Influence of EGR on Component Durability

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Exhaust Gas Recirculation Strategy

Recirculate the exhaust gas in the engine to reduce emissions

EGR will create a new environment in the engine with altered composition and temperature of exhaust gas and increased particulates

- Materials durability: engine and EGR components
- Design: mechanical/controls and packaging

EGR is a potential strategy to reduce emissions

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Corrosion Concerns

Concern for the engine and EGR system durability, functionality and health, especially at and beyond midterm life of the engine

- Hot corrosion at elevated temperatures
- Cold corrosion due to acidic condensation at low temperatures - cold climates and engine shutdown.
- Particulates:
  - High rate of erosive and abrasive wear
  - Particulate buildup and fouling of the lubricating oils

Corrosion Concerns

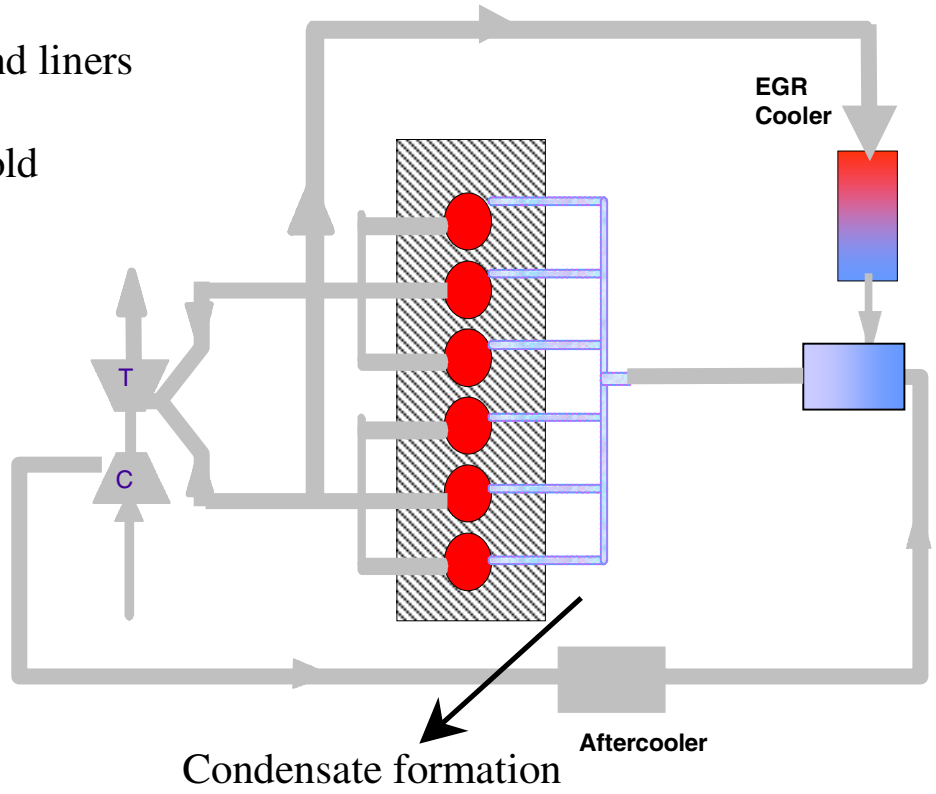
Piston-Ring and liners

Intake Manifold

Engine Valves

Exhaust manifold

Turbocharger



EGR cooler

Pipes

Joints, seals

Controls

Mixing mechanism

Components of potential corrosion concerns

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Materials Selection and Validation

- Determine the composition of the EGR exhaust and condensate in a 13-mode test engine

  Exhaust gas: Air + Sulfates + Nitrates + Organic acids + water

  Condensates are Acidic

- Simulate the compositions and conduct lab corrosion tests:
  - High temperature: static corrosion in simulated exhaust gas - compare to air
  - Condensate:
    - Immersion at temperature
    - Immersion at temperature and pressure
    - Electrochemical: polarization and Tafel techniques
  - Combination:
    - High temperature in exhaust followed by EC/immersion

