ROLE OF ENGINE AND DRIVELINE LUBRICANTS IN FUEL EFFICIENCY - SUMMARY REPORT

Energy Systems Division

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ROLE OF ENGINE AND DRIVELINE LUBRICANTS IN FUEL EFFICIENCY - SUMMARY REPORT

prepared by

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September 30th, 2017

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EXECUTIVE SUMMARY

- A virtual workshop was held on May 10, 2017, to obtain input from stakeholders on the role that lubricants can contribute to improving the fuel economy of on-road vehicles – with a focus on legacy vehicles.
- A ThinkTank collaboration tool was used to facilitate collection and real-time analysis of input provided by the participants. Input was in the form of numeric responses on the amount of fuel economy gains that the respondents felt are possible for light duty (LD) and heavy duty (HD) vehicles, the sources of the gains, and the barriers that will need to be addressed to achieve the fuel economy (FE) gains.
- Analysis of the “voting” exercise indicated:
 1. For LD legacy vehicles, a total vehicle improvement of 2.6% in FE is feasible – 1.4 % from advanced engine lubricants and another 1.2 % with advanced driveline lubricants.
 2. For heavy-duty legacy vehicles, a total vehicle improvement of 2.7% in FE is possible – 1.5 % from engine lubricants, and 1.2 % from driveline lubricants.
 3. Of the 1.4% FE improvements thought feasible for LD engine lubricants, 65% will come from improved rheological performance, while 35% will come from lower boundary friction losses.
 4. Of the 1.5% FE improvements thought feasible for HD engine lubricants, 78% will come from improved rheological performance, while 22% will come from lower boundary friction losses.
 5. For LD driveline FE gains totaling 1.2%, 49% will come from improved transmission fluids, 36% from improved axle lubricants, and 15% from greases (bearings).
 6. For HD driveline FE gains totaling 1.2%, 56% will come from improved transmission fluids, 32% from improved axle lubricants, and 12% from greases (bearings).
 7. Seven barriers were identified and ranked in terms of importance. The top three barriers included: a) durability and warranty concerns, b) costs to develop new lubricants and return on investment, and c) consumer education on benefits of fuel efficient lubricants.
- Fuel economy gains of this magnitude (2.5%), if implemented fleetwide, would amount to a reduction in petroleum consumption of 300,000 barrels of petroleum per day (assuming a daily consumption of 12 million barrels per day) and a reduction in CO₂ emissions of 125,000 metric tons per day.
- A one-hour open session discussed the barriers and identified several additional topics to address:
 1. Fleet operators are accustomed to a single oil (e.g., SAE 15W-40) supplied in bulk quantities. Switching over to a new lubricant will complicate the fleet logistics and, therefore, pose a significant barrier to adoption of new lubricant technologies.
 2. For beyond legacy vehicles, a question is: what is the role of advanced lubricants on the fuel economy of these vehicles, not only in terms of reducing frictional losses but also enabling advanced fuel efficiency strategies such as gasoline direct injection (GDI), turbocharging, alternative fuels, and advanced combustion concepts?
- A separate workshop addressing FE gains for new vehicles incorporating novel/new materials, coatings, engineered surfaces, and lubricants is recommended to assess the role of lubricants for the entire fleet.

BACKGROUND

With approximately 250 million LD and close to 11 million HD on-road vehicles, the US fleet consumes close to 12 million barrels of petroleum per day (Figure 1) and emits 5 million metric tons of CO₂ per day. A significant amount of the fuel consumed can be attributed to overcoming parasitic friction drag in engine and driveline components. Estimates about the amount vary and depend on many factors, including vehicle/component design, drive cycle, and lubrication properties. A simple rule-of-thumb is that parasitic friction losses in the engine consume approximately 10% of the fuel, while driveline components account for another 5%.

Figure 1: United States Petroleum Production and Transportation Consumption, 1970–2040; TRANSPORTATION ENERGY DATA BOOK: EDITION 35, Edition 35 of ORNL-5198

A considerable amount of research is taking place world-wide in the transportation sector to improve fuel economy and reduce emissions, including efforts focusing on the development of advanced tribological systems involving lubricants, materials, coatings, and engineered surfaces to reduce parasitic friction losses in engines (and drivelines). Clean-sheet approaches that combine both lubricants and hardware are expected to provide larger gains than approaches that only address lubricants; however, approaches that focus on lubricants may impact more of the 250 million vehicle fleet – provided they are backward compatible. Simply stated, a 1% improvement in fuel economy that can be applied to 250 million (legacy) vehicles would have a much larger impact than a 4% improvement on 15 million (new) vehicles that can incorporate both advanced lubricants and hardware.

