Validation of a sprinkling simulation with PreonLab

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Diploma Thesis – supported by Daimler AG

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Abstract

At the Chair of Automobile Engineering at the TU Dresden we are investigating and developing a tool chain for virtual water management for the automotive industry. In my diploma thesis, I did a feasibility study for predicting water paths on a car door. Therefore, I benchmarked several commercial and non-commercial CFD methods. PreonLab gave the best real world matching simulation results and furthermore outperformed other tools in terms of usability, performance, and post-processing possibilities.

Conventional approach

The ability to predict and control the water paths is crucial in the design stage of a car door. Rain water flows down the side window and the side of the door. However, some parts of the fluid run down the sealing and leak inside the door.
It is necessary to detect the flow path for improvements regarding reduction of water treatment.

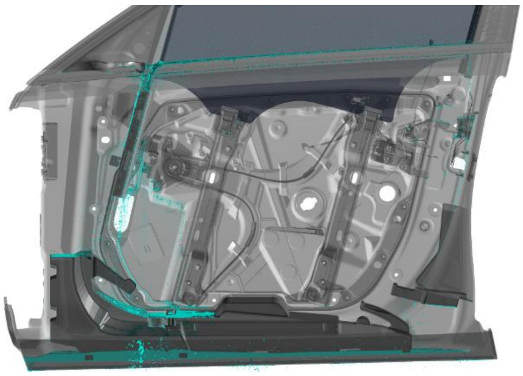


Image A: Flow path through a car door

The conventional approach to test the design with respect to water management is to build a test bench. This is cumbersome and expensive. First, the door needs to be built and installed in a test setup. Cameras and sensors need to be placed in multiple locations inside the door. And still, measured data are often not very revealing. This approach requires special hardware and moreover optimizations at the door are only feasible under high, costly efforts.

CAE - Fluid simulation

Virtual fluid simulations promise to make this easier in an early development phase (digital phase): A CAD model of the door is sufficient for testing in a virtual lab. However, for classical grid-based CFD approaches such scenarios are extremely challenging. The meshing of the geometries requires a lot of manual pre-processing time. In order to capture all water paths and tiny runlets, a very fine fluid resolution is required. Therefore, we are favouring particle-based approaches for water management in the automotive context. Due to their mesh-free nature, they are perfectly suited to simulate free-surface fluids in contact with complex-shaped geometries.

Advantages of PreonLab

PreonLab is an all-in-one simulation suite. It contains the particle-based Preon solver and various tools for pre-processing and post-processing required to set up and evaluate the simulation.

Usability

I was quickly able to use PreonLab due to its intuitive user interface which allows to easily set up a simulation. The 3D view directly shows the setup and simulation results. It is straight-forward to add and position cameras and sensors which is even possible after the simulation for post-processing purposes. Everything can be set and tweaked using the interface. With the integrated Preon renderer photo-realistic images can be rendered. This is very handy for an optical comparison of the simulation with images from the test bench.

No meshing for complex boundaries

In comparison to classical CFD methods, no time-intensive meshing is needed. For example, during the validation, one part of the CAD model did not match the real world part-version due to the shape effecting installation. Accordingly, a few details in the CAD model of this part needed to be optimized. With PreonLab, this was a matter of minutes: No remeshing needed.

Parameter estimation

In order to estimate the friction and adhesive parameters of the CAD model, a parameter study was performed. The material parameters were calibrated using isolated test set-ups for each material and then transferred to the complete test case.

Quality of results

We have particularly compared the water paths and the flow rates computed by the simulation with the data from the test bench. PreonLab predicted nearly all water paths correctly, including paths that bent around the geometries (see image B), and paths that streamed over the geometry edges. This proved to be a crucial quality benchmark as we realized that other tools were not able to simulate both effects at the same time, i.e., adhesion was either too exaggerated or too weak.

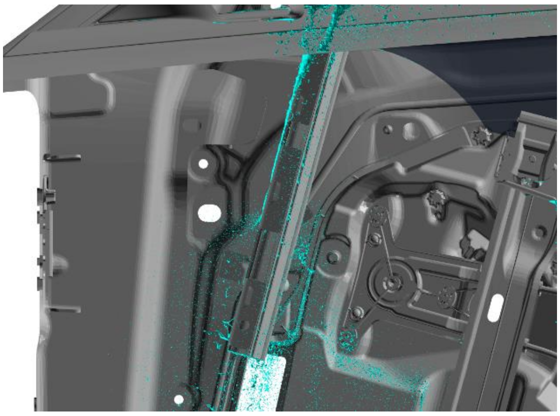
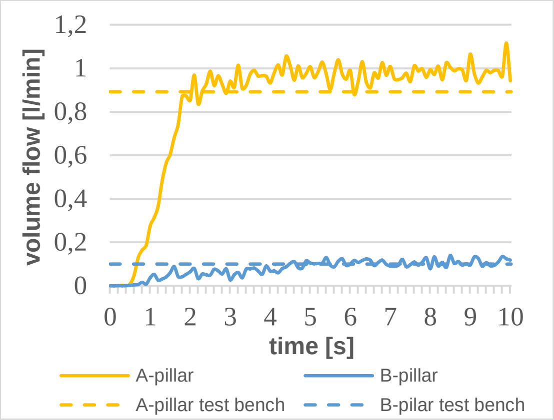


Image B: stream around the geometries

While the prediction of water paths is already helpful for testing and improving the door design in the early development phase, some design decisions require knowledge about the expected volume flow rates at certain positions. We therefore measured and compared the volume flow rates at the A- and B-pillar (see images). As it is very hard to capture and synchronize all real world conditions with the virtual test case, we declared a maximum deviation of 15% between simulation and real world data as tolerable. The results simulated with PreonLab are significantly below this mark. The simulated flow rates showed a maximum deviation of less than 10% at the A-pillar and less than 7% at the B-pillar.
For door raining, especially the adhesion between the water and the door is important. PreonLab was the only evaluated tool that was able to capture these effects.



Comparison of volume flow rates computed with PreonLab and flow rates measured at the test bench.

Speed

PreonLab proved to be much faster than the other evaluated tools, even those utilizing graphic cards for the computation. With PreonLab, I was able to use a significant finer resolution, gaining accuracy without losing lab time. One reason for the superior performance is that the Preon solver uses an implicit formulation which compared to, e.g., standard SPH solvers tolerates much larger time steps.

Conclusion

PreonLab is a user-friendly and fast program with reliable, real world matching results.