Heat Exchanger and Tank Optimization using ModeFRONTIER

ModeFRONTIER User’s Meeting
Plymouth, Michigan
November 5, 2013
Modine Product Lines

We design, engineer, test, and manufacture heat transfer products for a wide range of applications and markets:

- Light Vehicle
- Off-Highway
- Truck
- Engines
- Building HVAC
- Classroom HVAC
- HVAC&R Coils
Modine Products

- Cooling Modules
- Radiators
- Charge-Air Coolers
- A/C Condensers and Evaporators
- Transmission Oil Coolers
- Hydraulic Oil Coolers
- Power Steering Coolers
- Engine Oil Coolers
- Fuel Coolers
- Exhaust Gas Recirculation Coolers
- Hybrid Vehicle Battery Coolers
- Unit Heaters
- Roof Top Chillers

And few more…
Global Leader in Thermal Management

- Headquartered in Racine, Wisconsin
- FY 2013 revenue of $1.4 billion (fiscal year-end March 31st)
- Employee base of approximately 6,000 in 28 facilities across 15 countries
- Robust intellectual property portfolio with more than 2,400 patents awarded worldwide
- NYSE listed (ticker: MOD)

Vehicular & Off-Highway
- Systems and modules designed to reduce engine/vehicle temperature and capture exhaust for emissions control
- Enhances fuel economy, improves emissions profile and extends engine life

Commercial HVAC
- Efficient heating and cooling equipment that promotes indoor air quality and maintains precise temperature control
- Improves performance and reduces total operating costs

Emerging Technologies
- Significant investments in waste heat recovery, battery chillers, fuel cell and proprietary Origami™ technology platform
- Creates a competitive advantage and improved profitability.
Both the product development process and product quality planning process are part of the V-model for the system development lifecycle.
Modine Technical Centers

North America
- Racine, WI, USA

South America
- São Paulo, Brazil

Europe
- Bonlanden, Germany
- Leeds, England
Modine Technical Centers

- North America
  - Racine, WI, USA

- Europe
  - Bonn, Germany
  - Leeds, England

- South America
  - São Paulo, Brazil

Climatic Truck
Wind Tunnel Testing

Climatic Auto
Wind Tunnel Testing

Calorimeters

Mast Vibration

Pressure Cycle

Thermal Cycle
Integration CAE into Product Planning Process

- Detailed information early in design process
- Reduced experimental testing, design iterations
- Higher levels of reliability & quality
- Major savings in time & cost over traditional build and test techniques
Goals of Virtual Technology Group

Provide information about our products using CAE tools early in the design process to achieve highest reliability and quality with minimum experimental test and prototype builds during the project lifecycle.

<table>
<thead>
<tr>
<th>Physical Testing</th>
<th>Virtual testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicular wind tunnel</td>
<td>✔</td>
</tr>
<tr>
<td>Thermal performance</td>
<td>✔</td>
</tr>
<tr>
<td>Structural testing</td>
<td>✔</td>
</tr>
<tr>
<td>Thermal-cycle testing</td>
<td>✔</td>
</tr>
<tr>
<td>Pressure-cycle testing</td>
<td>✔</td>
</tr>
<tr>
<td>Durability testing</td>
<td>✔</td>
</tr>
<tr>
<td>Acoustic testing</td>
<td>✔</td>
</tr>
<tr>
<td>Corrosion testing</td>
<td></td>
</tr>
<tr>
<td>Chem. &amp; Metallurgical analysis</td>
<td></td>
</tr>
</tbody>
</table>
**ModeFRONTIER as Optimization Tool**

**OPTIMIZATION**

Setting Optimization Forward: Start from the Concept to be One Step Ahead

**COLLABORATION**

The Value of Collaboration in Multi-Disciplinary Design Processes

**INTEGRATION**

Integrating Simulation Tools for an Efficient Optimization Process

**Product Development**

- Platform for next or new generation of Modine products.
- Optimization of geometric parameters to meet heat transfer and pressure drop requirements, reducing weight and cost.

**Product Application:**

- Optimization of geometric parameters to improve flow distribution for certain application.
<table>
<thead>
<tr>
<th>Component</th>
<th>Accomplishments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiator tubes for Commercial Vehicles applications</td>
<td>• CFD/Thermal analysis focused on optimizing dimple pattern of new generation tube to improve performance and reduce pressure drop in narrower (next generation) radiators.</td>
</tr>
<tr>
<td>Turbulators for Radiators and Oil Coolers for Off-highway application</td>
<td>• CFD/Thermal analysis focused on optimizing geometric parameters to improve performance and reduce pressure drop of (next generation) turbulators.</td>
</tr>
<tr>
<td>Spiral Tube for Exhaust-Gas Recirculation Coolers for automotive applications</td>
<td>• CFD/Thermal analysis focused to optimize geometric parameters and determine commerciality of new generation of products.</td>
</tr>
</tbody>
</table>
Component: CAC tank for an Off-highway Customer

Accomplishments:

- CFD/Thermal analysis focused on optimizing vane location and orientation to improve flow distribution inside the heat exchanger.

---

# ModeFRONTIER as Optimization Tool

![Diagram](image)

<table>
<thead>
<tr>
<th>Component</th>
<th>Accomplishments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inlet</strong></td>
<td>• CFD/Thermal analysis focused on optimizing vane location and orientation to improve flow distribution inside the heat exchanger.</td>
</tr>
</tbody>
</table>

---

**1st Proposal**

![Graph](image)

**Optimized**

![Graph](image)
ModeFRONTIER as Optimization Tool

- Typical workflow for component development

Outputs to optimize:
- HX performance, pressure drop, weight and cost.
Goal:
- Heat exchanger optimization based on system/subsystem requirements.

Byproduct:
- Fundamental Research: Using automation to create virtual test data and strengthen our heat transfer and friction factor correlations.
Traditional Process:

- Departmental.
- Few designs to analyze.
  - Time spent in project hand-offs.
  - Optimization is “the best of few” constrained by project timeline.
Modine Target Process:

- Process-oriented.
- Analyst and designer setup workflow in ModeFRONTIER.
  - Design Optimization based on requirements.
  - If time is a constraint: Automation of Smart DOE.
- Future: Analyst to learn CAD synchronous (direct modeling) technology.
<table>
<thead>
<tr>
<th>Physical Testing</th>
<th>Virtual testing</th>
<th>Integration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicular wind tunnel</td>
<td>✓</td>
<td>Next step: Integration with system analysis software</td>
</tr>
<tr>
<td>Thermal performance</td>
<td>✓</td>
<td>Complete: CAD, CFD, and in-house thermal model integration</td>
</tr>
<tr>
<td>Structural testing</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Thermal-cycle testing</td>
<td>✓</td>
<td>Next step: Integration with FEA software.</td>
</tr>
<tr>
<td>Pressure-cycle testing</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Durability testing</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Acoustic testing</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Corrosion testing</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Chem. &amp; Metallurgical analysis</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

- With ModeFRONTIER, the ultimate goal is setting up a complete virtual design verification plan and report (DVP&R) that will speed up the design process.
QUESTIONS?