Engine Materials Compatibility with Alternate Fuels

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May 2011

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Project ID # PM039

Project Overview

Timeline

- Start – December 2009
  - intended start delayed almost 1 year by CRADA negotiations
- End – December 2012
- Percent complete ~ 33%

Budget

- Total DOE funding = $900K ($300K/y for 3 years)
- Partners are matching funding with 1:1 in-kind contributions
- FY10 funding received = $300K; FY11 funding expected = $300K

Barriers Addressed

Propulsion Materials Technology

A. Changing internal combustion engine component regimes
   - Task 1 - examine impact of new fuels on light duty engine components
   - Task 2 - collaborate with industry partners to characterize materials-related life-limiting mechanisms

Fuels and Lubricant Technology

E. Inadequate data on long term impact of fuel composition on durability of engine components

Partners

This project is a Cooperative Research and Development Agreement (CRADA) between ORNL and USCAR, LLC [includes GM (lead), Ford, Chrysler]

Project Objective

Conduct a systematic assessment of engine materials corrosion in ethanol fuel blends

Goals to reach this objective include:

- **develop a mechanistic understanding of corrosion associated with increased ethanol content in transportation fuels**

- **identify performance boundaries and material selection requirements for engine materials**

- **develop rapid test protocols to enable anticipation of potential problems in design (rather than simply react to problems after occurrence)**

A Potential Compatibility Concern with Utilization of New Fuels

Experience in Brazil with fuel blends up to E100 and more recent experience in the US and elsewhere with production and testing of flex-fuel vehicles (e.g., E85 fuel) has led to observations of corrosion not previously encountered with low-ethanol or ethanol-free fuels

General Strategy

Utilize laboratory exposures (controlled testing) and forensic analysis of materials returned from field testing (e.g., "dyno" testing) to assess corrosion rates and mechanisms of susceptible materials as a function of key fuel blend variables such as:

- ethanol content
- fuel contaminants
- temperature
- alloy composition and structure

An Integrated Approach to Examine Compatibility Issues Has Been Developed

Task 1: Laboratory corrosion exposures of coupon materials

Task 2: Surface analysis of materials exposed in field and laboratory testing

Task 3: In-situ extraction of gas and/or fluid from engine components

Task 4: Development of electrochemical test protocols for rapid evaluation of material/fuel combinations

Milestones – shaped around results

- **Extend literature review on material performance in ethanol fuel blends**
  Ongoing; Summary report Sept 2011

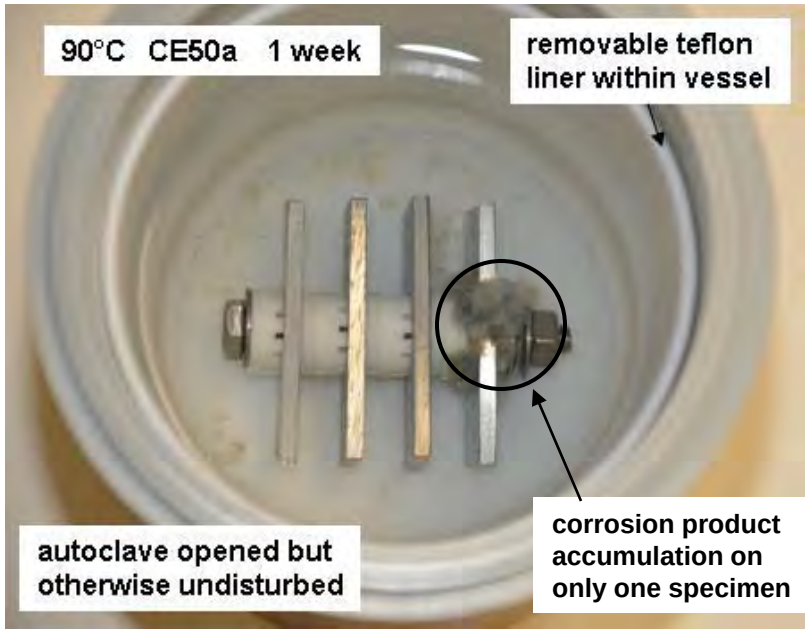
- **Design/construct system for high temperature corrosion tests in ethanol fuel blends**
  Completed; testing initiated and data compilation ongoing

- **Perform in-situ sampling of gas/liquid from engine components**
  Initiated; results Oct 2011

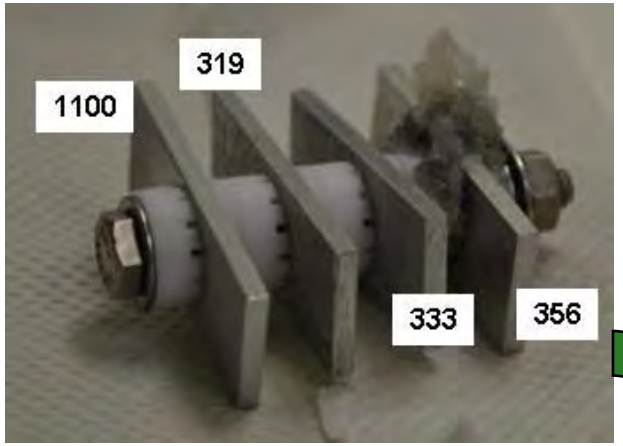
- **Perform baseline forensic analyses of components exposed in field/engine tests**
  Initiated; results July 2011

