MOBILITY ENGINEERING™

ENGLISH QUARTERLY

Vol : 5 Issue : 1 January - March 2018 Free Distribution

Lean and mean

India armed forces order new light-attack chopper developed by HAL

Hands-off driving is here

Cadillac's Super Cruise, autonomous-vehicle tech overview

HCCI engines

Overcoming the challenges

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The Indian Army and Air Foce recently ordered more than a dozen copies of the new Light Combat Helicopter (LCH) developed by Hindustan Aeronautics Limited. The LCH has twin turboshaft engines and is designed for agility, attack capability and high-altitude operations.

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Regulation's role in innovation

The auto industry can claim several historic battles with government regulation, which largely began to imprint itself on the transportation sector in the 1960s as general awareness broadened regarding man's effect on the environment. Almost in lockstep was a growing concern about the safety of automobiles as vast highway networks were built in the United States and Europe and speeds began to rise in conjunction with miles travelled.

In today's U.S., one of the Trump Administration's pillar promises is to throttle government over-reach that many believe has led to excessive regulation of all manner, including on the auto industry. So I wasn't surprised when, after a particularly involved session at SAE's seminal Government/Industry Meeting in Washington, DC in January, an engineer asked me if I thought regulation has helped or hindered automotive progress.

Having just met this pleasant person, I tried to be measured with my response, lest the conversation become political rather than mutually educational.

I pointed out that Mitch Bainwol, the president and CEO of the **Alliance of Automobile Manufacturers**, the prominent U.S. trade association that represents a dozen auto companies, noted in an earlier Government/Industry presentation that if proposed U.S. emissions standards remain in place, tailpipe emissions from a light vehicle in 2025 will be 99% cleaner than a vehicle from the "pre-controlled" era.

One could infer, I said, that regulation—in this case, the U.S.'s seminal Clean Air Act of 1970—was directly responsible for accelerating automotive progress in the reduction of air pollution. The 1970 Clean Air Act certainly spurred development of the catalytic converter—an innovation that few would suggest has been anything but immensely important for society. Regulations, as we all know, also have been the driving force behind many vital safety advances.

Maybe the real question is this: without regulatory impetus, would engineers develop certain advances on their own and would auto companies and suppliers finance and deploy them with the same vigor? Equally intriguing, the basic premise can be reversed: what about innovation borne from industry-related research that is subsequently made known to regulators who then decide to mandate it or otherwise include it in regulations?

The catalytic converter is an example of the first idea—government regulation hastening automotive progress. An example of the second is four-wheel antilock braking systems (ABS). No government or regulator told auto companies a vehicle must be able to brake without the wheels locking, or be able to apply full braking force while maintaining steering capability. For decades, engineers understood the desirability for ABS and once the technology became available, instituted it. Now, ABS is standard equipment virtually worldwide and for years has been mandated in many world markets.

So it seems obvious regulation can "help" automotive progress in the sense of forcing resources to be directed at a problem. But the wonderful thing about engineers is that many come to their work—and often, their work-related passions—from a multitude of vectors; impetus from regulation is just one possibility. The engineers who devoted time to ABS or self-cancelling turn signals or the automatic transmission didn't do so because a regulation demanded it, however. They did it because of professional ardour or the desire to create a better product.

My "final" answer, then, to the engineer's initial question: for good and bad, it's an increasingly regulated world, so make the best of it.

The U.S.'s President Trump is correct in emphasizing that many regulations are wrong-spirited and counter-productive. But it would be a mistake to discount the "focus" that regulation can inflict on research and development. To me, it seems the auto industry operates under a generally effective blend of the two. But if I have to make a choice, I'll take the intellectual curiosity of the individual engineer seeking to reduce boom in a tractor cabin (*see story on p. 40*) every time.

Bill Visnic, Editorial Director

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SAEINDIA News

Baja Mega Workshop, September in Coimbatore

Inauguration by Mr. K Venkataraj, DDG, SAEINDIA.

The BAJA SAEINDIA 2018 Mega Workshop was jointly conducted by SAEINDIA and Kumaraguru College of Technology (KCT), Coimbatore, on the college premises on September 23-24, 2017. The session was attended by students from 66 colleges all over southern India. The Workshop was inaugurated by the chief guest Mr. K. Venkataraj, Deputy Director General, SAEINDIA. This ceremony was enlightened with the invocation and lighting lamp by the chief guest and dignitaries on the dais.