Subject: The Vehicle Technology Office of DOE supports research on lubricants for passenger cars, light trucks, and heavy vehicles. This includes tribological research on basestock fluids, additives, materials, coatings, and designs. The Lubrication Virtual Workshop was held to solicit input from stakeholders on the role for research on advanced lubricants to improve the fuel economy of *legacy* vehicles – vehicles already on the road. The rationale was that since lubricants are changed/replaced frequently (1 to 3 times per year), an improved fuel efficient lubricant could be introduced in the market more rapidly than replacing vehicles whose average lifetime is 11-12 years (2015). Specifically, input was solicited from experts on the magnitude of potential fuel savings in engines and drivelines, as well as barriers to their implementation.

Scope: A one-day stakeholder meeting was originally scheduled to be held in parallel with the 2017 SAE World Congress (in Detroit). Invitations were sent to experts in the field – including vehicle OEMs, additive manufacturers, oil companies, and national labs to participate in the workshop. Three breakout sessions were developed – one on passenger car motor oil (PCMO), one on heavy duty diesel oil (HDDO), and a third on barriers to implementation of proposed solutions. A web-based collaboration software

(ThinkTank) was to be used to facilitate gathering and refining stakeholder input from the three breakout sessions.

Due to limited response, the face-to-face workshop was put on hold, and plans were made to host a virtual workshop/webinar to gather input. The virtual workshop agenda was revised to fit within a 2-3 hour time slot (rather than the 8-hour time slot allotted for the face-to-face meeting). Response to the virtual workshop was better – with commitments from 38 invitees to participate in the virtual workshop. The virtual workshop was structured to solicit input from the participants – which can be a challenge in webinars. This was facilitated by the ThinkTank web-based software.

WORKSHOP DESCRIPTION

The workshop was structured to solicit input from stakeholders to determine where the greatest potential exists for increasing fuel economy through the use of advanced lubrication technologies and what are the greatest R&D needs. Early in the planning stages, it was decided to focus on identifying the potential FE gains for legacy vehicles, instead of new vehicles, due to the size of the existing fleet vs. the number of new vehicles. In hindsight, this decision limited the size of potential fuel economy gains by constraining the use of new novel engine hardware that enables solutions such as low viscosity fluids.

An outline of the virtual workshop is included below:

1. Overview Presentation
2. Session 1 – Light Duty Vehicles
 - a. Engine Lubricants
 - i. What is the magnitude of FE gains (%)?
 - ii. Where will the FE gains come from (viscosity or boundary friction)?
 - b. Driveline Lubricants
 - i. What is the magnitude of FE gains (%)?
 - ii. Where will the FE gains come from (viscosity or boundary friction)?
3. Session 2 – Heavy Duty Vehicles
 - a. Engine Lubricants
 - i. What is the magnitude of FE gains (%)?
 - ii. Where will the FE gains come from (viscosity or boundary friction)?
 - b. Driveline Lubricants
 - i. What is the magnitude of FE gains (%)?
 - ii. Where will the FE gains come from (viscosity or boundary friction)?
4. Session 3 – Light Duty Barriers
 - a. Engine Lubricants
 - b. Driveline Lubricants
5. Session 4 – Heavy Duty Barriers
 - a. Engine Lubricants
 - b. Driveline Lubricants

Prior to the voting sessions, a brief overview was presented on the role of lubricants on fuel economy. The overview consisted of a short presentation describing the motivation for the workshop and the logistics of the real-time voting process. A copy of the presentation can be found in the appendix.

The workshop then proceeded to four sessions – one on LD vehicles, one on HD vehicles, and the third and fourth on LD and HD barriers. Following each series of questions/voting, time was allotted to discuss the results. A final session was an open discussion and included topics on the role of lubricants for both legacy and new vehicles. Several days in advance of the workshop, participants were invited to participate in a pre-workshop questionnaire that provided additional topics for discussion.

DISCUSSION OF RESULTS

Fuel Efficiency from Engine Lubricants:

Driven by EPA's CAFE (Corporate Average Fuel Economy) regulations, the LD vehicle industry has been working to improve the fuel efficiency of their vehicles since mid 1970s. Engine lubricants have made a small but important contribution to these efforts. However, in spite of the significant FE achieved through engine lubricants, some additional gains are possible for the legacy LD vehicle segment with further breakthroughs in the engine lubricant technology.

