and rotating domain is crucial aspect of any turbomachine equipment as a hydraulic pumps and turbines. This phenomenon is more important for cases without any flow direction devices such as guide vanes in turbines or vanes placed in the outlet diffuser of pumps. In this case the resulting flow structures in a form of interblade vortices are presented in the runner. One of the very first study on this mixing behavior in Kaplan turbine was presented in 1996 by Půlpitel [1]. Recently with more often operation of hydraulic turbines in speed-no-load regime, mainly due to the grid stability purposes, several studies were presented regarding the mixing phenomenon in the propeller [2, 3, 4] and Francis [5, 6] turbines. It was shown that the resulting flow structures in a from of columnar vortices attached on the turbine hub are not mandatory dependant on presence of turbine runner, which has rather passive role in this case. The results of these studies were one of the motivations for the work presented in this paper where the mixing mechanism is also studied but in a very simple geometry and without the driving mechanism of the guide vanes. Another motivation was previous research of spiral vortical structures carried out on bladeless swirl generator apparatus [7, 8, 9, 10]. Since this swirl generator was designed without any guide vanes or rotating blades the mixing (ensuring different swirl conditions) is realized in the chamber where the spiral part of tangential inflow meets the axial inflow, see figure 1.