On the first day, there were four sessions: "Challenges of BAJA" by Mr. Mukesh Tiwari, Deputy General Manager, **Mahindra Two Wheelers** Ltd., followed by "Vehicle Dynamics & Overall Testing Plans" by Dr. P. Parth Chattaraj, Additional Director, NATRIP; then a session on "Endurance testing" by Mr. Akhand Pratap, Project Manager, **Cummins India** Ltd. and the final session: "Design of Brake System" by Mr. K. N. Balaji, **Ex-Brakes India** Ltd., who is an expert in the design of braking systems. The day ended with a questionnaire session.

The second day of the Mega Design workshop started with a session on "Steering and Suspension Design" by Mr. Rajeev Mokashi, Consultant, Ex. Senior Director, R&D, **Gabriel India** Ltd. The session was followed by webinar on "Robust Design Practices" by Dr. K.C. Vora, Senior. Dy. Director & Head, ARAI Academy, Pune. Mr. Vinay Mundada, Consultant, Ex. VP, R&D, **Force Motors**, Pune, also joined the webinar and presented on the topic, "Vehicle Build Quality/Failure Analysis." The student design practices followed. Flaws in the design and how to effectively do failure analysis were shared through the webinar sessions. The experts' views were well-received by the students.

The Final session of the Mega Workshop was by Mr. Sanjay Nibandhe, Deputy Director, from ARAI, Pune, on the topic, "Effectiveness of Time & Quality Management." The Mega Design Workshop concluded with a Valedictory ceremony where all the guests were felicitated with mementos. On behalf of BAJA SAEINDIA, a memento was presented to the institution; it was accepted by Dr. R. S. Kumar, Principal, KCT for hosting the event.

SAEINDIA News

SAEINDIA Skill India Initiative, October in Coimbatore

The 2nd phase SAEINDIA SKILL INDIA INITIATIVE (S2I2) was launched at Sri Krishna College of Engineering and Technology (SKCET), Coimbatore on 27th September 2017. The formal inauguration of the event was done through Lamp Lighting by all the dignitaries on the dais. Welcome Speech was given by Dr. R.Soundararajan, Faculty Advisor, SKCET, Coimbatore followed by Introduction Speech by Mr. K. Venkataraj, Deputy Director General, SAEINDIA. Mr. C. Pradeep, Deputy General Manager, **Mahindra** gave a speech about Initiatives for Skill Development and Dr. P. Ashoka Varthanan, HOD, SKCET, Coimbatore, felicitated all the dignitaries including the Chief Guest Mr. D.K.Karthikeyan, Director - Projects, **Texas Ventures**. The technical sessions of the 2nd phase were conducted in October 2017 at SKCET, Coimbatore.

About 20 students participated, Course Module - 10 Days of classroom sessions and 7 days of industrial visit. Certification with grading to students based on assessment. Fifteen professional volunteers from the automotive industry imparted knowledge-sharing and training for the students. Eight colleges across India have already expressed Interest to host the event at their campuses to help scale-up this program in the future.

Dignitaries at the function.

Efficycle 2017, November in Phagwara

The 17th edition of the Efficycle event was successfully conducted on November 1-5, 2017 at Lovely Professional University (LPU), Punjab. The event was organized by the SAEINDIA Northern Section (SAEINS) in association with **Maruti Suzuki** (MSIL) and the **International Center for Automotive Technology** (ICAT). The event was held under the convenorship of Mr. U.D. Bhangale, Sr. GM, ICAT and supported by co-conveners Mr. Jitendra Malhotra, DGM, MSIL and Dr. Reji Mathai, Chief Research Manager, **IOCL** R&D.

Efficycle teams designed and fabricated the energy-efficient, human-powered three-wheeled hybrid-electric vehicles, which were propelled by two drivers simultaneously, along with an electric drive motor with a maximum motor output power of 400W. About 80 teams participated in the 2017 competition and the theme was “Drive Excellence Season.”

Teams registered for the technical inspection (TI) of their vehicles, which included a safety check, brake test, figure-8 test and electric inspection. They also entered static events such as a weight check, design evaluation, cost evaluation, build-quality evaluation. In addition, there was an innovation round and marketing presentation round in which the teams were judged by experts from automotive industries.

Teams that passed the technical inspection were able to participate in the dynamic events, which included the acceleration test, gradient-simulation test and drive excellence test. The teams finishing the respective dynamic events in least time were winners of the individual dynamic events. On the final day, the teams who cleared the technical inspection were allowed to participate in a 1.5-hour endurance race on a 2-km track with sharp turns and other difficulties.

The competition was followed by the valedictory ceremony and various awards to the teams and individuals:

Overall Winner - Team Velociracers—College of Engg., Pune

First Runner up - Team Zyklus—Galgotia’s College of Engg. & Tech., Gr. Noida

Second Runner up - Team Reventon—Guru Nanak Dev Engg. College, Ludhiana


Teams prepared for the endurance test.