Figure 2: Legacy LD Vehicles - Expected Fuel Efficiency Gains from Advances in Engine Lubricants

The HD vehicle industry, on the other hand, is relatively new to FE regulations. The first engine oil category to address HD vehicle fuel efficiency first appeared in the US market only in late 2016. Therefore, significant FE improvements remain to be realized for this segment.

To better understand the size of the residual FE gains that could accrue from technological advances in engine lubricants, the workshop participants were asked to give their best estimates of potential FE gains for both the legacy LD and HD vehicles, using a multiple-choice question format. The choices offered to the participants were 0.5%, 1.0%, 1.5%, 2.0%, and >2.0% FE.

Their responses are shown in Figures 2 and 3 for LD and HD vehicles, respectively. As expected, the responses varied from one extreme of the range to the other. For LD vehicles, while the most popular estimate was 2.0%, a large number of responses were in the 0.5% and 1% categories. For HD vehicles, the responses were symmetrically distributed around the 1.5% figure.

To obtain “group average” estimates of the responses, the following procedure was followed:

- Reduce the data set by eliminating equal-sized tails from both ends of the data. For instance, for LD vehicles, the response raw and reduced data sets were as follows:

% FE	% of Responses	
	Before reduction	After Reduction
0.5	24	14
1.0	24	24
1.5	14	14
2.0	28	28
>2.0	10	0

- Use the reduced data set to calculate the weighted average FE estimate.

Application of this protocol produced potential FE gains of 1.4% for legacy LD vehicles and 1.5% for legacy HD vehicles from improvements in engine lubricants.

Sources of FE Improvements in Engine Lubricants:

Energy losses in engines occur through a variety of pathways. However, only a few of these pathways can be affected by the lubricant. These can be broadly divided into two categories:

- Boundary friction losses due to the relative movement of engine parts, where significant metal-to-metal contact occurs such as piston ring and liner and valve train.
- Rheological losses due to movement of the lubricant against its own internal friction or due to viscosity

Figure 3: Legacy HD Vehicles - Expected Fuel Efficiency Gains from Advances in Engine Lubricants

Figure 4: Legacy LD Engine Lubricants - Relative Contributions of Various Formulation Parameters to FE

Over the years the lubricant industry as well as vehicle manufacturers have worked exhaustively to minimize both categories of energy losses. These efforts have resulted in low friction engine technologies, as well as highly friction modified and low viscosity engine lubricants. The question was posed to the workshop participants as to which of these two categories, boundary or rheological losses, will be the more important contributor of the residual fuel efficiency improvements going forward.

The results of the survey are shown in Figures 4 and 5. The participants overwhelmingly favored lubricant viscosity (or rheology) as the most likely source of future FE improvements for both LD and HD engine lubricants.

For HD engine oils, the group was even more emphatic in favoring viscosity as the more important factor than boundary friction for fuel efficiency improvements. This finding is entirely consistent with the long-held belief in the lubricant industry that much of the boundary friction has been driven out of the engine through generations of hardware advancements, thereby leaving lubricant viscosity as the only significant lever for affecting FE improvements.

Figure 5: Legacy HD Engine Lubricants - Relative Contributions of Various Formulation Parameters to FE

Fuel Efficiency from Driveline Fluids:

Literature suggests that roughly 10% of the energy output from the engine is lost to friction in different elements of the driveline system. A portion of these friction losses is actually essential to the operation of the driveline system. However, some of these losses can be reduced with improvements in the lubricating fluids used in the driveline.

The workshop participants were asked to provide their best estimates of the potential FE gains from driveline fluids using multiple choice questions very similar to those used for engine lubricants. The results from this survey are given in Figures 6 and 7 for LD and HD driveline fluids, respectively.

Figure 6: Legacy LD Vehicles - Expected Fuel Efficiency Gains from Advances in Driveline Fluids

Using the procedure described earlier, the weighted averages of the participant data gave 1.2% FE as the potential FE gains for driveline fluids for both LD and HD vehicles.

Figure 7: Legacy HD Vehicles - Expected Fuel Efficiency Gains from Advances in Driveline Fluids

Sources of FE Improvements in Driveline Fluids:

There are three main components in vehicle drive trains:

- Transmission – Automatic or power transmission in LD vehicles, manual type in HD vehicles
- Axle
- Various greased components

The workshop participants were asked to rank the lubricating fluids used in the three driveline components in terms of their relative importance of fuel efficiency contribution. The results are shown in Figures 8 and 9.

