Improved Fuel Economy through Formulation Design and Modeling

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Project ID: FT025

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Overview

Timeline

- Budget Period 1: Sep 2013 to Dec 2014
  - 100% completed
- Budget Period 2: Jan 2015 to Jun 2017
  - in progress
- Budget Period 3: Jul 2017 to Aug 2018

Budget

- Total Project Funding:
  - DOE share: $593,869
  - Valvoline share: $601,924
- Funding Received form DOE in Budget Period 1 : $168,634
- Funding Received form DOE in Budget Period 2 : $104,557

Barriers

- Reduce vehicle energy loss due to friction
- Maintain anti-wear performance of low viscosity lubricants
- Mitigate poisoning of emission catalysts

Partners

- Cummins Inc,
- National Renewable Energy Laboratory

Relevance and Project Objectives

Target level of performance:

- Engine oil fuel economy improvement (~2%)
- Axle oil fuel economy improvement (~0.5%)
- Transmission Fluid has smaller delta torque and similar max torque
- Whole system – greater than 2 % by SAE J1321
- Durability Penalty – None, no detriment seen to component life at 2,000 hours tear down after field test

Objective for Budget Period 2:

- Fuel Efficiency and Transmission Performance Verification Tests:
  NREL ISL 8.9L FE Verification Engine Test
  Valvoline Axle Oil Efficiency Test
  SAE#2 tests on the Transmission Fluids
- Measurement of Collective Fuel Economy Benefit in SAE J1321

Milestones

Milestone Title/Description	Planned Completion date	Actual Completion Date	Verification Method	Comments/progress/ deviation
1.A. Engine Oil Candidate 1: PC-11 Candidate, 5W-30, FE>2%	3/30/2014	3/14/2014	modeling	Modeling result show 2.04% FE improvement
1.B. Engine Oil Candidate 2: PC-11 Candidate, 5W-20, FE>2%	9/30/2014	9/29/2014	modeling	Modeling result show 2.12% FE improvement
1.C. Axle Oil Candidate 1 : J2360 Approved, 75W-90, FE>0.5%	3/30/2014	3/28/2014	modeling	Modeling result show 0.61% FE improvement
1.D. Axle Oil Candidate 2: J2360 Approved, 75W-90, FE>0.5%	9/30/2014	9/26/2014	modeling	Modeling result show 0.73% FE improvement
2.E. Transmission Fluid: Meets TES 295 Performances with Lower Viscosity	6/30/2015	6/26/2015	SAE #2 Test	One formula meets performance target
2.F. NREL ISL 8.9L Engine FE Verification Test, FE>2%	3/30/2015	8/24/2015	Engine lab testing	FTP cycle FE: Oil1 1%, Oil2 1.5% SET cycle FE: Oil1 1.7%, Oil2 1.1%
2.F. NREL ISL 8.9L Engine FE Verification Test, FE>2%	3/30/2015	3/21/2016	Engine lab testing	FTP cycle FE: Oil1 1.6%, Oil2 1.8% SET cycle FE: Oil1 1.3%, Oil2 1.4%
2.G. Axle Oil Efficiency Verification Test, FE>0.5%	6/30/2015	3/27/2015	Axle rig test	Observed 0.63 to 1.36% efficiency improvement
2.H. SAE J1321 FE Test of all oils, DOE Metrics and Analysis, Overall FE>2%	5/30/2017		Class-6 truck Track test	Test will be finished in May, 2017
3.I. Engine Durability Tests: SLT B Engine Evaluation Test of both Engine Oils	8/31/2018		Engine lab testing	
3.J. FE Retention and Durability Test of All Oils, Components Tear Down	8/31/2018		Field test	

Approach/Strategy

- Run formulation design metrics to meet rheological performance - - Combination of best ingredients from different suppliers.

- Run tribological bench top tests (MTM, HFRR, Four-ball, EHD) to pick the best candidate.

- Use proprietary modeling work to predict Fuel Economy performance.

- From bench to dyno to track to field tests.

- 2017 milestone and Go/No Go :
  Overall FE >2% from J1321 Vehicle Track Test.

Accomplishments before FY 2016 :

- Formulation, Modeling and Benchtop Tests
  - *all milestones were reached*.

