DOE/DOD Parasitic Energy Loss Collaboration

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Overview

Timeline

- Project start date FY 10
- Project end date FY 14
- Percent complete 15%

Budget

- Total Project Funding 325K
  - DOE Share 325K
  - Contractor Share* 250K
- FY 09 0K
- FY 10 325K

* TARDEC funding in FY09

Barriers

- Engine and Vehicle Efficiency
  - Reduce consumption of imported petroleum
- Reliability & Durability
  - Extreme Tribological Environments (DOD/TARDEC)
  - Low SAPS Lubricants (DOE)
  - EGR-Tolerant Lubricants (DOE)
  - Alternative-Fuel Lubricants (DOE)

Partners

- TARDEC
- Mahle
- DOD Vehicle OEMS (NDA – protected)
- Additive and Lubricant OEMs (NDA)

Project Objectives - Relevance

- Commercial and military ground vehicles have a number of common issues and concerns related to parasitic energy losses, reliability, and durability.
- Both DOE and DOD have active programs that focus on the development of advanced strategies and technologies to overcome critical barriers.
- Project Objectives:
  - Identify critical barriers related to parasitic friction losses, reliability, and durability common to commercial and military vehicles.
  - Establish DOE/DOD collaboration that utilizes key facilities and expertise to investigate, model, and understand fundamental tribological phenomena that impact fuel efficiency, reliability and durability.
  - Develop and implement advanced tribological solutions (lubricant, materials/coatings, surface texturing).
- Goal – Improve vehicle fuel efficiency while maintaining/improving reliability and durability.
- Milestones (new project for FY10)
  - Establish collaborative project on parasitic losses with DOD/TARDEC.
  - Identify tribological requirements common/unique to commercial/military vehicles.
  - Initiate/extend studies on impact of additives and materials on vehicle efficiency (friction) and reliability/durability (wear and scuffing).

Relevance - Fuel Efficiency/Consumption Challenges

- **Commercial Vehicles (DOE)**
  - On-road, urban/highway
    - 20 – 40 + mpg passenger car
    - 6 – 10 mpg heavy trucks
  - Well-established supply/delivery system
  - 12M bbl/day
  - $3-$4/gallon at the pump
  - 10 to 15 % of fuel consumed by engine and drivetrain friction

Cost of delivering fuel to field operations can be complex and expensive

- **Military Ground Vehicles (DOD)**
  - On-road & Off-road; high level of idle
    - HUMVEEs originally designed for 6-8 mpg actually experiencing 2 mpg
  - Complex logistics for delivering fuel to field operations
  - 0.4M bbl/day
  - $100 - $600/gallon delivered in the field
  - Driving schedule that includes long periods of idle increase frictional losses

Common goal to increase fuel efficiency:
a) 1-1/2 M bbl/day lost to friction – motivating the commercial sector to reduce parasitic friction
b) Increased fuel usage coupled with complex & costly fuel delivery logistics motivating the military sector to reduce parasitic friction

Relevance - Reliability/Durability Challenges

- **Commercial Vehicles (DOE)**
  - Implementation of emission control technologies
    - Aftertreatment devices require development of low-SAPS lubricants
    - Higher use of EGR introducing higher levels of soot and combustion products into lubricants
  - Development of alternative-fuel vehicles
    - Lubricity of alternative, non-petroleum based fuels
    - Fuel dilution of lubricants
  - Downsizing, lightweighting of vehicle components
    - Increased power density/stresses on critical engine and drivetrain components
    - Poor tribological properties of lightweight materials

- **Military Ground Vehicles (DOD)**
  - Accelerated failure of ground vehicles in SWA - extreme tribological environments
    - High temperatures – rapid degradation of lubricant properties
    - Sand/grit – accelerated wear of critical engine and drivetrain components
    - Vehicles must also function in arctic-temperatures – poor flowability
  - Loss-of-lubricant accidents
    - Survivability of engine, drivetrain, and other mission-critical components when lubricant supply is non-functional
  - Multi-function lubricants
    - Common lubricants for transmission and engine applications
      - compromised performance to achieve commonality in fluids.