Figure 8: Legacy LD Vehicles - Relative Contributions of Various Driveline Fluids to FE

For LD vehicles, the survey picked the power transmission fluids as the most important place to obtain fuel efficiency credits, followed by axle fluids. For HD vehicles, the order of importance was reversed for transmission and axle fluids, reflecting the fact that manual transmissions in HD vehicles are less likely to offer significant FE credits. As expected, the greased elements of the driveline were designated as the least likely source of FE gains for both vehicle types.

Figure 9: Legacy HD Vehicles - Relative Contributions of Various Driveline Fluids to FE

The foregoing conclusions can be summarized as follows:

- For LD legacy vehicles, a total vehicle improvement of 2.6% in FE is feasible – 1.4 % from advanced engine lubricants and another 1.2 % with advanced driveline lubricants.
- For HD legacy vehicles, a total vehicle improvement of 2.7% in FE is possible – 1.5 % from engine lubricants and 1.2 % from driveline lubricants.
- Of the 1.4% FE improvements thought feasible for LD engine lubricants, 65% will come from improved rheological performance, while 35% will come from lower boundary friction losses.
- Of the 1.5% FE improvements thought feasible for HD engine lubricants, 78% will come from improved rheological performance, while 22% will come from lower boundary friction losses.
- For LD driveline FE gains totaling 1.2%, 49% will come from improved transmission fluids, 36% from improved axle lubricants, and 15% from greases (bearings).
- For HD driveline FE gains totaling 1.2%, 56% will come from improved transmission fluids, 32% from improved axle lubricants, and 12% from greases (bearings).
- Seven barriers were identified and ranked in terms of importance. The top three barriers included: a) durability and warranty concerns, b) costs to develop new lubricants and return on investment, and c) consumer education on benefits of fuel efficient lubricants.

Barriers to Market Adoption:

A pre-workshop survey of the prospective participants provided a list of potential barriers that prevent or slow down the adoption of advanced lubricant technologies in the transportation industry. The top seven barriers were selected for further investigation as part of the workshop:

- Durability concerns and related warranty costs
- Consumer education of the lubricant role in FE
- Lack of consumer trust in FE benefits (closely related to the previous barrier)
- Lack of adequate return on investment for advanced lubricant developers
- Inefficient industry specification-setting process acting as disincentive to development of step-out technologies
- Lack of tribological science related to FE lubrication
- Lack of suitable additive and basestock technologies

Each participant was asked to select the top three from the list of seven barriers. The results of the survey are shown in Figures 10 and 11 for engine lubricants and Figures 12 and 13 for driveline fluids.

The survey clearly shows that vehicle durability is by far the most important barrier to rapid market uptake of advanced FE lubricants across the entire spectrum of vehicle types (light vs. heavy duty) and lubricant type (engine vs. driveline). Financial returns for the developers and consumer education were identified as the next set of barriers. Interestingly, the survey did not find the lack of suitable technology, either in the form of fundamental tribological understanding or additive technologies, as critical roadblocks to market adoption.

During the open discussion period, the workshop participants offered a number of insightful comments pertaining to the market barriers. Some of these comments are given below:

Figure 10: Legacy LD Vehicle Engine Lubricants - Barriers to Market Adoption

Figure 11: Legacy HD Vehicle Engine Lubricants - Barriers to Market Adoption

- For passenger cars, driveline lubricants are not replaced very frequently. There doesn't seem like there is much opportunity to impact the legacy fleet.
- From the consumer perspective, FE is simply hard to measure. They could get 0.5-1% benefit, but they will never know it.
- What would it take for OEMs and fleet operators to become more comfortable with backward compatibility of low viscosity lubricants?
- There are more FE fluids currently available in the HD market, but they are often not used for logistical reasons. Fleets will use 15W-40 because it is logistically more convenient.
- Low viscosity PCMOs, HDMOs, and driveline fluids exist and are sold today. How does DOE and the labs think they can influence what current vehicle owners do with their existing fleet?
- Fuel prices are relatively low right now. Consumer and commercial behavior might change if/when fuel prices spike.
- What type of outreach/consumer education is needed? Is it sufficient? Are there sites (trustworthy sites - not commercial) that can be made available?
- Components used to make an International Lubricant Standardization and Approval Committee (ILSAC) FA-4 oil are directionally more expensive than a conventional 15W-40 oil. That and the limited customer demand can influence product price.
- Industry and labs may know there is measurable FE improvement, but the consumer may not see it due to other operational variables such as tire deflation.
- What can pre-competitive research do to accelerate specification development?

