CRADA NFE-07-00995 – Materials for Advanced Engine Valve Train

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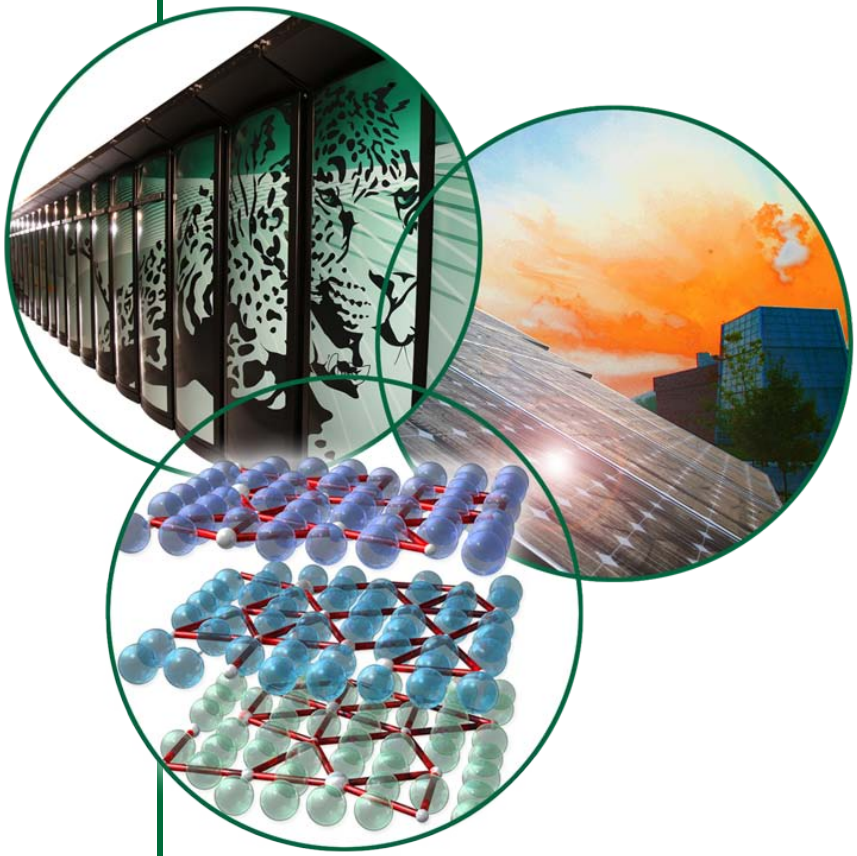

Project ID – PM022

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U.S. DEPARTMENT OF ENERGY

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OAK RIDGE NATIONAL LABORATORY
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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

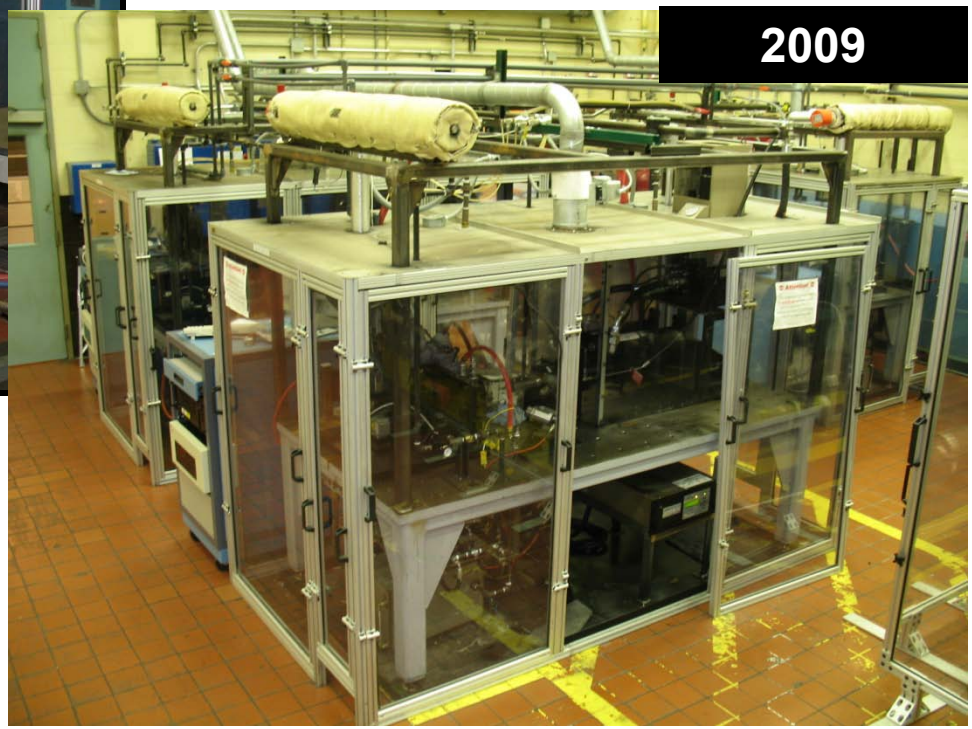
- Caterpillar and ORNL have characterized the root-causes of high temperature wear on engine and wear-rig tested standard valves and seats
- Caterpillar and ORNL have worked with seat-insert supplier to modify and test seats with more wear-resistance
- Caterpillar and ORNL have identified Ni-based superalloys 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)

