A. Abstract

Habilitation thesis ”Research in the Fields of Unconventional Heat Engines and Thermal Systems and Equipment” was written in order to obtain the habilitation certificate. The paper presents the main scientific achievements obtained after receiving the doctorate in Mechanical Engineering (spring 2005), the main fields of study addressed, as well as the evolution of academic and scientific career during this period. Also, the perspectives of the further development of the scientific and didactic career are presented.

The paper follows the guidelines for realization of the habilitation thesis published by CNATDCU regarding the structure and dimensions of the text, as well as all the other regulations in force. The thesis contains an abstract (A) and a main text (B) divided as follows: B1 - scientific, professional and academic achievements, B2 - plans for the evolution and development of the professional, scientific and academic career and B3 - References.

Chapter B1.1. presents a synthesis of the achievements of the author in the scientific, didactic and academic career after obtaining the PhD degree.

The candidate’s main didactic and scientific achievements in the Mechanical Engineering domain, were materialized in the publication of:

- 3 university coursebooks published with CNCSIS-accredited publishing houses, as author or first author (prior to 2005);
- 1 coursebook in electronic format (2018-2021);
- 2 laboratory and project textbook as first author or author (2018);
- 2 monographic books published in CNCSIS-accredited publishing houses (2012, 2018);
- 2 scientific papers published in Web of Science (WoS) -indexed journals, the author being as well corresponding author to one of them (2018, 2021);
- 4 scientific papers published in international database indexed journals (2007-2010);
- 28 scientific papers published in volumes of international scientific conferences, indexed in WoS and/or Scopus databases, another 2 being indexed in other international databases (2008-2020);
- 8 scientific papers published in indexed journals (2006-2012);
- 11 scientific papers published at not indexed international scientific conferences (2005-2013).

The impact of hereinbefore mentioned scientific endeavors is reflected in93 citations, from which 31 in papers published in WoS-indexed journals (2015-2021).

The author participated in:

- 4 contracts with an economic agent from Netherlands (as project manager, 2014-2017);

- 3 contracts won through national competitions, member (PN II, POSDRU, 2007-2010);

- 16 contracts with Romanian economic agents (2005-2013).

The abilities of the author as a team leader in research and didactic activities, and also as a team member, were mentioned in same chapter. The author also acted as a reviewer for Web of Science indexed journals Name and Name.

Chapter B1.2 presents a selection of the most interesting original results of the author's scientific research activities. The selected studies were grouped by domain, as follows:

- researches in the field of unconventional heat engines, namely:
    - Stirling engines;
    - Vuilleumier machines;
    - Ericsson engines;
    - thermal-acted compressors;
- researches in the field of hot water boilers;
- other various domains (gas turbines, thermodynamics, combined cycle power plants, renewable energies).

A physical and mathematical model for evaluation of the work lost due to leaks through cylinder - displacer gap of beta- and gamma- Stirling engines is described. The work yielded when working agent leaks are taken into account is calculated by integrating the differential expression of the volume variation work, considering the pressure changes inside the chambers of the machine. The formula obtained for the mass flow rate of leaks was used by several other researchers, and cited in five papers published in indexed journals.

Another physical and mathematical model was developed for a novel alpha-type Stirling engine with on-load variable displacement. The variable displacement is obtained through a planar quadrilateral linkage with one on-load movable ground link. Performances and power adjustment capabilities of such alpha-type Stirling engine were calculated and analyzed. An exemplification through the use of the numerical simulation was performed in this regard.

In the domain of Vuilleumier machines (tri-thermal thermal-acted heat pumps) a new model taking into account the friction losses appearing in the heat exchangers of the machine was presented. The pressure drop caused by friction inside a generic heat exchanger is determined. The coefficients of performance (COP's) calculated with the new model are smaller than the ones determined with the isothermal model. The adjustment of the theoretical models, aimed at taking into account the pressure losses inside the heat exchangers, allow for the emphasizing of phenomena that appear when changing the rotation speed.

A physical and mathematical model fit for estimating the maximum performances of a hot air Ericsson-type engine - an engine which is capable to run on renewable energy such as solar energy, geothermal energy or biomass - was also described. The computation program based on this new model allows for the study of the influences of the main parameters over the engine performances and to optimize their values.

During 2014-2019 period the author was involved in the development of a functional prototype of an unconventional heat engine of Ericsson-type. Some details of the research program were presented – initial design of the heat engine (based on a "hydraulic"

background), a proposed scheme for an engine designed to work with renewable low-temperature heat sources (e.g., solar energy), a section of the 3D model of the engine and a real picture of the prototype taken at first functioning tests are presented.

Some insights of the experimental researches about a condensing boiler with nominal output of 25 kW are also presented. The study concludes that an annual fuel saving up to 17.56 % is possible in real operating conditions, provided the condensing boiler is used instead of a traditional, non-condensing boiler. A proposal for renaming the efficiency in terms of the fuel's higher heating value was made, in order to avoid the confusion arising from the use of the term "efficiency" in a more than 100 % context. The study also concluded that the replacement of traditional boilers with condensing ones is, right now, economically unattractive, due to the higher cost of the latter.

Another theoretical study presented in the habilitation thesis deals with the domestic condensing boilers that use natural gas enriched with hydrogen as fuel. This is a possible solution for reducing the carbon dioxide emissions. The carbon emission mitigation and latent heat recovery potential of the condensing boilers which use natural gas mixed with hydrogen as fuel (for hydrogen volumetric fractions in the mixture from 0 to 100%) are the main subjects of the study. Besides the combustion characteristics, the fuel consumption and the overall energy saving potential of water vapor inside the flue gas are calculated for the specific case of a condensing boiler of 25 kW gross heat input.

In section B2 of the thesis the main plans for the evolution and development of the professional, scientific and academic career were presented.

The main professional objectives for the years to come are:

- keeping the curricula up to date;
- participation at courses / training programs for improving the teaching skills;
- improving the teaching aids and the infrastructure;
- publishing of new coursebooks, laboratory and project textbooks for students;
- coordination of more students for writing their diploma theses, or their MSc theses;
- coordination of PhD students.

The main scientific and academic objectives for the future are:

- enhancement of author's research competencies, both from theoretical and experimental points of view;
- to improve infrastructure used in research;
- to publish more scientific papers in WoS-indexed, renowned journals, and, through this, to improve the international visibility of author's results;
- continuing the development of the existing research projects and beginning some new.

Investigations about the polytropic model of the Stirling and Vuilleumier machines and of the way of including various types of losses in this model is a priority.