Simulation of the Interior Cabin
Warm-up and Cool Down using CFD

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Overview

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Introduction

• Climate system controls the cabin interior environment
• Aim to keep the occupants comfortable
• Deliver correct air flow and temperature
• Warming up
• Cooling down
• Reach occupant comfort levels as soon as possible
Introduction

• To predict comfort accurately you have to model the thermal behaviour in the cabin
• Modelling of the cabin thermal behaviour is a complex problem
• CFD provides a credible tool to solve such problems
• It allows designs to be readily analyzed through STAR-CCM+
• Enables reduced vehicle programmed timing to be met
• This work is aimed at providing the foundations to develop a full comfort model
• This study will focus on the cabin warm-up and cool down
Modelling

- The model was based on a Freelander 2

- The models are set up in accordance with the following:
  - Maximum warm up
  - Maximum cool down

- Experimental measurements were made in the Climatic Wind tunnel
Modelling

Geometry Used for Warm-up Simulations
Modelling

Maximum Warm-up

• A standard max warm-up test in the climatic chamber at -18°C
• The test is run at 50kph, 100kph and 0 kph in 30 minute intervals
• Transient model to simulate the warm-up from time zero to 90 mins
• CFD model was developed to simulate the transient thermal behaviour
• Heat Transfer Coefficients (HTC) calculated based on wind speed, materials, etc
• HTC are varied over time to match the different vehicle conditions
• Inlet temperatures are varied with time and are based on the measured values
Modelling

Maximum A/C Pulldown

- Modelled a standard max A/C Pulldown test in the climatic chamber at 43°C and a solar load of 1000W/m².
- The test is run at 50kph, 100kph and 0 kph in 30 minute intervals.
- Transient model to simulate the warm-up from time zero to 90 mins.
- Heat Transfer Coefficients (HTC) calculated based on wind speed, materials, etc.
- HTC are varied over time to match the different vehicle conditions.
- Inlet temperatures are varied with time and are based on the measured values.
Modelling

Maximum A/C Pulldown

• The thermal solar load soak was simulated to obtain realistic initial conditions
• The simulation was run until an average interior temperature of 60°C was achieved
• This will provide the correct initial temperature profile in the cabin

Initial temperature field in the cabin - Driver side section
Modelling

Maximum Warm-Up

• Computational mesh consisted of approximately 3 million Polyhedral cells

• 2 prism boundary layers on the fluid regions
Results

The plots show strong air flow movement in the footwell areas. The low velocity regions appear in the middle of the IP and towards the rear parcel shelf before exiting the cabin.
Results

Initial temperatures are high from the ducts. Steadily reduce as the flow enters the cabin and dissipates.

Coolest regions appear at the rear of the cabin near the parcel shelf and recesses of the rear seats. Regions of low flow. Lower temperatures also near the windows.

Temperature Streamline plots at time 5220 seconds
Results

Temperature contour plots over time

Solution Time 600 (s)

Solution Time 1800 (s)

Solution Time 1200 (s)

Solution Time 2400 (s)

10 minutes

30 minutes

20 minutes

40 minutes
Results

Temperature contour plots over time

60 minutes

80 minutes

70 minutes

90 minutes
Results

Comparison of Measured and Predicted Temperature Profiles

The comparison of the temperatures shows there is good agreement between the test and simulation. The worst case is never more than 5°C.

The predictions for initial 15 minutes for the driver are slightly high but the trends are very good over the time period of the test.
Results

Solution Time 10 (s)

Warm-up Temperature Profiles
Results

The plots show strong air flow movement in the region of the driver and front occupants heads. The flow reduces in the rear of the cabin and there is almost stagnant flow around the parcel shelf.
Results

Warmest regions appear at the rear of the cabin near the parcel shelf. The front half of the cabin is cooler due to the high flow and concentration of the vents towards the front occupants.

Temperature Streamline plots at time 5400 seconds
Results

Temperature contour plots over time

10 minutes

60 minutes

30 minutes

90 minutes
Results

The predicted trends of the temperatures is good. In the first 15 minutes it over predicts by 5°C by then levels off to within 1-2°C.
Results

The comparison of the temperatures shows there is good agreement between the test and simulation. The worst case is never more than 5°C.

The predictions for initial 15 minutes is the period where the largest discrepancies of around 5°C are observed.

As the test proceeds the simulated data is close to the measured values.
Results

Comparison of Measured and Predicted Temperature Profiles
Results

A/C Pulldown Temperature Profiles
Summary & Conclusions

• STAR-CCM+ has been employed to model cabin warm-up and pulldown simulations
• The simulations were compared to experimental data
• Overall comparison to experimental data showed good agreement
• Largest deviation being in the initial 600s where the simulation over predicts the warm up rate
• Largest deviation being in the initial 900s where the simulation over predicts the cool down rate
• Further work is underway to improve the predictions for the initial periods of the simulation
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Latest products designed using STAR-CCM+

Thank You For Listening

The End