Common need to improve reliability and durability of lubrication systems

Milestones

- **FY 2010**
  - Establish collaborative project on parasitic losses with DOD/TARDEC (completed)
    - Discussions in progress with industry
  - Identify tribological requirements common/unique to commercial/military vehicles (in-progress)
  - Initiate/extend studies on impact of additives and materials on vehicle efficiency (friction) and reliability/durability (wear and scuffing) – in-progress.

APPROACH

- **TEAM DEVELOPMENT**
  - Establish collaborations with key groups
    - TARDEC, vehicle OEMs, component suppliers, lubricant suppliers
  - Define common/unique requirements & barriers
    - Efficiency – current state-of-art
    - Reliability - challenges
  - Identify potential pathways to overcome barriers
    - Additive formulations
    - Materials
    - Surface finishing
  - Establish technical goals
    - Efficiency/friction, reliability, durability

- **EXPERIMENTAL**
  - Benchtop tests
    - Quantify standard tribological properties of candidate solutions
    - Model friction and wear and impact of surface finish, lubricant, and boundary friction.
  - Detailed characterization of tribo-film formation and impact of additives/materials
    - Leverage VT/Propulsion Material studies on friction modeling
  - Engine validation studies with TARDEC, lubricant suppliers, Vehicle OEMs
  - Implementation of technology
    - OEMs, lubricant suppliers

Accomplishments/Progress - Teams Established

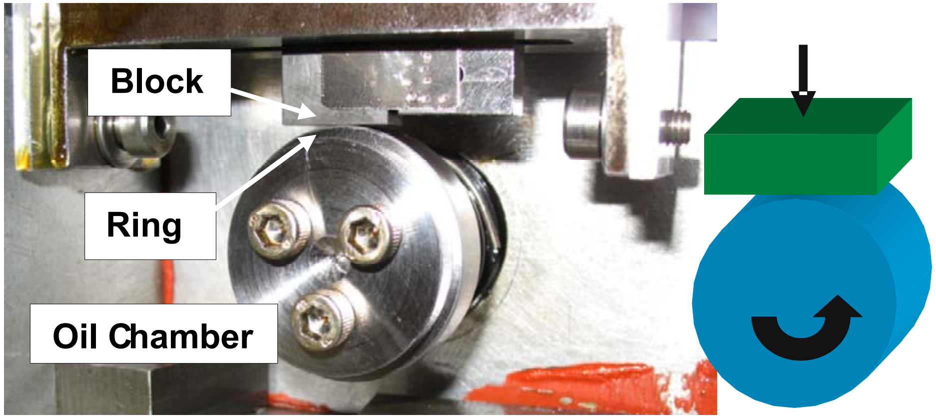
- Established working relations / collaborations with key staff at TARDEC – Fuels and Lubricants Technology Team
  - Discussions on developing coordinated project on investigation of protective tribofilms that extend reliability and lower friction under severe conditions.

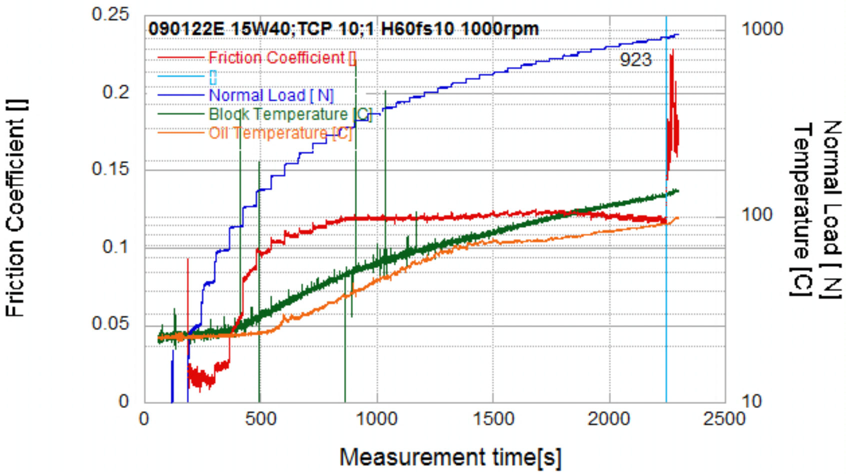
- Established contacts with DOD ground vehicle OEM (also commercial vehicle OEM) to develop collaborative project on parasitic energy losses.
  - Signed non-disclosure agreement identifying topics of interest

