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Review of the PhD dissertation of Mohammadsadegh Pahlavanzadeh, MSc. Eng., commissioned by the Chairman of the Council of Scientific Discipline Environment Engineering, Mining and Energy at the Silesian University of Technology (letter RIE-BD.512.40.2025)

1. Introduction

The doctoral dissertation of Mohammadsadegh Pahlavanzadeh, MSc. Eng. entitled "Assessment of the possibility of improving the momentum transfer in the flow between rotating discs " submitted for review is a series of 5 co-authored monothematic publications accompanied by a self-review report. It was prepared under the supervision of Prof. Włodzimierz Wróblewski, PhD, DSc, co-supervised by Dr. Krzysztof Rusin, at the Faculty of Environmental and Energy Engineering of the Silesian University of Technology. The dissertation contains: a title page, acknowledgements, table of contents, Author's statements on the thesis format, list of publications constituting the series of monothematic publications followed by the determination of Author's participation as a co-author in teamwork, abstract of the dissertation in English and Polish, nomenclature section, chapter I – being an introduction to the topic, chapters II to IV – guiding over the series of monothematic papers I to V, chapter V – being an additional study of the Candidate, summary and conclusions, bibliography, and appendices I to V – constituting copies of papers I to V belonging to the series of monothematic publications.

2. Characteristics of the PhD dissertation

The dissertation concentrates on improving the energy conversion in flow between rotating discs, with a special focus on the flow in Tesla turbines. In particular, modelling methods are discussed, and the effects of surface roughness and supply nozzle configuration on the Tesla turbine efficiency are evaluated.

In Chapter I, by way of introduction the author presents his motivations and literature review concerning Tesla turbines and their application in distributed energy systems, especially in the context of waste heat recovery and utilisation. Tesla turbines are found an interesting and innovative alternative to traditional expanders in waste heat recovery systems, by virtue of their simple construction. The flow in Tesla turbines is considered relatively complex, still living room for efficiency improvements. Especially high hopes are attached to the change in surface roughness, as the energy conversion in Tesla turbines is dominated by viscous forces. Thus, one subchapter is concerned with methods of modelling surface roughness in CDF codes. The literature review reveals gaps in research, which allows the Candidate to determine main objectives of the PhD thesis formulated as finding answers to 10 research questions listed in page 25 of the dissertation. For the sake of this review, they can be summarised as:

- finding the most suitable numerical approach for accurate simulation of flow between co-rotating discs in Tesla turbines, including modelling turbulence and surface roughness;
- finding the effect of gap size between co-rotating discs and surface roughness influence on flow characteristics and efficiency of Tesla turbines;
- finding the effect of number of nozzles and their configuration on the flow aerodynamics, efficiency, and output power of Tesla turbines.

Chapter II is a self-review report of

- paper I: Pahlavanzadeh, M., Rusin, K., Wróblewski, W., (2023), Evaluation of dynamic correction of turbulence wall boundary conditions to simulate roughness effect in minichannel with rotating walls, International Journal of Numerical Methods for Heat & Fluid Flow, https://doi.org/10.1108/HFF-03-2023-0160, and
- paper II: Pahlavanzadeh, M., Rulik, K., Wróblewski, W., Rusin, K., (2024). Application of roughness models to stationary and rotating minichannel flows, International Journal of Numerical Methods for Heat & Fluid Flow, https://doi.org/10.1108/HFF-05-2024-0379.

These papers explore various turbulence models for RANS modelling (three two-equation turbulence models including k–ω Shear Stress Transport (k–ω SST), k–ε with Standard Wall Function (k–ε SWF) and k–ε with Enhanced Wall Treatment (k–ε EWT)), and two roughness treatment approaches (a wall function modifications using velocity profile shifts, and the method of Aupoix, which adjusts turbulence quantities near the wall to reflect roughness effects. These all methods are applied to a series of test cases, beginning with flow over a zero-pressure gradient rough flat plate, then extending to stationary and rotating minichannels as in Tesla turbines. Positive validation of the effectiveness of the k–ω SST turbulence model combined with the Aupoix roughness method was found a major achievement of these investigations. It was also quantitatively confirmed that increasing surface roughness as well as gap size reduction can lead to increasing flow efficiency (gap considered here a space between the rotating discs).

In chapter III, Author undertakes a self-review of

- paper III: Pahlavanzadeh, M., Wróblewski, W., Rusin, K., (2024), On the Flow in the Gap between Co-rotating Discs of Tesla Turbine with Different Supply Configurations: A Numerical Study, Energies, https://doi.org/10.3390/EN17174472, and
- paper IV: Pahlavanzadeh, M., Wróblewski, W., Rusin, K., (2025), Evaluation of nozzle configuration impact on flow structures and performance in Tesla turbine, International Journal of Heat and Mass Transfer, https://doi.org/10.1016/J.IJHEATMASSTRANSFER. 2025.126900.