Figure 12: Legacy LD Vehicle Engine Lubricants - Barriers to Market Adoption

Figure 13: Legacy HD Vehicle Driveline Fluids - Barriers to Market Adoption

In addition to the written comments, the participants also had an opportunity to provide verbal comments during the open discussion period at the tail end of the workshop. The majority of the points

made during this period overlapped with the written comment summarized earlier. However, some comments during the open discussion addressed issues not previously mentioned:

- The cost of the new American Petroleum Institute (API) FA-4 FE lubricants for HD vehicles was brought up by a number of participants. In particular, the point was made that consumers find it difficult to justify the additional cost of the new lubricants against their perceived fuel economy benefits.
- One participant observed that for simplicity the workshop was focused on fresh oil fuel economy. However, in-service oil aging can have a significant negative effect on lubricant FE performance. This can be an especially important issue for HD engine lubricants.
- For legacy vehicles, particularly for LD vehicles, the OEMs have no incentive to retroactively approve lubricants of lower viscosity than that originally recommended for the vehicle. One of the OEM representatives at the workshop agreed with this assessment and offered that hardware durability is the biggest issue preventing the use of low viscosity lubricants in older vehicles.
- If the industry is locked into certain viscosity grades for the older vehicles as reflected in the tiering of the ILSAC GF-6A/B and API CK4/FA-4 specification, then is it possible to still achieve 1.4-1.5% FE gains from engine oils as suggested by the workshop? It was pointed out that if lubricant viscosity is constrained at the low end, then realizable gains might be only of the order of 0.5%.
- One of the HD vehicle OEM representatives said that while it is very difficult to convince customers to move to lower viscosity lubricants, the OEMs are making a concerted effort to do so because it helps them meet their greenhouse gas emission obligations.

Several attendees also pointed out that while it made sense to target legacy vehicles for relatively quick FE credits, future vehicle technologies hold much greater promise for large FE per unit benefits than legacy vehicles. Hence, one should not lose sight of the emerging lubrication requirements of the new vehicle technologies. As new fuel efficient hardware technologies are introduced, they bring new lubrication challenges with them. Lubricants of the future will be required to meet these challenges, thereby acting as enablers for the realization of the FE benefits of these technologies. This “technology enabler” role of lubricants is expected to deliver much greater contribution to FE than their direct contribution to FE via minimization of boundary and rheological friction losses.

CONCLUSIONS

This workshop was held to obtain stakeholder input on the role that lubricants can have on efforts to improve the fuel economy of vehicles – in particular, legacy vehicles. Responses to a series of questions indicated that participants felt that the FE of LD and HD vehicles could be improved by average values of 2.6 % and 2.7%, respectively. Engine lubricants would contribute about 50% of the FE gains for both LD and HD vehicles, and an equal contribution for driveline lubricants. The biggest gains from engine lubricants would come from using lower viscosity lubricants – about 2/3rds of the gains for LD engine lubricants, and 3/4ths of the gains for HD engine lubricants. The balance of the gains would come from improvements in technologies that reduce boundary/asperity friction losses.

Fuel economy gains of this magnitude (2.5%), if implemented fleetwide, would amount to a reduction in petroleum consumption of 300,000 barrels of petroleum per day (assuming a daily consumption of 12 million barrels per day) and a reduction in CO₂ emissions of 125,000 metric tons per day.

The magnitude of the improvements, approximately 2.5%, seems high considering historically fuel economy gains over the past four decades attributed to lubricant advances has been less than a few percent. However, all of the historical FE gains have been achieved primarily through improvements in engine lubricants, whereas the estimates in this workshop are based on potential improvements in fluids across the entire vehicle, i.e., engine as well as drive train. Secondly, the very real constraints on further reductions in lubricant viscosity imposed by the OEM oil recommendation for legacy vehicles will significantly limit the size of the realizable FE gains going forward.

The workshop focused on legacy vehicles – and did not include the effect of advanced lubricants and materials/coatings and engineered surfaces on FE. Significantly greater improvements are thought feasible for new vehicles. How much is debatable and will certainly vary depending on design and drive cycle and lubricant properties, and the participants agreed that a follow-on workshop focusing on new vehicles would be beneficial.

Of the seven barriers identified, reliability/durability was consistently identified as being the most crucial barrier that would need to be addressed, particularly for legacy vehicles where advanced, durable materials and designs are precluded. Any improvements in reliability/durability for a legacy vehicle would need to come from improved lubricant additives, which may be counterproductive to reducing asperity friction losses.

