Coupled Simulation of Air Conditioning & Engine Cooling System

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Concept of coupling

Why a coupled Simulation?
Independent System Models

1. Engine Cooling System
   a) The amount of heat released by Condenser into air is assumed

2. Air Conditioning System
   a) Air Mass Flow Rate from ECS simulation
   b) The amount of heat released by Condenser into air is different from 1a)

Goal – To remove assumptions and use real time air mass flow rate and amount of heat released by condenser
**Concept of coupling**

**Coupled Systems Model**

1) Real time air mass flow rate to Condenser effects the air conditioning system
2) Real time heat amount released by Condenser into the air effects the Radiator and Low Temperature cooler
System Model - Underhood Model

- Condenser
- Low Temp. Cooler
- Radiator
- Fans
System Model – Air Conditioning System Model

R1234yf

CONDENSER
connection

INTERNAL_HEAT_EXCHANGER_LOW_PRESSURE

INTERNAL_HEAT_EXCHANGER_HIGH_PRESSURE

TXV_Control

EVAPORATOR

PhTsDiagram

System_Init
Defined Boundary Conditions

- Pulldown driving cycle
  - Pre conditioning for 1 hour at 40°C
  - 32 km/h for 30 minutes
  - 0 km/h or stationary for 15 minutes

Cabin Temperature at Head Level

![Graph showing temperature over time](graph.png)
Calibration of Components: Air Conditioning System

1) Condenser
   - Characteristic map generated. Calibration factors according to this map
   - Testbench Calibration, within 3% deviation

2) Evaporator with Expansion Valve
   - Thermal Expansion Valve and Evaporator calibrated on a single testbench
   - TXV achieves target superheat, Evaporator calibration factors controlled by user
   - Pressures – within 5 %

3) Compressor
   - Characteristic map generated with pressures, refrigerant mass flow rate and rotation speed

4) Internal Heat Exchanger
   - (same process as in Condenser)
Calibration of Components: Engine Cooling System

- Radiator
- Low temperature cooler for Charged Air
- Auxiliary coolers
- FAN - Pressures & Rotation Speed as boundary conditions, Air Mass Flow Rate maximum deviation = 0.05 kgps

*(All coolers calibrated on testbench as in Condenser)*
Results

Air Temperature after Evaporator – Deviation max. 2°C
Evaporator Power- 5.2kW(max)
Results

High Pressure – max. deviation 5%

Condenser Refrigerant Entry Pressure (System High Pressure)
Results

Low Pressure – max. deviation 3%
Results

Radiator Coolant Entry Temperature – Deviation max 2.5%

Radiator Coolant Entry Temperature

Temperature [°C]

Time [s]

Measurement
Simulation
Results

Auxiliary Cooler Right Coolant Entry Temperature
Max deviation 2.5%
Results

Low Temperature Cooler for Charged Air - Coolant Entry Temperature

Maximum deviation 2.5%
Results

Auxiliary Cooler Left – Maximum deviation 2.5%

Left Auxiliary Cooler Coolant Entry Temperature

Temperature [°C]

Time [s]

Measurement

Simulation
Summary

- Good results achieved with a deviation of 6% in results in the air conditioning system model and that of 3% in the engine cooling system model
- User friendly Post-processing tool
- Easy System initialisation
- Simulation Time: 2 hours 21 min
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