DIGITAL INDUSTRIES SOFTWARE

Getting the product right the first time

Using thermal simulation for the design of automotive multimedia systems

Executive summary

Continental's automotive group, a system supplier for international automotive original equipment manufacturers (OEMs), has three divisions: chassis and safety, powertrain and interior. The interior division is split into four business units: instrumentation and driver human machine interface (HMI), infotainment and connectivity, body and security and commercial vehicles and aftermarket.

The business unit infotainment and connectivity covers radios, connected radio and entry navigation, multimedia systems, telematics, device connectivity and software and special solutions, with an emphasis on entertainment, information, navigation and communication.

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Introduction

One of the greatest challenges for automotive multimedia systems is they must operate in a wide range of environmental conditions:

- Temperatures ranging from -40 Celsius (°C) to +100°C
- Wide range of power supply voltages, ~4.5 volts (V) to 16.0 V
- Superimposed alternating voltages
- Electrostatic discharge (ESD) polluted environment, up to +/-15 kilovolts (kV)
- Full range of humidity (0 to 100 percent)
- Chemical influences
- And with stringent design criteria:
- Mechanical strength and stability (static/dynamic): vibration and mechanical shock
- Strong limitations on size and weight
- Strong requirements regarding risk of injury (head impact) and product liability

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A world away from physical prototyping

Designing systems to meet such requirements requires much more than physical prototyping after the design is complete. Indeed, Continental's vision is to get the product right the first time by using simulation-based design decisions. As a result, simulation is now highly integrated into the design process.

Continental undertakes full 3D system-level modeling, with all thermally relevant and air flow parts included in the simulation. The geometry representation is based on mechanical computer-aided design (MCAD) data, with export/import of all relevant parts and modules from the CAD system. However, the geometry representation can involve both simplification and idealization. The complexity used depends on the simulation objective: less detail would be used for the analysis of various initial concepts, whereas more details would be included in the model for a mature design.

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Continental's competitive edge is know-how

Continental has developed considerable in-house know-how associated with building and validating thermal simulation models (using Simcenter™ Flotherm™ software models) of their complex electronic systems and subsystems, covering both the physical hardware and potential cooling solutions.

Hardware related

- Housing: single DIN (a standard created by the German Institute for Standardization), double DIN, customer-specific
- Compact disc (CD), hard disc drive (HDD), digital versatile disc (DVD) drives (CD ROM, video), changer
- Shielding frames
- Front displays: cold cathode fluorescent lamp (CCFL), light-emitting diode (LED) backlight
- Connectors and cables
- Components: main central processing unit (CPU), processors, memory
- Printed circuit boards (PCBs)
- Modules: power supply, drives, Global Positioning System (GPS), telephone, amplifier, tuner, display, etc.

Cooling solution related

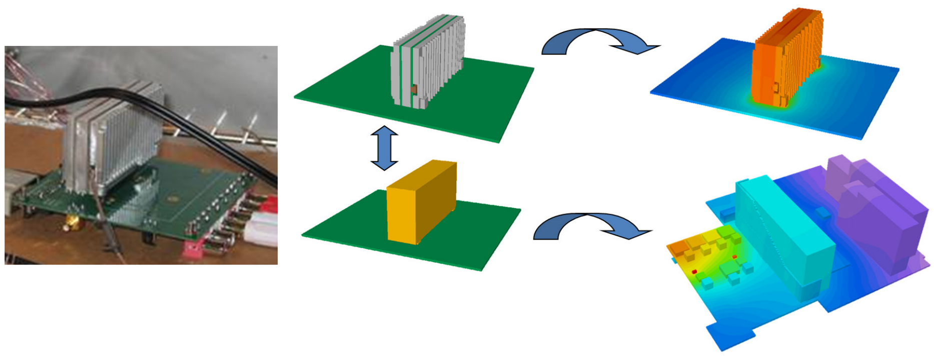
- Fan (type, characteristic curve, direction)
- Contact resistance (conductive paste, etc.)
- Vents, filters (free area ratio, pressure loss)
- Heatsinks, heat pipes, heat spreaders
- Integrated circuit (IC) packages (type, size, thermal model type)
- Thermally conductive gap pads, etc.
- Environmental conditions
- Power dissipations
- Location of sensors for measurement

Uncertainties arising from the various unknowns at each stage in the design process, modeling assumptions and simplifications are mitigated using validation, as the following two examples illustrate.

Examples

1. Tuner-module modeling

This can be modeled as a single block with homogeneous power dissipation distribution, as a detailed model with all the internal electrical components and shielding represented, or anywhere in between. In Continental's experience, a simplified model is often sufficient for a complete system analysis. However, conclusions on the internal component temperatures are drawn from a reference simulation as depicted in figure 1.

