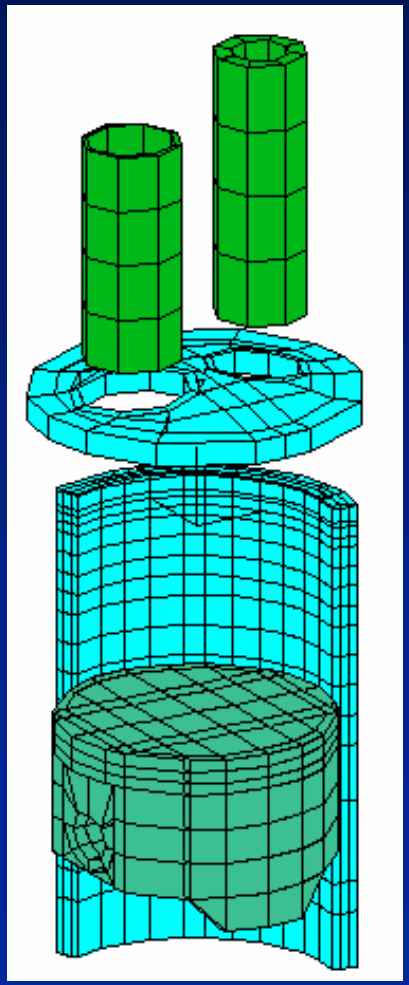
Coupled Engine/Cooling System Simulation and its Application to Engine Warm-up

GT-POWER & GT-COOL

What Is Coupling?

- GT-POWER and GT-COOL link at cylinder component finite element interface
- Allows cylinder wall heat transfer to simultaneously effect cooling system, oil system, and engine performance
- Application of boundary conditions

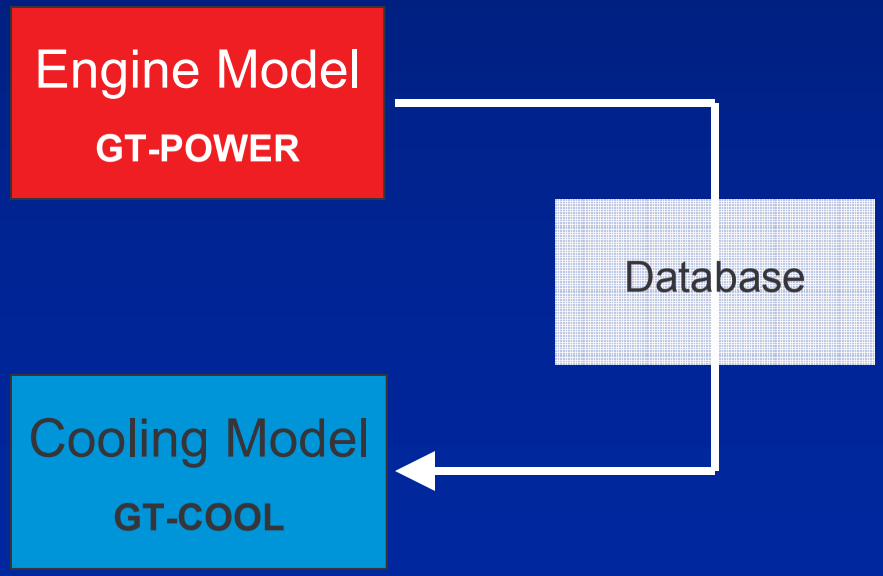


Why Use Coupling?

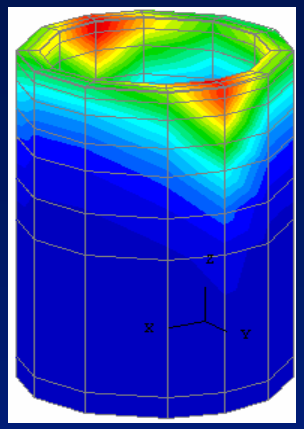
- Study interactions due to engine/cooling system interfaces
  - cylinder structure
  - oil cooler
  - mechanical pump
  - mechanical fan
  - EGR cooler
  - charge-air-cooler
  - etc.
- Evaluate cooling system control strategies
- Study engine warm-up
  - after treatment devices
  - engine performance
- Vehicle test cycle analysis