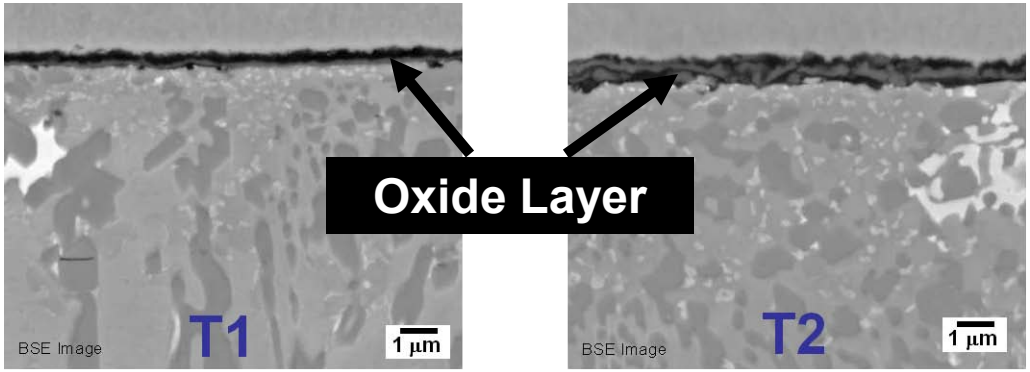
Technical Accomplishment - Caterpillar Valve Rig Testing Upgrade

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



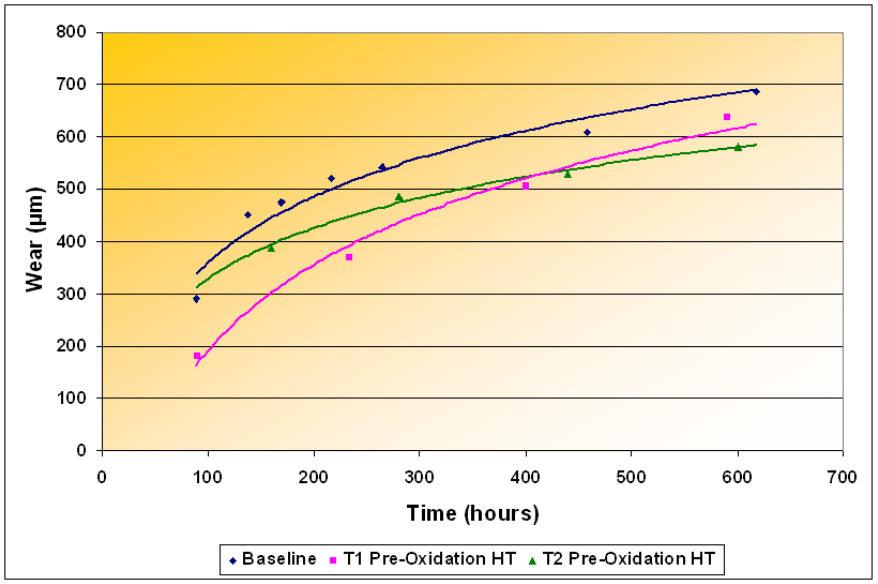
- ✓ Two addition rigs
- ✓ Update original rig
- ✓ Portable CMM device

