Design optimisation for silver print heating circuits

As automotive systems become more advanced, the demand for efficient, high-performance components continues to grow. Working with a manufacturer in the automotive glazing sector, we've supported the development of a more integrated approach to designing the silver print heating circuits used in windscreens, helping improve both performance and reliability.

Our team worked in collaboration with the customer's Modelling & Simulation team to modernise and enhance their existing design process. The project focused on developing a more flexible, integrated and scalable approach, combining modelling, simulation and optimisation into a unified workflow. The result was a prototype toolchain that enabled more accurate design exploration and faster iteration.

Challenge

The existing design process relied heavily on spreadsheet-based tools alongside separate simulation workflows. While this approach had been effective, it introduced several limitations. The spreadsheet was used as an initial low-fidelity stage of the design process before running more computationally intensive finite element models.

However, it constrained how circuit geometries could be represented, making it difficult to capture more complex designs. At the same time, the lack of integration between design tools and simulations meant that optimisation was manual, slowing down iteration and limiting the ability to fully explore the design space. Our customer required a solution that could Improve flexibility, reduce manual effort, and bring design and simulation into a single, coherent process. Through discussions and workshops, it became clear that a connected automated approach was needed to achieve their objectives.

Solution

We began by reviewing the existing toolset and mapping the full design workflow. This provided a clear understanding of how the individual tools were being used and where improvements could be made. From this, a new architecture was proposed to better connect each stage of the process.

A core step involved transforming the existing Excel-based hot line calculation tool, used to define and evaluate heating circuit layouts, into a Python-based application. This removed constraints around fixed grid representations, allowing circuit geometries to be defined more realistically. It also created an opportunity to introduce automated optimisation, enabling the tool to iterate designs to achieve target power density distributions across the heating circuit without the need for manual intervention.

The use of open-source tools removes the need for expensive software licences, helping to reduce overall cost.

A streamlined workflow enables faster design iteration.

Alongside this, our team developed a finite element modelling capability using the MOOSE framework.

An automated meshing tool was created to convert input data into simulation-ready models, which could then be executed efficiently using high performance computing. This approach allowed us to incorporate more advanced physics into the analysis, such as temperature-dependent material properties, to improve the accuracy of the simulations.

Bringing these elements together, we established a fully integrated pipeline. Both the Python tool and the finite element model operate from a shared input file, creating a closed-loop process that links design, simulation and optimisation. This significantly improves the feedback between each stage and creates a more streamlined workflow.

Results

To validate the new toolchain, the customer provided a set of test cases based on existing designs. These included outputs from both the original spreadsheet tool and Abaqus simulation models.

CFMS demonstrated strong agreement between the new MOOSE-based simulations and the Abaqus results, providing confidence in the accuracy of the approach.

The Python-based tool was also successfully validated, offering a more versatile alternative to the original spreadsheet. The project concluded with the delivery of a fully functional prototype, supported by installation guidance, documentation and example test cases to support evaluation by the customer.

Benefits

The new workflow represents a significant step forward for the customer in how heating circuits can be designed and analysed.By integrating modelling and simulation into a streamlined process, we have enabled faster iteration, improved design flexibility and more accurate performance insights. The reduction in manual steps also supports greater efficiency, allowing engineers to focus on optimisation rather than process management.

Importantly, the prototype provides a scalable foundation for future development, giving the customer the tools needed to continue advancing their design capabilities. The use of open-source tools also removes the need for expensive software licences, helping to reduce overall cost.

Future development

During the project, several opportunities for further enhancement were identified. These include extending the modelling of more complex circuit configurations and continuing to develop the representation of material behaviour.

One particularly promising direction is the potential to bypass intermediate calculations and perform optimisation directly on finite element models. This could further streamline the workflow and unlock additional performance gains.

“This fantastic collaboration demonstrates that HPC tools are no longer just for researchers. With easier access to modern simulation tools and compute, placed in the hands of engineers, a whole new set of possibilities is unlocked.”

Guy Johns - Chief Technologist, CFMS