Heavy Vehicle Propulsion Materials

Cost-Effective Smart Materials for Diesel Engine Applications

Background

Numerous studies have shown that varying the rate and the shape of fuel injection cycles and using multiple injections per cycle can significantly increase the fuel efficiency of diesel engines and lower their NOx and particulate emissions. The need for multiple-injection capability during power combustion cycles has stimulated research into the development of high-speed, low-cost piezoelectric actuators. Piezoelectric actuators can potentially cycle twice as fast as solenoid actuators, enabling the engine designer to match the fuel system and engine aftertreatment requirements for optimal performance.

To achieve sufficient stroke, a multilayered piezoelectric stack with electrodes between each layer is required. The high sintering temperature for lead zirconium titanate (PZT) necessitates the use of palladium-alloy electrodes, which adds to the cost significantly. Consequently, the development of new materials which sinter below the melting point of silver will enable mass production of lower-cost actuators.

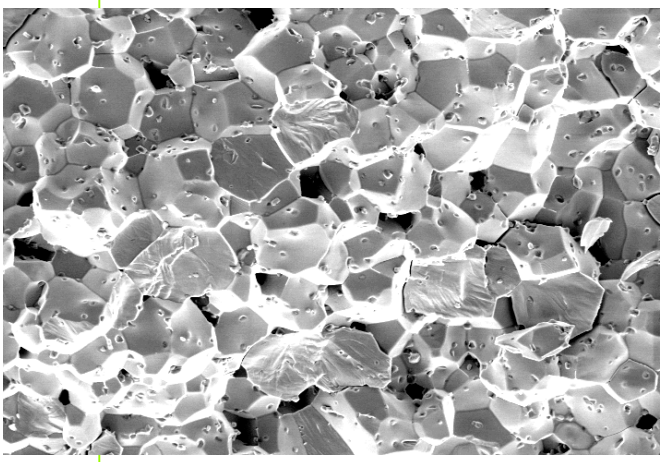
The Technology

A commercial PZT powder was modified by adding a sintering aid and a transition metal oxide to improve the piezoelectric properties. This combination results in a material that reaches full density by heating for 3 hours at temperatures below the melting point of silver. The piezoelectric properties are similar to those obtained with powders sintered at a 200°C higher temperature.

Biaxial strength testing shows that the sintering aid lowers the fracture strength of sintered die-pressed disks, but the addition of a ceramic with the correct particle size range increases the strength nearly to the value for high-temperature sintered PZT.

Cylindrical, multilayered actuator stacks with silver electrodes have been manufactured from the modified powder by laminating disks cut from tape cast sheets. The layer thickness is such that the actuator can be stroked by applying a voltage attainable

Less dependence on foreign oil, and eventual transition to an emissions-free, petroleum-free vehicle



SEM photo at 2500X of ORNL low-temperature PZT containing a ceramic strengthening aid.

by the electrical system in a heavy vehicle.

A fuel injector actuator must operate for several millions of cycles during its lifetime. ORNL has developed a laboratory-scale reliability test rig to measure the change in stroke as a function of the number of actuations. The stroke of a commercial product that has been tested diminishes after only a few million cycles.

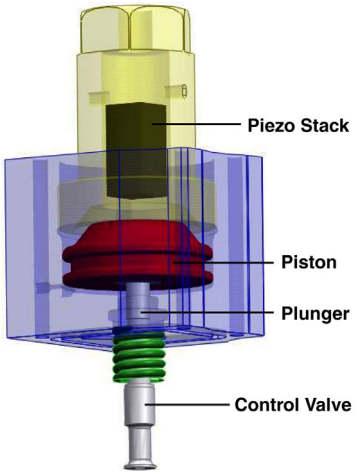
Commercialization

A collaborative project with Detroit Diesel Corporation and Wayne State University is developing a piezoelectric control valve actuator. The first phase of the project focused on characterization of the piezo stacks and fuel injection application validation via static and dynamic tests. The piezo stacks gave shorter response times compared to solenoid-actuated systems. Electric current and preload requirements were optimized at specified voltage levels.

Because displacement of the piezo stack is in the range of microns, the required control valve motion was achieved through design and development of an hydraulic amplification system. The cost and complexity of piezo actuation will be reduced for fuel systems that can use valves with shorter strokes and therefore not require motion amplification.

Benefits

- Use of PZT stacks fabricated using the ORNL low-sintering-temperature PZT reduces the cost of the actuator by allowing the use of lower-cost silver interlayer electrodes
- A ceramic agent added to the ORNL composition increases the strength and may thus enhance the reliability and lifetime of the actuator.



Where Can I Find More Information?

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