Approach to select and validate materials for EGR application

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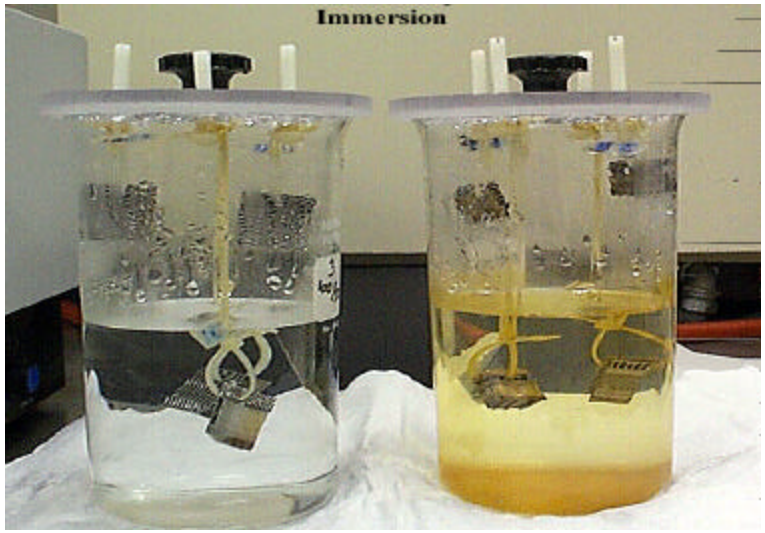
Immersion in Condensate Solutions



Materials and processing effects - Joining Technology

Immersion test revealing differences in corrosion between materials as well as various joining technologies

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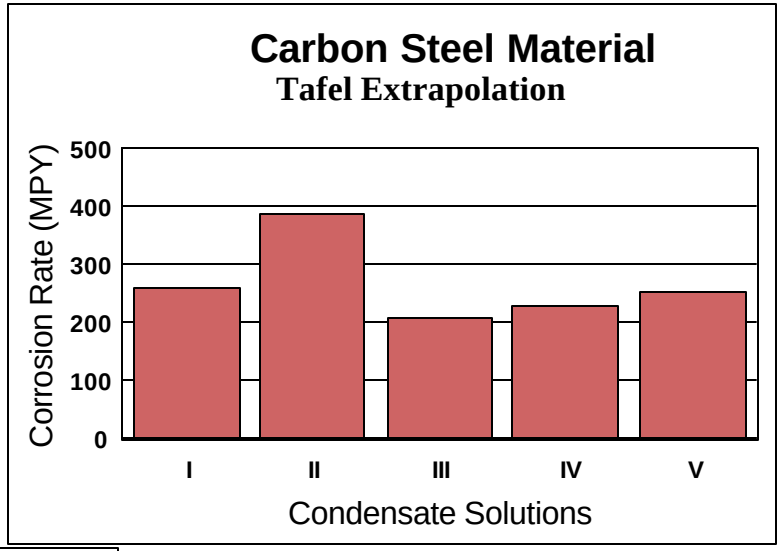
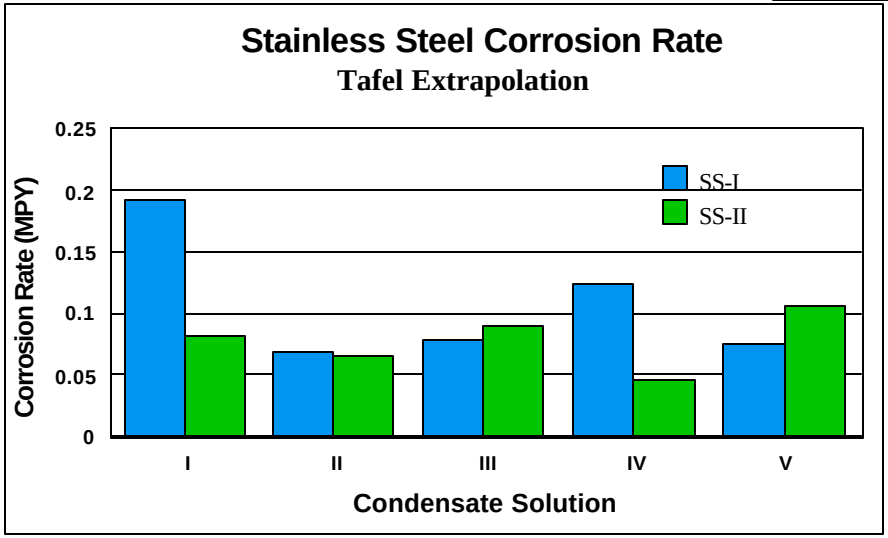
Electrochemical Testing in Condensate Solutions





