Overview

Timeline
• Project began – October, 2007
• Project ends – December, 2010
• Project is 70% complete, but 24 month CRADA extension is being negotiated with Caterpillar due to technical success and commercialization opportunities

Budget
• Total Project Funding
  • DOE Share -$700,000
  • Caterpillar - $700,000
• FY09 Funding - $225,000
• FY10 Funding - $169,000 to date

Barriers
• Barriers addressed include:
  • Difficulty in simultaneously increasing efficiency and reducing emissions
  • HECC Technologies increase operating temperatures of diesel exhaust valves

Partners
• Caterpillar’s Tier I suppliers for exhaust valves and seat-inserts
• Materials producers for component suppliers
**Objective**

This CRADA project is relevant to a key technical gap in Propulsion Materials that supports the following Advanced Combustion Engine goal:

**2015 Commercial Engine – Improve Efficiency by 20% over 2009 baseline efficiency**

**Technical Objective** – Higher temperatures (>700-750C) cause unacceptable wear between exhaust valves and seat inserts, and reduce durability

**Impact** – Better exhaust valves and seat inserts with reduced wear at higher temperatures will have an immediate commercial impact on enabling more efficient diesel engines
Approach

• Caterpillar and ORNL have characterized the root-causes of high temperature wear on engine and wear-rig tested standard valves and seats

• Caterpillar and ORNL have worked with seat-insert supplier to modify and test seats with more wear-resistance

• Caterpillar and ORNL have identified Ni-based superalloys with more temperature capability than standard 31V alloy used for exhaust valves

• Caterpillar and ORNL have worked with valve supplier to obtain prototype valves and test specimens made from new superalloys with better high-temperature capability
Milestones

• FY2009 – Complete initial CAT® rig-tests for wear-resistance of modified seat inserts (July, 2009, done)

• FY2009 – Identify Ni-based superalloys with more temperature capability for improved exhaust valves (September, 2009, done)

• FY2010 – Obtain mechanical testing specimens and prototype exhaust valves from new Ni-based superalloys (December, 2009, done)

• FY2010 – Complete initial CAT® rig-tests for wear-resistance of upgraded exhaust-valve alloys (August, 2010, on-track)
Technical Accomplishment - Caterpillar Valve Rig Testing Upgrade

Significant additions were made to valve and seat insert testing capabilities to support HPVM CRADA testing

- Two addition rigs
- Update original rig
- Portable CMM device
Technical Accomplishments – Wear-Resistant Seat Inserts

• Pre-oxidation provides lower total wear to BOTH valve and seat insert
• Oxide reforms on seat insert after initially wearing away
• 20 – 25% wear improvement after 600 hrs of valve rig testing
• Production Intent: March 2011

160-250nm oxide layer provides solid-state lubrication

Cumulative Wear (Valve + Seat Insert)

Cumulative Linear Wear Rates
Technical Accomplishments – Upgraded Exhaust Valves

ORNL identified commercial Ni-based alloys 1 and 2 as being Better than std 31V alloy for exhaust Valves above 700-750C

Yield Strength (YS, ksi)

High-temperature tensile and creep-rupture data both show significant benefits of new Ni-based superalloys with more temperature capability
Technical Accomplishments – Upgraded Exhaust Valves also Resist Wear

- Significant improvement in high temperature strength
- Ni-based 1 prototype valves show over 200% reduction in wear at 850°C, ~480 hrs
- Ni-based 2 prototypes wear testing in-progress
Collaboration and Coordination with Other Industrial Partners

• Caterpillar’s seat maker had to accept, test and validate the process modifications for improved wear-resistance

• Caterpillar’s seat maker will put modified seat-inserts into production

• Caterpillar’s valve maker had to obtain rod-stock of new upgraded Ni-based superalloys from alloy producers (2)

• Caterpillar’s valve maker had to machine mechanical properties test specimens for ORNL, and manufacture new prototype exhaust valves for Caterpillar to test from new Ni-based superalloys
Future Work – Need for CRADA Extension (2y)

• Caterpillar will continue to rig-test new prototype valves, while ORNL will continue creep-test specimens of new Ni-based superalloys

• Tested prototype valves and creep specimens will then be characterized and analyzed at ORNL

• Engine-tests of the durability of modified seat-inserts and upgraded exhaust valves will then lead to commercial production
Summary

• Caterpillar and ORNL have addressed critical high-temperature wear issue between seat inserts and exhaust valves for diesel engines

• Caterpillar and ORNL have clearly identified root-cause microscopic nature of wear attack for both seat-inserts and exhaust valves

• Caterpillar and ORNL have used pre-oxidation to mitigate wear on seat-inserts, and solution is ready for commercialization

• Caterpillar and ORNL are using critical knowledge to select and test Ni-based superalloys with more performance at higher temperatures to further mitigate wear