Abstract

The habilitation thesis presents a synthesis of the author's scientific and technical achievements after obtaining the doctorate. The entire material presented in this paper presents the author's activity, carried out within the CDI activity, which started in the Politehnica University of Bucharest and continued in the National Institute for R&D in Electrical Engineering ICPE-CA, where I carry out my work until now. The paper begins with the presentation of the main research activities initiated and implemented as the main researcher in fundamental research, applied research / technological development and services, in the framework of some projects coordinated by the author. The collaboration with the university and economic environment is highlighted, as well as the significant results (models/prototypes, patents) what substantiated the published scientific papers.
This paper is structured into six chapters, with the scientific directions approached. In the last chapter, the perspectives of post-habilitation professional development are presented.

The first chapter refers to the preliminary research dedicated to the experimental activity to understand / deepen the phenomenon of oxygen transfer from air to water, but also to the dimensioning of the aerator devices s in order to obtain the best aeration efficiency. The study shows the importance of aerator optimization in terms of material, geometry, conditions specific to each application (airflow, pressure gradient, aerator geometry). Based on these results as well as those on the pressure losses on the aerators, the standard aeration efficiency (SAE) was calculated and the global efficiency curves were plotted.

Since the variations in efficiency for dissolved oxygen transfer for different aerators are large, up to 10 times, this study's results are significant for designing aeration systems according to the specific needs and capacity of each application.
A database was created with the energy and aeration performance of various aeration devices, tested on a dedicated stand (Patent RO 125997 B1, 28.02.2012), published as Bunea F, Ciocan GD, Ch 17: *Experimental study of standard aeration efficiency in a bubble column*, Desalination and water treatment, InTechOpen Book Chapter, edited by: Dr. Murat Eyvaz, p. 349-368, 2018, DOI: 10.5772/intechopen.76696.

In the **second chapter**, an experimental approach is presented for the morphological characterization of an aeration column, with the liquid phase at rest, respectively the geometry and size of the air bubbles, simultaneously with the induced velocity of the water and the ascent velocity of the bubble. The measurement method, image processing and results are presented. Special attention is paid to the study of the water aeration process, where the morphology of air bubbles is an important parameter for the characterization of oxygen transfer. Experimental investigation of two-phase water-air flows is also essential. Modern experimental methods such as PIV and shadowgraphy are used to simultaneously characterize both phases and the phase interaction. A database was created on the morphology of bubble columns, aeration characteristics and induced flow and the results were published at several scientific events including: Murgan I, Bunea F*, Nedelcu A., Ciocan G., Experimental setup to study two phase flows for environmental applications, October 9-13, Cluj 2018EENVIRO, E3S Web of Conferences 85, 07010 (2019).

Chapter three presents the research activity to determine the characteristics and capabilities of some innovative water aeration systems with applications in hydraulic machines, to maximize the content of dissolved oxygen in water, with minimal energy consumption. The optimization of

the turbine water aeration process emphasizes the quality of the aeration process and not only the quantity of air circulated, respectively on: the increase of the air-water interphase area, their retention time, the pressure drop on the aeration devices. It is intended that the device proposed for aeration be non-invasive, so as to influence as little as possible the hydraulic circuit of the water, and therefore to affect as little as possible the efficiency of the hydraulic machine. In this sense, I have developed a laboratory installation for the small-scale study of turbine water aeration solutions, which allows testing in the laboratory of aeration devices equipped with interchangeable plates, in order to design aerators that can be mounted in the draft tube cone of hydraulic turbines. The stand enables the reliable study of complex phenomena such as turbulent, dispersed gas-liquid flows with adverse pressure gradient, where the mass transfer across the interface is a dynamic process associated with the dynamic interface and the interface area varies along the flow.