Technical Accomplishments – Wear-Resistant Seat Inserts

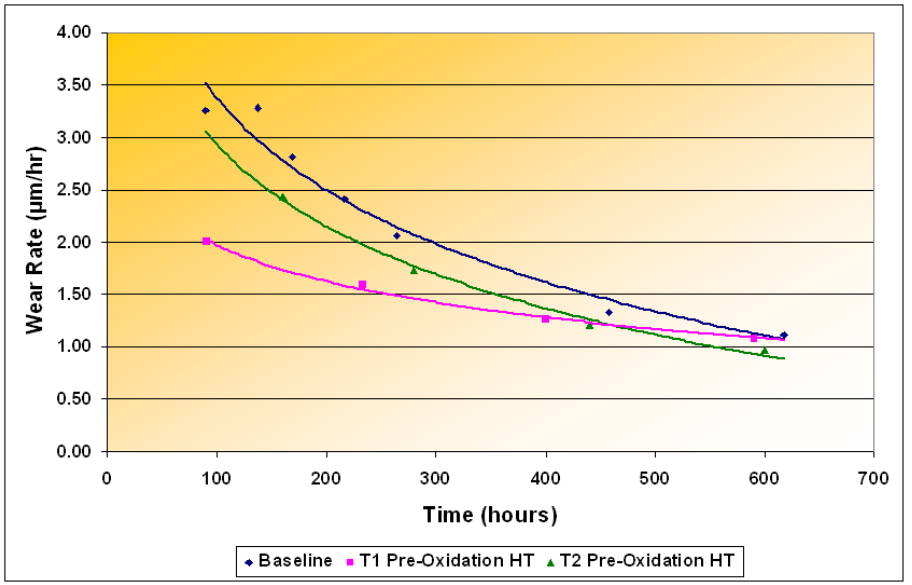


160-250nm oxide layer provides solid-state lubrication

- 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



Cumulative Wear (Valve + Seat Insert)

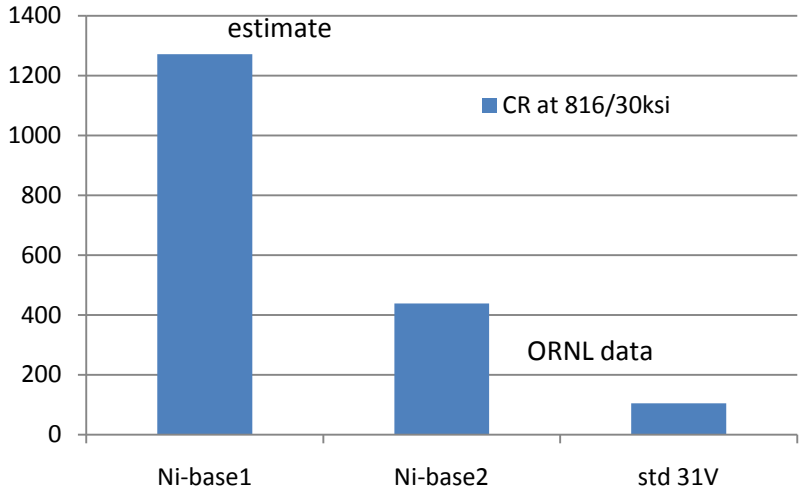


Cumulative Linear Wear Rates

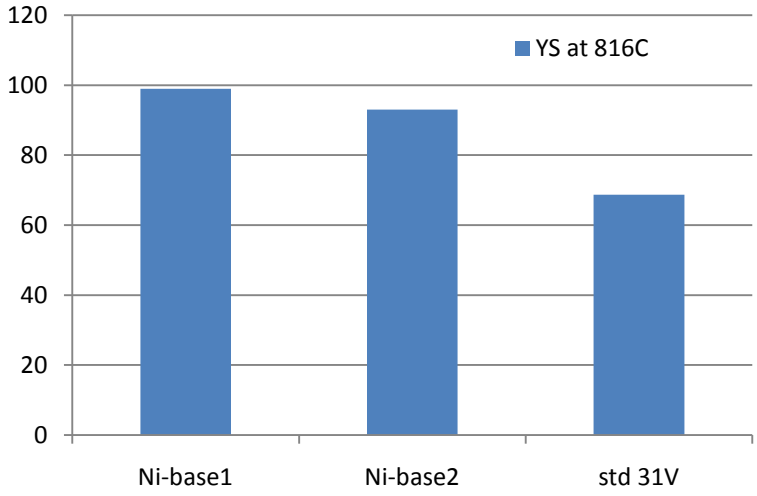
Technical Accomplishments – Upgraded Exhaust Valves

