The Progress in Tank-Filling Simulation

As in other areas of vehicle development, CFD simulation is of growing importance for the development of fuel tank systems.

Restricted space in vehicles is significantly influencing the shape of tanks nowadays and does not leave much freedom for the design of filler pipes and placement of other components. Recent progress in SWIFT enables engineers to analyze tank designs early in the development process including consideration of packaging and performance of the tank systems. The simulation of complex multi-phase flow by means of a full 3D state-of-the art Euler-Euler description turned out to be the most appropriate approach in terms of accuracy, computational efforts and flexibility. Conservation equations for momentum, mass, energy and turbulence quantities are solved for each phase and the interaction of the phases is taken into account by coupling terms. Air and fuel flow with distinct interfaces as well as a continuos mixture of air and a mist of small droplets and the transition from one stage into the other are naturally regarded. Additionally a VOF (Volume Of Fluid) module is available in SWIFT to support free surface tracking. The extension of the system by additional phases as fuel vapor or foam is possible.

Employing SWIFT multi-phase, these problems can be addressed:

- premature switch-off
- back splashing
- design of ventilation systems
- sloshing

The entire tank system, consisting of the nozzle, filler pipe, tank and ventilation system are modeled for the simulations (Fig. 1). In case of specific questions just particular areas are selected for the calculations:

In case of premature switch off for back splashing, only the nozzle, the upper part of the filler pipe and for European systems, the connection of the ventilation system - is sufficient.

In case of sloshing simulations only the tank is required.

After the import of CAD data, the different parts of the tank systems are meshed independently with FAME and are connected by arbitrary interfaces. The ACT-Technology which is also basis of SWIFT´s multi-phase approach, facilitates the use of arbitrary interfaces and no penalties in terms of computational efforts or accuracy have to be paid. Different areas are meshed with different grid resolution in order to cover all relevant physical phenomena with highest efficiency.

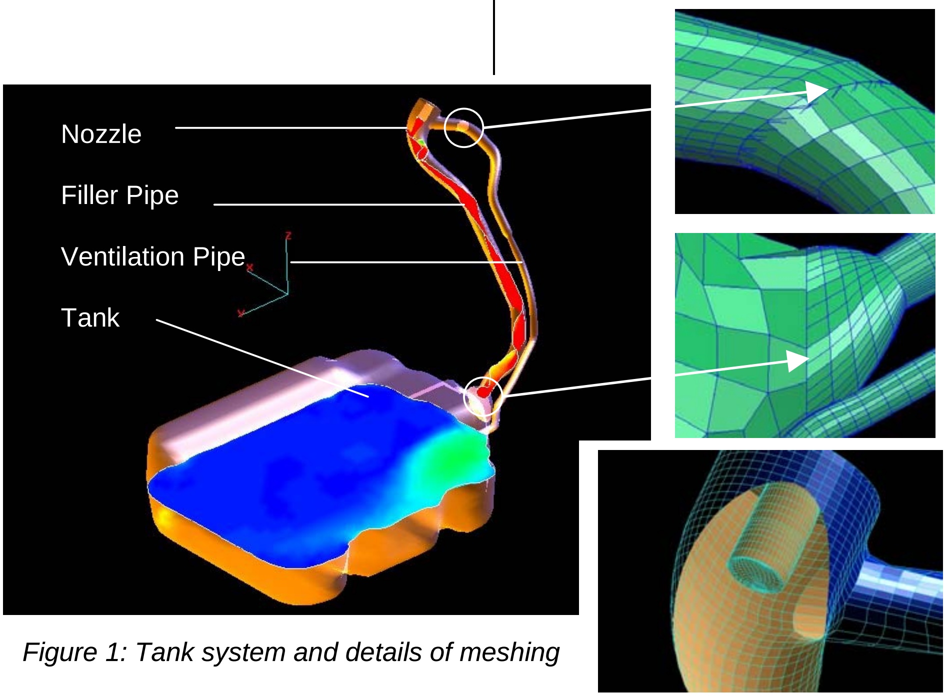

Figure 1: Tank system and details of meshing

In Fig. 2 and 3 a case with problem-free tank filling is compared with a case displaying premature switch-off as an example of the SWIFT approach.

For the first case, fuel enters the tank system, hits the walls of the filler pipe at a relatively long distance from the nozzle (Fig.2) and runs smoothly along the filler pipe into the tank . In this case fuel is not transported back and neither premature switch-off nor back splashing are observed.

Configuration 2 is less favourable than the previously described one. The fuel hits the filler pipe much closer to the nozzle and at a problematic angle of the filler pipe (Fig. 3). Fuel flows back up the filler pipe and due to a splashing process a fuel rich

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mixture of droplets and air is transported to the sensor hole of the nozzle. The fuel at the sensor hole reaches a critical concentration within a short period, after 0,16s, and, as observed in experiments, the nozzle switches off.

These examples demonstrate the various multiphase flow structures in tank systems. SWIFT is a proven tool for this application and an effective support for the design of such systems even before prototypes are built.

Literature:

Wiesler, B., Greif, D., Alajbegovic, A.: „Recent Progress in Tank-Filling Simulation“, October, 1-2, 2002, VDI Würzburg

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Grogger, H.;Philipp, H.;Alajbegovic, A.;Kolbinger, H.-J.;Nurna, P. Two-Phase Flow Calculation of theTank Filling - JSAE Spring Convention,
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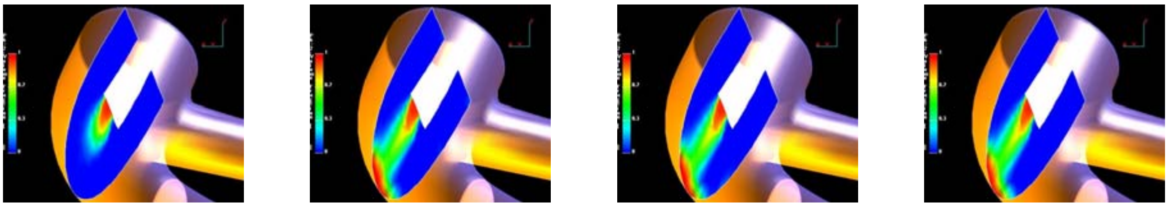
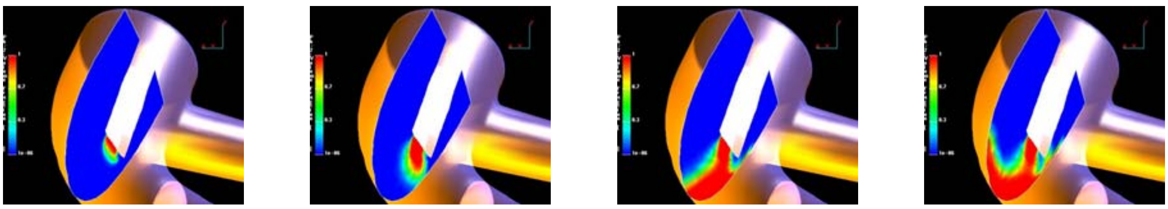


t = 0,005 s | t = 0,02 s | t = 0,05 s | t = 6,3 s

Figure 2: Prolem-free tank filling



t = 0,025 s | t = 0,02 s | t = 0,1 s | t = 0,16 s

Figure 3: Premature switch-off

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