1D-3D Co-Simulation of an Aircraft Environment Control System

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Credits

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Overview

- Motivation for work
- Reasons to couple 1D-3D
- Developing the Co-Simulation Model
- Results
- Conclusions
Motivation for work

- Investigate the cooling load discharge in the cabin
- Passenger Comfort and Safety
- Working With Aerospace Customers
- Enhancing Virtual Prototyping Capabilities
- Fulfilling customers’/partners’ R&D Initiatives
Reasons to Couple 1D-3D

Benefits:
- 3D CFD and 1D System Models are complementary
- Best of Both Worlds
- Mutually improved Boundary Conditions
- Mutually improved Data Quality and Simulation Results
- Customers want it

Issues:
- Resources
  - Diverse Hardware and Operating System
- Capabilities
  - Support – needs to be highly skilled
  - Co-Simulation – potentially challenging
Developing the co-simulation model

1D – Air Distribution System Modeling

- Analyze large aircraft air distribution
- Evaluate duct re-routing scenarios
- Study mixing of fresh and re-circulated air
- Conduct “what if” scenarios on duct sizing

Enabling

- Understand system interactions
- Help meet passenger flow rate requirements
- Help guarantee proper temperature and pressure

Mass Flow Results (kg s\(^{-1}\))

System Pressures (N m\(^{-2}\))
Coupling 1D and 3D CFD

Best of Both Worlds

3D CFD
- Better technique for modeling larger ‘open’ volumes with complex flows.
- Gives better appreciation of factors affecting passenger comfort

System model
- Fast to set up and very quick to analyze

Method
- Partial CFD Model of Cabin in STAR-CCM+ 4.06.011
- Full ECS system model in Flowmaster v7
- MpCCI 4 Code Coupling Interface
MpCCI Code Coupling Interface

- Open interface through API
- Generic coupling concept
- Flexible mapping workflow:
  - Ramping and under-relaxation
  - Support for dynamic remeshing in code
  - Handling for orphaned nodes
- Flexible coupling schemes
  - Asynchronous buffered communication
  - Subcycling support
  - Coupling on demand
MpCCI Code Coupling Interface

- Abaqus 6.10
- ANSYS 11, 12
- Flowmaster v7
- MD Nastran 2009 R4, 2010
- MSC.Marc 2007r1, 2008r1
- PERMAS 12
- RadTherm 9.1, 9.2
- Samcef (prototype)
- STAR-CD 4
- STAR-CCM+ 4
- other CFD Codes (commercial and research)
MpCCI Coupled Interaction with Tools
ECS Heat Load Simulation

- Volumetric Flow Rate of the Cooling Pack: 0.526 m³/s
- 302.15°K at the inlets
- Heat Transfer Steady State Solution
  - Pressure of 1.2 bar used for 3D CFD initial BC values
Cabin Heat Load Simulation

- Steady state soak period
- Momentum and Energy equations are solved
- 451,481 Tetrahedral Elements
- Cabin is set up to 302.15°K
Cool-Down Simulation

Combine Both Models
- Transient Heat Transfer Simulation
- Cooling Pack Temperature set to 282.65°C
- Time step 1s
- Cool-Down Period 600s

Co-Simulation Quantities
- Inlets:
  - Flowmaster: Temperature and Pressure
  - STAR-CCM+: Mass Flow Rate
- Outlets:
  - Flowmaster: Pressure
  - STAR-CCM+: Mass Flow Rate and Temperature
Co-Simulation results

Averaged Temperature Passenger Cabin

Temperature (K)

Time

288.9°K
Co-Simulation Results

0s

120s
Co-Simulation Results

360s

600s
Conclusions

- Aerospace Applications
- Challenging
- Realistic Simulation Possible
- Changes in 1D Model Affect 3D Model