Team Efficycle 2017.

SAEINDIA News

EGA Two-Wheeler Hybrid Championship virtuals, October in Bengaluru

The virtual round of India's first Two-Wheeler Hybrid competition— Electrifying Green Aspirations (EGA)—for young student engineers was organized by the SAEINDIA Bengaluru Section (SAEIBS) in association with **TVS Motors** and was conducted on October 14, 2017 at the Institute of Quality and Leadership (IQL), TVS Motors, Bengaluru. About 19 teams were registered for the event from various colleges across Karnataka, Tamilnadu and Madhya Pradesh.

The chief guest, Mr. Jayram, Dean, Institute of Quality and Leadership (IQL), inaugurated the event and in his welcome address explained to the students the benefits in participating in the competition. Mr. Damodaran Subramanian, Managing Director, **Safran Aerospace Engineering**, delivered the keynote address on the future of mobility in the aerospace domain.

Experts from companies such as **ASM Technologies**, **General Motors**-Technical Center India and TVS Motor Company, Kaizenat, constituted the jury. Each participating team presented its ideas to build the two-wheeler hybrid vehicle by addressing recent advances in safety, efficiency and other challenges. Of the 19 participating teams, 12 teams were selected for the final round, which was scheduled for February 2018. The selected teams were tasked to build the hardware to take part in the final event.

Team EGA with one of the participating teams.

Mr. Vinay Harne, President of New Product Development, TVS Motor Company, graced the concluding valedictory function and interacted with students on future technologies such as hybrids, electric vehicles, solar energy and fuel cells. Mr. Anoop B. Srinivasan, Mr. Krishnan and Mr. K. P. Murthy, Vice Chairman, SAEIBS, Mr. C Subramanian, Mr. Kannan of SAEIBS and the team of volunteers from TVS, together with Mr. Rakesh D R, EGA Coordinator, Mr. Prashanth and Mr. Dhanush of SAEIBS, made the event more successful.

Tractor Design Competition 2018 workshops, October in Chennai

The SAEINDIA Southern Section (SAEISS) organized the Tractor Design Competition Workshops in October 2017 at SRM University, Chennai and Kongu Engineering College, Erode. Some 390 students from various colleges participated in both the workshops. After the formal inaugural function at both the locations, the participants were given a brief outline about the Tractor Design Competition 2018 Workshop.

Chennai: On the first day, Mr. K. N. Balaji (automotive consultant) handled a session on automotive brakes. Mr. S. Shanmugam, Vice Chairman, SAEISS, conducted a session on the manufacturing, assembly and costing aspects of tractors. On the second day, Mr. Muruganantham, **Siemens** Pvt. Ltd. handled a session on AMEsim commercial simulation software, followed by Mr. N. Ravikumar, B. S. Abdur Rahman University, who handled the fundamentals of chassis. Mr. A. Armstrong, MC Member SAEISS and Mr. C. SivaKumar, event champion, along with other members, answered student questions. Mr. C. Sivakumar delivered the vote of thanks.

One of the workshop sessions.

Workshop participants.

Erode: On the first day, Dr. E. Rajasekar, Professor IRTT, Secretary SAEISS, delivered a session on tractor dynamics, followed by Mr. Karthikeyan, Chief Design Engineer, TAFE, who conducted a session on transmission systems. The workshop's second day saw Mr. S. Radhakrishnan, (retired) Vice-President (R&D) from **Rane TRW Steering Systems** Ltd, educating the participants about steering systems. Mr. C. Sivakumar delivered the vote of thanks.

A World In Motion Regional Olympics

The contest full of fun and challenges for school students, A World In Motion (AWIM), has two main ingredients in its innovative hands-on physical-science curriculum designed by the Society of Automotive Engineers (SAE), USA. The AWIM program started in the U.S. and India is the second country to conduct an AWIM competition at the national level for school children.

The AWIM competition encourages students to work as a team to apply scientific design concepts and explore the principles of laws of motion, inertia, force, momentum, friction, air resistance and jet propulsion to create moving vehicles such as a skimmer and balloon powered Jet-Toy cars.

New Delhi: On October 24, 2017 at Mapple Emerald Hotel, Rajokri, New Delhi SAEINDIA Northern Section (SAEINS) conducted AWIM Regional Olympics 2017 for the Delhi Region. More than 200 students from 23 schools across Delhi participated in the competition for both the Jet-Toy and Skimmer categories. The event was supported by industry volunteers from **Maruti Suzuki India** Ltd. and more than 80 student volunteers from the nearby colleges. The teams from Tagore International School, Vasant Vihar won the 1st prize in both the Jet-Toy and Skimmer categories.

