Development of thermal system simulation for HEV
(Thermal Management Analysis with Air-Conditioner)

NISSAN MOTOR CO., LTD.  Masaaki Kubo
Tsuyoshi Yamamuro

RENAULT NISSAN TECHNOLOGY &
BUSINESS CENTRE INDIA Pvt LTD  Raghu Vamsi
Kodaboina
1. Background and Motivation of this Work
2. Overview of Simulation Model
3. Validation Results
4. Effect of Sub Components
5. Effect of Heat Recovery System
6. Conclusions
Important to make correct decisions during the planning phase of a vehicle to avoid repetition and extra cost during development phase.
Background and Motivation

- Version 2: Integration of A/C and Heater model with Thermal Management model, to study more realistic condition

- Drive System
- Control System
- Energy
- Transmission
- Engine System
  - Lubrication
  - Structure
  - Friction
  - Combustion

- Air Conditioning System
- Battery System
- High voltage cooling system
- Cooling system
Contents

1. Background and Motivation of this Work
2. Overview of Simulation Model
3. Validation Results
4. Effect of Sub Components
5. Effect of Heat Recovery System
6. Conclusions
Overview of Simulation Model

**Input**
- Vehicle speed

**1D model for predicting electric & fuel consumption**
- Engine torque & speed
- Vehicle speed
- Engine oil temperature
- Engine water temperature
- T/M oil temperature
- ENG/TM friction
- Electric power consumption of each parts

**Output**
- Electric consumption & Fuel consumption
  - Oil & Water temperature
  - Temperature of each parts

- Motor torque & speed
- Vehicle speed
- Engine oil temperature
- T/M oil temperature

**1D model of cooling system for high voltage parts**
- Water temperature
- Temperature of each parts

NISSAN
Overview of Simulation Model

**Input**
- Vehicle speed

**Output**
- Cabin temperature
- Refrigerant temperature
- Compressor power loss
- Electric consumption & Fuel consumption
- Oil & Water temperature
- Temperature of each part
- Water temperature
- Temperature of each part

Models:
- 1D model of Cabin
- 1D model of Air Conditioner system
- 1D model for predicting electric & fuel consumption
- 1D model for cooling system for Engine & T/M
- 1D model for cooling system for high voltage parts
Evaporator (cooler) is connected to the HVAC & Heater Core (Heater),
An Auto setting model to control temperature is already implemented in
the model predicting the cabin temperature
Over View of Engine Thermal Model

- Engine structure is finely divided and the contact surface is where heat capacity & thermal conductivity is set. Heat is generated in the model by Engine cooling loss, Engine and transmission friction loss.
- Heat from engine is utilized by connecting heater and cabin in this model.
Contents

1. Background and Motivation of this Work
2. Overview of Simulation Model
3. Validation Results
4. Effect of Sub Components
5. Effect of Heat Recovery System
6. Conclusions
Validation Results of A/C & Cabin Model (Cooling Condition)

Better accuracy of cabin temperature is observed due to detailed configuration of each component.
Validation Results of Thermal Management Model

Model is tested for LA4 Cold Mode as driving cycle and in high speed climbing mode

LA4 Cold Mode

Hill Climbing Mode

Better accuracy between the simulation and the measured data was observed for different driving conditions
Validation Results of Heater & Cabin Model (Heating Condition)

Better accuracy is achieved in heater and cabin model

Heating test

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient temperature</td>
<td>0 degC</td>
</tr>
<tr>
<td>Humidity</td>
<td>50%</td>
</tr>
<tr>
<td>Blower setting</td>
<td>Full power</td>
</tr>
<tr>
<td>Cabin condition</td>
<td>Fresh air</td>
</tr>
<tr>
<td>Driving mode</td>
<td>Vehicle speed 40km/h</td>
</tr>
</tbody>
</table>

Heating test

- Air of heater outlet
- Cabin

Better accuracy is achieved in heater and cabin model
Contents

1. Background and Motivation of this Work
2. Overview of Simulation Model
3. Validation Results
4. Effect of Sub Components
5. Effect of Heat Recovery System
6. Conclusions
Effect of AC System

- Heat dissipation from condenser has significant effect on the engine coolant temperature

<table>
<thead>
<tr>
<th>Cooling test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient temperature</td>
</tr>
<tr>
<td>Humidity</td>
</tr>
<tr>
<td>Blower setting</td>
</tr>
<tr>
<td>Cabin condition</td>
</tr>
<tr>
<td>Driving mode</td>
</tr>
</tbody>
</table>

![Diagram showing temperature changes with A/C on and off for engine coolant and transmission oil](image)
1. Background and Motivation of this Work

2. Overview of Simulation Model

3. Validation Results

4. Effect of Sub Components

5. Effect of Heat Recovery System

6. Conclusions
Effect of Heat Recovery System with Nissan’s After Treatment model is simulated for Fuel Economy
Effect of Heat Recovery System

Changing the location of the Heat Recovery System has immediate effect on the emissions
Contents

1. Background and Motivation of this Work
2. Overview of Simulation Model
3. Validation Results
4. Effect of Sub Components
5. Effect of Heat Recovery System
6. Conclusions
Conclusions

- Thermal Management Model, A/C Model and Nissan’s After Treatment Model are all integrated together and simulated using one software tool – GT Suite

- Simulation results agreed relatively much with the experimental results on comparison

- Thermal devices like HRS can be integrated to this model

- Position of HRS after the catalyst is the better location for better emission control and fuel economy is not so much affected
Thank you for your attention