Comparison of corrosion rates
Identification of high risk materials

Electrochemical tests gave direct comparison between materials and and general corrosion trends

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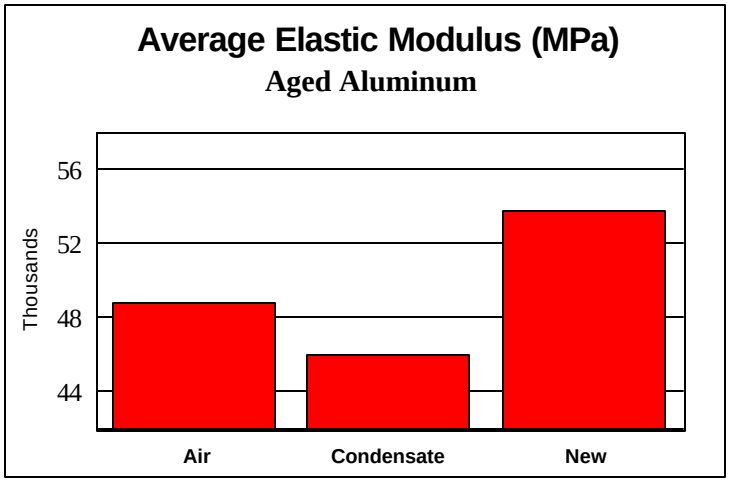
Immersion in Condensate Solutions at High pressure and Temperature



Testing of Aluminum
at high pressure and temperature

Testing under pressure can simulate engine applications

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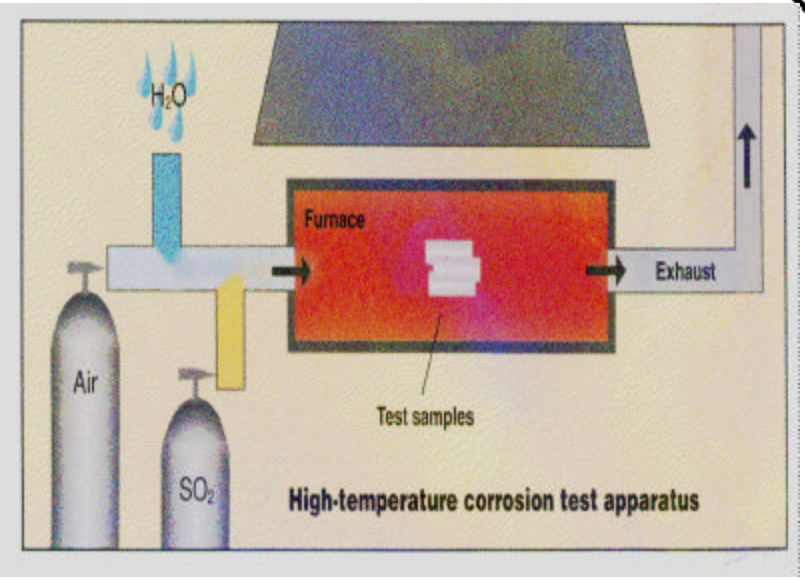
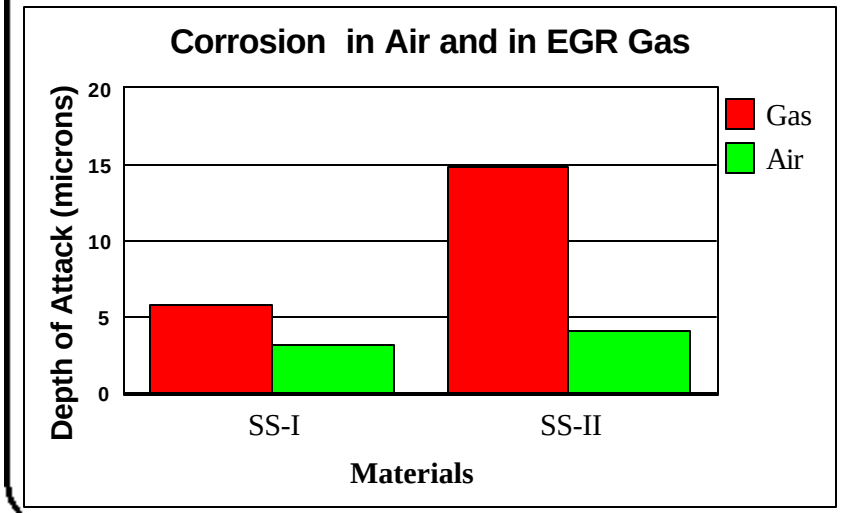
Testing in Simulated EGR Exhaust Gas





