News about applications, products and services

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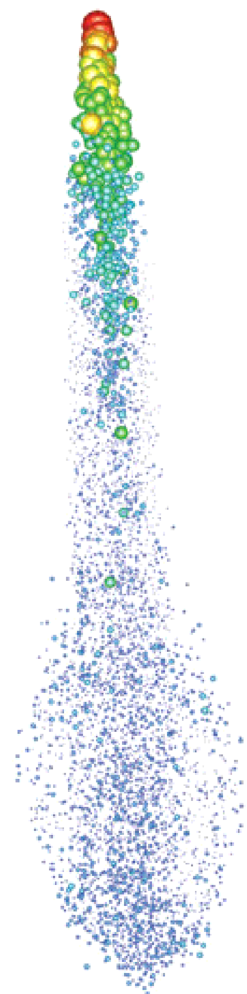
CFD simulation reducing diesel soot



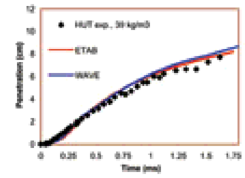
VTT Technical Research Centre of Finland is a multidisciplinary contract research organization providing a wide range of technology and applied research services for its clients, including private companies, institutions and the public sector. VTT Processes, one of six research units of VTT, is a technology partner specifically for the energy and process industries, searching for new growth areas and pioneering new technologies for the benefit of both its clients and the environment.

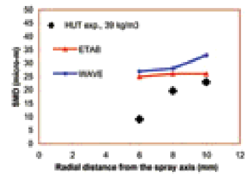
VTT Processes applies the latest research techniques to the sort of challenges and problems that face the energy and process industries, such as decreasing emissions and controlling climate changes, introducing production processes that require even less resources and using an increasing amount of renewable and recycled raw materials.

Computational fluid dynamics (CFD) is a crucial tool for the Center, which works closely with the diesel engine industry and requires increasingly accurate ways to measure fluid flow to improve performance and reduce emissions. There are twenty CFD engineers working at VTT Processes on various applications, many of whom use the powerful CFD solver, STAR-CD from the CD adapco Group.

Ossi Kaario, Research Scientist and diesel

Ossi Kaario, Research Scientist and diesel engine specialist at VTT, has recently been investigating cascade atomization and the break up of liquid fuel jets during the diesel combustion inside the cylinder, with a view to improving the efficiency and cleanliness of diesel engines. "The resulting spray from the break up of liquid fuel jets has a direct impact on emissions and how an engine performs," he explains. "Accurate simulations of this process are the key to improvements in this area, since measurement facilities can’t offer up the sort of analysis opportunities that we need."





Top: Spray penetrations for the ETAB and WAVE computations compared with experimental data

Bottom: Drop sizes expressed as Sauter mean diameter (SMD) for the ETAB and WAVE computations compared with experimental data

In the past, a lack of real experimental data has hampered attempts to make significant improvements in atomization and droplet break up. However, recent advances, both in the gathering of experimental data and also in simulation techniques, are beginning to have an impact for researchers like Kaario.

"When we are talking about diesel engines, it is fundamentally important to predict the break up process of the sprays correctly, because of the impact this has on the performance of the engine," says Kaario. "When the droplets are broken up into smaller parts, the surface area of the drops increases and this has a big effect on evaporation and the subsequent mixing of the fuel. This in turn affects the combustion of the fuel. So in order to have any kind of accuracy and reliability in the simulations, we have to have the best possible droplet break up model."

Reducing emissions is the ultimate goal for the researchers at VTT Processes and with diesel engines the problem is soot emissions. "Currently, our understanding of the best way to reduce soot emissions is to increase the injection pressure and reduce the diameter of the nozzle hole," explains Kaario. "Pushing the same amount of fuel through a smaller hole creates potential problems from a design point of view, and this is where accurate CFD simulations can really come into their own. The emissions are generally produced after the spray has evaporated, and we use other models to show how the soot and NOx [nitrogen oxide] form, but without an accurate break up model our predictions for these emissions lack a degree of authority."

For Kaario and his team, the benefits of simulation go beyond the usual cost and time savings, as he explains: "Real experiments are extremely important, and I'm sure they always will be, but if you just do experiments you don't get such a good understanding of the processes. Combination of measurements and simulation is the key."

"For example, even if we don't have accurate enough models to say that we have this exact amount of soot from the cylinder, we get a good understanding of the processes involved - we really understand more about what is happening and why. If you just do experiments the results will be very accurate, but you won't know why. That is the difference."

Several mathematical models exist to calculate the break up of liquid fuel jets. The break up criterion is determined by linear drop deformation dynamics and the associated drop break up condition. Break up occurs when the normalized drop distortion exceeds a critical value.

Kaario has been working with the father of the Enhanced Taylor Analogy Break up model (ETAB), Franz Tanner, from the Michigan Technological University. "The TAB model was the first model used for describing the droplet break up when it is injected into high pressure diesel systems," explains Kaario. "This had its limitations, so Tanner created the enhanced version. Tanner and I spent the best part of a year in Michigan implementing his model into STAR-CD."

Working with the ETAB model within a 3D simulated environment gives us much greater analysis capability," he continues. "Using

STAR-CD, we are able to solve the whole problem. So we can say that, for example, at this particular point in the cylinder, this is the temperature, pressure, emissions and so on."

As well as ETAB, VTT has also been working with the WAVE model. This has been implemented into STAR-CD and VTT is working with both models to create the optimum break up simulation. "The WAVE model currently in STAR-CD is one of the first versions," explains Kaario. "But Professor Martti Larmi at the Helsinki University of Technology - another of our research partners - has implemented one of the latest versions of WAVE into STAR-CD with impressive results. Between WAVE and ETAB we are now at the cutting edge of spray modeling."

Having created an accurate break up model, it is then possible to begin optimizing diesel engine design. The simulation model is tuned to an existing engine, which can be modified to test different designs, by varying the cylinder geometry or the injection parameters.

Satisfied that the results from STAR-CD have reached an impressive level of accuracy, Kaario is now beginning to focus his attention on creating a complete combustion model. He will use the results from his spray modeling to model the subsequent combustion of the fuel within the diesel engine. "Once you are up and running with STAR-CD, you can do almost anything," he says. "Because we can implement new models into it, there are no limits what we can achieve."

For details regarding applications outlined in this press release please contact the CD adapco Group