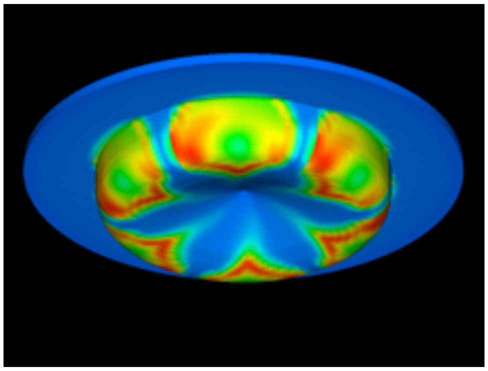
Convergent Thinking Applies Darwinism to Develop Better Diesel Engines

by Erin Hatfield

Computer-aided testing in engine research is nothing new. But how about using Darwinism to improve diesel engine design?



Using a combination of computational fluid dynamics (CFD), genetic algorithms and advanced visualization, scientists at Convergent Thinking, an engineering firm in Madison, Wis., have furthered their quest for a better diesel engine.

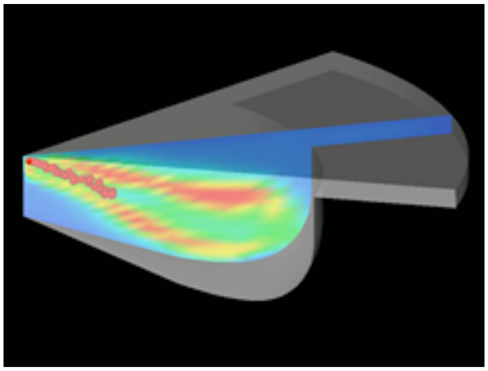
Genetic algorithms are mathematical operations most commonly used in biological studies to explain and predict the Darwinian theory of survival of the fittest for a particular gene in a group of organisms. Convergent Thinking has adapted this practice for diesel engines, substituting physical parameters within an engine for genes.

Efficiency vs. Emissions

Diesel engines are more efficient than their gasoline counterparts. Gasoline engines compress a mixture of air and fuel, most often mixed in a carburetor or through fuel injection, and ignite that mixture with a spark. Diesel engines compress only air and inject fuel directly into the cylinder, using the heat generated from the compressed air to light the fuel spontaneously. To generate this heat, the air in diesel engines must be compressed at a much higher ratio than that of a gasoline engine. This higher compression ratio leads to better fuel efficiency.

These advances in efficiency don't come without a cost. Diesel engines are more complex than gasoline engines because of the machinery required to compress and inject the fuel. The engines also have higher emissions due to the type of combustion that occurs. Early improvements in the engine's design were the result of trial and error, a process that is neither cost- nor time-effective. Hardware and software advances have enabled computer simulations and animated visualizations that reduce the amount of raw materials and time needed to test key design parameters.

Beyond the Inner Workings



Due to the complexity of changing an engine's shape, most advances in diesel engine efficiency deal with internal workings such as fuel injection velocity and timing. Using KIVA CFD software and EnSight visualization software from CEI (Apex, N.C.), Convergent Thinking has been able to see inside a physical engine to better understand how the internal workings affect its efficiency.

During the CFD tests, the combustion chamber shape typically remains the same. The visualizations allow scientists at Convergent Thinking to see the physics of fuel combustion within an engine and determine where enhancements can be made. Significant improvements have been made, for example, by increasing the operating pressures of the fuel injectors.

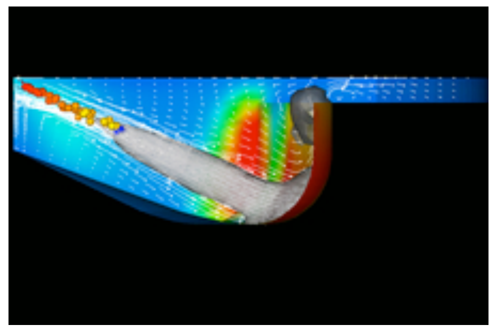
Convergent Thinking is now going beyond the internal workings of a diesel engine to examine the close link between fuel injection and engine geometry. Past results suggest that traditional engine geometry doesn't take full advantage of new injection systems. With new computational and visualization advances, both the physics and chemistry from internal engine combustion can be analyzed and physical parameters tweaked for better performance.

"EnSight allows us to visualize how the engine geometry is affecting the flow field, fuel injection, combustion and emissions," says Dr. Peter Senecal, an engineer with Convergent Thinking. "Typically when parameters such as air pressure and exhaust gas recirculation are optimized, emissions reduction can be sufficiently explained using simple line plot graphs. To understand what effect combustion chamber geometry has on combustion and emissions, however, more complex three-dimensional visualizations are needed."

The Evolution of an Engine

The complex interaction between fluid dynamics and engine geometry requires that Convergent Thinking use genetic algorithms to further improve its CFD findings. The engineering firm runs genetic algorithms based on the optimized engine settings, allowing them to simulate the performance of a group of engines, each with a slightly different design.

"With the simulations and genetic algorithms," says Senecal, "we are able to do what no one else to our knowledge is doing: computationally design a diesel engine over a wide range of operating conditions, allowing for both very general combustion chamber shapes and calibration parameters in the optimization."



After running the genetic algorithm scenarios, the computer models select the best performer from a group of trials, much like natural selection in biological evolution, and combine characteristics from that engine with those of other high performers. The engines with these "genes" are simulated using the same CFD and visualization process as in past studies. Senecal then rates the engines on their fuel efficiency and the amount of soot and nitrate wastes they generate.

Convergent Thinking's findings have helped optimize engine design for increased efficiency and lower emissions - two things of great importance to engine manufacturers and environmentalists.

"We can now indicate to designers the variables that are most important or ones that might have been overlooked had the computer not identified them," says Senecal. The computational studies, for example, have highlighted the importance of injecting fuel in short bursts instead of a single stream, increasing the surface area of the fuel and leading to a cleaner and more efficient burning.

The Next Generation in Two Weeks

The simulation of one engine cycle, less than a tenth of a second in real time, might take several days to complete. Making the same changes to a physical engine and running the tests could hypothetically take several years due to the large number of design perturbations incorporated in a genetic algorithm search.

It typically takes Senecal and his colleagues two weeks to run a series of tests, resulting in engine designs that produce significantly lower emissions without sacrificing fuel economy. At the University of Wisconson, where Senecal developed the methodology, his engine optimization tool resulted in a design that consumed 15 percent less fuel than a standard engine while producing one-third the amount of nitric oxide and half the soot.

"With EnSight, we are able to visualize the fuel injection, flow structures and emissions locations for the optimum engine designs," says Senecal. "These visualizations allow us to analyze the designs and figure out why they have low emissions. The findings are of interest to many engine manufacturers who need to meet very strict upcoming emissions mandates."

Using CFD, genetic algorithms and advanced visualization, Convergent Thinking is helping speed the evolution of engine designs that have been relatively untouched for decades.

###

CEI Press contact: Amanda Baley, 919-363-0883