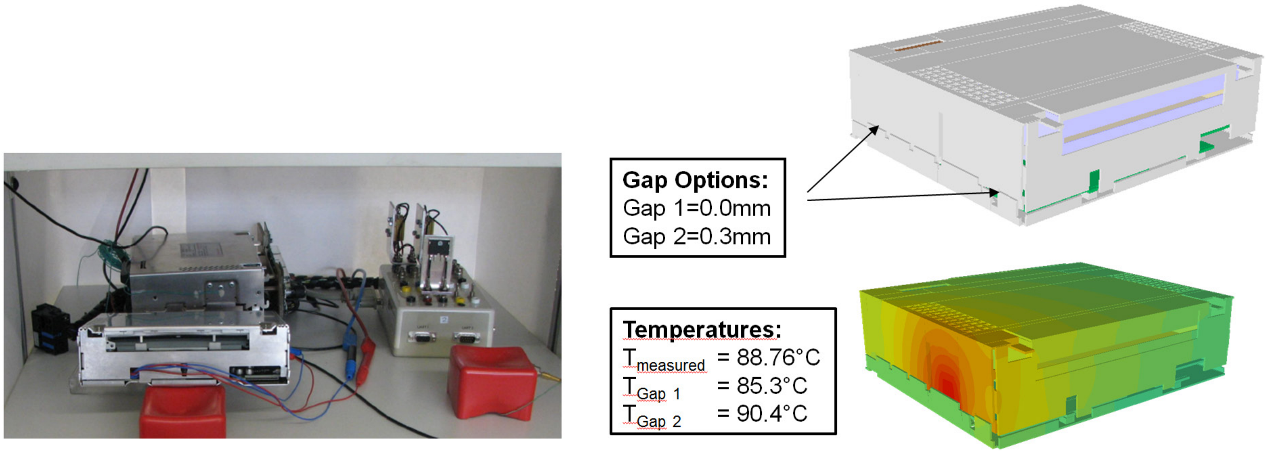


Single block (system level) and detailed (reference) representations of tuner module.

2. Chassis model verification

A part of the chassis is used as a heatsink for amplifier cooling. An important aspect of the chassis is the extent to which the brackets on the top and bottom covers are in thermal contact (related to manufacturing tolerances). Verification of modeling assumptions is the key to improving model fidelity. Therefore, a prototype of the product was measured and the results used to compare against the simulation model. Scenario 1 (gap 1) considers the gap to be fully closed (perfect thermal contact) whereas scenario 2 (gap 2) has a gap of 0.3 millimeters (mm), so there is effectively no thermal contact between the covers. By comparison with the measured case temperature, the results for scenario 2 (with gap) seems to be the best representation of the bracket's contact.

We selected Simcenter Flotherm for several reasons, but primarily for its robust solution capabilities. The Simcenter Flotherm object-associated Cartesian meshing is instantaneous, fully automatic and most importantly guarantees a mesh that produces accurate simulation results even when geometry changes are made to the base model. This is something we need for our multidisciplinary design optimization (MDO) activities. It is also worth mentioning its modeling and result evaluation capabilities made it the best solution for us.



Verification of case thermal contact modeling assumption.

Beyond high-fidelity simulation

Continental's focus on simulation does not stop at building and validating thermal models. Design decisions made to improve the thermal design can impact the mechanical, electrical and electromagnetic performance of the product. Faced with this problem, a major question facing Continental's designers is: How can we achieve design flexibility and enable better design decisions before the freedom for such decisions is eliminated?

The answer to the challenge requires analysis of the product's behavior for all disciplines as well as the identification of independent and coupled system variables. Multidisciplinary design optimization (MDO) techniques with simulation, optimization (with discipline-dependent objectives and constraints) and design-of-experiments (DOE) and response surface methods are suitable means to solve this design problem. Indeed, DOE tools are the foundation for concept exploration and robust design. Two major aspects of DOE are the planning and statistical analysis of numerical simulations.

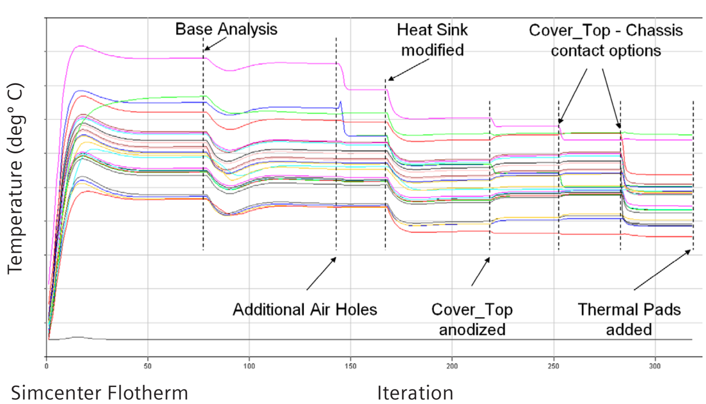
The possible number of discrete and continuous design variables is extremely high. Screening simulations support the selection of the major factors (design drivers) to be included as design variables in the MDO. Even so, the computational effort required can be immense.