Accomplishments and Progress – Task 1

Autoclave testing in simulated fuels indicates conditions under which some blends are aggressive and some aluminum alloys susceptible to substantial corrosion



Laboratory corrosion exposures



coupon rack prior to cleaning

aluminum alloy 356 coupon after cleaning; very high corrosion rate in crevice area

Accomplishments and Progress – Task 2

Surface analysis of materials exposed in field

Identification of cylinder heads exhibiting intermittent corrosion is on-going

Partners have offered several engine heads for initial (baseline) analysis

Dyno testing has recently identified additional potential components for study

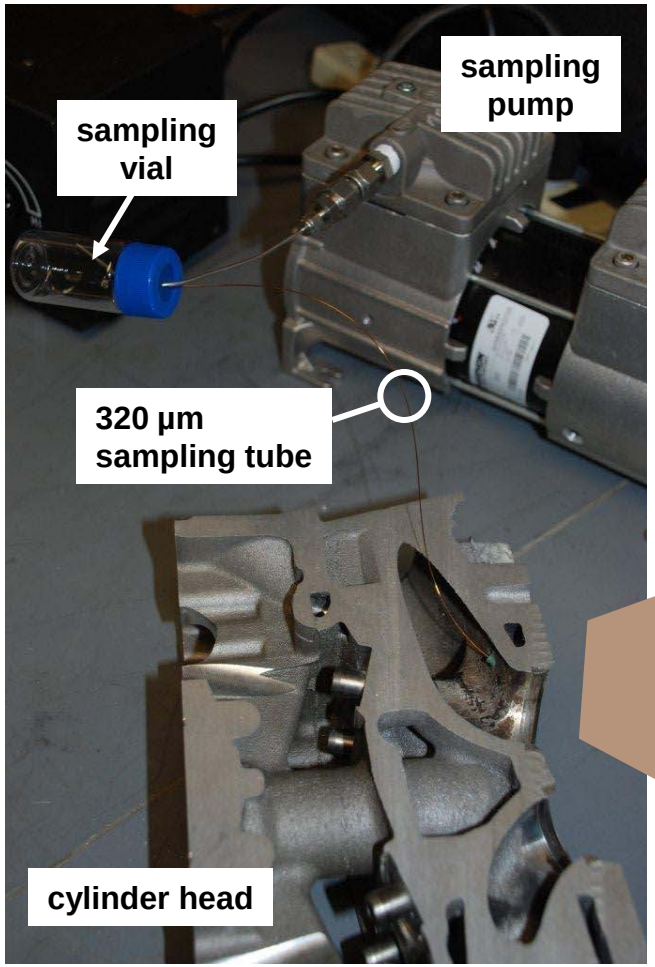
Methods to identify corroded components – as well as protocols for appropriate sectioning and cleaning techniques for each component – are being developed

Specimens being prepared for scanning electron microscopy and identification of corrosion products

Laboratory exposure tests will be manipulated to ensure corrosion products generated correspond to those found on actual engine components

Accomplishments and Progress – Task 3

In-situ extraction



Initial efforts have been completed to demonstrate a proof-of-principle device for sampling of gas/fluids from the cylinder. A cylinder head provided by the USCAR partners was sectioned and a small diameter hole (to accommodate a 320 µm diameter tube) drilled behind the intake. Initial tests to withdraw water from this area were successful.

Six heads have been drilled such that sampling ports provide access within each cylinder

Engine testing with in-situ sampling expected to begin in May 2011

Laboratory test environments will be manipulated to ensure correspondence with in-situ sampling results

Accomplishments and Progress – Task 4

Development of rapid electrochemical tests

- **Test development has not yet been initiated, pending results of literature searches, lab testing, and evaluation of components returned from service that will direct experiment design**

- **Task 4 has a Go/No-Go milestone at the end of year 2 (Sept 11) to determine the relative feasibility of electrochemical testing in fuel blends compared to continued coupon exposure**

Future Work

- Extend aggressive laboratory testing using autoclaves
  - expand blend variables to identify corrosive combinations of fuel and materials
  - focus on aluminum alloy variation in test matrix
- Complete in-situ sampling of gas/fluids from engine components as a function of operating variables
- Complete surface analyses of engine components as available
- Pursue Go/No-Go milestone associated with electrochemical testing

Summary

- This project facilitates collaboration with industry partners to characterize potential life-limiting corrosion of engine materials as a function of new fuel compositions

- In the first year of this effort, several tasks were initiated to enable the overall objectives
  - laboratory exposure of specimens in high temperature ethanol fuel blends reveals some conditions under which aluminum corrosion occurred; testing is ongoing
  - engine heads have been successfully modified to permit sampling during engine operation
  - engine heads suitable for analysis of baseline conditions and localized corrosion have been identified and analysis protocols are being developed
  - literature searching for relevant compatibility information is ongoing