Thermodynamic Simulation of Vehicle Hydrogen Tanks

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Today is a revolutionary stage for vehicle industry. Diesel cars are to leave production lines, greens win more chairs at EU parliament, global warming becomes a serious topic. Consequently, accompanied with the E-cars, fuel cell hydrogen cars eventually open the market. However, this is a new industry that yet to tackle many questions. Development of H2 technology is of high priority at Audi and the main goal is to bring forth new and creative ideas in to this very new product.

The scope of our presentation is to give an overview on challenging topics regarding simulation of high-pressure compressed H2 tank that mainly faced due to diverse thermodynamic behaviors of hydrogen within the operational conditions. Furthermore, this talk will look into the most important aspects of a hydrogen system that can be extensively designed, tested and optimized using CFD. In addition, it will be explained how OpenFOAM is currently used and what parts have been modified or are planned to be amended for investigation of a hydrogen system.

Two typical thermal investigations consist of temperature variation of the gas temperature inside the tank during the filling and defueling the tank. The main concern is to identify the temperature variations on the inner layers of the tank in order to ensure that the temperature value stays in the allowed range of -40 to 85 C. The challenge for type IV tanks rises, as carbon fiber (CF) has a quite small heat transfer coefficient thus heat loss from the tank is considerably slow. Looking into such problems within CFD calculations, the complexity of the models increases once adjoined components such as the valves, the pipes and pressure regulators are taken into account. In this case, applying high pressure at the inlet of the system leads to subsonic velocity inside the valve, whereas the flow velocity inside the tank is much smaller. Simulation of such cases is computationally expensive, thus to avoid high costs, components are simulated using different numerical techniques. In our simulations, the pressure drop during the filling process in different stages of a hydrogen valve is simulated by rhoCentralFoam as a density-based solver, but the same type of investigation for defueling process is modelled with slightly modified rhoPimpleFoam as a usual pressure based solver. For simulation of filling and defueling process, the valves are not directly included, but an especial boundary condition contributes the valve pressure loss on the tank's flow.

Numerical results were verified by internal test measurements and previous published investigations. Results show a quite good agreement between the test and CFD. Moreover, especial mesh treatments such as mesh coarsening in some parts of the model showed of improvements in computational time.