NCR Region: On October 25, 2017 at Mapple Emerald Hotel, Rajokri, New Delhi, the SAEINDIA Northern Section (SAEINS) conducted AWIM Regional Olympics 2017 for NCR Region. More than 150 students from nearly 15 schools across NCR Region participated in the competition for both Jet-Toy and Skimmer categories. The event was supported by industry volunteers from Maruti Suzuki India Ltd. and more than 40 student volunteers from the nearby colleges. The teams from Presidium School, Sector 57, Gurugram and Delhi Public School, DLF City, Gurugram won the 1st prize in the Jet-toy and Skimmer categories, respectively.

Solapur Region: On November 11, 2017 at Shri Siddheswar Montessori School, Solapur SAEINDIA Western Section (SAEIWS) conducted AWIM Regional Olympics 2017 for the Solapur Region. More than 80 students from nearly 10 schools across the Solapur Region participated in the competition for both Jet-Toy and Skimmer categories. The event was supported by industry volunteers from Automotive Research Association of India, **John Deere** and **Eaton Technologies** and more than 10 student volunteers from the nearby colleges. The teams from Valentine Circle School, Solapur and Orchid School, Solapur won the 1st prize in the Jet-Toy and Skimmer categories, respectively.

Haryana Region: On November 18, 2017 at Jai Parkash Mukand Lal Innovative Engineering & Technology Institute, Radaur, Yamuna Nagar, the SAEINDIA Northern Section (SAEINS) conducted AWIM Regional Olympics 2017 for the Haryana Region. More than 200 students from nearly 25 schools across the Haryana Region participated in the competition for both Jet-Toy and Skimmer categories. The event was supported by industry volunteers from Maruti Suzuki India Ltd. and more than

Testing the prepared Jet-Toy.

Certificates presented to one of the participating teams.

SAEINDIA News

60 student volunteers from the nearby colleges. The teams from Delhi Public School, Kurukshetra and Mukand Lal Public School, Yamunanagar won the 1st prize in the Jet-Toy and Skimmer categories, respectively.

Ahmedabad Region: On November 25, 2017 at the plant of **Vestas Wind Technologies** Pvt Ltd, Ahmedabad, the SAEINDIA Western Section (SAEIWS) conducted AWIM Regional Olympics 2017 for the Ahmedabad Region. More than 80 students from nearly 10 schools across Ahmedabad Region participated in the competition for both Jet-Toy and Skimmer categories. The event was supported by industry volunteers from Vestas Wind Technologies Pvt Ltd, Automotive Research Association of India, John Deere and Eaton Technologies and more than 15 student volunteers from the nearby colleges. The teams from Nandej Primary School No. 1, Ahmedabad and Best Primary School, Ahmedabad won the 1st prize in the Jet-Toy and Skimmer categories, respectively.

Kutch Region: On November 29, 2017 at Shree Navchetan Andhjan Mandal School, Madhapar, Bhuj, the SAEINDIA Western Section (SAEIWS) conducted AWIM Regional Olympics 2017 for the Kutch & Bhuj Region. More than 48 students from six schools across the Kutch & Bhuj Region participated in the competition for both Jet-Toy and Skimmer categories. The event was supported by industry volunteers from Automotive Research Association of India, John Deere and Eaton Technologies and six student volunteers from the nearby colleges. The teams from Chanakya Academy, Bhuj and Army Public School, Bhuj, won the 1st prize in the Jet-Toy and Skimmer categories respectively.

Pune Region: On December 17, 2017 at SNBP International School, Rahatani, Pune, the SAEINDIA Western Section (SAEIWS) conducted AWIM Regional Olympics 2017 for the Pune Region. More than 200 students from nearly 16 schools across Pune Region participated in the competition for both Jet-Toy and Skimmer categories. The event was supported by industry volunteers from Vestas Wind Technologies Pvt Ltd, Automotive Research Association of India, John Deere & Eaton Technologies and more than 150 student volunteers from the nearby colleges. The teams from Mother Theresa High School, Kharadi, won the 1st prize in both the Jet-Toy and Skimmer categories.

Kolhapur Region: On December 19, 2017 at KIT's College of Engineering, Kolhapur, the SAEINDIA Western Section (SAEIWS) conducted AWIM Regional Olympics 2017 for the Kolhapur Region. More than 80 students from nearly 10 schools across the Kolhapur Region participated in the competition for both Jet-Toy and Skimmer categories. The event was supported by industry volunteers from **IFM Electronics**, Automotive Research Association of India, John Deere and Eaton Technologies and more than 15 student volunteers from the nearby colleges. The teams from SGI Residential School, Kolhapur and New Model English School, Kolhapur, won the 1st prize in the Jet-Toy and Skimmer categories, respectively.