- Axle Rig Efficiency Test
  - *Observed 0.63% to 1.36% efficiency improvement.*
  - *Milestone reached.*

- SAE #2 Test on Transmission Fluids
  - *The candidate has smaller delta torque than the baseline while max torque is similar.*
  - *Milestone reached.*

- NREL 8.9L Engine Efficiency Test Results
  - *FTP cycle (urban driving) FE: Oil1 1%, Oil2 1.5%*
  - *SET cycle (highway driving) FE: Oil1 1.7%, Oil2 1.1%*
  - *Milestone (2%FE) not reached.*
  - *Reformulation needed, re-testing at Valvoline's own cost.*

FY 2016 Accomplishments: Re-Formulation and Re-Testing of Engine Oils at NREL

- Re-Formulated the Two Engine Oil Candidates

- 2nd NREL 8.9L Engine Efficiency Test Results (at Valvoline's Cost)
  - *FTP cycle FE: New Oil1 1.6%, New Oil2 1.8%*
  - *SET cycle FE: New Oil1 1.3%, New Oil2 1.4%*
  - *Milestone still not reached.*

- Recalculation Using Ref Oil 1 only for FTP cycle:
  - *New Oil1 1.8%,* ***New Oil2 2%***

- Prepared and Shipped All Oils to TRC for SAE J 1321 Test
  - *The test started in November, 2016. Got stranded due to weather conditions not meeting the requirements (ambient temperature above 40° F and wind speed less than 15 mph)*

Response to Previous Year Reviewers' Comments

This project was not reviewed last year.

Collaborations and Partnerships

Cummins – Supportive Project Partner

- Input on engine oil property requirements
- Engine testing procedure

National Renewable Energy Laboratory – Project Partner

- Engine oil FE verification testing

Transportation Research Center, Inc. – Sub-Contractor

- J1321 test

Suppliers of Lubricant Components

- Afton
- Evonic
- Infineum
- Lubrizol

Remaining Challenges and Barriers

- DI package updates with PC-11 requirements
  - the PC-11 FA-4 has not been finalized.
- Testing facility schedule conflicts
  - delays has been an issue.
- Discrepancy between modeling and dyno testing
  - reformulation may be needed but it takes time

Proposed Future Work for Budget Period 2 & 3

- Finish the ongoing SAE J 1321 test at the Transportation Research Center Inc. in East Liberty, OH.
  - *Greater than 2% total fuel efficiency is expected, which is also Go/no-Go criteria*.
  - *This will complete the work for Budget Period 2.*

- If SAE J 1321 results pass Go/no-Go, proceed to Budget Period 3 running
  - *SLT B Engine Evaluation Test on both engine oils to appraise their durability performance*
  - *Fuel Efficiency Retention and Durability Test on all the three types of oils through field test*.

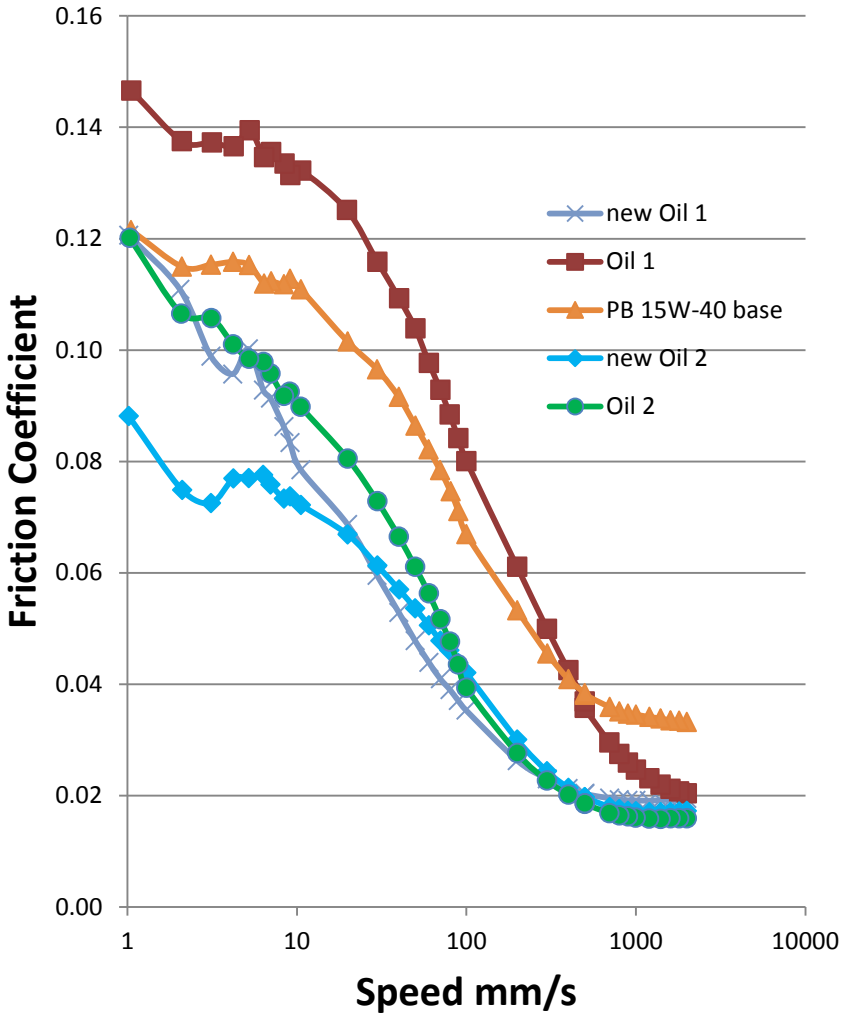
Any propsed future work is subject to change based on funding levels.

