NEWS

Michigan Tech Uses CFD, Visualization to Help Design Cleaner Diesel Engines

by Anna Turnage

With gas prices rising, automakers are considering producing more diesel-powered cars and trucks. But while diesel engines may be more efficient than gas engines, the emissions have long been considered a major pollutant and health risk.

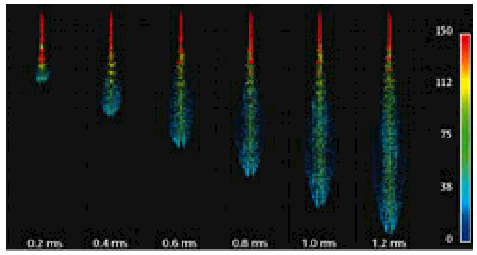
Scientists at Michigan Technological University are using the KIVA3 computational fluid dynamics (CFD) code and advanced visualization software to better understand and eventually help reduce harmful diesel engine emissions. The research is being conducted for Waertsilae Ltd., a Finnish company that manufactures and develops medium- to slow-turning diesel engines. But it could also have far-reaching benefits for the industry as a whole, says Franz Tanner, associate professor in the Department of Mathematical Sciences at Michigan Tech.

Why is Diesel Exhaust Harmful?

The majority of trucks, buses, trains and ships in the U.S. are powered by diesel engines. The exhaust from these vehicles contains more than 450 different chemical components. California officials have designated more than 40 of these chemicals as toxic air contaminants.

According to the

According to the American Lung Association, untreated exhaust gases from diesel engines emit 100 times the sooty particles of gasoline engines. They account for 26 percent of the total hazardous particulate pollution from fuel combustion sources in the air and 66 percent of the particulate pollution from on-road sources. In addition, diesel engines produce about 20 percent of the air's total nitrogen oxides, a major contributor to ozone depletion and smog.

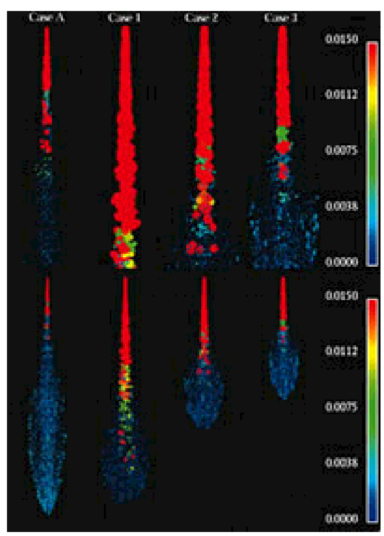


Evolution of a non-evaporating diesel spray with an injection pressure of 300 bar and a gas pressure of 15 bar. The coloring reflects the size of the droplet radii. click here for full-size image.

Atomization Modeling

The main difference between gasoline and diesel engines is the injection process. A traditional gasoline engine intakes a mixture of gas and air, compresses it, and ignites the mixture with a spark. A diesel engine takes in air, compresses it, and then injects fuel into the compressed air. The heat of the compressed air lights the fuel spontaneously.

The injection process, called atomization, is the target of Michigan Tech's research. Atomization is the process of turning a liquid into a fine spray. Think of the atomizer on a bottle of perfume. In a diesel engine, atomization occurs when high-pressure liquid fuel jets are injected through a nozzle into the engine's combustion chamber. The jets atomize and fuel evaporates and mixes with air to create combustion.



Jet breakup lengths and drop size distributions for non-evaporating diesel fuel sprays at 1.2 ms after start of injection. The top row is an enlargement of the breakup

The performance of diesel engines is directly tied to the atomization properties. If the process does not work right, a spray of large fuel droplets occurs and combustion is poor. The quality of the fuel sprays determines the efficiency of the combustion process and the associated formation of pollutants.

enlargement of the breakup region and illustrates the simulation of a fragmented liquid core. click here for full-size image.

"The effect of atomization on engine efficiency and pollution can be considerable," Tanner says. "Insufficient atomization limits the evaporation process in the engine and leads to inefficient engine operation and pollution formation such as soot and unburned carbohydrates. On the other hand, well atomized fuel jets can considerably increase the undesired nitric oxide production."

The main goal of modeling the atomization process is to predict and develop fuel injection strategies that lead to cleaner and more efficient combustion devices, he says.

Visualizing Droplet Formation

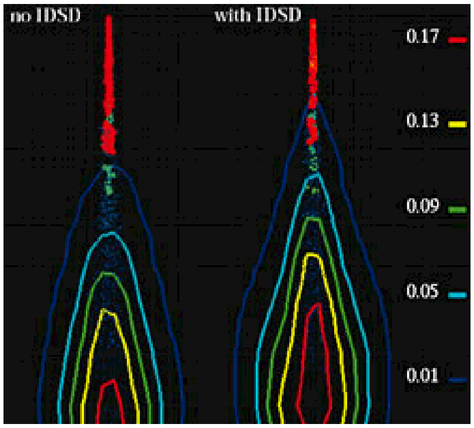
Tanner and his colleagues use a KIVA3-based CFD code as their modeling platform. KIVA3, developed originally at Los Alamos National Laboratory, is a Fortran-based finite difference code used to design and analyze internal combustion engines. Tanner runs most of his computations and visualizations on a multiprocessor Sun Enterprise.

Tanner specifically wants to visualize velocity distributions and the size of the droplets during the atomization process. He also wants to see where and when fluctuations in the drop concentration occur throughout the spray process.

Tanner uses EnSight software from CEI (Apex, N.C.) to visualize his computational results. EnSight generates animated visualizations of 3D flow and scalar fields, drop size and velocity distributions of simulated sprays, and other processes central to diesel combustion.

"The fragmented liquid

"The fragmented liquid core at the nozzle exits is visualized to obtain information about its length and drop-size distribution," Tanner says. "EnSight visualizations are invaluable in the investigation of fluctuations in the drop concentration. In addition, the visualization of many gas phase properties, such as the fuel vapor mass fraction and the ignition locations, have proven to be very useful in assessing the spray behavior for evaporating and reacting sprays."



Contour plots of the fuel mass fraction distribution in the certerplane of a spray computation without (left) and with the initial drop size distribution. click here for full-size image.

The software also allows access to any location at any instant of the simulation process. "This gives us insight into the liquid-gas phase transition behavior in multi-phase flows," says Tanner.

Searching for a New Tool

The results of Tanner’s work have so far proven to be beneficial in developing a useful computational tool for combustion studies.

The atomization breakup model has been implemented into the commercial STAR-CD code as part of a collaboration with the International Combustion Engine Laboratory at Helsinki University of Technology in Finland.

The models have also helped Waertsilae Ltd. build an improved fuel and water injection system for large two-stroke diesel marine engines.

Using the advanced KIVA3 code and EnSight software, the research team has made strides in unlocking the secrets behind the atomization process, which holds the key to making diesel engines more efficient while producing fewer pollutants. Tanner’s research is now focusing on improving the speed, stability and accuracy of the algorithms within the code.

"With this knowledge, we can develop a reliable, predictive tool to be used in the design process of combustion systems," Tanner says.

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