One-way Coupling

- GT-POWER and GT-COOL models run separately
- GT-COOL uses gas side boundary conditions obtained from a previously run GT-POWER simulation
- In cylinder FE component temperatures solved in GT-POWER and again in GT-COOL



New Objects in GT-COOL



- Engine Cylinder Structural Conduction Object
- Generalization of EngCylTwallSolution
  - Variable resolution 3-D cylinder model added
  - Ports (intake/exhaust) have been added to the solution
- Automated generation of in-cylinder component FE models (just like before in 'EngCylTWallSoln')
- Has pre-defined multiple ports, through which other thermal primitives can be attached (ThermalPipe, ThermalMass, etc.)

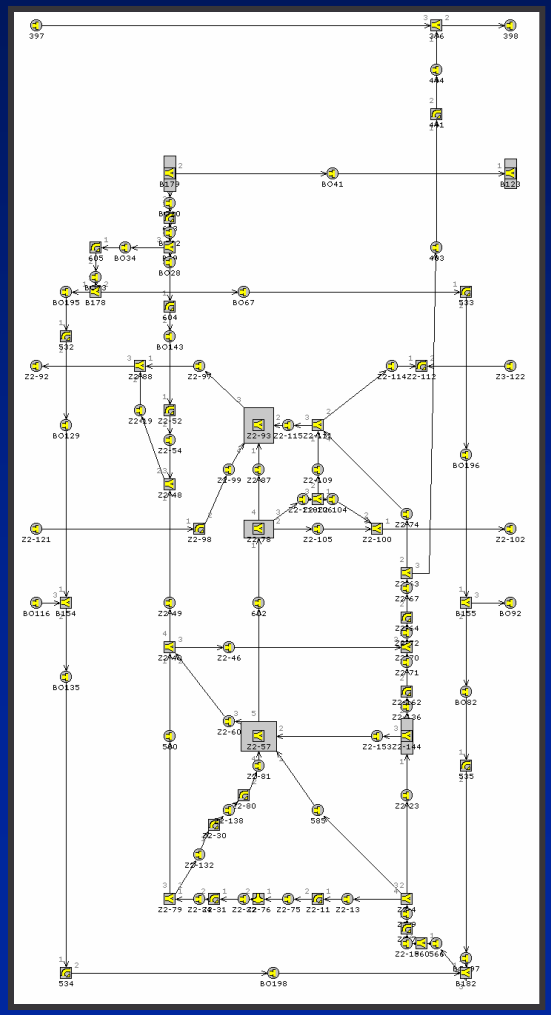
- Engine Cylinder Gas Boundary Conditions Object
- Obtains Gas Boundary Conditions from previously run GT-POWER simulation or from user input

