Thermal Modeling Process Optimization

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Abstract

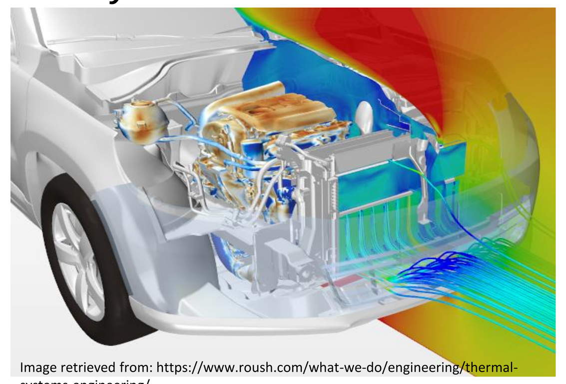
Company XYZ conducts thermal validation using two approaches: full vehicle and local thermal models. In order to perform these analysis, three different software are used. STAR-CCM+ is used to run full vehicle models, while TAITherm and ANSA are used for the local models. STAR-CCM+ and TAITherm local model simulations were performed in order to compare their results and validate that STAR-CCM+ can be used for both full vehicle and local models. On all test cases, STAR-CCM+ presented robust results and savings in total simulation time. Therefore, STAR-CCM+ was recommended as the preferred software for thermal validation. The consolidation of the thermal space under one software will also represent a significant reduction in licenses, immediately supporting the bottom line of the company.

Introduction

For the developmental and validation process of a vehicle, automakers invest millions of dollars to create the best possible product for their customers. With the increasing complexity of the vehicle systems and the move from the industry to the electric vehicle (EV) sector, the automakers need more efficient validation processes that can save money and time.

In order to thermally validate a vehicle, different scenarios must be tested. Typically, these scenarios are at high temperature, high solar loads and grade changes were the vehicle could surpass the temperature limits for some of its components. By performing these tests, the durability and performance of the vehicles can be examined under the worst-case scenarios a customer can face. Two methods can be used to thermally validate a vehicle: prototype research vehicle (hardware) and virtual simulations.

There are two models that can be used to conduct a virtual thermal validation of a vehicle. The first model is a full vehicle model. This type of approach uses the complete vehicle inside a simulated wind tunnel. The second type is a local model. This type of model only uses certain subsystems of the vehicle.



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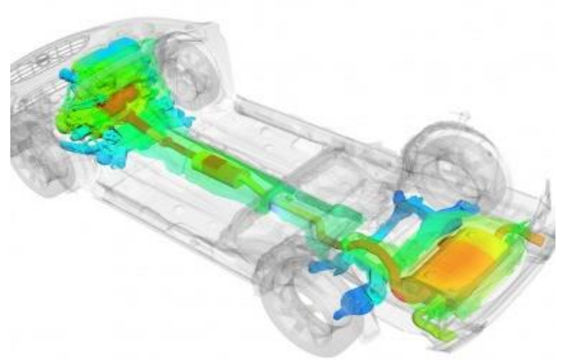

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Full Vehicle and Local Thermal Simulations

Problem

At the moment, Company XYZ utilizes different Computational Fluid Dynamic (CFD) software to conduct virtual thermal validation. The full vehicle model is prepared and conducted entirely in STAR-CCM+ (CFD software). The local model uses two different software. The geometry preparation for the local models is done in ANSA (CAE software) and the fluid dynamics part of the simulation is run later in TAITherm (CFD software).In order to consolidate the thermal space into one CFD software, the solving capabilities for both CFD software need to be compared and analyzed to verify correlation when adding the same boundary conditions.

Methodology

Test Cases Conducted

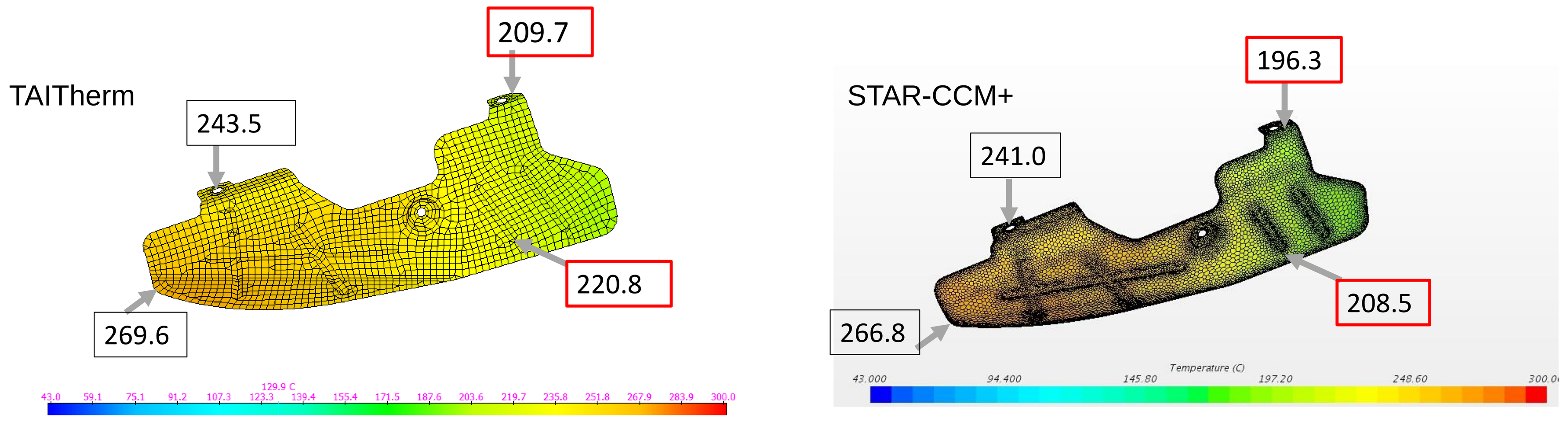
Steady State Simulation	Transient Simulations
Simple geometry	Simple geometry 48 minutes transient (warm up+ grade + soak)
Geometry with multiple parts	
Geometry with variable thickness	Simple geometry 4-hour Thermal Sequence
Fluid domain/ stream	

