A B S T R A C T

The habilitation thesis entitled "**Studies and Research on the Performance of Thermal Systems and Their Optimization**" presents the main scientific results of the author in his research career subsequent to the PhD dissertation. The thesis reflects the evolution of the academic, scientific and professional activity of the author, as well as the main areas of development, while offering an overview of the most significant scientific achievements in the field of mechanical engineering.

Chapter I of the habilitation thesis summarizes the achievements of the author in his scientific career, which began with specific research activities in the framework of the PhD program. The research activity within the scientific projects started during the final stage of this program.

The author contributed to 12 scientific research projects and contracts after the PhD dissertation, out of which 8 were won through national competitions (CNCIS, CEEX, PN II and PN III projects) and remaining 4 were research contracts involving the economic environment abroad. The following topics in the field of thermal energy systems were studied within these projects and contracts:

- The use of biomass in cogeneration installations based on micro-scale gas turbines;
- Development of multi-fuel pulse combustion chambers;
- Development of fog generating installations for crop protection against unfavorable environmental factors, using pulse combustion chambers;
- Development of compressors with high compression ratio in one stage;
- Energy systems with oxy-combustion;
- Biogas plants efficiency improvement;
- Development of energy systems based on Ericsson engine and using solar energy for heating the working fluid.

The author's activity in collaborative research projects is also detailed herein. These projects involved hot water condensing boilers and their additional systems as well as energetic optimization of gas (micro)turbines, cogeneration installations and combined cycles power systems.

Based on the experience gained by participating in the research projects and contracts, several areas of author's competence were defined.

Chapter II deals with the main original results of the author's scientific research activity. By capitalizing on the results of the research projects and contracts presented in the first chapter, the candidate has developed and published 59 scientific papers after the PhD dissertation, as follows: 34 papers as first or single author, 30 papers in journals and conference proceedings indexed by ISI - Web of Science and Scopus and 29 papers in conference proceedings indexed in other international databases. In addition, 5 books were

developed after the PhD dissertation – three educational books and 2 specialized books. They are published by CNCSIS certified publishers or are accessible as web resources.

The most relevant scientific contributions of the author after his PhD dissertation are presented within this chapter. Self-assessment of these contributions was performed in relation with the competence areas of special interest for the author had concerns and which yielded results in a sustained manner during this period, namely:

- Construction and optimization of steam and hot water boilers;
- Combined cycle power plants;
- Energy systems based on renewable sources;
- Physical-mathematical modeling of unconventional machines, especially Stirling and Vuilleumier.

Chapter III presents the evolution of the academic and professional career as well as the results in educational area. The academic positions successively occupied by the candidate and the disciplines in his responsibility were specified.

The educational materials created by author – course books, project and laboratory manuals – in the view of updating and developing the bibliographic resources dedicated to the students of the Faculty of Mechanics are presented in this chapter. Herein the main laboratory facilities developed by the author for educational purposes are also indicated.

Chapter IV is a synthesis of the author's research work developed after the PhD dissertation and materialized in scientific papers published in journals or proceedings of prestigious scientific conferences. This work is mainly focused on analysis and optimization of thermal systems in the view of performance maximizing, emissions mitigation and energy generation from renewable sources.

The author's experimental and theoretical investigations on condensing boiler technology are described herein. The experimental study on performance of a condensing boiler with nominal output of 25 kW, performed in 2017 in Romania, indicated that replacement of a traditional boiler in good operating condition with a condensing boiler is economically unattractive in typical cases. The UE policies for the reduction of pollution and fossil fuel consumptions implied among others a transition from traditional to condensing boilers for domestic use. As pointed out, such transition can feature reduced attractiveness for the general public unless attractive financial measures, like subsidies, are implemented. On the other hand, the experimental study on a condensing boiler system with nominal output of 60 kW had shown that the price of thermal energy produced in the analyzed system is lower with 21…30% than the price of thermal energy coming from the district heating system (the study was conducted in February 2020 and considers the natural gas price at that moment). In terms of investment with strict reference to the boilers prices, the payback period is 1.6…2.3 years in this case.

