Thermal Cycle CFD simulation of a Charge Air cooler

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Who are we?

- **Private Sector Program – National Center for Supercomputing Applications @ UIUC**
  - High performance computing – resources, consulting, benchmarking for Industrial users
  - Technical consultancy

- **National Digital Engineering and Manufacturing Consortium (NDEMC)**
  - Public-Private consortium - focusing on providing high-performance impact to small and medium manufacturers.
  - Private investors & Public funds
  - Technical providers - NCSA, Ohio Supercomputer Center, and Purdue University
Objective

- Simulate Thermal Fatigue Cycle test using CFD, FEA and Fatigue Analysis
- Successfully train and educate SME (Small and Medium Enterprises) on Modeling and Simulation
- To reduce physical testing time and expedite product development in SME’s design process
Problem Statement

- Develop methodology and resources to digitally simulate the charge air cooler (CAC) thermal cycle test
- Charge Air Cooler – Thermal stress during operation
- Thermal Cycle test – Required to validate design
- Transient Conjugate Heat Transfer Simulation
  - Solve for Fluid and Solid Temperature
  - Thermal value from CFD can be mapped onto Structural Model
  - Stress induced due to temperature distribution can be calculated using FEA
  - Output from FEA is used for Fatigue Analysis
Simulation Driven Development

- Physical Testing Time – in months
- Simulation Time – Pre-Processing to Post-Processing in weeks
- Possibility to simulate different designs
- Gives better insight about the Physics
Geometry

- Inlet and Outlet Tanks
- Tubes with Fins for Heat transfer
- Air Fins for heat exchange and Headers for Support
Mesh

- Polyhedral and Prism layer mesh for fluid and solid parts
- Extruded the tubes to minimize the mesh size
- Utilized Embedded Thin mesher for thin volumes
- Mesh size is about ~15 million elements
Simulation Setup

- Fluid
  - Unsteady
  - RANS – SST K-Omega
  - Segregated Flow and Temperature
  - Polynomial Density
  - Air

- Solid
  - Segregated Solid Energy
  - Constant Density
  - Unsteady
  - Aluminum
Benchmark

iForge – 2048 Intel Cores

<table>
<thead>
<tr>
<th>CPU’s</th>
<th>Time / cycle (hrs)</th>
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<tbody>
<tr>
<td>16</td>
<td>40</td>
</tr>
<tr>
<td>32</td>
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<td>15.14</td>
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<td>1024</td>
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Results- Temperature Distribution

Solution Time 140 (s)

Solution Time 280 (s)
Results – Velocity Contour

Solution Time 140 (s)

Solution Time 280 (s)
Results – Vector Plot

Velocity Vector Colored by Temp

Solution Time 140 (s)

Solution Time 280 (s)
Results – Streamlines

Solution Time 140 (s)

Solution Time 280 (s)
Cycle-Cycle Comparison - Simulation

Solution Time 140 (s)

Solution Time 420 (s)

Solution Time 280 (s)

Solution Time 560 (s)
Cycle-Cycle Comparison – Experiment

140 Seconds

420 Seconds

280 Seconds
Next Steps

- Transfer Thermal data onto a FEA model using Data Mapper within STAR-CCM+
- Perform FEA Analysis using ABAQUS
- Coupled Fluid-Structure Interaction Analysis using STAR-CCM+ & ABAQUS
- Validation of the CFD model
Acknowledgement

- SME partner for model creation and setup
- OEM Partner and NDEMC for the support
- PSP & NCSA for computational and technical resources
- CD-adapco for meshing tech support
Thank you!