Analysis of Screw Compressors and Expanders using SCORG and GT-SUITE

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Agenda

- Introduction into Modelling of screw machines and SCORG
- SCORG – GT Suite integration
- Case studies

Conclusions & Future work

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City, University of London, EPSRC, Howden, Trane, UTRC, Goodrich, Kobelco, PDM Analysis Ltd, Simerics, Star-CCM+, ANSYS, CFX Berlin, Vert, GT, Ferrara University… for support to develop methods for modelling PD screw machines and SCORG.
Screw Machines
Compressors, Expanders, Pumps, Motors
Common Goals in Development of Screw Machines

• Optimize screw machine performance and efficiency
• Minimize internal leakage
• Reduce unwanted noise and pulsations
• Properly size bearing supports in the machine
• Understand how the machine will perform in a surrounding system
• Understand what happens at operating points not found in testing
• Find optimal design in a timely manner for fastest speed to market
• Reduce physical testing to keep development costs low
Mathematical models for calculation of positive displacement screw machines

**Differential methods** based on continuum principles (macroscopic)

A. Thermodynamic chamber model:
   Simple(r), many assumptions made, fast, limited accuracy

B. 3D Computational Fluid Dynamics (CFD) model
   Complex, fewer assumptions, slow(er), gives more detail

C. Integrated models:
   Not as complex as 3D but more accurate than Chamber model

**Differential methods** based on kinetic theory (microscopic)

D. 3D Lattice Boltzmann method
   Solves discrete Boltzmann equation on grid lattice, suitable for parallel computing, multiphase flows and moving meshes
General conservation equation – continuum

\[ \frac{d}{dt} \int_V \rho \phi dV + \int_S \rho \phi (\mathbf{v} - \mathbf{v}_b) \cdot d\mathbf{s} = \int_S \Gamma \phi \text{grad} \phi \cdot d\mathbf{s} + \int_S \mathbf{q}_\phi \cdot d\mathbf{s} + \int_V q_{\phi V} \cdot dV \]
PDM Analysis Ltd is the leader in providing solutions for modelling, analysis and design of rotary positive displacement machines.

- **SCORG™** - modelling platform for positive displacement machines
- PDM Analysis Ltd is Spinout from City, University of London;
- Complete modelling solution for all types of screw machines
- Extensive expertise in design and analysis of screw machines

**SCORG™**

- Screw compressors, expanders and pumps, internally and externally geared machines, vane compressors, expanders and pumps etc...
- CFD analysis of positive displacement machines
- Thermodynamic analysis of all types of screw machines
- Profile calculation, bearing loads, thermal and flow analysis

http://pdmanalysis.co.uk/about-us/
Using SCORG for Screw Machine Development

- **SCORPATH**
  - Rotor Profile Design

- **SCORG™**
  - User profile import & transform
  - Grid generation rotor & port domains
  - Preliminary performance
  - Pre-processing & boundary conditions
  - Force calculation & Boundary mapping

- **CAD**
  - SW, ProE, Catia, AutoCAD, Inventor

- **Test and Manufacture**

- **GT-SUITE**

- **CFD/CCM**
  - Ansys CFX, Pumplinx, StarCCM+, Fluent
Using SCORG for Screw Machine Development

**Module**

### Profile and Geometry Analysis
- Profile Import/Generation
- Profile Editing
- Design of screw machines
- Chamber volume
- Ports and Leakage Areas

### Thermodynamics Chamber Model
- Calculation of Gas Pressure, Temperature
- Calculation of Leakages and Efficiencies
- Calculation of Power and Flow rate
- Calculation of Forces and Boundary map

### 3D Grid Generation and CFD Analysis
- Generation of grids for Rotor domains
- Generation of Grids for ports
- Pre processing for CFD Solvers: Simerics PD, ANSYS CFX, Star CCM+, Fluent, OpenFOAM