These papers explore the comparison of RANS and LES modelling of the Tesla turbine domains. The RANS model is supplemented with the k–ω SST turbulence model. The LES model is WMLES, which can also be classified as a hybrid RANS/LES approach as it integrates the SGS Smagorinsky model with the mixing length model for the near wall region. These models are applied to the calculation of Tesla turbines with various nozzle numbers, angles and configurations (with one-to-one and one-to-many supplies). It is found that the WMLES model is more computationally demanding, however, it captures transient fluctuations with greater fidelity, at the walls and in the regions of disc tip – inlet jet interaction. The less demanding k–ω SST model as compared to WMLES only slightly overestimates the wall shear stress and torque (by ~4.25%) and provides a sufficiently accurate prediction for general flow behaviour.

It was also found that a higher nozzle count (40 nozzles in a one-to-one configuration) increases the mass flow rate and power output (by up to a factor of four with respect to 6 nozzles) but at the same time decreases the system efficiency (by ~16%) due to complex jet interactions. One-to-many nozzles are found considerably less efficient in terms of generated power and flow efficiency than one-to-one nozzles supplies due to increased disc tip – inlet jet interactions leading also to increased inlet jet–boundary layer interactions.

Chapter IV is a self-review report of

- paper V: Pahlavanzadeh, M., Rusin, K., Wróblewski, W., Rulik, S., (2025), Roughness effects on flow in Tesla turbine with parametric adjustment of porous layer model, Physics of Fluids. https://doi.org/10.1063/5.0247548/3329214.

This paper is concerned with simulation of surface roughness effects in a disc turbine with the help of the porous medium layer (PML) model, supplementing the RANS (with k–ω SST) model. The porous medium layer alters the flow resistance, adding an additional term to the momentum equation (according to the Brinkman-Forchheimer-extended Darcy equation). All governing equations, including turbulence equations and viscosities are subject to appropriate adjustments due to the value of porosity. The obtained results are compared with those of the Aupoix model and validated by theory and experimental data (for a rough flat plate).

Three values of surface roughness for a Tesla turbine are investigated, and for higher roughness values, the PML model shows slightly increased turbine powers and efficiencies as compared with those of the Aupoix model.

Chapter V is a short description of the Author's additional study concerning the effects of surface roughness on Tesla turbine flow of two low-boiling media – R1234yf and n-hexane. The porous medium layer model presented earlier was used. The calculations were made in a wide range of rotational velocity, yielding complete flow characteristics of the investigated disc turbine. The best efficiency point for R1234yf is found at 5000 rpm, whereas for n-hexane at 12 000 rpm (rough discs). The surface roughness significantly improves turbine efficiency: for R1234yf, the flow efficiency increased from ~18% to ~27%, for n-hexane, the efficiency increased from ~8% to ~15%.

Then, the self-review report is summarised and several conclusions were drawn. Although LES provides a detailed insight into flow structures and transient phenomena, especially near the disc tips where flow fluctuations are dominant, RANS simulations with the k–ω SST model still remain a practical tool for parametric studies due to lower resource demands and accepted accuracy. The Aupoix model and the porous medium layer offer reasonable resolution of surface roughness effects, and it was found that the efficiency of disc turbine flows can be considerably increased by implementation of appropriate surface roughness. It was also found that appropriate number and arrangement of inlet jet nozzles (preferably one-to-one) are crucial for the efficiency of disc turbines.

3. Evaluation of the PhD dissertation

The presented PhD dissertation constitutes a series of thematically coherent publications co-authored by the supervisor and co-supervisor. A self-review report contains an informative material, summarising the enclosed series of publications. The Author has solved a non-trivial research task characterized by a high level of complexity, therefore demonstrated the ability to independently solve scientific problems and use appropriate research methods. The. All goals assumed for this PhD dissertation have been accomplished. The valuable results obtained in this thesis make a significant contribution to the discipline of Environment Engineering, Mining and Energy.

Among the elements of the dissertation that constitute the original and distinctive scientific achievements of the Author, I consider:

- first of all, the development of numerical tools for high-surface roughness disc turbine flows; the next original achievement is the analysis of the effect of surface roughness on flow characteristics and efficiency of the considered disc turbines;
- another important original element of the work is the analysis of the influence of inlet jet nozzle configurations on the energy conversion and flow efficiency of the investigated disc turbines.