TIFAN virtual, November in Pune

TIFAN Virtuals 2017 group.

On November 5, 2017, the SAEINDIA Off-Highway Board conducted the virtual round of its unique competition named TIFAN (Technology Innovation Forum for Agricultural Nurturing) for engineering and agricultural engineering students at Pimpri Chinchwad College of Engineering and Research (PCCoE&R), Ravet, Pune.

Mr. Krishnat Patil, General Manager, **John Deere India** and TIFAN convener, welcomed all the distinguished dignitaries on stage and narrated the journey of TIFAN and its goal to engage the talent from the country to the real-life challenges of the agricultural sector. Dr. Kamal Vora, Sr. Dy. Director, ARAI & Chairman, SAEINDIA Western Section (SAEIWS), shared the SAEINDIA vision for developing talent and technology in the mobility industry. He also shared the Automotive Mission Plan 2026 from the Government of India.

The virtual round of competition was inaugurated by Dr. Pitam Chandra, Honorable Ex-Director, Central Institute of Agricultural Engineering (CIAE), Bhopal, as chief guest and Dr. V. M. Mayande, Honorable Ex-Vice-Chancellor and Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, as guest of Honor. Dr. Chandra shared his thoughts on the Role of young engineers in solving the challenges of the agricultural sector during his speech. In his speech, Dr. Mayande touched on India's need for agricultural mechanization and its current challenges.

Students from 28 colleges across India participated in Virtual TIFAN round. Most of the teams devised new innovative designs for a self-propelled onion harvester. Judges from different industries were pleased with the thought process from students and provided valuable suggestions for further improvements in the student designs. The shortlisted colleges after this round will go for the final round, where they must demonstrate actual machines in the field. The final was scheduled for Mahatma Phule Krishi Vidyapeeth, Rahuri in March 2018.

SAE International President visits New Delhi, Chennai, Bengaluru and Pune

Presidents Malhotra (left) and Patton (right) deliver their speeches.

On December 4, 2017, SAEINDIA and the Federation of Indian Petroleum Industry (FIPI), in association with the Automotive Component Manufacturers Association of India (ACMA) and Society of Indian Automobile Manufacturers (SIAM), organized a program titled "The future of IC engines and liquid fuels for transportation" at New Delhi.

Dr. R.K. Malhotra, Director General, FIPI and President, SAEINDIA, delivered the inaugural address highlighting the present domination of fossil fuels in the world and India's energy mix, saying this trend will continue in future. He mentioned that though the share of renewables is expected to increase in the energy mix, as reported by various global energy agencies, renewables still will not be able to displace a major share of fossil fuels from the energy mix. As per projections, the demand for oil in India is expected to more than double by 2035, primarily driven by the transportation and petrochemicals sectors.

The inaugural address was followed by a panel discussion. The panellists: Dr. Teich Christian, VP – **Bosch**; Dr. SSV Ramakumar, Director (R&D) – **IOCL**; Mr. Vikram Gulati, Country Head & VP (External Affairs) - **Toyota Kirloskar Motors**; Mr. Ashok Taneja, Managing Director & CEO - **Shriram Pistons & Rings** and Mr. Harjeet Singh, Executive Advisor-Tech, **Hero Moto** Corp. Mr. Deepangshu Dev Sarmah, Editor-in-Chief, *Auto Tech Review*, was the moderator of the session. The panel discussion was followed by a question-and-answer session in which panellists addressed questions from the audience.

After the panel discussion, Mr. Doug Patton, President - SAE International and Executive Vice President & Chief Technology Officer - DENSO International America, was invited to present on "The IC Engine – Is it dead again?" In his presentation, Mr. Patton highlighted the globally changing scenario in the field of mobility, with a push towards electrification. The highlights of his presentation:

- Passenger-car applications for electrified vehicles will increase—with limitations
- Plug-in hybrid-electric vehicles will play a major role in electrification
- On highways, light, medium and heavy-duty applications will remain primarily on diesel
- Agriculture and construction equipment will remain on diesel
- IC Engines will continue to survive

The program was concluded with closing remarks from Mr. C.V. Raman, Senior Executive Director (Engineering) - **Maruti Suzuki India** Limited and Chairman of the SAEINDIA Northern Section (SAEINS). He stated that it is essential to have a long-term plan that should provide for any disruption. He added that the vision of the country for controlling emissions and transitioning to e-mobility is commendable and various technologies should be examined for achieving the ultimate objective of carbon dioxide reduction. Mr. Raman thanked the organizers, presenters and panellists for the insightful program and the discussions that emerged during the session.