Application to Engine Warm-up in cooperation with DAF Trucks

Application Details

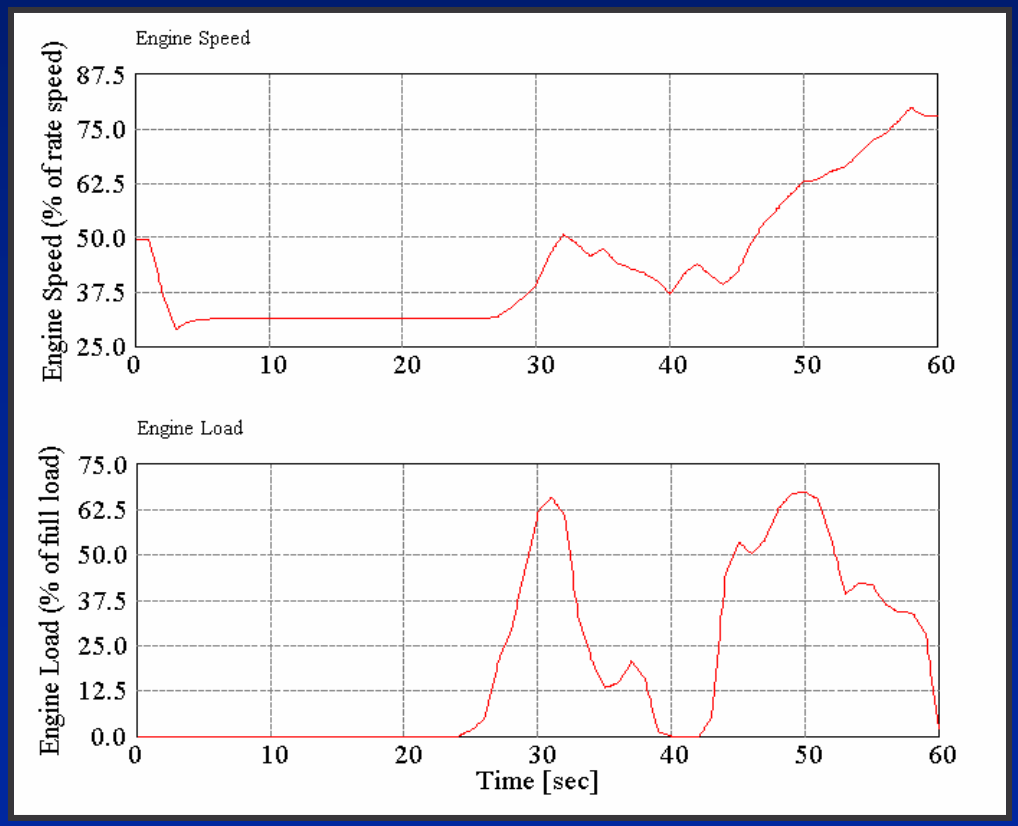
- DAF Trucks 6 cylinder 12.9L turbocharged diesel modeled in GT-POWER
- Cooling system with 1-D approximations to engine block and head coolant passages (calibrated with 3-D CFD)
- Strategy: Accelerate cylinder structure warm-up by increasing exhaust back pressure