The prevailing part of the self-review report is written correctly in terms of content, using correct English, advanced terminology, and with due precision of formulations. The description of key issues is concise and correct. The presented concepts are also properly illustrated. However, there are quite a few exceptions, which may raise questions. One may find also some mistakes, or inappropriate formulations (but not many), some of them will be pointed out below.

Title and Abstracts:

- "...momentum transfer...", "Momentum diffusion and kinetic energy transfer...", "Dyfuzja pędu oraz transfer energii kinetycznej..." – these expressions are right, especially in the context of investigating surface roughness effects in flows, where these effects are dominant. However, it should also be noted that Tesla turbines working on air or ORC media are still thermal machines, and they may not be zero-reaction turbines, meaning that there still might be some pressure gradient in the rotor domain and further expansion within the disc-to-disc space, that is downstream of the nozzles. While manipulating with nozzle configuration, one might also expect changing the turbine reaction. Thus, instead of saying about "momentum or/and kinetic energy transfer", sometimes it may be more appropriate to say about energy transfer in general.
- page XI, line 2 – "on-to-one" should be "one-to-many" as the other leads to higher fluctuations and flow losses.

Nomenclature:

- The list is quite long but not complete. Turbulence quantities such as ε or ω are missing.
- The symbol τ (called tangential stress) is in conflict with $\tau_{i,j}$ as in Eqs. 11, 12 (this should be called total shear stress). This mistake is also repeated in papers I-V.
- Specific internal energy should have a unit of J/kg or m^2/s^2.
- Greeks could have an alphabetic order.

Chapter 1.3:

- The aims are basically OK, however, they could have been formulated in a more concise way.

Chapter 2.2:

- Eqs. (10)-(14) are basically OK also for RANS, however, in these equations $\tau_{i,j}$ is the total shear stress, not "wall shear stress" (line 1 below Eq. 12), nor "turbulent stresses" (line 4 below Eq. 12). Here, the total shear stress consists is a sum of viscous stress and turbulent stress. Here, also the heat flux q includes turbulent heat flux.
- Turbulent viscosity itself was not specified. It would be desired to give a formula for the turbulent viscosity μ_t together with Eqs. (13)-(14). Also, how the turbulent heat flux was calculated?

Chapters 2.3-2.4:

- There is no information what medium flows over the rough plate and between the discs? This information is also lacking in some other chapters. Wherever it is not stated otherwise, the reader should assume that the flowing medium is air.

Chapter 2.5:

- Page 32, line 9: "...will cause a few cells in the normal direction to the wall. " – sentence not finished.

Chapter 3.3:

- Table 1. Could you explain the difference in inlet jet angle and gauge pressure between configurations N6 and N40? It could also be helpful to have pressures at the inlet to the nozzles, and at the outlet from the disc-to-disc space. How does the Tesla turbine reaction change between configurations N6 and N40?

Chapter 4.2:

- How does the porosity α change streamwise and cross-stream? In the form of an algebraic equation?

Chapter 4.4:

- line 7: What does it mean ".. without fine near-wall meshing.." in the context of the $k-\omega$ SST turbulence model used?

Chapter 5.4:

- Validation of results in water could be moved to Chapter 4, since it also appears in paper V.

Chapter 5.5:

- page 51, line 5 from top:, "The ORC is a thermodynamic process..." – expression not precise;
- page 52, line 1-2 from bottom: "...the main flow field is maintained to be constant...," – not precise too;
- Table 3: It could be helpful to have pressures at the inlet to the nozzles, at the inlet to the disc-to-disc space, and at the outlet.
- page 54, line 1 from top: "...advection..." – not precise too;
- page 57, last paragraph from bottom: What do you mean by "...the flow blockage..." or "...the flow blockage causes a reduction in the tangential component and an increase in

the radial component of the velocity..."? Do you mean supersonic flow effects and choke flow (Fig. 14)?

- page 58, line 2 from top: Where do you observe reverse flow in the disc-to-disc space?
- Page 59: Please, explain the difference in velocity patterns for different media?

The selection of citations is appropriate for the scope of the dissertation. Minor mistake – citation 21 is repeated as 60.

4. Final conclusion.

The PhD dissertation submitted for review is characterized by a high level of research and is an original solution to the scientific task. The Author has demonstrated extensive knowledge in the field of turbine flow modelling. The presented results of the dissertation have a utilitarian value as the Author has shown how to increase the disc turbine efficiency. Few comments included in this review do not undermine my high assessment of the dissertation. In conclusion, I state that the PhD dissertation of Mohamaddsadegh Pahlavanzadeh, MSc Eng., meets the requirements for PhD dissertations set out in the Act of 20 July 2018 – Law on Higher Education and Science, and I request that the dissertation be admitted to public defence.

Podpisał Piotr Lampart