Summary

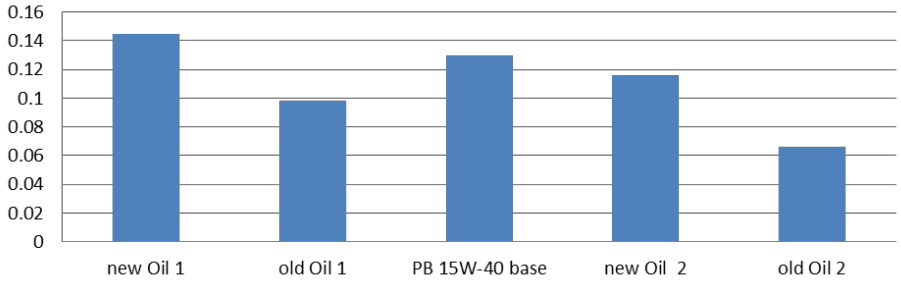
- The re-formulated engine oils have better FE performance in NREL ISL 8.9L Engine FE Test.
- The test results are very close to the 2% target, specifically for the New Oil 2 in FTP cycles.
- Since FTP cycle reflects more on real world driving conditions especially for Class-6 trucks, these results are very encouraging for the project to pass overall 2% FE in SAE J 1321 Test.

Technical Back-up slides

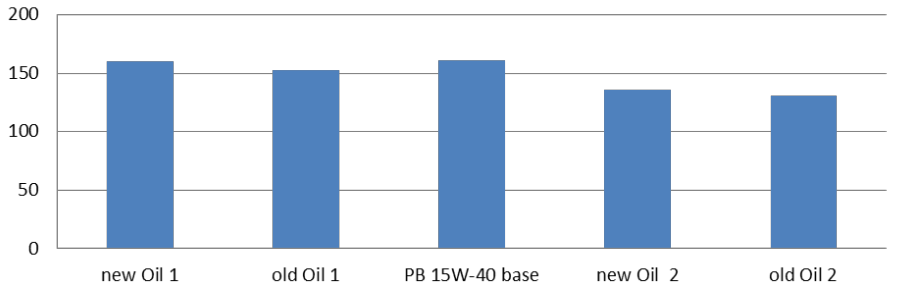
MTM Stribeck Curve at 125°C & 1 GPa



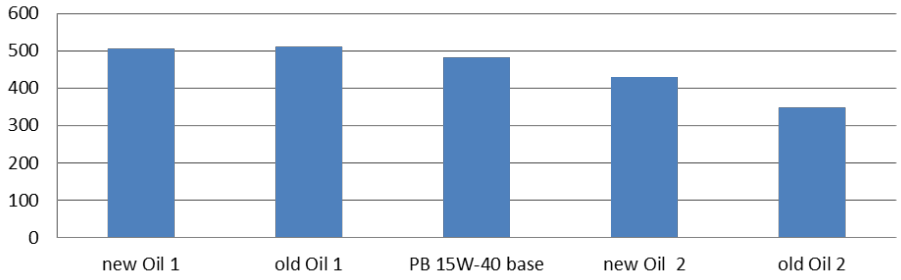
HFRR friction at 125°C & 1.25GPa

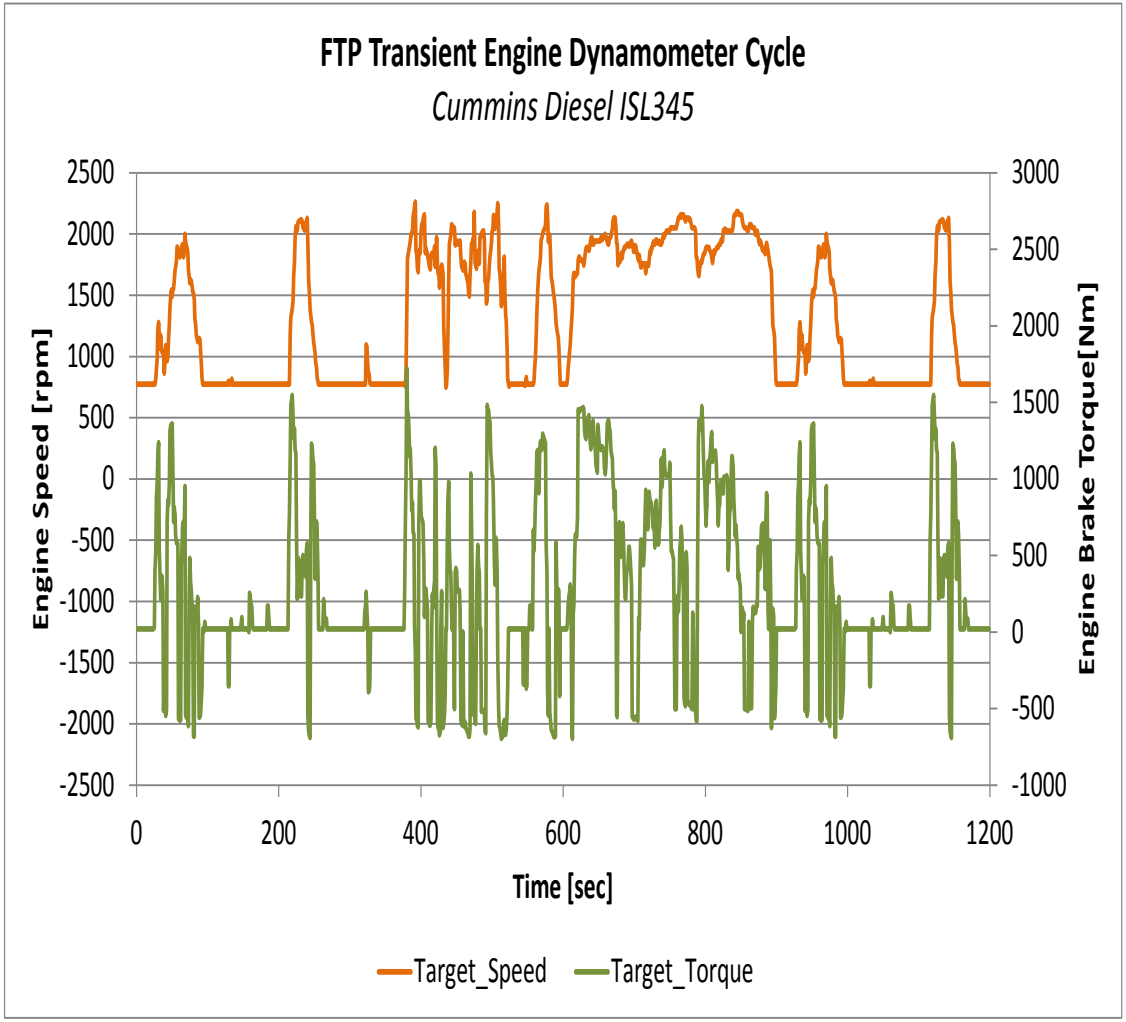


HFRR Wear on Ball (µm)



4-Ball Wear Scar (µm)