The use of hydrogen enriched methane as fuel for condensing boilers represents another subject of author's research work, which emphasized the viability of this technology. As effect of the methane enrichment with hydrogen, the flame temperature increases. Accordingly, NOx emissions increase too. The results show that the increasing of NOx

emissions can be inhibited by slowly increasing the air excess coefficient (e.g. from 1.3 to 1.4 when hydrogen volumetric fraction in fuel mixture increases from 0 to 80%). By this method, the boiler efficiency does not decrease below the reference case, when boiler operates with pure methane.

Another research topic of the author is represented by combined cycle power systems. A study on the waste heat recovery from the flue gas of a gas-steam combined cycle power system based on Orenda OGT15000 gas turbine is presented. The analyzed method consists in addition, downstream the heat recovery steam generator, into the power system configuration of an organic Rankine Cycle unit. The analysis showed that overall efficiency of the power plant increases by only 1,1…1,19% but the subsequent economy with fuel costs is significant, of 16000…16500 Euro per year.

The possibility of integrating the small scale combined cycles power units into the hybrid power systems of cars was also analyzed. The research indicates that the efficiency of the proposed power unit is higher with 5% than the efficiency of the most advanced internal combustion engines, which currently are the typical solution for car propulsion, as stand-alone units or in hybrid configuration. The analyzed power unit, operating with compressed natural gas, has CO_2 emissions rate about 30% lower than most advanced Diesel engines used in terrestrial propulsion. Volumes of the condensing system's heat exchanger and heat recovery steam generator – the component with decisive role in which the size and mass of the power system are concerned – allow the integration of the power system inside the car body.

The study on the conversion of the straw energy potential (and also of other types of waste biomass) into a hot air turbine power plant is the last presented study in chapter 4. Two configurations were studied – one in open cycle and the other in semi-closed cycle. The research shows that the efficiency of the open cycle power plant is lower than the efficiency of a conventional similar gas turbine engine, however the efficiency of the semi-closed cycle power plant is higher (33.6% versus 31.4%). Hence, the hot air turbine power plants can be assumed as attractive solutions for the straw disposal problem, especially when the change of the plant location and/ or independency of the water sources are imposed.

Team leader and teamwork skills of author in research activity as well as his teaching management skills are emphasised in ***Chapter V***. On one hand, these skills have been proven within the developed scientific projects and contracts. On the other hand, they have been confirmed by the permanent preoccupation for developing the bibliographic resources dedicated to the students and for updating the laboratory facilities. Herein the recognition and the impact of the author's scientific activity are also highlighted, especially by citations in recognized publications, indexed by *Web of Science* or *Scopus*.

As result of the scientific activity recognition in the academia, he acted in international conferences as reviewer, member of the scientific/ organizing committee and chairman and in scientific journals as reviewer. It should be noted that these activities involved, among others, leadership role and responsibilities, representing good opportunities for improving the team leader skills.

Chapter VI summarizes the main research perspectives and the development intentions for the university career. The issues envisaged for the future evolution of the author's

professional and scientific career are referred by considering both components of the academic system, namely education and research.

Herein the objectives in educational approach and the actions considered for their fulfillment are present. These objectives are:

- Continuous improvement of the teaching skills and teaching methodology; participation in continuous training programs; continuous improvement of the teaching/ assessment method and of the electronic self-assessment/ assessment method.
- Updating the curricula, reinforcement of the educational infrastructure, development of new course books, project and laboratory manuals for continuous increasing of the educational process quality and for meeting the job market expectations;
- Continuing engagement with students in specific activities, especially coordination for bachelor/ master theses elaboration, guidance in developing scientific activity and tutoring activity;

The following medium- and long-term objectives are set to ensure further results in the scientific research:

- Enhancement of the competencies of the research team by both self improvement and recruitment of new team members – young researchers as well as experienced researchers;
- Development of the research infrastructure;
- Increasing the national and international visibility of the research especially by increasing the number of articles published in high impact scientific journals;
- Development of new scientific projects.

The author envisages to continue scientific studies in the field of the hot water condensing boilers. The experimental studies on the use of hydrogen enriched methane as fuel for condensing boilers, the development of biomass fueled condensing boilers, modelling of the intensified flue gas - water heat transfer in the condensing (cold) region of the heat exchangers and the development of a pulse combustion condensing boiler with aerodynamic valve are the main subjects for further research.

The studies on the combined cycles power plants and organic Rankine cycles will be also continued. The investigations on the miniaturization of these systems for widening their application field – currently relatively limited – is the main priority.