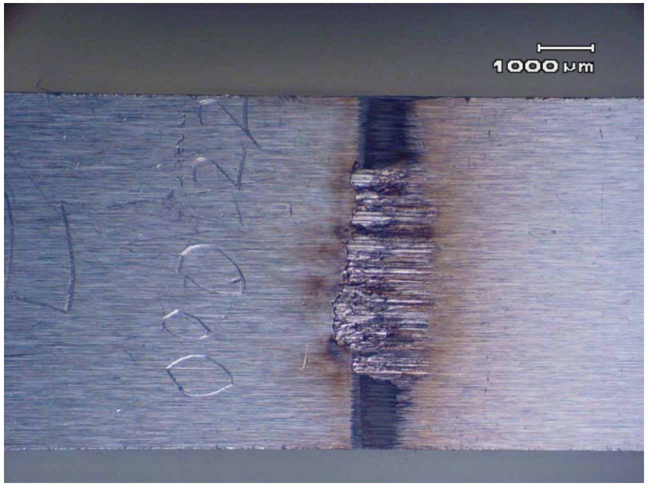
- Existing working relations / collaborations with engine component supplier(s)
  - Exchange of components, treatment of components, evaluation of components
  - Development of proprietary software (by supplier) to interpret experimental data on tribological properties
  - Exchange of prototype lubricants/additive formulations and exchange of data with lubricant OEMs

Accomplishments/Progress – Completed Initial Studies on the Impact of Additives on Scuffing

- Block-on-ring configuration used to quantify critical scuffing load (ASTM G77, D2714, D3704)
- Performed detailed study on the impact of 5 additives (boric-acid, tricresyl phosphate, boron nitride, graphite, and moly disulphide) on the scuffing resistance of a certified, mil-spec mineral oil



