Standardizing the Next Generation of Military Vehicle Cooling System Simulation

Mary Goryca, US Army Tank-Automotive Research, Development and Engineering Center

Neil Slyva, Flowmaster USA
Standardizing the Next Generation of Military Vehicle Cooling System Simulation

Goryca, Mary Slyva, Neil

USATACOM 6501 E 11 Mile Rd Warren, MI 48397-5000

Approved for public release, distribution unlimited

The original document contains color images.
Agenda

- Process overview
- Current approach to system validation
- Alternative method to system validation
- Method validation process
- Results
- Next Steps
### Process Overview

<table>
<thead>
<tr>
<th>CURRENT APPROACH</th>
<th>ALTERNATE METHOD</th>
<th>VISION</th>
<th>PILOT PROJECT</th>
<th>STRATEGY</th>
</tr>
</thead>
</table>
| To measuring the adequacy of military cooling systems is to conduct vehicle Full Load Cooling tests | Complement the testing process    | Develop and integrate a powertrain cooling simulation capability | MTV  
PIP  
Improve cooling  
Conduct FLC Test  
Capture data | Create a FLC simulation  
Based on vehicle test data  
predict critical fluid temps. |
| Production vehicles  
Controlled laboratory environment  
Simulating field operating conditions | Complement the testing process  
Informed decisions  
Minimize Testing  
Maximize Test Results | Selected a 1D fluid flow analysis commercial software to build the FLC simulation tool | 6x6 Truck  
Multiple variants  
Common Chassis | Validate  
Compare results  
Check accuracy |

- **VISION**
  - MTV  
  - PIP  
  - Improve cooling  
  - Conduct FLC Test  
  - Capture data

- **PILOT PROJECT**
  - 6x6 Truck  
  - Multiple variants  
  - Common Chassis

- **CURRENT APPROACH**
  - To measuring the adequacy of military cooling systems is to conduct vehicle Full Load Cooling tests

- **ALTERNATE METHOD**
  - Complement the testing process  
  - Informed decisions  
  - Minimize Testing  
  - Maximize Test Results

- **VISION**
  - Develop and integrate a powertrain cooling simulation capability

- **PILOT PROJECT**
  - 6x6 Truck  
  - Multiple variants  
  - Common Chassis

- **STRATEGY**
  - Create a FLC simulation  
  - Based on vehicle test data  
predict critical fluid temps.
Current Approach

Products Tested
- Complete Vehicles
  - Combat
  - Tactical
- Powertrains
  - Engines
  - Transmissions & Components
- Radiators
- Air Cleaners
- Grilles
- Roadwheels/Tires

Testing Services
- Qualification/Acceptance
- Performance/Durability
- Research/Development
- Evaluation of Field Problems
- Product Improvement Programs

Test Capabilities
- Vehicle Tests
  - Full Load Cooling
  - Fuel Consumption
  - Heat Soak
- Performance Tests
  - Engine
  - Transmission
  - Radiator
  - Air Filter

Propulsion Systems Laboratory

06CV-190
Current Approach

Powertrain cooling tests conducted on tactical & tracked vehicles

Unique environmentally controlled test chamber
50 ft high x 80 ft in dia
Ambient Air up to 160°F

Solar Radiation 355 Btu/hr-ft²
Dynamometer Absorption up to 70,000 ft-lb per side
Air Flows ≤ 20 mph

Monitor critical temps to ensure they are within allowable limits.
Two main tests evaluate vehicle cooling systems.

**FULL LOAD**
- Ambient Air = 120°F
- High Load
- Low Engine Speed
- Coolant = 50/50 Ethylene Glycol/H₂O

**FULL POWER**
- Ambient Air = 120°F
- Low Load
- Max. Engine Speed
- Coolant = 50/50 Ethylene Glycol/H₂O
Alternative Method

Vehicle Based

- Multiple Variants
- System Improvements
- Additional Components

Current Challenges

Test Limitations

- Schedule
- Budget
- # Tests

Fast and Accurate Cost Effective Tool

Accurately Predict Vehicle Critical Temps

Vehicle Based

SAE®
Alternative Method

Software Criteria

- User friendly, fast and accurate
- Cooling components advanced and ready to use
- Simultaneous solving of component solutions
- 3D visualizing capability
- Cost effective
- Fully supported and routinely updated
- Steady state and transient capabilities
Pilot Project - Medium Tactical Vehicles

Commonality
- Chassis
- Drive Train
- Spare Parts
- Tools

Differences
- Payloads
- Mission Requirements
- TAC Design
- TAC Location

Common Chassis
- M1083 Cargo Truck
- M1098 Wrecker

Material Handling Equipment
- M1090 Dump Truck

Load Handling System
- M1087 Expandable Van

MTV

M1088A1 Tractor

06CV-190
Pilot Project - MTV Test Matrix

Conventional methods only allowed 40% of the desired results to be captured within this test matrix.