Blue Ribbon CXO conclave, December in Chennai

The SAEINDIA Automotive Board hosted the Blue Ribbon CXO Conclave on December 6, 2017 at Chennai, during the visit of Mr. Doug Patton, President SAE International, to India. The Conference was attended by 50 CXO's from the automotive and IT industries.

Mr. Patton, who is also the Executive Vice President of Denso, delivered a detailed presentation about intelligent mobility and the transition to the future; he also went into depth on cybersecurity in the connected-vehicle era. Mr. Patton visualized the mobility Society image in the future touching on widespread use of IT services, the smart grid, automated driving and social control. He also identified the cyber risk in the future and the need to embrace countermeasures to ensure proper cybersecurity. He had a short video clip highlighting this factor and how cyber risk can be managed by proper safe-

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Thought-provoking panel discussion.

SAE International President Doug Patton delivers his lecture.

guards in terms of products and production facilities.

Dr. Wilfried Aulbur, Managing Partner at **Roland Berger** India, spoke on connected trucks and the effect of cybersecurity in the Indian automobile market. As driving progresses from connected and assisted to highly and fully automated, he said the customer need for safety, security and data privacy becomes paramount. The "zombie cars" scenario as shown in the movie "Fate of the Furious," where cars are turned into weapons for a cyber-terrorist attack, could become a reality in an environment where autonomous-driving capabilities are widespread. Hence, with all the advantages that modern technology brings for automotive driving, the cybersecurity threats that emanate from vectors such as internet based attacks, hardware attacks, near-field wireless attacks and sensor attacks must be taken very seriously, Dr. Aulbur said.

The topic for the panel discussion was automotive cybersecurity, threats and industry readiness. The Panellists were Ms. Naveena Swamy, Chief Innovative Officer **IITM**, Mr. Kaushik Madhavan, Director, **Frost & Sullivan**, Mr. Sanjeet Srivastava, Managing Director, **Accenture Technologies**, Mr. Magesh Srinivasan, Global Head—Connected Cars, **HCL Engineering & R&D Services**; Mr. Vinod Senthil Founder & CTO of **Infysec**, was the Moderator. Four out of the five panellists were from the IT industry, technology-solution providers and IT-related services with particular relevance to the automotive industry.

The panellists agreed that India has a long way to go in creating preparedness to face the emerging challenges in terms of connected vehicles and cybersecurity. They also felt the industry transformation will be driven by advances in information technology rather than from the automotive industry. The panel discussion was followed by an interesting and interactive question-and-answer session which brought out the general awareness about the new domain of connected vehicles occupying a major space in future development of the automotive industry.

T.R. Sathyanarayanan Memorial Lecture, December in Chennai

The SAEINDIA Southern Section (SAEISS) organized the International President Meet and T.R. Sathyanarayanan Memorial Lecture on December 7, 2017 at Hotel Ramada Plaza, Guindy. Mr. S. Sriraman, Chairman SAEISS welcomed Mr. Doug Patton, SAE International President and Mr. Murli Iyer, Global Executive Advisor, SAE International.

Mr. S. Sriraman and Mr. Patton presented the Lifetime Achievement Award to Dr. G. Padmanabham, Dr. P. SivaKumar, Dr. A. Ramesh, Dr. V.M. Periasamy, Dr. Sivanandi Rajadurai, Dr. D.A. Subramani, Dr. V. Ganesan and Mr. S. Govindarajan in appreciation for their leadership and extraordinary contributions to the society. They also presented the Automotive Champions of Chennai awards to Dr. N. Saravanan, Mr. R. Velusamy and Mr. B. Viswanath as a token of appreciation for their leadership and contributions to the society.

Champions of SAEISS presented their activities to the dignitaries, followed by the presentations shared by all the divisional chairmen. Mr. T. Kasiraja, Treasurer SAEISS, gave the inaugural address for the T.R. Sathyanarayanan Memorial Lecture by noting the achievements of Mr. T.R. Sathyanarayanan as MC Member of SAEISS. He introduced Mr. Patton and his lecture on "Challenges in Cybersecurity."

Mr. Patton started his lecture with a small potato chip and explained how the cybersecurity is affecting the sales of potatoes. He then presented the background of cybersecurity and its implication in the automotive industries, since the automotive industry is moving towards the online will have to face such cybersecurity-related issues in future. He also gave an example of how a car was hacked in middle of the highway and was made to switch off its engine—all done remotely by an online hacker. He also urged the automotive community to increase its attention to the cybersecurity field.