**Toolset**

- Different angle setting for radial and axial discharge ports
- Sealing line for measured profiles
- Setting relative/absolute pressure for liquid injection
- Thermodynamic performance with water injection
- Multiple oil injection holes
- Integration with GT-SUITE
- Grid generation for Internally geared Screw Machines
- Grid generation for Vane Machines
- ANSYS FLUENT Parallel UDF

**New features in V5.7**
Process of Calculating Screw machine performance

• Step 1: Use SCORG to setup rotor profile and thermodynamic conditions and generate 1D chamber volume/area/leakage profiles
Process of Calculating Screw machine performance

- Step 2: Calculate performance using SCORG (Option 1)
Process of Calculating Screw machine performance

- Step 2: Calculate performance using GT-SUITE within SCORG (Option 2)

Post-processing is performed within SCORG
Process of Calculating Screw machine performance

- Step 2: Calculate performance using GT-SUITE with SCORG INPUTS (Option 3)

Post-processing is performed within GT-SUITE
Process of Calculating Screw machine performance

• Step 3: Customize GT-SUITE model for additional physics including:
  • Analyse machine in a surrounding system
  • Analyse NVH pulsations
  • Add thermal management model surrounding the machine for optimal cooling strategy
  • Explore drivetrain dynamics
Process of Calculating Screw machine performance

• Step 4: Use bearing load calculation from SCORG to calculate bearing losses in GT-SUITE and perform rotor-dynamics and modal analysis

Bearing forces from SCORG passed as inputs to GT-SUITE detailed bearing models
Case Study: Drum 3/5 Compressor

Oil free Screw Compressor - XK18 3/5 ‘N’ Profile, CD 93

- Main Rotor OD, 127.446mm
- Gate Rotor OD, 120.380mm
- L/D Ratio, 1.6
- Wrap Angle, 306°
- Built in Vi, 1.9
- Displacement: 1787 cm³/rev
- Clearances:
  - Interlobe 170 µm
  - Radial 160 µm
  - End Axial 160 µm
Case Study: Drum 3/5 Compressor
Results of Case Study: Drum 3/5 Compressor

Mass Flow Comparison to Test

Average Mass Flow Rate at PR = 2.375

Bearing load predictions from SCORG at PR = 2.1, 25C Inlet, 6000 RPM
Case Study: Oil-injected 4/6 & 4/5 Compressor

Compressor Case Setup

- Suction temperature: 25 °C
- Suction pressure: 1.021 bar
- Discharge temperature: 76.85 °C
- Discharge pressure: 6, 8, 10, 12, 14 bar (five cases were calculated for each of the profiles)
- Speed: 2925 RPM
- Oil injection: pressure -1.5bar relative to discharge pressure, temperature 61.5°C
- Working Fluid: Air as an ideal gas.

Original 4/6 rotors

Reduced centre distance N profile rotors

N profile rotors

4/5 N profile rotors
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Case study: GL51 twin screw expander (Dortmund University)

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Conclusions

- It is important to calculate performance and optimize screw machines

- SCORG™ multi-chamber thermodynamics, is widely used to calculate screw machines

- SCORG™ unique grid generator allows CFD with Pumplinx, Ansys-CFX, Star-CCM+, Fluent and OpenFOAM,

- **Integrated solution** of SCORG and GT-SUITE offers accurate and fast solution for system integration of screw machines in their system

- **Future activities:** Extend integrated solution with bearing losses, system modelling, examples in automotive application, more collaboration with industry

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Only full-length papers (4 to 8 pages) will be accepted for oral presentation at ISROMAC 18. Accepted papers will be published in the IOP Journal of Physics: Conference Series, a fully indexed and citable open access online journal. Please submit first your abstract (maximum 300 words) in the IOP management system \textcolor{red}{HERE} by registering and using “Submit Abstract”. Guidelines and format for abstract and full paper are provided \textcolor{red}{HERE}. More information can be found in www.isromac2020.com.

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