Innovative Air Conditioning for Hybrid and Electric Vehicles

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Summary

- Scenario
- Air Conditioning and Thermal Comfort
- New automotive air conditioning concepts
- Inversion Cycle Heat Pump
  - System lay-out & design
  - Prototype development
  - Test results
  - Conclusion & Next Steps
- Compact Refrigeration Unit
  - System lay-out & design
  - Prototype development
  - Test results & Performances
  - Conclusions & Next Steps
- Integrated vehicle thermal management
Scenario

The worldwide scenario of road transport is moving towards a new generation of vehicles with very low CO$_2$ emission, where the powertrain and auxiliary electrification plays a key role.

In this context the vehicle auxiliaries systems will be redesigned to assure:

- Same or even higher performance
- Higher energy efficiency
Air Conditioning & Thermal Comfort

The Heating, Ventilation and Air Conditioning assure:
- Deicing
- Defogging
- Thermal comfort

Thermal engine
- heating power normally available

Electric or Hybrid traction
- thermal energy lower or totally missing

Energy-demand of the system (B-segment vehicle):
- 6 kW of heating power air @ 60 °C
- 4 kW of cooling and dehumidification air @ 5 °C
- 0.8 kW for heat rejection 1500 m³/h
- 0.5 kW for ventilation 500 m³/h
New automotive A/C concepts

Heat pumps are devices designed to move thermal energy from two heat sinks in both directions. This allows the heat pump to provide both the heating and the cooling function if installed on a vehicle. CRF has investigated two different approaches to realize this kind of A/C system:

1. **Refrigerant Cycle Inversion:**
   Heat pump can work as a standard A/C system or, thanks to a cycle inversion valve, in the opposite way

2. **Coolant Flow Inversion:**
   The refrigerant cycle works always in the same way while, thanks to water cooled heat exchangers, hot and cold water are used for cabin comfort in all seasons
Inversion Cycle Heat Pump

Same SP dashboard heat exchanger

Plate Heat Exchanger

Electric Compresso
Inversion Cycle Heat Pump
System Lay-out & Design

A/C MODE
The coolant loop can be used also for cooling the electronic circuits.

HEAT PUMP MODE
The coolant loop allows the heat transfer from the power electronics into the cabin.

ON/OFF TXV
Two on/off TXV have been used. The coil allows to optimize the expansion function in both directions, switching off the circuit branch when not in use.
Inversion Cycle Heat Pump
Prototype Development

CAD STUDY ➔ HEAT PUMP INSTALLATION ➔ ENGINE BAY INSTALLATION E/E WIRING
Cool Down Test

Energy Consumption: 2 kWh

A/C Conditions:

- Max Cold
- Maximum blower speed
- Vent distribution
- Recirculation

Climatic chamber condition: T = 40°C ; R.H. = 50%

BETTER THAN THE STANDARD PRODUCTION PERFORMANCE
Inversion Cycle Heat Pump
Tests Results (2/2)

Warm Up Test

A/C Conditions:
- Max Hot
- Maximum blower speed
- Floor distribution
- Recirculation

Test Condition: 1h @ 50 [km/h]

Climatic chamber and cabin start-up condition: T = 0°C

QUITELY COMFORTABLE CONDITION WITHOUT HEAT SOURCE!

[Graph showing temperature changes over time with different mean values and conditions]
Inversion Cycle Heat Pump
Conclusions & Next Steps

- Dual Loop Approach → Water Cooled Condenser
- System ready to cool others auxiliaries
- More compact layout
- Reduced refrigerant charge up to 40%
- Performances in A/C mode better than the Standard mechanical system
- Performances in HP mode lower than the standard mechanical system but quite comfortable cabin temperature without heat source
- Good COP and electrical power consumption managed by the energy saving strategy → impact on the autonomy around 20%.

NEXT STEPS

- Heat pump optimization → dehumidification management
- New ethanol heater used as an heat pump range extension
Compact Refrigeration Unit (CRU)

- Cold coolant
- Intermediate Heat Exchanger
- Thermostatic Expansion Valve
- Water Cooled Condenser
- Hot coolant
- A/C compressor

CRF patent EP1990221
Compact Refrigeration Unit
System Lay-out & Design (1/2)

CRU POWERED BY
MECHANICAL COMPRESSOR

DENSO

CRU WITH INTEGRATED
ELECTRIC COMPRESSOR

MAHLE
Compact Refrigeration Unit
System Lay-out & Design (2/2)

- Optimized pipes lay-out
- Plate heat exchangers
- IHX

- New TXV position \(\rightarrow\) optimized SH
- Pre-charged and seal system
- Optimized refrigerant charge
- Electric compressor
CRU test & performances

CRU Cool-down test performance

A/C HP reduction:
- Driving – 4 bar
- Idling – 8 bar

Fuel Consumption Results (NEDC cycle @ 28 °C, 50% r.h.)

Fuel consumption with A/C ON: – 3%
A/C Fuel over consumption: – 30%

Air-to-Derating (ATD) index

Increase of ATD index:
- IVECO TARGET: > 40°C
- Standard Production: 44 °C
- TIFFE: 49 °C (ΔT = +5 K)
Integrated Vehicle Thermal Management

Concept with dual loop cooling approach
Integrated Vehicle Thermal Management

Refrigerant Loop
Integrated Vehicle Thermal Management

High Temperature Coolant loop
Integrated Vehicle Thermal Management

Low Temperature Coolant Loop
Integrated Vehicle Thermal Management

Cabin Coolant Loop
Integrated Vehicle Thermal Management

Batteries Coolant Loop

Coolant Temperature: mix

Diagram showing various components and flow paths in a vehicle thermal management system, including EXP VASE, LT RAD, HT RAD, ENGINE, WCAC, INV, Drive Line, BATT, WCND, IHX, CHL, AIR Cooler, RISC, and CMP.
Integrated Vehicle Thermal Management

On-Board Installation
Compact Refrigeration Unit
Conclusions & Next Steps

- CRU is a promising solution in order to have **cold water** and **hot water** available for auxiliaries thermal management
- Dual loop integrated approach allow to manage the auxiliaries thermal load using **only one LT radiator on the front end** → **Overhang reduction**

**NEXT STEPS**

- **Test on the CRU used as an heat pump** without refrigerant cycle inversion
- **Test on the integrated thermal management system**
Contacts

Thank you!

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