Several Configurations:
- Radiator/Fan (Base/Replacement)
- Air Conditioning (on/off)

Multiple Variants:
- Cargo
- X-Van
- Wrecker
- Dump

A Range of Tractive Effort/Weights in high ambient temperatures
Full Load Cooling System Simulation

Objectives

- Create a FLC system simulation based on vehicle test data that predicts critical fluid temperatures.
- Validate and compare simulation results with test results.
- Use simulation to complement testing.
Full Load Cooling System Simulation
FMTV Fluid and Thermal Systems

Engine Coolant System

Air Conditioning System

Engine Oil System

Transmission Oil System
Thermal system interaction:
Full Load Cooling System Simulation 1-D System Model Set Up
Full Load Cooling System Simulation 1-D System Model Inputs

System Boundary Conditions

Ambient Conditions

Heat Exchanger Performance

Engine Drive Components

Engine Heat

CAC

Radiator

Water Pump

Aux TOC

TOC

06CV-190
Full Load Cooling System Simulation Comparison with Test
Full Load Cooling System Simulation - Coolant Temperatures

Coolant Temp at 0.6 TE/WT - Vehicle #1

Coolant Temp at 0.55 TE/WT - Vehicle #2

Coolant Temp at 0.55 TE/WT - Vehicle #3

Coolant Temp at 0.55 TE/WT - Vehicle #4
Full Load Cooling System Simulation - Air Temperatures

- **Air Temp at 0.6 TE/WT - Vehicle #1**
  - Test: 116°F
  - Simulation: 116°F

- **Air Temp at 0.55 TE/WT - Vehicle #2**
  - Test: 110°F
  - Simulation: 110°F

- **Air Temp at 0.55 TE/WT - Vehicle #3**
  - Test: 105°F
  - Simulation: 105°F

- **Air Temp at 0.55 TE/WT - Vehicle #4**
  - Test: 110°F
  - Simulation: 110°F
Full Load Cooling System Simulation - Oil Temperatures

Oil Temp at 0.6 TE/WT - Vehicle #1

116°F Test  116°F Simulation

Oil Temp at 0.55 TE/WT - Vehicle #2

110°F Test  110°F Simulation

Oil Temp at 0.55 TE/WT - Vehicle #3

105°F Test  105°F Simulation

Oil Temp at 0.55 TE/WT - Vehicle #4

110°F Test  110°F Simulation
Next Steps - Additional Variables

- **Performance**
  - Equal or better than existing exchanger under same operating conditions
- **Variable Geometry**
  - Height, width, and depth
- **Variable Location**
Next Steps - Performance Characteristics

Charge Air Cooler Nusselt Number vs. Re12 vs Re34 V3

CAC Nu v Re1-2 v Re3-4
Next Steps - Automated Approach
### Next Steps - Results

#### Top Tank Temperatures

<table>
<thead>
<tr>
<th>Heat Exchangers</th>
<th>Vehicle A</th>
<th>Vehicle B</th>
<th>Vehicle C</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>180°F</td>
<td>200°F</td>
<td>210°F</td>
</tr>
<tr>
<td>Y</td>
<td>180°F</td>
<td>200°F</td>
<td>210°F</td>
</tr>
<tr>
<td>Z</td>
<td>180°F</td>
<td>200°F</td>
<td>210°F</td>
</tr>
</tbody>
</table>
Next Steps - Observations

- Simulation accurately represents cooling system performance
- Thermal simulation simplified complex interactions
- Initial validation process utilized:
  - Pre-processed component test data
  - Comprehensive vehicle test data
- Process enables rapid and accurate analysis
  - Heat exchanger options
  - Multiple vehicle variants
- Validating process for future heat exchanger evaluation
Thanks for attending!

Questions?

Mary Goryca, US Army Tank-Automotive Research, Development and Engineering Center

Neil Slyva, Flowmaster USA