Engine block and head coolant passages for one cylinder



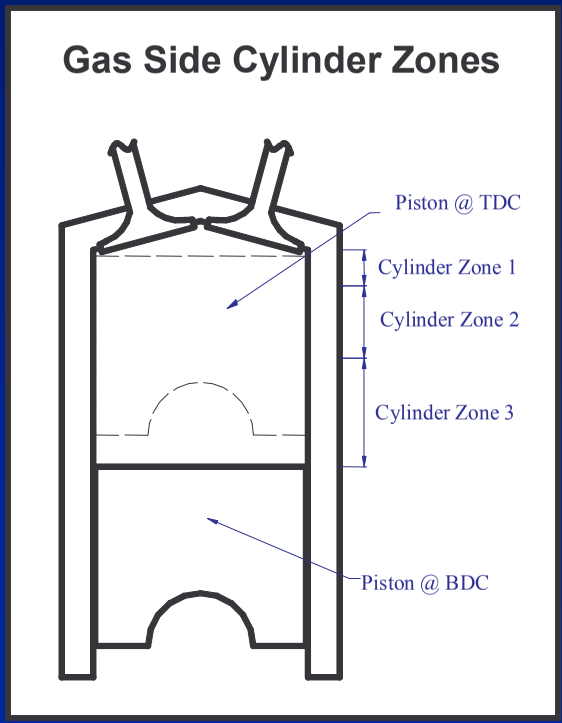
Model Setup

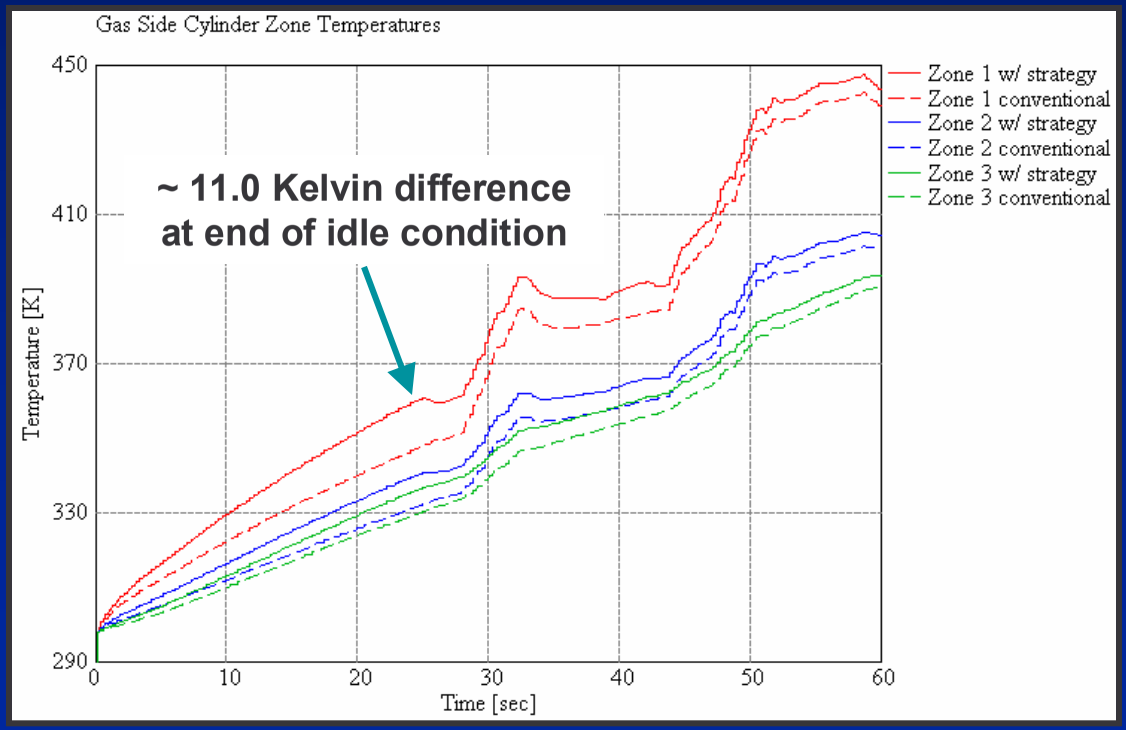
- Simulate engine in GT-POWER over full range of speeds and loads for conventional and increased back pressure cases
- Simulate cooling system in GT-COOL through 60 second cold start transient while referencing engine gas boundary conditions



Gas Side Cylinder Results (I)

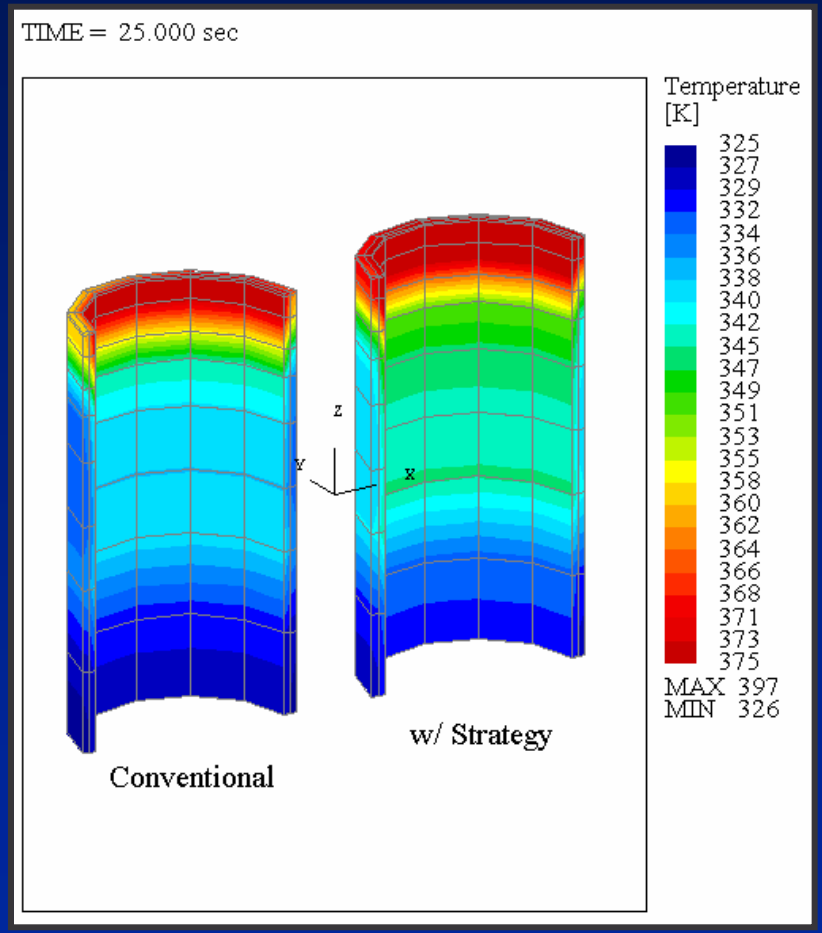
- Temperatures spatially averaged over three zones
- Accelerated warm-up in each zone with increased back pressure