The presented experimental measurements aim to optimize the dispersed aeration process in turbulent flows in hydraulic turbines, respecting both, the parameters of the flow in a turbine and the voids fraction imposed by hydraulic machine builders in order to not degrade the performance of the turbine. Several aerators were characterized by determining the standard oxygen transfer rate and standard aeration efficiency of each. Another parameter taken into account is the energy consumption associated with air injection to maintain the hydraulic performance of the turbine. The experimental stand (Patent RO131118/2018) was designed and built for the testing and optimization of aerators that can be used in hydraulic turbines, based on which several scientific papers were developed, among which stand out: Bunea F., Ciocan G.D., Oprina G., Băran G., Băbuţanu C, *Hydropower impact on water quality,* 2010, Environmental Engineering and Management Journal, 9, 11, 1459-1464.

For certain industrial applications, increasing the energy efficiency of industrial equipment and installations, requires knowledge of the simultaneity of the phases characteristic of the flow. **Chapter four** presents a characterization of these flows by determining the instantaneous velocity fields of the two phases and processing the experimental data obtained using specific processing and post-processing programs. Thus, the paper presents experimental studies using the Particle Image Velocimetry technique to determine the velocity fields and the volume of cavitational vapors developed in the flow, but also a software dedicated to synchronous measurements from specific turbulent, biphasic flows for the simultaneous characterization of the two phases (air-water) and their interaction over time.

A configuration of the PIV measurement system for biphasic application was developed and used. Experimental data processing methods are presented, which are the basis of several scientific papers, among which two publications in WOS yellow zone journals are noteworthy:

- Bunea F., Nedelcu A., Ciocan G.D., *Prediction of water aeration efficiency in high turbulent flow*, Desalination and Water Treatment, 85 (2017), 55-62;
- Murgan, F. Bunea*, G. Ciocan, *Experimental PIV and LIF characterization of a bubble column flow*, Flow Measurement and Instrumentation 54 (2017) 224–235.

Air injection through a prototype made within a research project coordinated by the authors is presented in the **fifth chapter** of these works. Aeration is controlled according to the oxygen deficiency in the water, through a non-invasive device, located on the wall of the draft tubr cone of a turbine so as not to influence the flow. After analyzing the energetic and mechanical performances of the turbine with the installed aeration device, an automated aeration control

system is presented, so that it operates with minimal energy consumption and reaches the level of dissolved oxygen imposed by the user.

The implementation of the prototype aeration device (Eurasian Patent no 036765/17.12.2020 B1), in an in-situ turbine, served as a demonstrator for the use of the device in an industrial configuration as well as for demonstrating its influence on the energy parameters of the turbine. A relevant work that is based on the activity foreseen in this chapter is: Bunea F.; Ciocan G.D., Bucur D.M., Dunca G., Nedelcu A. *Hydraulic Turbine Performance Assessment with Implementation of an Innovative Aeration System*. Water 2021, 13, 2459.

In **chapter six**, a hydrokinetic turbine assembly is presented, with the generator placed at the circumference of the rotor blades, thus resulting in an experimental model with a compact design, easy to transport and use. The experimental model consists of a cassette rotor turbine, directly coupled with an electrical generator with permanent magnets, located in the same casing is "Hydrokinetic eco- Power System for ultra-low head water streams" (HyPER). It was developed within a RDI project, coordinated by UPB, in partnership with ICPE-CA (project manager Bunea F.) and Smart Mechanics. The system is based on the combination of classic hydraulic turbine and permanent magnet generator elements, studied in an innovative compact assembly. The power generated by the HyPER model reached 6.3 W, and it was tested for water flow velocities between 0.3 m/s and 1.1 m/s, with rotating speeds ranging from 30 rpm to 220 rpm These values were limited to the operational possibilities of the laboratory stand.

A hydrokinetic turbine prototype was built and tested in situ to demonstrate the efficiency of this type of turbine. A first presentation of these results was made at a specialized conference in the field: Bucur D M, Dunca G, Bunea F*, Chihaia R A, Grecu I S, Mitruț R, *Experimental investigation of small axial hydro-kinetic turbines*, 31th IAHR Symp. on Hydraulic Machinery and Systems, 2022, IOP Conf. Ser.: Earth Environ. Sci. 1079 012020.