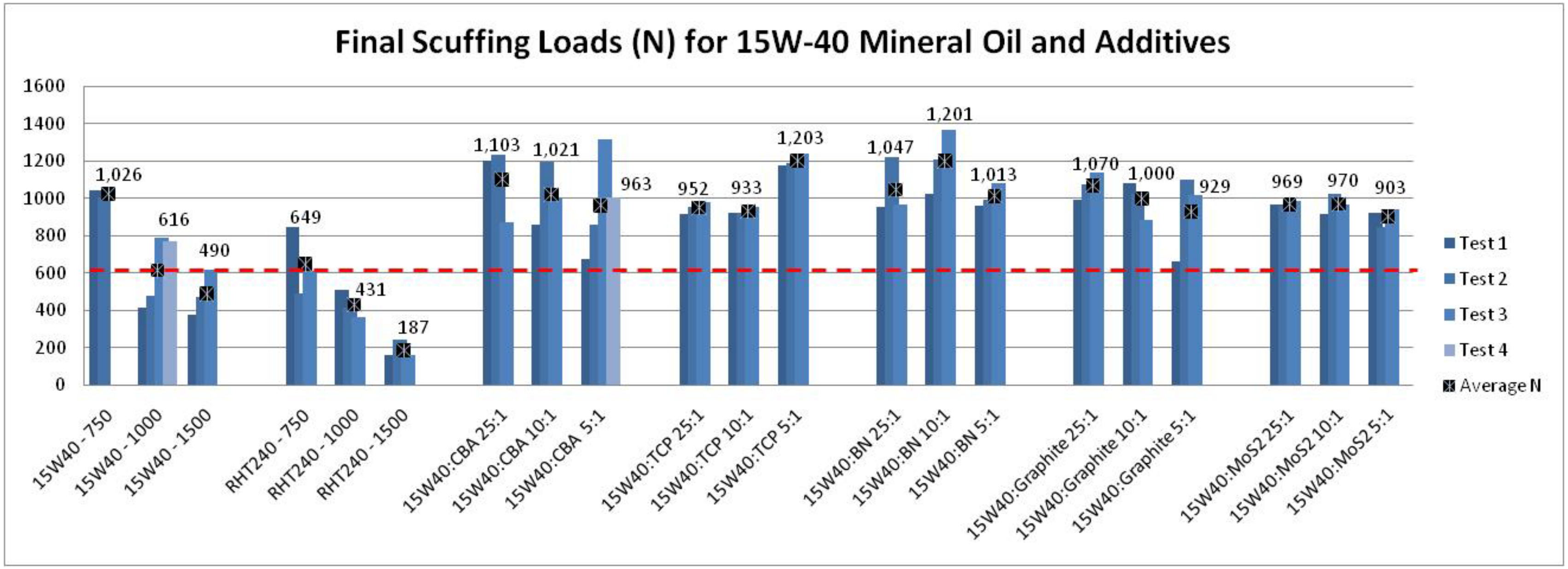




Friction behavior (left) and scuffing failure appearance (right)

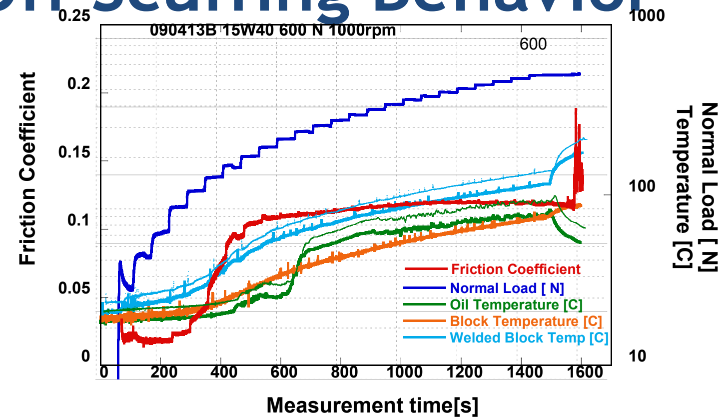
Accomplishments/Progress - Scuffing - cont'd

- Two commercial additives identified that extended scuffing behavior during fully lubricated conditions
- Figure below shows measured scuffing loads for different combinations of speed, additive type, and additive concentration.
  - Tests and characterization efforts are continuing to examine microstructure of two additives (boric-acid and tricresyl phosphate.