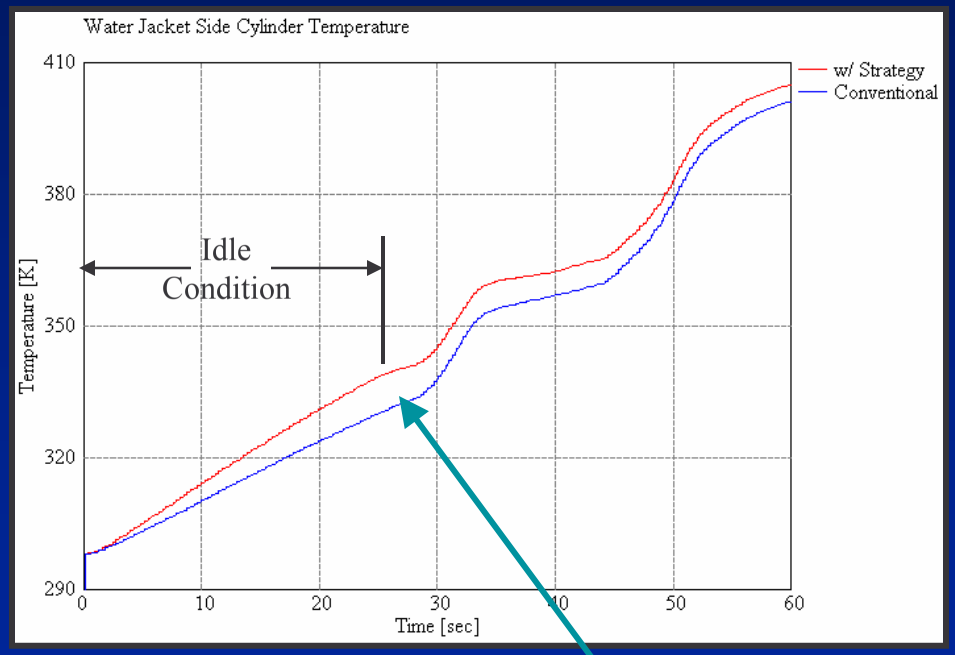
Gas Side Cylinder Results (II)

- Gas side cylinder wall surface temperature at time = 25 seconds
- Higher overall temperature with increased back pressure



