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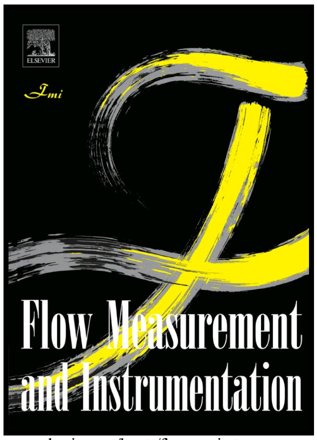

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A practical approach to use the thermodynamic efficiency method for flow measurements

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Abstract

The thermodynamic efficiency method represents the most accurate technique to measure the efficiency of hydraulic machines exceeding 1 kJ/kg of specific energy. On large-scale machines, it is common to use this method also to measure the discharge by simultaneous measurement of the mechanical power. This is either done iteratively or by the use of analytical solutions for simple test setups. We present here an extension of these analytical solutions to arbitrary test setups and conditions, which appear in practical applications. A sign convention has been introduced to harmonize relevant test codes, which deal with performance testing of hydraulic turbines and pumps, in the future.

Keywords: water, thermodynamic method, mass flow, flow rate, turbine, pump, efficiency

1. Introduction

Since the invention of the thermodynamic efficiency method (TDM) in 1920, it has been widely used to determine the hydraulic efficiency of water turbines and pumps [1]. Instead of calculating the efficiency with power values, this method is using terms of total enthalpies, which require the measurement of the thermodynamic state functions (e.g., pressure, density and temperature) and the kinetic energy. Since the portion of kinetic energy is of minor order, the total enthalpy depends marginally on the mass rate of fluid flowing through the machine. Therefore, there is no need to measure the flow rate accurately and its value is either estimated or indicated by a secondary flow meter. Nowadays, it is common to use TDM and power measurement to provide firstly, the volumetric flow rate and secondly, the efficiency to reduce the measurement uncertainty. This can be done by iterative calculations or by using analytical formulae for simple test setups, which avoid any mass flow exchange with the environment or auxiliary systems [2].
The authors present a generalization of the solutions given in Ref.[2]. They reveal a complete set of analytical solutions for the mass flow rate applicable to any test setup, which can appear in practice. A sign convention is defined which provides consistent formulae without ambiguity. The subsequent sections use the term *fluid*

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