Modeling of Combustion Processes Improves Engine Efficiency

ENERGY EFFICIENCY AND RENEWABLE ENERGY

OFFICE OF TRANSPORTATION TECHNOLOGIES

Transportation

FOR THE 21ST CENTURY

Background

Vehicular fuel economy is heavily dependent upon engine efficiency, which in turn largely depends on the way fuel is burned within the cylinders of the engine. Higher in-cylinder pressures and temperatures lead to increased fuel economy, but they also create more difficulty in controlling the combustion process. Poorly controlled and incomplete combustion can cause higher levels of emissions and lower engine efficiencies. In order to optimize combustion processes, engine designers have traditionally undertaken manual engine modifications, conducted testing, and analyzed the results. This iterative process is painstakingly slow and costly and does not lend itself to identifying the optimal engine design specifications. In response, scientists from the Los Alamos National Laboratory (LANL), with support from the Office of Transportation Technologies, initiated development in 1983 of an advanced computational fluid dynamics (CFD) modeling code (KIVA) that accurately simulates the in-cylinder processes of heat engines.

The Technology

KIVA is a three-dimensional, multicomponent model capable of simulating multiphase (liquid and gaseous) flow under steady-state and transient conditions. KIVA solves unsteady equations of motion coupled with equations simulating the fuel spray based on user-defined engine specifications (e.g., compression ratios, engine speed, fuel injection timing, and duration). KIVA is invaluable for modeling liquid phase fuel penetration and vaporization leading to a better understanding of combustion propagation. In order to maximize the efficiency of an engine, it is necessary to burn as much of the fuel as possible. The recent release of the KIVA 3V model permits not only in-cylinder calculations but also full-engine-cycle calculations in virtually any 2- or 4-stroke engine design. KIVA permits users to combine the modeling results with a computer graphics package to visualize the combustion process. For example, colors are used to identify the temperatures of combustion at different locations within the engine. By plotting colors the user can visualize the ignition of the fuel/air mixture and the evolution of flame propagation and combustion throughout the chamber. This information is used to make design modifications to create better controlled, more efficient combustion. By simulating the modifications using KIVA, the designers can significantly reduce engine development time, reduce costs, and more precisely identify optimal engine parameters.

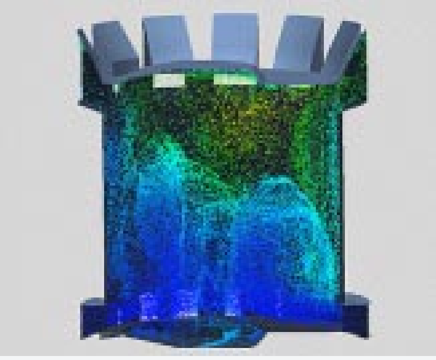
Commercialization

The KIVA modeling code was introduced in 1985 and has quickly become the industry standard for multidimensional combustion modeling. KIVA's code has been integrated into most of the top CFD modeling programs and is used by the automotive and heavy-duty diesel engine industries to develop energy-efficient, emission compliant internal combustion engines. For example, General Motors has used KIVA in the development of direct-injection, stratified charge gasoline engines as well as the fast burn, homogeneous-charge gasoline engine. Cummins Engine Company uses the KIVA code to help engineers examine fuel spray-airflow interactions in its heavy-duty N-series diesel engines. Furthermore, KIVA can be easily adapted for a variety of other applications, such as gas turbines, ramrockets, continuous spray combustors, and Bunsen burner flames.

Benefits

Using KIVA in engine design can

- **increase engine efficiency by up to 10%**
- **reduce development time by 60%**



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