Contribution ID: **28** Type: **not specified**

Data-Driven Model Selection and Performance Assessment of Solar Chimney Systems Using CFD and Multivariate Analysis

The increasing complexity of engineering systems and the growing demand for sustainable energy solutions require robust data-driven approaches for performance evaluation and decision-making. Solar Chimney Power Plants (SCPPs) constitute a promising renewable energy technology; however, their optimal design remains challenging due to the interaction of multiple physical and environmental variables, as well as external operating conditions.

In this work, we propose a methodology that combines Computational Fluid Dynamics (CFD) simulations with multivariate statistical analysis to support model selection and performance assessment of different SCPP configurations. A dataset is generated from numerical simulations considering key variables such as air velocity, temperature, pressure, and mass flow rate, along with geometric design parameters of the system.

The proposed approach focuses on the joint analysis of multiple performance indicators in order to identify the most suitable configuration under different operating conditions. Statistical techniques, including correlation analysis and multivariate exploratory methods, are used to study the relationships among variables and to evaluate the global behaviour of each design alternative. Additionally, the methodology allows the detection of dominant factors influencing system performance.

In particular, Chernoff faces are employed as an integrative visualisation tool to represent multiple variables simultaneously, enabling an intuitive and comprehensive comparison of competing models. This approach facilitates the identification of patterns that may not be evident through traditional univariate or bivariate analysis.

The results provide a practical and interpretable framework for model selection in complex engineering systems, supporting decision-making based on multiple criteria. This methodology is aligned with current trends in data-driven engineering and offers potential extensions to reliability assessment, uncertainty analysis, and optimisation in other industrial applications.

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Track Classification: Spring Meeting