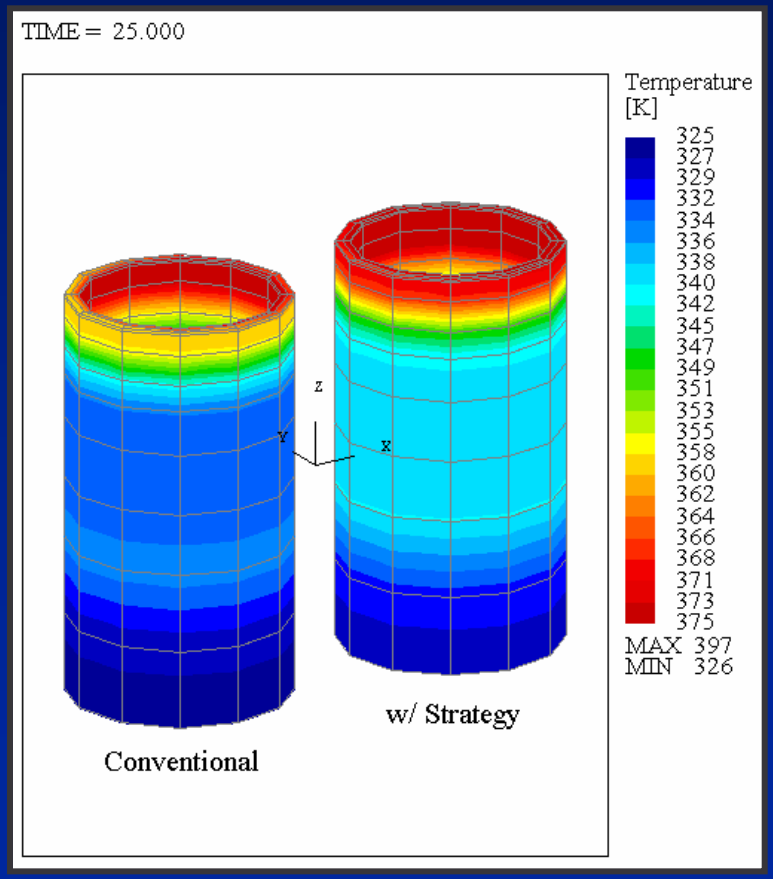
Coolant Side Cylinder Results

Coolant water jacket spatially averaged surface temperature



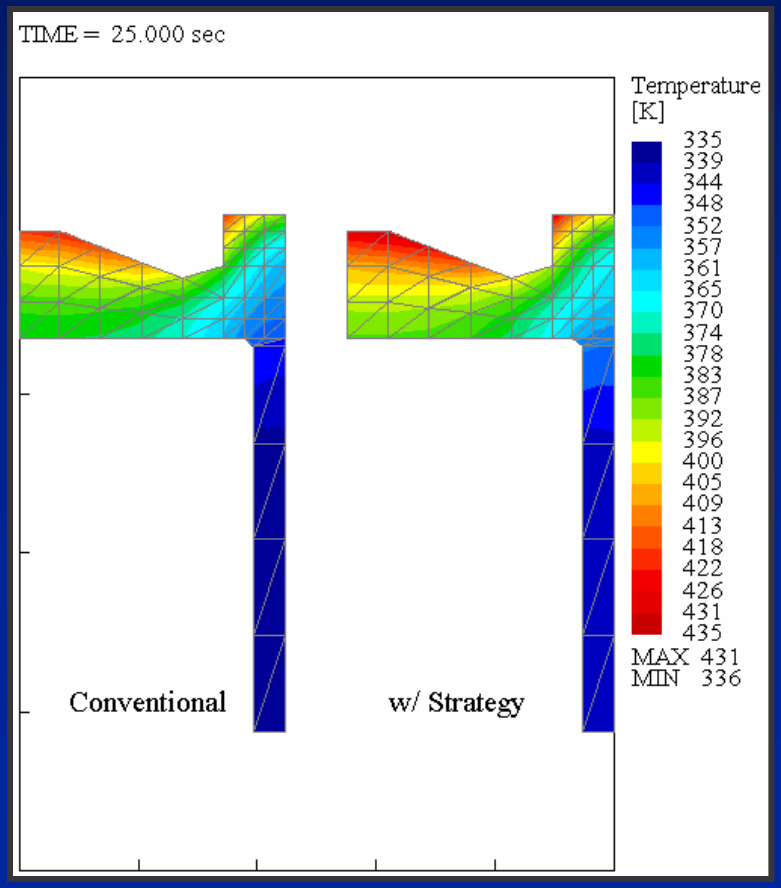
~ 8.0 Kelvin difference at end of idle condition

