Overview

Timeline
• Project began – October, 2007
• Project ends – December, 2012
• Project is 70% complete, with 24 month CRADA extension last year

Budget
• Total Project Funding
  • DOE Share -50%
  • Caterpillar – 50%
• FY10 Funding - $275,000
• FY11 Funding - $225,000

Barriers
• Changes in internal combustion regimes
  • Materials properties of exhaust valves will need to change to accommodate higher temperatures and pressures
• Lead time for materials commercialization
• Cost

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 Thermal Efficiency by 20% over current 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 identified several 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

• Caterpillar is performing accelerated wear-rig testing of prototype valves of new alloys; ORNL is performing elevated temperature tensile and creep-testing to verify properties of new alloys
Milestones

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

• FY2011 – Complete initial rig-tests for wear-resistance of exhaust-valves of new Ni-based superalloys at Caterpillar (November, 2010, done)

• FY2011 – Complete initial creep-rupture testing of new Ni-based superalloys for exhaust valves at ORNL (February, 2011, done)
Technical Accomplishments – Upgraded Exhaust Valves also Resist Wear

- Significant improvements in high temperature strength and wear resistance

- Ni-based 1 prototypes show
  - 2.7x improvement in wear life at 850°C
  - 2.2x improvement in wear life at 740°C

- Ni-based 2 prototypes show
  - 1.5x improvement in wear life at 850°C
  - 2.0x improvement in wear life at 740°C
Technical Accomplishments – Upgraded Exhaust Valve Alloys Have Better High-Temperature Strength

Commercial Ni-based alloys 1 and 2 were chosen because they were stronger than std 31V alloy above 700-750°C

- New Ni-based alloys 1 and 2 both show higher yield strengths (YS) than standard 31V alloy
- Both new Ni-based alloys have similar YS at both 816 and 871°C

Tensile Tests to Measure Yield Strength at High Temperatures
Technical Accomplishments – Upgraded Exhaust Valve Alloys Have Better High-Temperature Strength

Commercial Ni-based alloys 1 and 2 were chosen because they were stronger than std 31V alloy above 700-750°C

• New Ni-based alloy 1 has much more creep resistance than alloy 2 or standard 31V alloy at 871°C
• New Ni-based alloy 1 has similar creep-strength advantage at 816°C
• Differences in creep-resistance among the 3 alloys are much larger than tensile properties differences

Creep Tests to Measure Rupture Life at High Temperatures

![Creep-Rupture at 871°C/15ksi graph](image)
Collaboration and Coordination with Other Industrial Partners

• Caterpillar’s seat maker is providing upgraded seat-inserts to test with upgraded valve alloys

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

• Caterpillar’s valve maker produced mechanical properties test specimens for ORNL, and manufactured new prototype exhaust valves for Caterpillar to test from new Ni-based superalloys
Future Work – Aging, Wear-Rig Testing and Engine Testing

- Caterpillar will complete rig-test new prototype valves at various temperatures
- ORNL will complete aging (5000 h) and test mechanical properties of new Ni-based superalloys after aging
- Microstructural analysis of wear-tested valves and creep specimens will continue at ORNL
- Engine-tests of the durability of modified seat-inserts and upgraded exhaust valves are next
Summary

- Caterpillar and ORNL previously clearly identified root-cause microscopic nature of wear attack for both seat-inserts and exhaust valves.
- Caterpillar and ORNL used critical knowledge to select 2 new Ni-based superalloys with more performance at higher temperatures to further mitigate wear.
- Caterpillar wear-rig testing of prototype valves at 850°C shows superior performance of Ni-based superalloy 1 compared to standard 31V alloy exhaust valves.
- ORNL creep-rupture testing at 816-871°C shows superior creep-resistance of Ni-based alloy 1 compared to standard 31V exhaust valve alloy.