

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 Bessel 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.

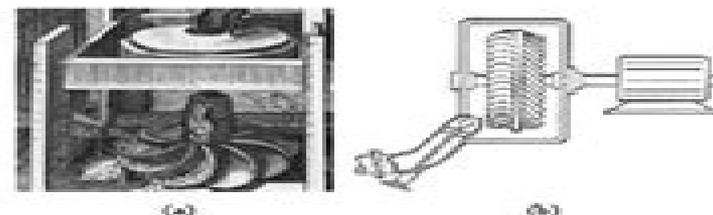


Fig. 1 (a) Earliest design of Giovanni Branca (b) Sketch of the Turgo type design

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 Georng [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 Bessel 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

Manuscript received July 23, 2007. This work is co-funded by the European Social Fund (75%) and National Resources (25%) - Operational Program for Educational and Vocational Training II, and particularly the Program Pythagoras.

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Table of Contents Flow Modeling And Runner Design Optimization In Turgo

1. Understanding the eBook Flow Modeling And Runner Design Optimization In Turgo
 - The Rise of Digital Reading Flow Modeling And Runner Design Optimization In Turgo
 - Advantages of eBooks Over Traditional Books
2. Identifying Flow Modeling And Runner Design Optimization In Turgo
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Flow Modeling And Runner Design Optimization In Turgo
 - User-Friendly Interface
4. Exploring eBook Recommendations from Flow Modeling And Runner Design Optimization In Turgo
 - Personalized Recommendations
 - Flow Modeling And Runner Design Optimization In Turgo User Reviews and Ratings
 - Flow Modeling And Runner Design Optimization In Turgo and Bestseller Lists

5. Accessing Flow Modeling And Runner Design Optimization In Turgo Free and Paid eBooks
 - Flow Modeling And Runner Design Optimization In Turgo Public Domain eBooks
 - Flow Modeling And Runner Design Optimization In Turgo eBook Subscription Services
 - Flow Modeling And Runner Design Optimization In Turgo Budget-Friendly Options
6. Navigating Flow Modeling And Runner Design Optimization In Turgo eBook Formats
 - ePub, PDF, MOBI, and More
 - Flow Modeling And Runner Design Optimization In Turgo Compatibility with Devices
 - Flow Modeling And Runner Design Optimization In Turgo Enhanced eBook Features
7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Flow Modeling And Runner Design Optimization In Turgo
 - Highlighting and Note-Taking Flow Modeling And Runner Design Optimization In Turgo
 - Interactive Elements Flow Modeling And Runner Design Optimization In Turgo
8. Staying Engaged with Flow Modeling And Runner Design Optimization In Turgo
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Flow Modeling And Runner Design Optimization In Turgo
9. Balancing eBooks and Physical Books Flow Modeling And Runner Design Optimization In Turgo
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Flow Modeling And Runner Design Optimization In Turgo
10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
11. Cultivating a Reading Routine Flow Modeling And Runner Design Optimization In Turgo
 - Setting Reading Goals Flow Modeling And Runner Design Optimization In Turgo
 - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Flow Modeling And Runner Design Optimization In Turgo
 - Fact-Checking eBook Content of Flow Modeling And Runner Design Optimization In Turgo
 - Distinguishing Credible Sources
13. Promoting Lifelong Learning

- Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
14. Embracing eBook Trends
- Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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