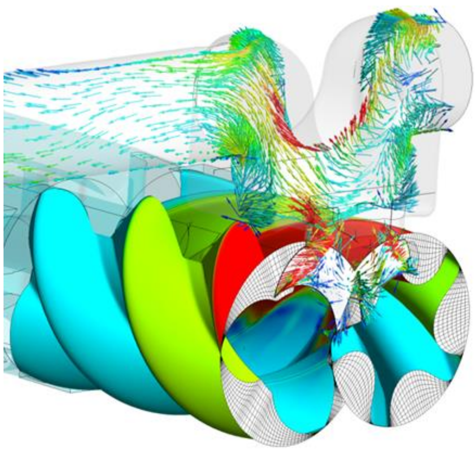
Master Thesis Project proposal

PDE-based grid generation techniques for industrial applications

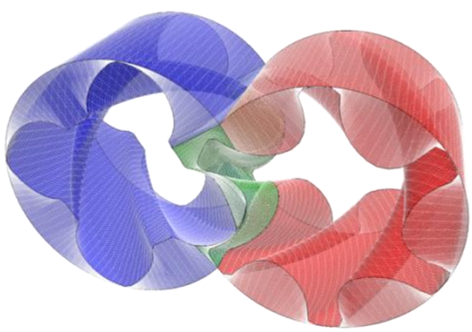
Problem description

Rotary positive displacement machines (PDMs) like the twin-screw rotary compressor shown on the right are widely used in industry to increase pressure of air and other gases, e.g., for large industrial applications such as transport or gas or gas processing, industrial refrigeration, food freezing and storing, air-conditioning chillers or to operate high-power air tools such as jackhammers and impact wrenches. Their widespread utilization makes PDMs particularly attractive for computer-aided analysis and optimization both from an environmental and an economic point of view since even small performance improvements immediately translate to significant savings in terms of energy consumption and CO2 emission.



SCORG™, developed by the Centre for Compressor Technology at City University London and offered as commercial product through PDM Analysis Ltd., is the market-leading software tool for the computer-aided design, analysis and optimization of PDMs. It provides sophisticated grid generation techniques for creating computational grids and interfaces to established simulation packages like Ansys CFX, Star CCM++ or OpenFoam. to investigate the complex and time-dependent flow behavior inside the machine.

Computational grids can be considered a special case of parametric geometry models which have been studied by the Computer-Aided Geometric Design community since decades. In [Hi20], a computational framework for generating high-quality parametric models for rotary twin-screw compressors has been derived and implemented as a proof-of-concept software tool in Python. In short, the parametric geometry model is created by solving a nonlinear second-order partial differential equation (PDE) problem, which determines the position of grid nodes (control points of the parametric model). The main difference to existing PDE-based grid generation approaches is the use of a novel type of numerical method – Isogeometric Analysis (IGA) – which enables unparalleled solution approaches not possible with finite differences and standard finite element methods.



Project goals

The aim of this master project is to integrate the IGA-based grid generation framework into the software SCORG™ and validate it for several type of PDM machines. A prototypical implementation in Python will be provided. Alternatively, the open-source IGA library G+Smo (Geometry + Simulatio Modules) that is developed by the supervisor's group together with colleagues in Europe can be used, which requires the reimplementation of the framework but offers the possibility to explore novel concepts from scratch and focus on the computational efficiency of the PDE-based grid generation procedure which becomes crucial for industrial applications.

Time schedule

The project foresees the following tasks:

1. Familiarization with the mathematical modeling of PDMs based on [Ko06, St05].
2. Familiarization with the basic concepts of Isogeometric Analysis [Co05] and its use in PDE-based parametrization techniques [Hi20] and the references therein.
3. Integration/reimplementation of the PDE-based grid generation framework into SCORG™ and its validation for PDM benchmark profiles. This task includes numerical simulations using Ansys CFX to investigate the suitability of the computational grids for CFD analysis.
4. Application of the developed grid generation framework to hook and claw pumps (https://www.youtube.com/watch?v=0z1zIug6m3M) whose profiles differ from the PDM benchmark and, if necessary, adjustment of the computational framework.
5. Writing of the thesis and presentation of the results.

Contact

For more information about this project contact Dr. Matthias Möller (m.moller@tudelft.nl). The project will be co-supervised by Dr. Rane Sham (sham.rane@pdmanalysis.co.uk) and Prof. Ahmed Kovacevic (A.Kovacevic@city.ac.uk) from City University London. SCORG™ webinars are available at https://pdmanalysis.co.uk/webinar-series/ upon free registration.

Bibliography

[Co05] Cottrell J., Hughes, T., and Bazilevs Y. Isogeometric Analysis: Towards integration of CAD and FEA. Wiley. 2005.

[Hi20] Hinz J., PDE-based Parameterization Techniques for Isogeometric Analysis Applications. PhD Thesis, Delft University of Technology, 2020.

[Ko06] Kovacevic A., Stosic, N., and Smith I. Screw Compressors. Three Dimensional Computational Fluid Dynamics and Solid Fluid Interaction. Springer. 2006.

[Ko13] Kovacevic A., Rame S., and Stocis N. Grid Generation for Screw Compressors with Variable Geometry Rotors. *International Journal of Aerospace and Lightweight Structures* (Vol. 3, No. 2), 2013.

[Mö18] Möller M. and Hinz J. Isogeometric Analysis Framework for the Numerical Simulation of Rotary Screw Machines. I. General Concept and Early Applications. *IOP Conference Series: Materials Science and Engineering* (Vol. 425, No. 1, p. 012032), 2018.

[St05] Stosic N., Smith I., and Kovacevic A. Screw Compressors. Mathematical Modelling and Performance Calculation. Springer. 2005.