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Numerical and experimental study for the selection of Tesla turbine geometry

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Abstract

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One of the greatest challenges of power engineering is ensuring the continuity of electricity supplies. Due to the growing energy demand and emission limits, one of the proposed solutions is the use of distributed cogeneration systems located in the vicinity of the receiver. The key element of such a system is the expander. The Tesla turbine, due to its unique features, can be a cheap alternative to the currently used expanders.

The research presented in the doctoral thesis concerned the selection of geometric features of the Tesla bladeless turbine in order to maximize its performance. This goal was achieved with the use of numerical and analytical methods as well as experimental research. The research carried out on a small prototype of a turbine with a rotor diameter of 73mm and 5 discs allowed a preliminary estimation of the turbine's potential. Experimental tests performed on a compressed air stand allowed the determination of the power and efficiency characteristics, which were used to validate the numerical model. The maximum power of the turbine was 81.9W and its efficiency was 10.8%. The numerical model made with the use of the ANSYS CFX package was characterized by a high degree of complexity. The multi-stage analysis of both the selection of the computational area and the numerical mesh indicated critical places in the model geometry, where more accurate discretization was necessary, as well as areas essential to ensure a stable solution process. Qualitative and quantitative analysis of the influence of turbulence models on the obtained results was performed and the models were validated against the experimental data. Comparison of the turbine performance predicted from the numerical analysis and that obtained from the experiment showed good agreement.

The experience gained from the first stage of the research was used to design and manufacture a new turbine model with 5 discs with a diameter of 160mm. As a part of the work, a new test rig was constructed, operating under atmospheric air supply and negative pressure at the outlet. The measurement system was created on the basis of the LabView software and made it possible to record the most important parameters of the turbine, including power, mass flow rate, temperatures and static pressures in various components of the turbine. The turbine design process used both analytical and numerical methods. The manufactured turbine in the reference configuration had 4 converging nozzles with a minimum cross-section height of 2.85mm and was continuously supplied with air. Its flexible design made it possible to carry out tests with various configurations of the rotor and nozzles. The new numerical model was improved by including a model that takes into account the laminar-turbulent transition in the numerical scheme. The maximum power determined experimentally for the pressure ratio of 1.88 was 126W, and the maximum efficiency was independent of the pressure ratio and totalled 8.3%. Relative differences in power prediction between numerical analysis and experiment were on average 10%, with ideal precision for rotational speeds below 10 000 rpm. The results obtained from the analytical models available in the literature were compared with the results obtained from numerical analyses. The comparison showed a good agreement of the pressure and the peripheral velocity distributions in the models taking into account the compressibility of the medium. Optimization of the turbine was made using a meta-model based on the Kriging method. The objective function was the

efficiency of the turbine, and the optimised variables were: the angle of the nozzles, the minimum cross-section of the nozzles, the inter-discs gap, the rotational speed and the pressure ratio. The statistical analysis confirmed the earlier conclusion that the pressure ratio does not affect the maximum efficiency, therefore this parameter was omitted in the second optimization stage. The highest efficiency for one inter-disc gap was 35%, for the entire numerical model of the turbine it was less than 17%, while the experimental measurement showed 13.8%.

The conclusions from the conducted research allowed defining the critical structural nodes of the Tesla turbine and also allowed the formulation of general hints on how to improve its efficiency.