Low-Cost, High-Temperature Alloy

Stirling engine technology uses power from an external heat source to fuel vehicles. The engine transmits thermal energy and must operate in adverse environments of extreme heat, corrosion, stress, and repeated cycling. Engine efficiency increases with higher operating temperatures, requiring special alloy materials for high efficiency, reliability, and longer lifetimes.

Before 1981, Stirling-engine structural components were fabricated from high-cost imported materials, such as cobalt, chromium, and nickel. Although these materials performed well, commercial introduction of Stirling engine technology has been impeded by economic factors and by the lack of a reliable source for the alloy components. Consequently, DOE with the National Aeronautics and Space Administration sponsored research by academic institutions and private sector firms to develop a low-cost replacement alloy with equivalent properties.

The new alloy surpassed expectations. It exhibits a superior lifetime, is far cheaper, and uses entirely domestic resources, with the exception of nickel imported from Canada. In addition to its Stirling engine applications, this alloy could penetrate high-temperature structural material markets throughout the United States, particularly for conventional automotive heat engine applications.

Energy efficiency benefits are expected to rise as the alloy achieves market penetration because this material will make higher engine operating temperatures possible. By reducing dependence on strategic imported materials, this research effort has directly enhanced our national security.

Simulation of Automobile Engine Processes with Color Graphics—KIVA II

The transportation sector consumes about 20 quads of liquid fuels each year, creating a tremendous incentive to develop more efficient engines. Engine efficiency largely depends on the fuel spray in the combustion chamber of the engine and on the ability of the engine to consume the fuel/air charge completely. Therefore, it is of increasing interest to designers and manufacturers of internal combustion engines to be able to represent an evaporating fuel spray by numerical calculations of chemically reactive fluid flows.

KIVA II is the latest in a series of multidimensional computer codes that allows numerical simulation of internal combustion engine processes. Developed at Los Alamos National Laboratory, KIVA II solves unsteady equations of motion in a turbulent mixture of gases that react chemically, and these are coupled to equations for a vaporizing fuel spray. The user provides the engine specifications (e.g., bore, stroke, compression ratio, and piston-top geometry), a specific starting time (e.g., the time the intake valve closes), and an ending time (e.g., the time the flame completely consumes the mixture of fuel and air). KIVA II solves the equations for a finite number of very small computational cells that represent the space in which combustion takes place, i.e., between the fixed engine cylinder and the top of the moving piston.

The user can also combine the results of the KIVA II computations with a computer graphics package to visualize the combustion process. For example, different colors may be used to differentiate ranges of temperatures that are computed for the various cells. By plotting the colors for each cell in three-dimensional space, the user can see how the fuel/air mixture is initially ignited and how the flame grows from the initial ignition point and spreads throughout the combustion chamber.

KIVA II has been accepted as the industry standard for development of automotive engine models. The program now is being used extensively by the automotive industry worldwide to help develop energy-efficient, EPA-compliant engines. General Motors has used KIVA II in developing engines such as the direct-injection, stratified-charge and the fast-burn, homogeneous-charge engines. Cummins Engine Co. uses the KIVA II code to help engineers examine fuel spray-airflow interactions in their diesel engines.

KIVA II can easily be adapted to a variety of other applications by modifying the general structure of its program. Such applications include continuous spray combustors, Bunsen burner flames, and nonreacting sprays.

Lubrication at Elevated Temperatures

Advanced designs for low-heat-rejection engines present two significant tribological challenges, namely, lubrication at elevated temperatures and lubrication of ceramic materials. Anticipated peak