In order to compare and analyze both software capabilities, several test cases were performed. Same geometry and boundary conditions were applied for each of the separate tests. All test cases included the three modes of heat transfer: convection, radiation and conduction. The comparison of both software was done by conducting thermal mapping of the surfaces. Boundary conditions included material emissivity, ambient temperature and heat transfer coefficient. In some cases, the virtual simulation results were compared to hardware data. For all test cases, the time for geometry/mesh generation and solution were recorded in order to quantify the potential simulation time (employee productivity) that can be saved by consolidating the thermal modeling under STAR-CCM+.

For all the simulations conducted in TAITherm, the geometry parts and mesh were prepared using ANSA. The mesh used for steady state simulation was a surface mesh with a virtual thickness that was inputted in TAITherm. The geometries for transient simulations were meshed as surface mesh and as solids separately. The simulations conducted in STAR-CCM+ were prepared, meshed and conducted on the same software. All the geometries executed in STAR-CCM+ were meshed as solids.

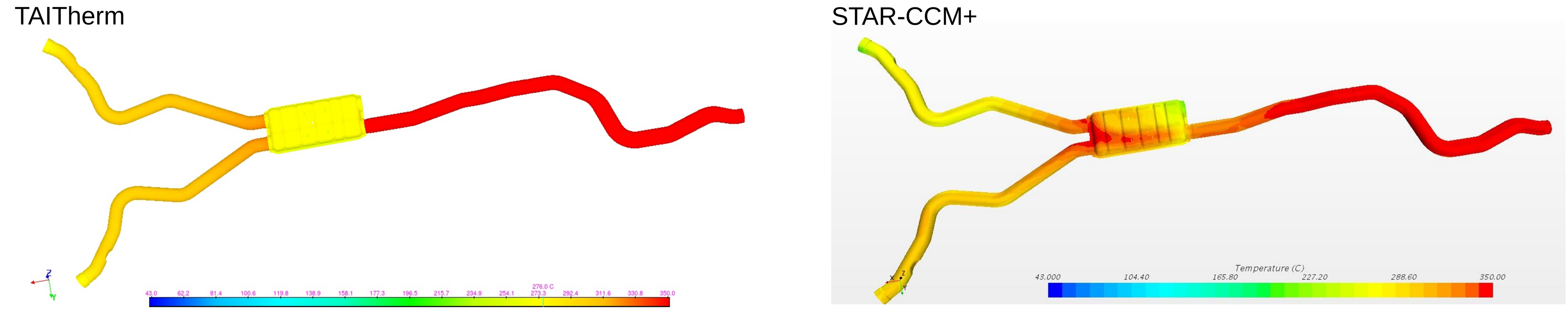
Results

The test cases presented on the methodology were conducted for this study. For the first two steady state simulations (simple exhaust and heat shield and geometry with multiple parts) there weren't any major difference between the solutions given by TAITherm and STAR-CCM+. The first discrepancy with the solution of both software was encountered when conducting the simulation for geometry with variable thickness. This was expected because TAITherm uses a virtual thickness that is applied to the entire geometry. Therefore, changes in the geometry thickness are not considered and are ignored for the calculation of heat transfer.



