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Local linear stability analysis of a draft tube vortex

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Abstract. This study investigates the connection between flow stability properties and the vortex phenomenon at two different operating points in a hydraulic turbine. The base flow vortex is based on experimental data from previous studies [1, 2]. Using experimental measurements at the turbine outlet (upstream of the draft tube), Susan-Resiga et al. [1] proposed a mathematical model of the turbine vortex, combining rigid body motion and two Batchelor vortices with different core radii. The mean flow is described by the velocity components $U_b = [0,V\theta,Vz]$. Having the mean flow expression as the base flow, a local stability analysis is performed for two different operating points (two different baseflows). The local stability analysis assumes that the perturbation is small compared to the mean flow dynamics such that the Navier-Stokes equation can be linearized around the mean flow. Following [3], the turbulent viscosity ($\nabla\cdot[(\nu + \nu_T)(\nabla u + (\nabla u)^T)]$) is taken into account and ν_T is derived from the experimental data [2]. At OP1 (Part-Load Regime), the flow rate is approximately 97% of the best efficiency point (BEP). The most unstable mode at this point has an azimuthal wavenumber of m = 2. At OP2 (BEP), the dominant instability is an axisymmetric mode (azimuthal wavenumber (m = 0)) for all axial wavenumbers (k). These findings are consistent with the experimental observations [4]. For OP1, the instability mode is concentrated near the centre of the flow. The vorticity distribution of the most unstable mode is localized near the axis which coherent to the experimental observation. For OP2, no clear instability is observed as it is BEP and can be interpreted by the sustained axisymmetric mode found in stability analysis.

References

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