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

Creep-Rupture Life (h)

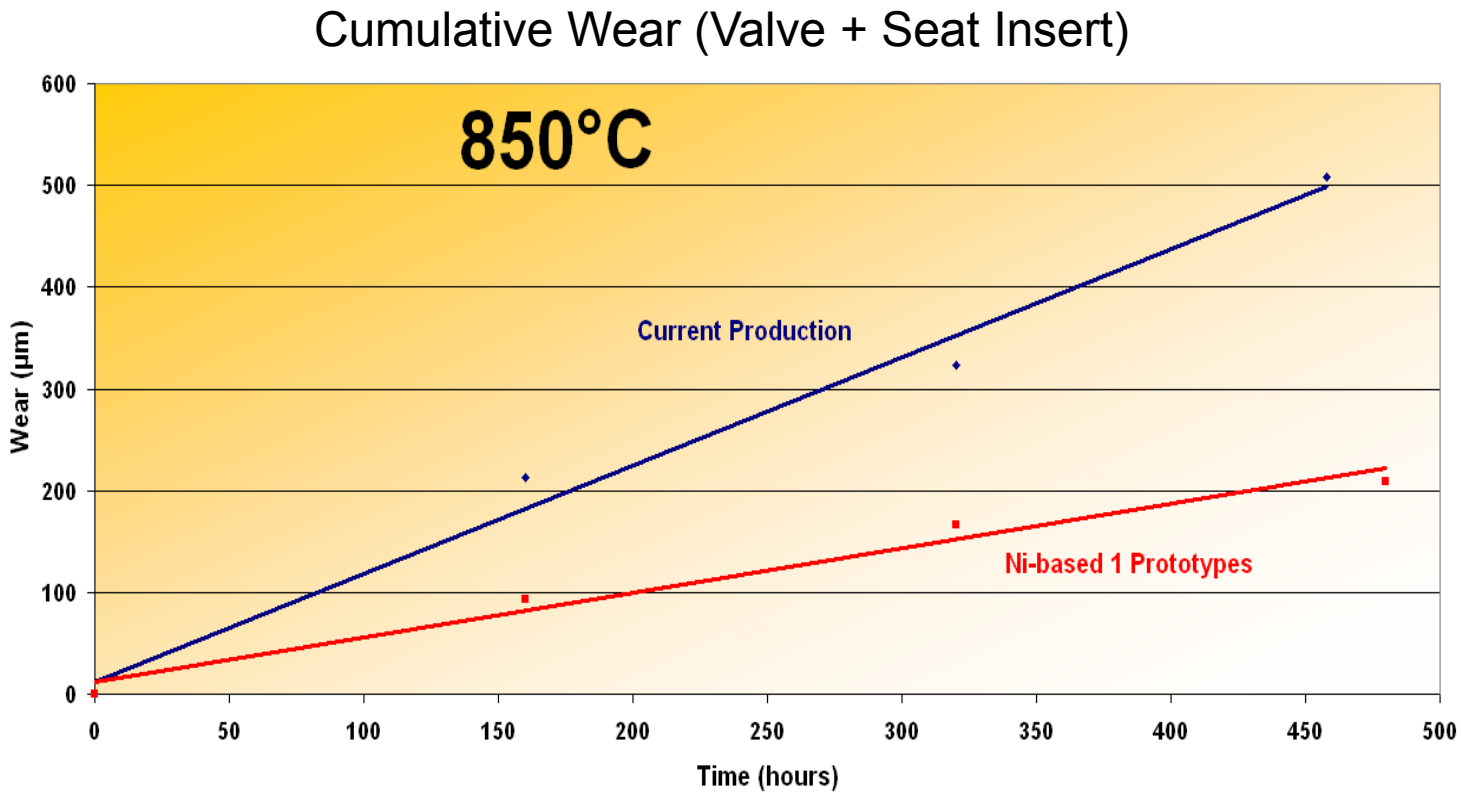


Yield Strength (YS, ksi)



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