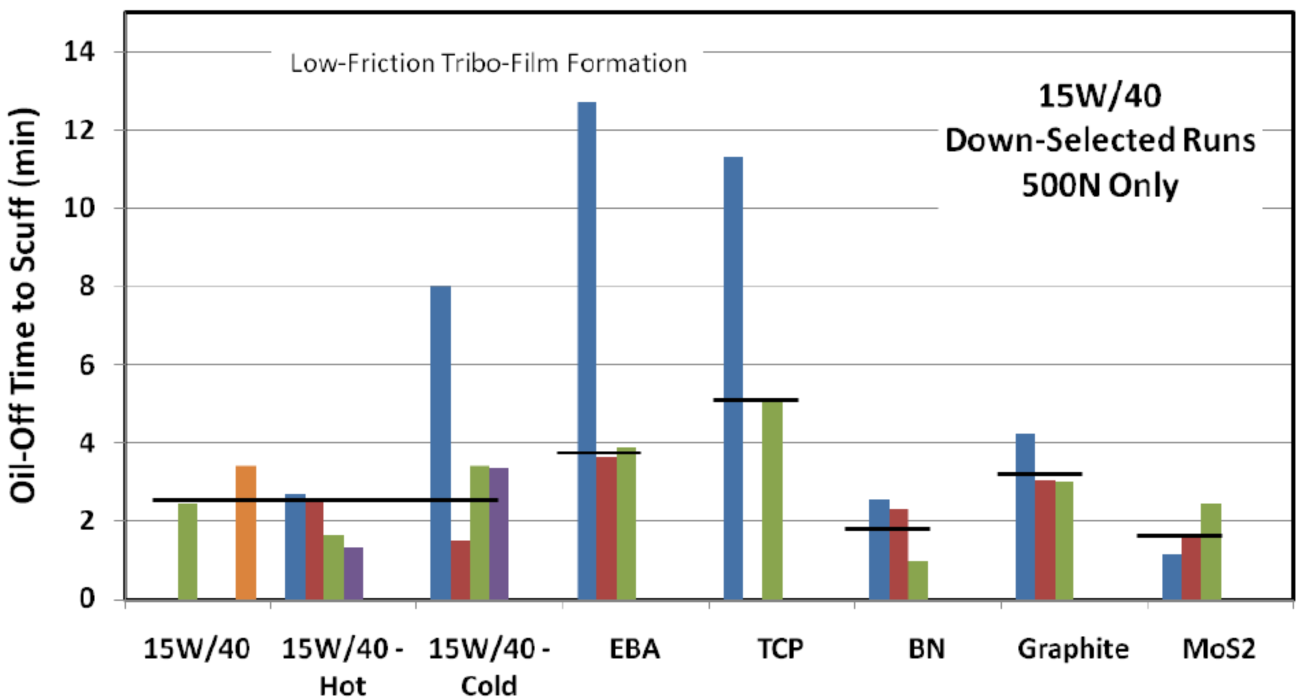


Accomplishments/Progress – Technical: Examined Impact of Additives on Oil-Off Scuffing Behavior

- Performed detailed study on the impact of 5 additives (boric-acid, tricresyl phosphate, boron nitride, graphite, and moly di-sulphide) on the scuffing resistance of a 15W-40 oil under **starved** lubrication conditions.

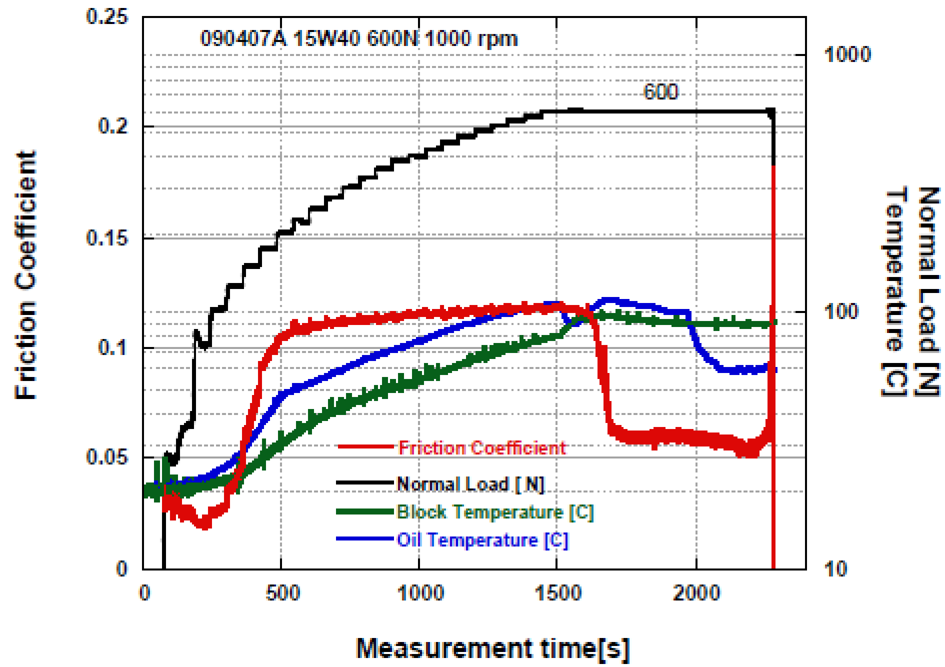


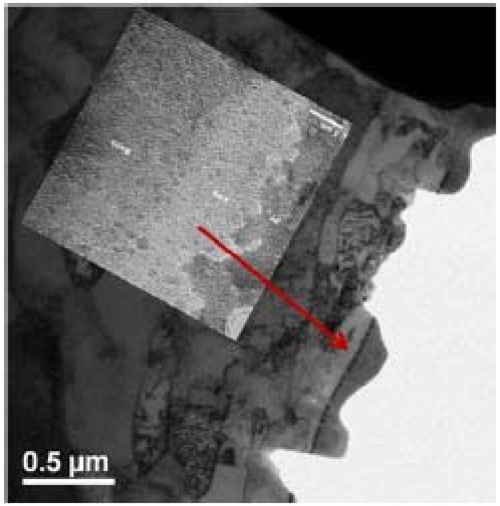
- Load adjusted to 600N, oil drained, measured time to onset of scuffing
- Failure time extended up to 100 %
- Frequently observed formation of low-friction film