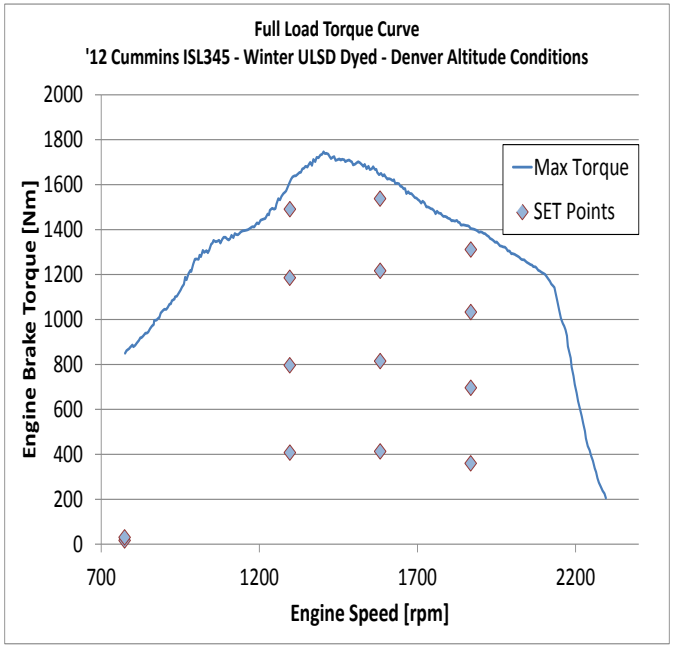


Engine Dyno Test Results

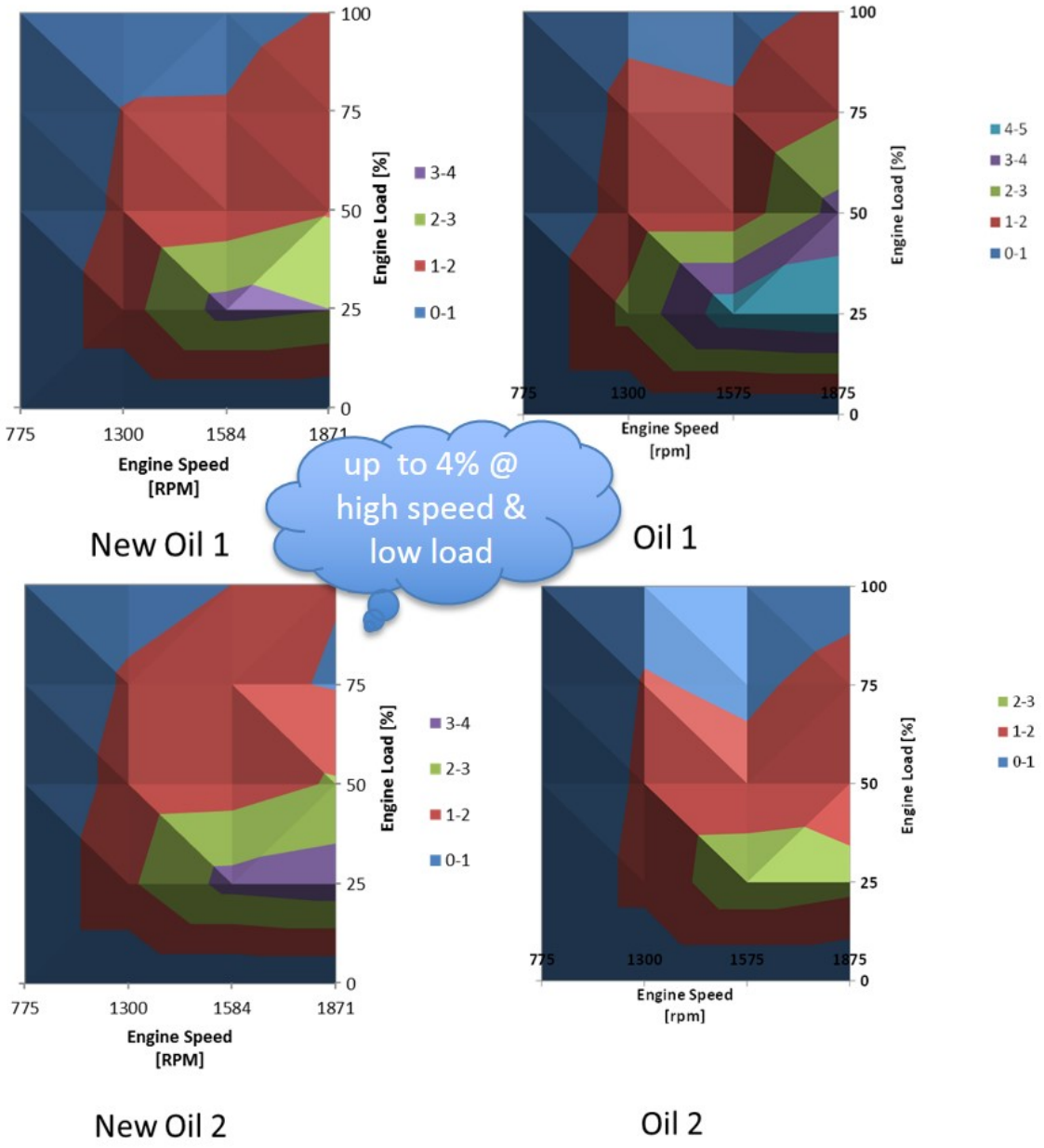
NREL ISL 8.9L Engine FE Test Result (%)	
FTP Cycles	
Oil 1	1
New Oil 1	1.6
Oil 2	1.5
New Oil 2	1.8

Engine Dyno Test Results

2010 Supplemental Emissions Test (SET cycles)



NREL ISL 8.9L Engine FE Test Result (%)	
SET Cycles	
Oil 1	1.7
New Oil 1	1.3
Oil 2	1.1
New Oil 2	1.4



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