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A numerical case study: Bovet approach to design a Francis turbine runner

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Abstract

In this study, analytical calculation and numerical simulations were performed to design a Francis turbine runner blade. Single blade was designed by using Bovet approach. Blade geometry was created by using Ansys Bladegen V16.1. Grid model has been generated by using Ansys Meshing, with using fine mesh quality, tetrahedron type mesh. k- Ɛ turbulence model have been selected for steady state analysis. Pressure distributions are obtained on meridional plane and also on suction and pressure sides of the blade. The results of the numerical analysis showed that, Bovet design approach is able to calculate a runner that has an efficiency of 1% different with respect to committed efficiency. At the inlet of the suction side, the negative pressure is observed, that can cause cavitation and oscillation.

Keywords:

1. Introduction

In recent years; due to the decline of fossil fuels, there is a tendency to renewable energy sources. One of the biggest and also well-known recipe of producing green energy is hydroelectric power plants. According to U.S. Geological Survey, the percentage of producing energy from hydro turbines is %16 in the world [1]. There are generally five types of hydraulic turbines are used in Hydraulic Power Plant technology. Hydraulic turbines are classified due to head and flow rates. Figure 1 shows that the selection of hydraulic turbines by using head and flow rates [2]. Francis turbine is the most used hydro turbine type and it is suitable for working with wide-spectrum of head and flow rates. The most important part of a Francis turbine is the runner that transforms the hydro energy to mechanical energy. In general

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turbine runner is composed of blades which have complex geometries. Thereby, in order to get efficient turbine, design of the runner has high priority. The blades, constructed the runner, have very complex shapes, so to design blades analytically causes many complications.

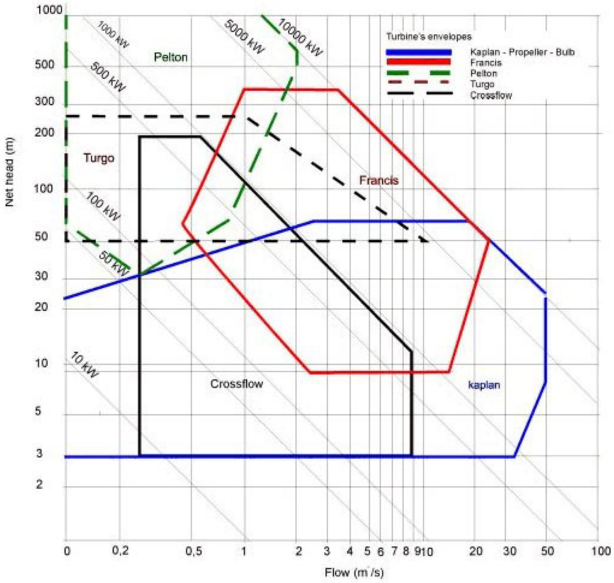

Fig. 1. Radial turbine selection chart by net head - flow [2].

There were many studies about Francis turbine design in the literature. One of the most important design approach of Francis turbine runner is Bovet method which uses empirical equations to obtain parameters of Francis type hydro turbine runner [3]. In Bovet method, the dimensionless specific speed value is the main parameter to determine whole turbine dimensions. Miloş and Bârglâzan [4] investigated the refurbishment of the hydraulic turbine's runner, medium head Francis by CAD technique. The authors were used Bovet approach to calculate meridional channel and blade splines. It is seen that the authors preferred parabola arcs method to obtain leading and trailing edges profile. Conformal mapping method is used to design the turbine runner. By rectification of the flow velocities, the flow streamlines at the inlet of the runner is matched with the streamlines of wicket gates. Therefore, swirl at the outlet of the runner and pressure oscillations in the draft tube are reduced. Choi et al [5] studied rehabilitation of a 500 kW Francis turbine runner by changing internal parameters of the runner while using the old turbine components such as spiral case, guide vanes and spiral casing. Part by part optimization method is used. It was achieved a model which has improved cavitation characteristic with extremely smooth performance over a much wider range of operations compared to the existing design. The improved runner and different guide vane operating conditions were tested experimentally. According to experimental tests, the total efficiency of the turbine was increased about 9.93 percent. Numerical simulation of cavitating turbulent flow in a high head Francis turbine at part load operation was conducted by using OpenFOAM code in the study of Zhang and Zhang [6]. k-ω SST turbulence model was used for calculating Reynolds averaged Navier-Stokes equations. A repetitive solver was performed while residual values of convergence criteria were set to 10-5 grade. As a result of this study, the authors indicated that numerical approach is a suitable tool to analyze cavitation behavior. Numerical setup which is constructed by using OpenFOAM codes was able to simulate cavitation characteristics. Anup et al [7] conducted a study on temporary numerical validation in a Francis turbine by using ANSYS CFX Solver. In their study k-ε with Kato – Launder correction and SST turbulence models were used and also Large Eddy Simulation (LES) and Reynold Stress Models have been adopted for numerical approach. During the design of Francis turbine, the important phenomenon, that is pressure fluctuation due to rotor-stator interaction and occurrence of vortex rope in draft tube were investigated numerically at partial load operation condition [7]. Thapa