Coolant side cylinder wall surface temperature at time = 25 seconds

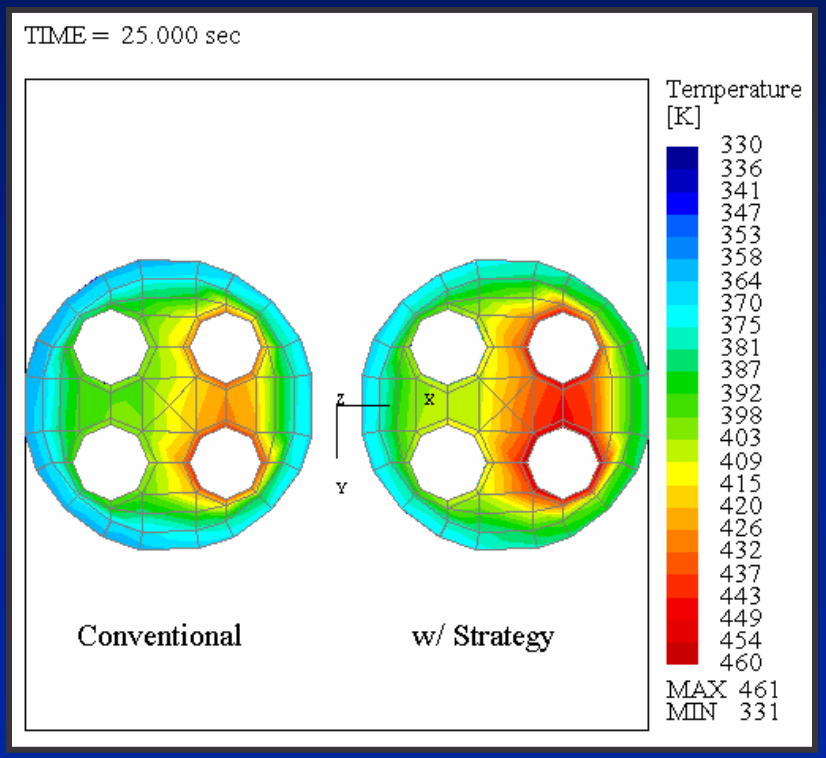


Piston and Head Results

Piston temperature cross-section at time = 25 seconds

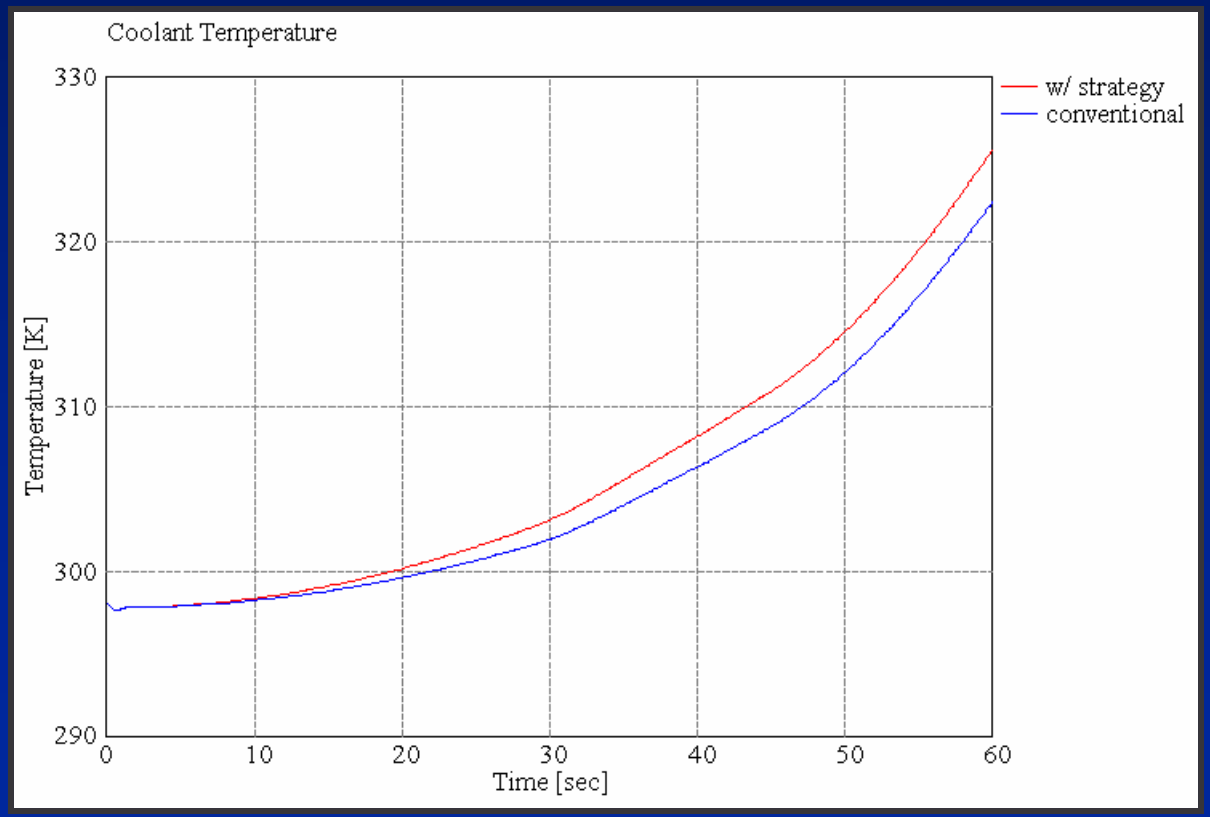


Gas side head surface temperature at time = 25 seconds



Coolant Results

- Engine outlet coolant (water) temperature is ~ 1 Kelvin higher at end of idle condition



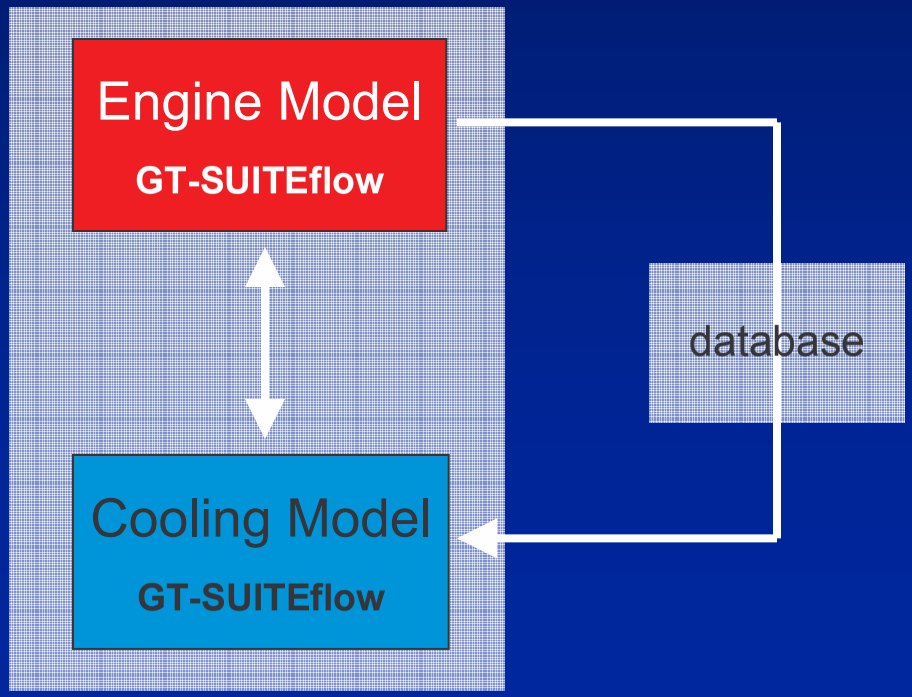
Study Conclusions

- Increasing exhaust back pressure will accelerate cylinder structure warm-up
- The strategy is most effective at idle conditions

Future Versions

Fully-Coupled

- **Fully integrated tool that encompasses the two systems: *Cooling System + Engine System***
- **Gas Side and coolant boundary conditions obtained from same simulation**
- **Cylinder connects directly to structural conduction object**
- **Captures interactions between systems**



Questions?