As a side note, a recent article in the Society of Tribologists and Lubrication Engineers (STLE) trade journal *Lubes'N'Greases* (May 2017, vol. 23, issue 5) on Group III's Heavy Duty Aspirations discussed recent industrial observations on the new API heavy duty lubricants introduced in late 2016 (CK-4 and FA-4). The article indicates that "...simply reducing the viscosity grade to SAE 10W-30 (from an API CK-4 SAE 15W-40 baseline lubricant) will deliver a 1 to 4% improvement in fuel economy without lowering the HTHS [high temperature high shear] viscosity. Further improvements (2 to 5%) can be made by lowering the viscosity of the oil to an SAE 5W-30. The use of FA-4 oils with 2.9-3.2 cP HTHS will add additional fuel economy benefits." Other suggest that the newer API category significantly extends drain intervals.

Acknowledgment

This work was supported by U.S. Department of Energy, Energy Efficiency and Renewable Energy, Office of Vehicle Technologies, under contract DE-AC02-06CH11357. The authors would like to acknowledge the support of the Advanced Combustion Fuels and Lubricants Program team (Kevin Stork and Michael Weismiller) and the workshop participants for their valuable insights and contributions.

APPENDIX A: Virtual Workshop Outline

May 10, 2017 (1PM – 3:30PM EDT)

Organizers

Jai Bansal – ANL

George Fenske – ANL

Mark Adkins – Think Tank

Agenda

- **Introduction (10 Min)**
 - Organizers, Participants
 - Ground Rules for Information Sharing
 - Housekeeping
 - Think Tank
- **Workshop Overview (10 Min)**
 - Motivation
 - Objectives
 - Format
- **Workshop (120 Min)**
 - Light Duty Vehicles
 - Heavy Duty Vehicles
 - Barriers
 - Participant Feedback on Workshop (10 Min)

APPENDIX B – Participants

Arup Gangopadhyay	Ford
Greg Shank	Volvo Truck Technology
Greg Braziunas	Daimler – Detroit Diesel Trucks
Mesfin Belay	Daimler - Detroit Diesel Trucks
Fred Girshick	Infineum
Jun Cui	Infineum
Caroline Laufer	Infineum
Scott Halley	Lubrizol
Steve Przesmitzki	Aramco Services Company
Xin He	Aramco Services Company
Shawn Whitacre	Chevron Lubricants
Andre Swartz	Southwest Research Lab
Brian Decker	Southwest Research Lan
Peter Lee	Southwest Research Lab
Ewa Bardasz	Energetics
Jun Qu	Oak Ridge National Lab
George Fenske	Argonne National Lab
Jai Bansal	Argonne National Lab
Layo Ajayi	Argonne National Lab
Cinta Lorenzo Martin	Argonne National Lab
Nick Demas	Argonne National Lab
Bob Erck	Argonne National Lab
Lelia Cosimbescu	Pacific National Lab
Kevin Stork	DOE
Mike Weismiller	DOE
Carlton Reeves	DOE ARPA-E
Mark Adkins	Think Tank
David Haedtler	Think Tank

ROLE OF ENGINE AND DRIVELINE LUBRICANTS IN FUEL EFFICIENCY

ASSESSMENT OF REALISTIC FE IMPROVEMENT GOALS AND BARRIERS TO COMMERCIAL REALIZATION

JAI BANSAL
Argonne National Laboratory

GEORGE FENSKE
Argonne National Laboratory

MARK ADKINS
ThinkTank

Virtual Workshop
Wednesday, May 10th, 2017
1:00 PM – 3:30PM

LAYOUT

- Introduction (10 Min)
 - Organizers, Participants
 - Ground Rules for Information Sharing
 - Housekeeping
 - Think Tank
- Workshop Overview (10 Min)
 - Motivation
 - Objectives
 - Format
- Workshop (120 Min)
 - Light Duty Vehicles
 - Heavy Duty Vehicles
 - Barriers
- Participant Feedback on Workshop (10 Min)

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ORGANIZERS

➤Jai Bansal

- Argonne National Laboratory
- Retired 2014 from Infineum as Chief Scientist & Global Technology Advisor
- 39 Years with Exxon Mobil family - last 30 in lubrication additives

➤George Fenske

- Argonne National Laboratory
- Section Manager – Tribology and Thermal Mechanics
- 44 years with National Laboratory

