Reciprocating Compressor Modeling: A Comparison between 3D-FSI and GT-SUITE 1D Simulation Results

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Agenda

• Nidec Global Appliance: Company Overview
• Reciprocating Compressor: Product Overview
• Reciprocating Compressor: 3D Fluid-Structure-Interaction Model
• Reciprocating Compressor: GT-SUITE 1D Model
• Simulation Results: 3D FSI x GT-SUITE 1D
• Conclusions
Reciprocating Compressor: Product Overview

Compressor must compress the fluid refrigerant:
- with less energy consumption as possible
- with high volumetric efficiency as possible
- as quietly as possible
- reliable and safely
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**VOLUMETRIC EFFICIENCY:**
- Noxious Volume
- Discharge Valve Backflow
- Suction Valve Backflow
- Super Heating
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Reciprocating Compressor: 3D FSI Model

Mesh:
- CFD: ~900k nodes, ~470k elements
- FEM: ~2.2k nodes, ~11k elements

Simulation Time:
- 3.0 days
- 4 cycles

HP Z640 Workstation Intel® Xeon® CPU E5-2690 v3 @2.60GHz x2
Reciprocating Compressor: GT-SUITE 1D Model

- **Suction Valve Stiffness**
- **Suction Valve Natural Frequency**
- **Effective Areas of Flow and Force**

- **Discharge Valve Stiffness**
- **Discharge Valve Natural Frequency**
- **Effective Areas of Flow and Force**

**Mechanism Dynamics**

**Fluid Dynamics Domain**
Simulation Results: 3D FSI x GT-SUITE 1D

GT-SUITE 1D Simulation Time:
3 minutes
30 cycles
Intel® Core™ i7-4810MQ CPU @2.80GHz x2
Simulation Results: 3D FSI x GT-SUITE 1D

DOE to identify the design parameters able to solve the problem:
Discharge Valve Stiffness: 4 levels
Discharge Valve Natural Frequency: 4 levels
Total: 16 runs

![Volumetric Efficiency Diagram](image)

![COPind Diagram](image)
Simulation Results: 3D FSI x GT-SUITE 1D

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Volumetric Efficiency

COPind

Target Area
Simulation Results: 3D FSI x GT-SUITE 1D

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Discharge Valve Stiffness: 4 levels
Discharge Valve Natural Frequency: 4 levels
Total: 16 runs

- Current Discharge Valve design
- Feasible points, using current Discharge Valve concept

Volumetric Efficiency

COPind

Target Area

DV Stiffness vs. DV Natural Frequency

DV Stiffness vs. DV Natural Frequency

Current Design

Feasible points, using current Discharge Valve concept
Simulation Results: 3D FSI x GT-SUITE 1D

SOLUTION:
ADD A "BOOSTER VALVE"

3D FSI Reference
3D FSI Proposal

GT 1D Reference
GT 1D Proposal

F (N)

valve lift (mm)
Conclusions and Next Steps

• If calibrated, the CFD 1D simulation with GT-SUITE is able to deliver similar results comparing to 3D Fluid-Structure-Interaction simulation, with much shorter simulation time.

• To calibrate a CFD 1D model, it was necessary to adjust:
  • Suction Effective Areas of Flow and Force
  • Discharge Effective Areas of Flow and Force
  • Suction Valve Damping
  • Discharge Valve Damping

• Next Steps with GT-SUITE Model:
  • Modeling the heat transfer phenomena (on going)
  • Modeling the mechanism for friction losses evaluation (on going)
  • Modeling the mechanism for vibration evaluation
  • Modeling the transient behaviour: start-stop, starting, stalling, pull-down
  • Modeling the real valves geometry: 3D FEM inside GT-SUITE