Mr. S. Sriraman presented the gift for Mr. Patton and Mr. Murli Iyer as a token of gratitude. Mr. T.S. Soundara Rajan, son of the beloved T.R. Sathyanarayanan, proposed the vote of thanks and thanked Mr. Patton for his lecture. He also thanked all the participants and invited all for the dinner.

SAEINDIA News

Visit to WIPRO Aerospace Division, December in Bengaluru

On December 8, 2017, after landing at Bengaluru, the SAEINDIA Aero Board team, along with SAE International President Mr. Doug Patton, visited the **Wipro** Aerospace Division, which is close to the International airport at Bengaluru.

Blue Ribbon CXO Conclave, December in Bengaluru

The SAEINDIA Automotive Board hosted the Blue Ribbon CXO Conclave on December 8, 2017 at Bengaluru, during the visit of SAE International President Mr. Doug Patton to India. The Conference was attended by 57 CXOs from the automotive and aerospace industries. Mr. Patton made a detailed presentation about intelligent mobility and the transition to the future and went into depth on cybersecurity in the connected-vehicle era.

Mr. Satish Sundaresan, Managing Director, **Elektrobit India** Pvt. Ltd., spoke about the threats, current automotive industry adoption trends, opportunities for companies and challenges facing the auto industry in terms of legislation. He illustrated with a live project which carried out in Germany. As automotive driving progresses from connected and assisted to highly and fully automated, the need of customers for safety, security and data privacy becomes paramount. Hence, with all the advantages that modern technology brings for automotive driving, the cybersecurity threats that emanate from vectors such as internet based attacks, hardware attacks, near-field wireless attacks and sensor attacks must be taken seriously. In his opinion, India's connectivity will be driven significantly by the commercial-vehicle market, adding that telematics applications are the name of the game. However, contrary to other markets, India's telematics market is dominated by aftermarket as well as entry-level (GPS-based) solutions.

Mr. Shree HARSHA, Business Consulting Director,

WIPRO Aerospace Division visit.

Transportation & Mobility Industry of **Dassault Systemes**, spoke about automotive OEMs around the world in helping them in digital transformation and proving the business value of applying 3DS technology to solve business uncertainties. Deploying 3DS solutions, he said, are **General Motors**, **Toyota** Motor Company, **Nissan** and **Honda** in Japan, **TATA Motors**, **Ashok Leyland** and **Volvo Eicher** in India, and **FAW Mold and Die**, **SAIC**, and **Chery Auto** in China.

Hence, he said, from an Indian perspective it is important to be prepared for cybersecurity threats, but with the current relatively low level of penetration of connected vehicles there is no reason to panic. On the contrary, for Indian service providers, cybersecurity is a unique opportunity to further entrench themselves in global automotive supply chains.

Seminar at Infosys, December in Mysuru

On December 9, 2017, the SAEINDIA Bengaluru Section (SAEIBS) organized a seminar at Narayanamurthy Center of Excellence, **Infosys**, Mysuru. The seminar was composed of two sessions, one by SAE International President Mr. Doug

Team BRCC Bengaluru.

SAEINDIA News

Seminar venue.

The team enjoys time with AWIM students.

Patton and the second by Dr. Ravi Kumar G.V.V., Associate Vice President & Head, Advanced Engineering Group, Infosys.

Mr. Patton started his lecture on cybersecurity with explanations of associated terminologies, its usage and what it is about. He also briefed about securing for future generations and gave detailed impressions on development of the world's first automotive cybersecurity standard. He also presented video of remotely hacking a vehicle as an example of the cybersecurity issue.

Dr. Ravi Kumar gave a presentation on the holistic approach on industrial security–an Industry 4.0 journey. He started with industrial IOT by seeking the vision; that is, instrumented, integrated, informed, intelligent. He also spoke about the adoption of IoT within a fast-changing industrial landscape and what it means to Industry 4.0 with a holistic approach for industrial security. He concluded with a holistic security concept.

Interaction with AWIM participants, December in Pune

On December 12, 2017, SAE International President Doug Patton visited S N B P International School, Rahatani, Pune,

Event participants.

to interact with AWIM school participants, volunteers and teachers. He was given a traditional welcome at the school.

Later, **Eaton** Volunteer Mr. Kiran Patil gave them a briefing about the involvement of Eaton Volunteers and support given by the school for hosting Regional Olympics consecutively for the third time. Mr. Patton and Mr. Iyer were then escorted to the amphitheatre for Vedic Chants performed by school children, followed by AWIM student demonstrations of AWIM Jet-Toys and their theme presentation on the Jet-Toy. They also addressed the school children and wished them well for future endeavors. They praised the efforts of industry volunteers and teachers towards making AWIM activity worthwhile for the school children.

