Analysis of Insulation Structures Applied to Aftertreatment Using GT-SUITE

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Outline

- Drivers for Thermal Management
- GT-SUITE Capabilities
- Skin Temperature Study
- Model Applications
- Conclusions
Drivers for High Efficiency SCR

- In US, on-highway trucks face lower NOx emissions standard
- In Europe, focus is on NOx “RDE” (real-world driving emissions)
- For off-highway equipment, no-EGR engines with higher engine-out NOx are increasingly popular
Thermal Management for SCR

SCR System Needs Heat

- Engine
  - Current Technologies and Strategies
  - Future Technologies
- Exhaust Aftertreatment System
  - Passive Technologies
  - Active Technologies
Capabilities of GT-SUITE

- GT-SUITE includes key aspects of thermal physics
- Aftertreatment module provides for many layers surrounding a component, each with the following parameters:
  - Thickness
  - Temperature-dependent values for thermal conductivity, heat capacity and density
  - Emissivity of outer surface

\[
\dot{Q}_{tot} = \dot{Q}_{CV} + \dot{Q}_{CD} + \dot{Q}_{RAD}
\]
Skin Temperature Study

- Objectives: Validate customer requirements and consider lower-cost design option

- Test details:
  - Natural gas burner and blower
  - Steady-state flow rate with inlet temperatures of 450 or 630°C

- Dual-shell design, with insulating blanket or air gap
Skin Temperature Correlation

- For a given axial position, measured value varies around perimeter
- For model, input layer thickness values and thermal properties for insulating blanket or air
- In general, model validates very well
- Slight under-predicts for air gap design at higher temperature
  - Emissivities set to 0.3; lower value increases skin temperature, but is not reasonable
  - Influence of natural convection in the air gap?
Potential Model Applications

• Requirements definition and design optimization for exhaust components
  – Air-gap fabricated manifold
  – Insulated downpipe
  – Converter, including cones

• Evaluation of alternative system architectures, including close-coupled configurations
• Primary function of mounting mat (MM) is to provide spring force to retain substrate in “inner shell”
• MM is ceramic fiber-based, so also functions as insulation
• “Installed density” of MM is greater than insulating blanket, yet thermal conductivity is equivalent or lower
Example: Mounting Mat Design

• Design for cost reduction:
  – Dual-shell, with air gap (DSAG)
  – Single shell with improved MM
    • Reduced density (a), thermal conductivity (b) or heat capacity (c)
  – Single shell with thicker MM

![Graphs showing skin temperature over simulation time for different materials and conditions, including Reduced MM thermal conductivity and Increasing MM thickness, in mm.](image-url)
Conclusions

• GT-SUITE enables detailed modeling of multi-layered insulation structures on aftertreatment components
• Modeled SCR skin temperatures show good correlation with measurements
• Model is applicable to many thermal management problems:
  – AT component design optimization
  – Thermal management requirements definition
  – Examination of close-coupled architectures
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