➤Mark Adkins

- Chief Collaboration Officer with ThinkTank
- 28 years – Facilitation, Research & Software Development

3

EXPECTED PARTICIPANTS

<u>Name</u>	<u>Organization</u>	<u>Name</u>	<u>Organization</u>
Arup Gangopadhyay	Ford	Mayur Shah	Lubrizol
Chintan Ved	Ford	Scot Halley	Lubrizol
Avinash Singh	GM	Kaustav Sinha	Oronite
Todd Fitz	Honda	Mark Devlin	Afton
Haiyang Tang	Fiat Chrysler	Don Smolenski	Evonik
Greg Brazunas	Detroit Diesel	Peter Lee	SwRI
Mesfin Belay	Detroit Diesel	Brian Decker	SwRI
Greg Shank	Volvo	Andre Swarts	SWRI
Shawn Whitacre	Chevron	Carlton Reeves	Dept of Energy (ARPA-e)
Ian Taylor	Shell	Mike Weismiller	Dept of Energy - VTO
Dan Arcy	Shell	Kevin Stork	Dept of Energy - VTO
Brian Humphrey	PetroCanada		
Steve Przesmitzki	Aramco Research	Layo Ajayi	Argonne National Lab
Fred Girshick	Infineum	Jun Qu	Oak Ridge National Lab
Caroline Laufer	Infineum	Ewa Bardasz	Independent Consultant
		Lelia Cosimbescu	Pacific Northwest National Lab
		Jon Luecke	National Renewable Energy Lab

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PRE-WORKSHOP SURVEY

- Thanks to all those who participated in the pre-workshop survey
- Very incisive and valuable information
 - Helped shape the workshop questionnaire
 - Information will be included in the final report and shared with all participants
- Headline themes
 - Engine durability - Backward compatibility, warranty concerns
 - Consumer acceptance
 - Expensive – development as well as product
 - Complex process for category development
 - ...
- Data to be summarized in final report and shared with all participants

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GROUND RULES FOR INFORMATION SHARING

- During the workshop
 - No attribution to individual participants
 - No sharing of raw data collected during the workshop
 - However, since any discussion during the workshop will be seen/heard by all participants, participants should share only nonproprietary information
- After the workshop
 - This slide deck will be sent out to all participants after the workshop
 - Results will be summarized in a report and shared with all participants in near future

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HOUSEKEEPING

- **ReadyTalk concierge will manage the communication during “Open Discussion” sessions**
 - Dial *1 (Star 1) to “raise hand”
- **Any objection to recording of oral discussion?**
- **At this time everyone should be logged on to Think Tank online application**
 - This application will be used to collect your input during the workshop
- **Think Tank screen layout will be discussed next**
 - Facility to input comments on every screen
 - Ability to upload documents by participants

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Anonymous – Structured Collaboration – Exceptional Results

PICKING AN EXPECTED PERCENTAGE

Light Duty (Legacy) Vehicles - Engine Oil FE contribution

LIGHT DUTY ENGINE OILS - LEGACY VEHICLES		PICK ONE	+
Double click here to add description / instructions		Click on 1 item	
1	Using current state-of-the art as baseline, how much more FE contribution can be expected from engine oils for legacy LD vehicles?	0	
1.1	0.5 %	0	☐
1.2	1.0 %	0	☐
1.3	1.5 %	1	☐
1.4	2.0 %	2	☒
1.5	>2.0 %	0	☐

Type comments in cloud

VOTE ☒

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AFTER YOU CLICK VOTE YOU WILL SEE THIS

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Heavy Duty (Legacy) Vehicles - Engine Oil FE contribution

HEAVY DUTY ENGINE OILS		PICK ONE
Double click here to add description / instructions		Description
1	Using current state-of-the art as baseline, how much more FE contribution can be expected from engine oils for legacy HD vehicles?	0
1.1	0.5 %	☒
1.2	1.0 %	☐
1.3	1.5 %	☐
1.4	2.0 %	☐
1.5	>2.0 %	☐

VOTE CAST

Your vote has been cast.

VOTE ☒

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VOTING TO 100%

Light Duty (Legacy) Vehicles - Engine Oil FE contributing factors

BALLOT ITEMS	PICK PERCENTAGE
<i>Double click here to add description / instructions</i>	<i>Choose 1 to 100 for each item</i>
1 For legacy LD vehicles, what fraction of the engine oil FE contribution will come from:	
1.1 Reductions in the viscosity	70
1.2 Reductions in the boundary friction	30

VOTE ☒

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WE WILL REVIEW RESULTS OF 4 VOTES

Written comments with Jai offering verbal thoughts

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GENERAL WRITTEN COMMENTS & VERBAL

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Light Duty (Legacy) Vehicles - General comments on engine+driveline lubricant FE

GENERAL COMMENTS

Give us some context for your thinking on why you voted the way you did in the previous exercise (e.g., studies, models/simulations, experiments, etc.)