Accomplishments/Progress - Technical: Formation of Low-Friction Tribofilm that Delayed Scuffing

- Frequent observation of a low-friction tribo-film during oil-off scuffing studies. When observed, the onset of scuffing was significantly increased.
  - Implications for energy efficiency
  - Implications for reliability and durability





- Applied advanced characterization technique (focused-ion-beam spectroscopy – FIBS) to examine structure and composition of tribo-films formed during tribolological interactions.
  - Understand fundamental mechanisms involved in the formation of protective, low-friction tribo-films – work in-progress

Collaborations/Coordination with Other Institutions

- Project involves collaborations with the following institutions to evaluate low-friction (fuel efficiency) and durability/reliability:
  - DOD/TARDEC [government] – Force Projection Technologies / Fuels and Lubricants Technology Team – provide guidance on DOD requirements, contacts with suppliers, and collaboration on lubricant characterization and testing.
    - Development of engine and drivetrain lubricants
  - DOD Ground Vehicle OEM [industry]- provide guidance on vehicle needs/requirements and potentially will provide samples of oil from vehicles used in the field.
    - Non-disclosure agreement signed
    - OEM also produces commercial utility trucks
  - Engine component supplier [Mahle - industry]– provide prototypic engine components
    - Rings, pistons, & liners
    - Modeling of friction and wear during benchtop tests
  - Lubricant supplier(s) [industry] – provide baseline and experimental oil formulations.
    - Mil-spec oil – engine & drivetrain
    - Commercial lubricants – nanoadditives

Proposed Future Work:

- Model impact of low-friction strategies on vehicle efficiency – commercial and military ground vehicles
  - Obtain input on ‘typical’ driving schedules (commercial vs. military)
  - Apply driving schedules (engine maps) to predict changes in friction mean effective pressure (FMEP)
  - Scale fuel economy to indicated mean effective pressure (IMEP)
- Evaluate the impact of candidate low-friction technologies (additives, component materials/coatings, and surface texture) on friction, wear, and scuffing performance.
  - Benchtop friction and wear tests using ring/skirt - on – liner tests
  - Benchtop scuffing tests - 4-ball, and block-on-ring configuration.
  - Comparison of baseline vs. advanced candidate technologies
    - Surface finish (plateau honing vs. slide honing)
    - Baseline mil-spec & commercial lubricant vs. advanced additized lubricants)
  - Characterization of field-tested lubricants (commercial & militiary)
  - Validation of Friction/Wear modeling software (Mahle Virtual Tribology Laboratory)
    - Prediction of friction and wear performance based on surface texture and lubricant rheological properties
- Establish test program with TARDEC/Vehicle OEM to validate advanced concepts on engine/drivetrain simulation rigs

Summary:

- New project started in FY 10 builds on prior DOD collaboration - identifies common issues & concerns between commercial and military vehicles to leverage R&D projects to develop advanced fuel-efficient technologies.
- Relevance – project addresses DOE’s goals to improve vehicle efficiency and vehicle emissions
- Approach – research conducted in laboratory settings, using advanced benchtop rigs to quantify tribological properties of candidate technologies (lubricants, additives, coatings, and surface texture). Measurements of friction, wear, and scuffing resistance. Detailed characterization of tribo-film formation leverages Boundary Layer Lubrication project.
- Technical Accomplishments – preliminary studies on scuffing performance of mil-spec lubricants have identified two candidate additives that enhance the formation of low-friction tribo-films that are scuff-resistant. Demonstrated application of FIBS to characterize structural and chemical make-up of tribo-films.
- Collaborations – Coordination and collaboration of the project with key parties and co-sponsors: TARDEC – Fuels and Lubrication Technical Team, Heavy-Vehicle OEM*, Component Supplier (Mahle), and Lubricant OEMs*.

* - names with-held subject to non-disclosure agreements