Variable Thickness Simulation Thermal Mapping

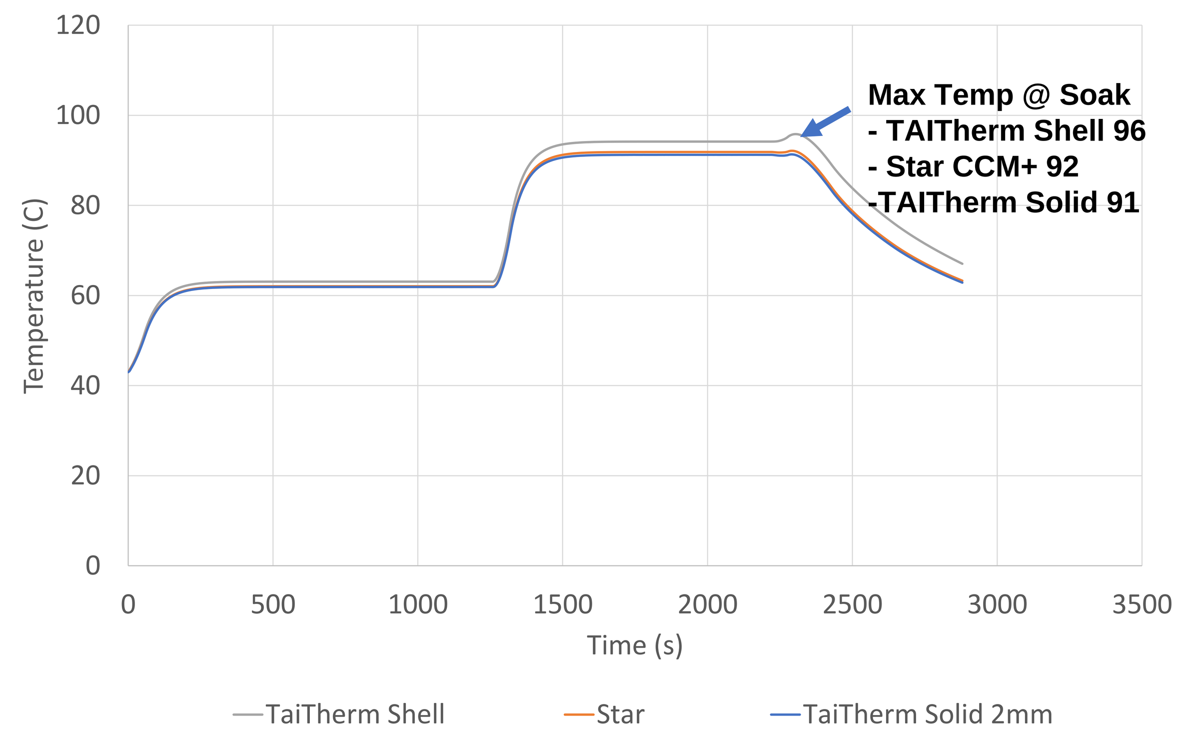
Differences were also encountered when using the fluid domain/fluid stream capabilities on the software. The fluid domain/fluid stream simulation has the goal to recreate a moving fluid inside a cavity and calculate the resulting temperature of the fluid based on heat transfer. In order to perform this type of simulation, boundary conditions needed to be added to the fluid apart from the boundary conditions of the system. The fluid had an assigned inlet temperature of 500°C and a mass flow rate of 0.08 kg/s for both software.



Fluid Domain/Fluid Stream Simulation Thermal Mapping

When analyzing the results, it was noted that in some spatial regions the difference between both software was above 20C. The differences between the two software results are driven by how each one creates the fluid inside the parts. TAITherm uses a fluid node approach, therefore the flow is only 1D. Since TAITherm solves the fluid as a 1D, there are no velocity profiles inside the pipe. In STAR-CCM+, the fluid is continuous and 3D. Therefore, the fluid inside the exhaust interacts with the pipe walls. In order to understand which of the software was the most representative of a real scenario, the data was compared with hardware test data. STAR-CCM+ correlated better with hardware data.

For transient analysis, two different simulations were performed. First simulation performed was a 48 minute transient case with warm-up, grade and soak. For this simulation, it was noted that there was a consistent difference between TAITherm and STAR-CCM+. This difference got accentuated at the peak of the grade simulated. Even though 4°C is under an acceptable level of discrepancy, a new simulation was performed using a solid mesh for TAITherm. The solid mesh would let the geometry have a real thickness once the simulation had to be run in TAITherm. It was noted that STAR-CCM+ and the TAITherm solid mesh variant correlated perfectly. A 4-hour thermal sequence was also analyzed, same behavior on peak grade was noted. In this case the discrepancy between TAITherm and STAR-CCM+ was of 6°C.



Simple Case 48 Minutes Transient Plate Temperature

In order to compare both software from a productivity standpoint, the solution (geometry and software preparation) times were recorded for each of the simulations. While TAITherm presented better simulation times, all STAR-CCM+ simulations presented a savings in total productivity time.

Conclusion

The results of this study showed that STAR-CCM+ can perform local heat transfer modeling with similar fidelity as TAITherm. It was noted that when using a fluid domain approach, STAR-CCM+ solved the simulation in a more accurate way presenting results that correlated with hardware data. On transient simulations, STAR-CCM+ results correlated better with TAITherm solid meshing, indicating that a solid mesh approach tends to be more accurate. The study showed that STAR-CCM+ has faster model preparation, therefore employees can use the time saved on other tasks increasing their productivity. Also, employees are very familiar with STAR-CCM+ because full vehicle models are performed entirely on this software.

STAR-CCM+ demonstrated to be capable of performing local models, therefore its use is recommended. This study was of strategic value to the thermal validation space as it will result in a transfer of work from one software to another, enabling a significant reduction in licenses which will immediately support the bottom line of the company.

References

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