

Flow Modeling and Runner Design Optimization in Turgo Water Turbines

John S. Anagnostopoulos, and Dimitrios E. Papantonis

Abstract—The incorporation of computational fluid dynamics in the design of modern hydraulic turbines appears to be necessary in order to improve their efficiency and cost-effectiveness beyond the traditional design practices. A numerical optimization methodology is developed and applied in the present work to a Turgo water turbine. The fluid is simulated by a Lagrangian mesh-free approach that can provide detailed information on the energy transfer and enhance the understanding of the complex, unsteady flow field, at very small computing cost. The runner blades are initially shaped according to hydrodynamic theory, and parameterized using Bézier polynomials and interpolation techniques. The use of a limited number of free design variables allows for various modifications of the standard blade shape, while stochastic optimization using evolutionary algorithms is implemented to find the best blade that maximizes the attainable hydraulic efficiency of the runner. The obtained optimal runner design achieves considerably higher efficiency than the standard one, and its numerically predicted performance is comparable to a real Turgo turbine, verifying the reliability and the prospects of the new methodology.

Keywords—Turgo turbine, Lagrangian flow modeling, Surface parameterization, Design optimization, Evolutionary algorithms.

1. INTRODUCTION

TURGO water turbines belong to the impulse type hydraulic machines along with the more common, Pelton turbines. Turgo turbines are well suited to replacing low head multi-jet Pelton or high head Francis turbines with poor part load efficiencies, and they can be used in medium to high heads, from 15 to 300 m. Like Pelton, Turgo turbine has a flat efficiency curve and provides excellent part-load efficiencies hence it constitutes the best solution for large flow rate variations. Also, it can operate for long periods and minimum wear when the water is laden with silt and other entrained matter.

The Turgo turbine was first patented by a European company in 1919, although the earliest design dates back to

the end of the sixteenth century (Fig. 1a). The water jet enters one side of the runner and exits through the other (Fig. 1b). This allows for a more efficient escape of 'used' water, which does not interfere with the incoming jet. Hence, larger jet and flow rates can be treated compared to a Pelton runner of same diameter. As a result, a Turgo turbine has higher specific speed and smaller size than a Pelton turbine for the same power. This compensates for its more complex design and more difficult manufacturing process. Moreover, the smaller runner diameter allows to obtain a higher angular velocity, so that the turns multiplier in the coupling with the electrical generator can be avoided, decreasing the costs and increasing the mechanical reliability of the system.

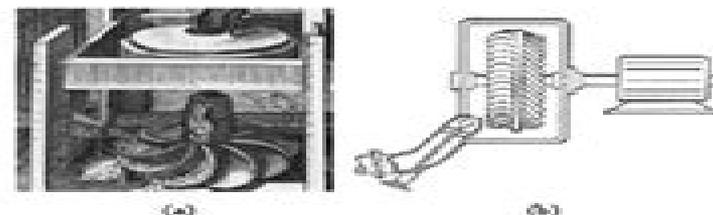


Fig. 1 (a) Earliest design of Giovanni Branca (b) Sketch of the Turgo type design

Very few scientific articles can be found in the literature dealing with the design of Turgo runner, and only few companies construct this turbine type worldwide. In most books and manuals that include impulse turbines description the Turgo turbine is referred simply as a variant of the Pelton turbine. An extended description is first given in Gibson [1], but without any information about dimensioning and design of the runner. Some interesting elements for dimensioning and standardization of small Turgo turbines are given in the manuals of Georoug [2], [3], as well as by Bednar [4].

The numerical modeling and analysis of the flow in a Turgo runner, along with a preliminary design optimization study of its blades, is the aim of the present work. To achieve this, the inner surface of a blade is initially designed according to hydrodynamics theory and using Bézier polynomials, while a mesh-free Lagrangian method is adopted for the simulation of the free-surface flow developed on the blade surface. In order to improve the hydraulic efficiency of the initial design, a

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Methods for Design Optimization Using High Fidelity Turbulent Flow Simulations Chaitanya Anil Talnikar, 2015 Design optimization with high fidelity turbulent flow simulations can be challenging due to noisy and expensive objective function evaluations The noise decays slowly as computation cost increases therefore is significant in most simulations It is often unpredictable due to chaotic dynamics of turbulence in that it can be totally different for almost identical simulations This thesis presents a modified parallel Bayesian optimization algorithm designed for performing optimization with high fidelity simulations It strives to find the optimum in a minimum number of evaluations by judiciously exploring the design space Additionally to potentially augment the optimization algorithm with the availability of a gradient a massively parallel discrete unsteady adjoint solver for the compressible Navier Stokes equations is derived and implemented Both the methods are demonstrated on a large scale transonic fluid flow problem in a turbomachinery component

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