Medium- and heavy-duty truck research propels efficiency to meet future needs

May 17 2018

Fueled by the rise of e-commerce and fast shipping services like Amazon, consumers have come to expect their goods at their doorstep in a matter of days and even hours—not weeks. This on-demand culture coincides with the expansion of transportation technologies, connectivity, and automation, and together, these changes are shaking up an important cornerstone of American transportation—our vital dependency on medium- and heavy-duty trucks.

Class 8 trucks deliver about 80 percent of goods in the United States and account for around 22 percent of total transportation energy usage. Their significant role in enabling business transactions and consuming fuel makes them prime targets for change that will better support America's evolving mobility and delivery needs.

To meet future needs, the U.S. Department of Energy's (DOE's) Argonne National Laboratory is on the leading edge of research to improve the efficiency and utilization of these vehicles, lower emissions, and reduce American's dependence on foreign oil. The laboratory's researchers tackle this work across multiple fronts.

Along with pioneering advanced engine concepts and controls, researchers evaluate emerging technologies to empower decision-makers in both private and public sectors. These research efforts are enhanced by industry and government partnerships, and by leveraging Argonne's world-class facilities and collaborating across disciplines to accelerate innovation.

With diverse expertise and resources for fundamental combustion recipes and vehicle evaluation, high fidelity multi-physics modeling, machine learning, and predictive analytics, Argonne contributes to the evolution of medium- and heavy-duty technology for the future.

Partnering to pioneer advanced engines

Argonne lends its expertise in medium- and heavy-duty technology for two major collaborations that are advancing efficiency. One is DOE's 21st Century Truck Partnership, where government and industry partners have joined forces to identify research areas of need and accelerate the development of new technology.

Argonne also works with Navistar in DOE's SuperTruck II, a large-scale collaboration in which teams of manufacturers are working to significantly improve the efficiency of Class 8 trucks. Specific targets include a 100 percent increase in freight efficiency and 55 percent brake thermal efficiency, which measures how well an engine converts fuel energy into mechanical energy.

Through this collaboration, Argonne researchers are working to pinpoint advanced combustion approaches that can deliver on these efficiency targets. This work builds on DOE's SuperTruck I, which had similar goals and in which Argonne also partnered with Navistar.

"We're excited to collaborate with Navistar again on this important work. We want to use our extensive experimental engine expertise to develop innovative approaches for improving efficiency," Research Manager and Argonne Engineering Project Lead Thomas Wallner said.

Optimizing high-efficiency engines

Optimization is necessary to engineer more efficient engines and requires not just a deep understanding of how materials and components work together, but also tools that can quickly comprehend combustion processes. Argonne delivers on both aspects with its combined combustion modeling expertise and high-performance computing capabilities.

Truck manufacturers and other stakeholders leverage these two capabilities to speed the development of advanced engine parts, like advanced ignition systems. Argonne's ongoing CRADA (cooperative research and development agreement) with Cummins and Convergent Science Inc. exemplifies the value these capabilities bring to the process.

In this partnership, Argonne experts are optimizing fuel spray injector models used in the company's in-house design. The models predict a phenomenon known as cavitation, whereby fuel converts from liquid to vapor. The process can erode the injector and hinder performance if not addressed prior to production.

Having a clear understanding of how cavitation occurs can enable improvements that fix or mitigate the problem, and employing computational modeling in the process saves time and money.

"Using modeling methods and high performance computing, you can predict the problem and understand how and why it's happening, which saves industry on experimental costs," said Argonne Computational Multi-Physics Section Manager Sibendu Som. "The time and money you save, you can put toward engineering ways to address the problem, whether that means changing the material or design or position of parts."

Optimizing operations

Efficiency can be improved not just by optimizing the engine but also by

optimizing individual vehicle controls and goods delivery. Smarter routing and controls can help improve fuel efficiency and cost savings and, at the system level, minimize congestion and other disruptions.

So, in addition to engine optimization, Argonne researchers model energy and mobility in entire city systems to evaluate the impact of emerging technologies. They also explore ways to evaluate routing based on fuel use, time, and environmental impacts. Such models can help companies maximize operational efficiency by recommending routes that save energy and time and vehicle technologies best suited for specific routes, for example.

Researchers exploit deep learning to optimize their models. Deep learning is a form of machine learning that uses a class of algorithms called "deep neural networks," which mimic the brain's simple signal processes in a hierarchical way. They're particularly useful in analyzing complex properties.

"Saving time on simulation frees us to ask a lot more questions about how vehicles will be used in the future and how new technologies will influence them," Vehicle and Mobility Simulation Manager Aymeric Rousseau said. "Our target is to eventually employ machine learning to improve operational efficiency without the need for high fidelity simulations."

Real-world evaluations of emerging technologies

To be adopted, new medium- and heavy-duty technologies must first be proven to meet a specific industry's need, and deliver superior benefits. Argonne can evaluate various medium- and heavy-duty technologies to deliver those insights, helping decision makers understand where investments and research and development efforts should be placed.

In one project for Fedex, researchers compared one of the company's medium-duty vehicles with two early-stage electric vehicles and benchmarked their performance against a baseline diesel engine model. Argonne's analysis focused on measuring the relative energy consumption of each technology.

To provide real-world insights, researchers used Argonne's advanced testing tools, including its in-house dynamometers and test cell that can simulate a wide range of environmental conditions. They combined testing with a cost analysis based on sample proprietary routes.

This work generated critical factual data that helped Fedex understand what technologies were most cost effective based on their energy consumption, and helped guide business investment decisions.

"Our analysis does many things, including helping stakeholders understand what technologies reduce costs and benefit consumers and the environment, not just for today but for tomorrow as well," said Research Engineer Forrest Jehlik.

"We can also help industry partners match their needs to the right technology. For example, we can help a company understand how much battery power they would need to support their operations by using electric vehicles. Given that the cost of these vehicles is largely determined by the cost of the battery and high power electronics, having this kind of insight can provide real savings."

System optimization

The full scope of Argonne's analysis capabilities does not stop at cost analyses; it go even deeper with the help of broad models. With its patented GREET model, Argonne can deliver full carbon life-cycle analyses for up to 85 different vehicle and fuel combinations. In

addition, Argonne's modeling tools POLARIS and Autonomie enable researchers to model mobility and energy in entire cities.

The lab will continue pushing the boundaries of medium and heavy technology from all different angles. Argonne's multifaceted capabilities and approaches are helping the nation attain energy independence and support innovation across the energy sector.

"The question is not if things will change, but how," Rousseau said. "We provide the insight to help our partners understand how things might change and empower them to make choices on how to prepare for those future changes."

Provided by Argonne National Laboratory

Citation: Medium- and heavy-duty truck research propels efficiency to meet future needs (2018, May 17) retrieved 8 May 2024 from https://phys.org/news/2018-05-medium-heavy-duty-truck-propels-efficiency.html

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