Two major aspects of DOE are the planning and statistical analysis of numerical simulations.

Sequential design improvements

Changes that improve the overall design, for expample. the compromise between the product's mechanical, electrical and electromagnetic compatibility (EMC) performance, and additional constraints such as temperature limits, manufacturability or cost allow sequential improvements to be made.

For each discipline these improvements can be visualized as improvements against the base design. In the case of the thermal design, these can be visualized as changes in monitor point temperatures that match the locations chosen for sensors that will be used to instrument the physical prototype.



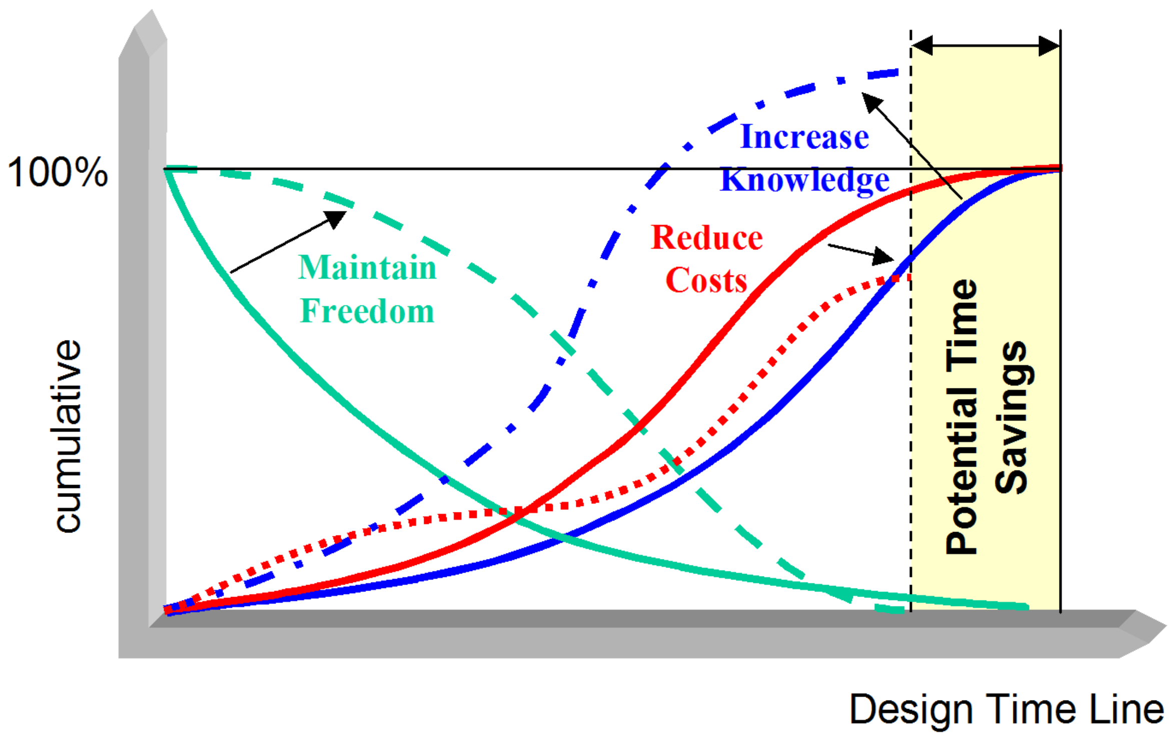
Sequential concept/design improvements from MDO for multimedia system.

Conclusion

Modern radio and navigation systems such as multimedia systems for automotive applications are highly complex systems with a large variety of mechanical and electrical components and assemblies. The design of these automotive multimedia systems must fulfill requirements from mechanical stability and thermal management to electromagnetic compliance and optical homogeneity and, therefore, requires the interaction of mechanical, electrical and software engineers. Interdisciplinary knowledge is essential.

Continental must react quickly to changing customer requirements. Products must be developed with customer confidence, quality, costs and design time in mind. MDO has been found to be a suitable means for finding better design solutions in a multidisciplinary environment.

Simulation supports knowledge generation and a deeper understanding of product behavior at lower cost, in shorter time and with increased product flexibility, leading to increased customer confidence in our products.



Impact of design freedom on cumulative cost and knowledge.

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