- 1. Multiple barriers exist on different levels, ranging from customer acceptance/awareness, industry acceptance - warranty implications, and technical barriers - does the technology and understanding needed to develop fuel efficient lubes for legacy vehicles even exist.
 - 1.1 Barriers are: (1) price, (2) OEM approval of grades to ensure warranty coverage, (3) lack of evidence that new FE oils are suitable for legacy engines - in fact for HD vehicles, the new FA-4 oil is not backward compatible, so in fact evidence exists that suggests such oils should not be used.
- 2. Two pathways to reduce parasitic friction - reduce viscous shear losses, and reduce boundary/asperity losses. Barrier to reducing viscous losses is the impact this will have on durability & reliability. As viscosity drops, more and more asperity contact will occur leading to greater contact between components.
 - 2.1 Need to differentiate between "running in wear", and wear after "running in". Higher wear during the "running in" phase is acceptable provided wear is low after "running in" is finished. If lower viscosity oils enable faster "running in" this could be an advantage.
- 3. How will advanced solutions/technologies find their way into the market in a manner that customers and/or fleet operators apply them - most likely will bring these to the market through A out for trucks; new GFS (AM) now under development for spark ignited vehicles.
 - 3.1 There is a need to accelerate the uptake of FA-4 oils. At the moment, many OEMs are being fairly conservative, and some OEMs have actively discouraged the use of FA-4 oils.
- 4. For NA market, the only way enhanced FE lubricants can penetrate the market is via API specifications. The other requirement is that such lubricants should be "backward compatible". W there is no pathway for increase FE lubes to the market.
 - 4.1 In addition to API specs, some OEM specific requirements may be in place - this could be one way to accelerate the uptake of FE oils.

Click here to add GENERAL COMMENTS

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WORKSHOP - MOTIVATION

- Improvements in FE and emissions are key areas of interest to DOE
- DOE regularly sponsors programs to advance technologies that contribute to FE and emissions performance
- Programs cover all aspects of transportation industry
 - Vehicle hardware
 - Fuels
 - Lubricants
- Lubricant contribution potential is thought to be relatively modest but readily leveraged across entire vehicle population
 - New as well as legacy vehicles
- This workshop is designed to assess whether significant FE gains remain to be achieved through lubricants for legacy vehicles

WHY LEGACY FLEET?

- Legacy vehicle population is very large relative to new vehicle sales
- Fleet turnover is slow (>11 years for LDV, >14 years for HDV)

- Advancements through hardware technology take long time to be felt in the market place
- Any improvement based on legacy vehicle expected to deliver immediate benefits

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NO ONE THINKS THIS WILL BE EASY

- FE engine oils for light duty segment have been intensely worked on for last 45+ years
 - HD segment only recently entered the fray
- Driven by engine durability concerns, backward compatibility of engine lubricants has been severely challenged for the first time...tiered categories
 - ILSAC GF-6A, GF-6B
 - API CK-4, FA-4

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WORKSHOP OBJECTIVES

- **To obtain realistic assessment of**
 - Magnitude of incremental FE gains from lubricants
 - Primary source(s) of these gains
 - Major barriers to realization of these gains
- **Variables**
 - Light duty vehicles – engine and driveline
 - Heavy duty vehicles – engine and driveline
- **Boundary conditions**
 - North America
 - Legacy vehicles
 - Fresh oil FE only (avoids complexity of oil ageing effects)

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WORKSHOP FORMAT

I - Light Duty Vehicles	Engine Lubricants	How much incremental FE? Where will it come from?
	Driveline Lubricants	How much incremental FE? Where will it come from?
II - Heavy Duty Vehicles	Engine Lubricants	How much incremental FE? Where will it come from?
	Driveline Lubricants	How much incremental FE? Where will it come from?
III - Light Duty Vehicles	Engine Lubricants	Barriers?
	Driveline Lubricants	Barriers?
IV - Heavy Duty Vehicles	Engine Lubricants	Barriers?
	Driveline Lubricants	Barriers?
V - Participants feedback on workshop		

- **Time allocated between sessions for open dialog**

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