EGR exhaust gas is more corrosive than air at high temperature

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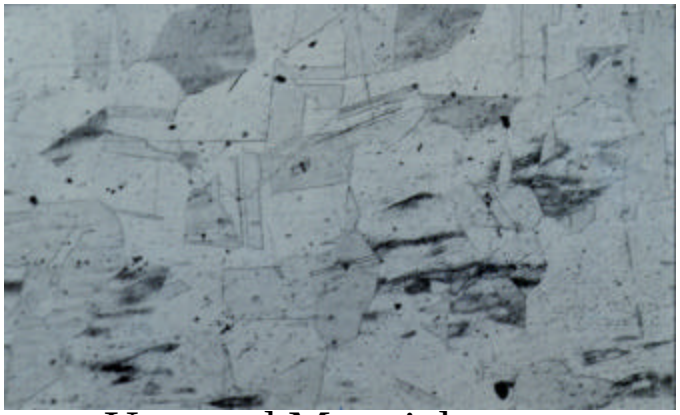
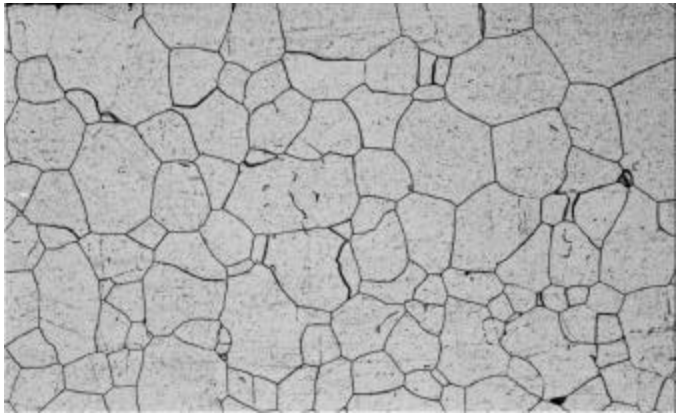
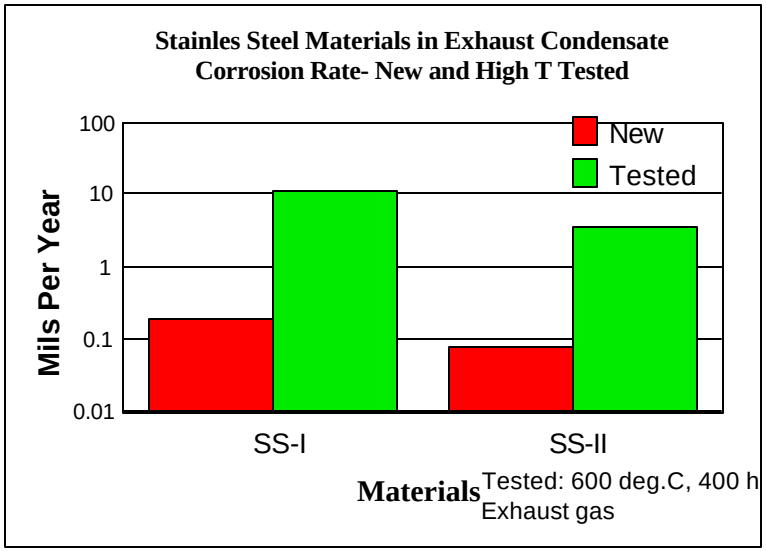
Corrosion rate in EGR Gas and Condensate



Untested Material



High-T tested Material



Sensitization resulting from high temperature exposure increases the corrosion rate in condensate. Cyclic effect could be detrimental

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Conclusions

- Serious concerns exist for the corrosivity of the EGR environment
- EGR exhaust gas is more corrosive than air at high temperature
- Condensates of EGR exhaust gas are acidic and corrosive
- Cyclic exposure to exhaust gas followed by exposure to condensate increases the corrosion rate of materials

Materials Strategy

- Utilize focused corrosion tests in simulated exhaust gas and condensate to determine best material choices for various components
- Conduct engine tests with the down selected materials
- Conduct field tests utilizing the selected materials and evaluate durability of the materials

- Serious time constraints exist for materials selection, validation, and development