Eminent lecture, December in Pune

The Eminent Speaker Series lecture on "The Future of IC Engines and Liquid Transport Fuels" was organized on December 12, 2017 at ARAI, Pune, which included participation from about 60 engineers, scholars, students and faculty in the discipline of engineering. The speaker for the lecture was Mr. Doug Patton, President of SAE International and Executive Vice President & Chief Technology Officer, DENSO International America, Inc. He is responsible for climate control, engine management systems and components, engine electrics, safety products, cluster, navigation and body electronics and small-motor engineering.

The highlights of the lecture:

- Discussion on future improvements in the mechanical engineering field
- Impact of electric vehicle technology improvements in field of mechanical engineering
- Advantages and disadvantages of electric vehicles over IC engines and liquid-fuel vehicles
- Scope to improve the IC engines and liquid-fuel-based vehicles
- Hybrid-electric vehicles
- IC engine usage trends in different market segments
- Comparison of IC engine, hybrid vehicles and electric Vehicles
- Next-generation variable-compression systems

Mrs. Rashmi Urdhwareshe, Director, ARAI & Vice President and Chair Membership Board of SAEINDIA, felicitated Mr. Patton with a memento as a token of appreciation. Mr. Narahari P. Wagh, Secretary, SAEIWS, proposed the vote of thanks for the event.

iTEC India 2017, December in Pune

View of the event's large attendance.

Team iTEC INDIA 2017 with the chief guest.

iTEC INDIA 2017, the country's second International Transportation Electrification Conference, was inaugurated by Dr. Abhay Firodia, President, SIAM and Chairman, **Force Motors** Ltd. The three-day conference on December 13-15, 2017, was held at The Westin hotel in Pune and jointly organized by SAEINDIA, the Institute of Electrical and Electronics Engineers Industry Applications Society (IEEE IAS) and the Automotive Research Association of India (ARAI). The focus of the conference was on the theme "Electric vehicle ecosystem—Resetting the future of mobility."

Present at the event were: Mr. Doug Patton, President, SAE International; Mr. Murli Iyer, Executive Advisor, Global Affairs, SAE International; Dr. R. K. Malhotra, President, SAEINDIA & Director General, Federation of Indian Petroleum Industry (FIPI); Mrs. Rashmi Urdhwareshe, Chair, Steering Committee of iTEC INDIA 2017 Director, ARAI & Vice President, SAEINDIA; Dr. Tomy Sebastian, President Elect, IEEE IAS & Director of Motor Drive Systems, **Halla Mechatronics**, Michigan, USA; Mrs. Ujjwala Karle, Chair, Organising Committee of iTEC INDIA 2017 & General Manager, ARAI; and other members of iTEC INDIA 2017.

iTEC INDIA 2017 is supported by the Department of Heavy Industry, Government of India. A display of the latest electric vehicles highlighted the **Nissan** LEAF and **Mahindra** Reva e20, among others. The conference addressed technical interests related to the electrification in the transportation sectors including but not limited to, electric cum hybrid vehicles, plug-in-hybrid vehicles, railroad and off-road vehicles. iTEC INDIA 2017 also had an array of papers spanning a wide variety of topics. In addition, the event comprised panel discussions, short courses and tutorials, presentations, exhibitions and ride and drives of electric vehicles. About 120 technical papers were presented at the conference by participants from different countries.

The conference covered topics including Power Electronics and Electric Motor Drives, electric Machines, Sensors and Actuators, Battery and Battery management System, electric, Hybrid Electric, Plug-in-hybrid vehicles, Electric Vehicle System Architectures, Smart grid, Electrical Infrastructure and V2G, Fuel Cell applications in Transportation, Electrical Systems and Components for Sea, Undersea, Air, Rail and Space Vehicles.

The 3-day conference featured 30-plus keynotes from eminent speakers, including Mr. Jun Iwamoto, Chief Engineer, **Honda** R&D Co. Ltd., Japan; Mr. Blandow Volker, Global Head, E-mobility, **TUV** SUD, Germany; Dr. Guenter Fraidl, **AVL**, Austria; Prof. Ashok Jhunjhunwala, Indian Institute of Technology, Madras; Dr. Shankar Akella, **Siemens** Industry Software, Chennai; Taro Aoyama, **Toyota Kirloskar Motors** Ltd.; Mr. Greg Harris, **Horiba** MIRA, UK; Dr. Prabhakar Patil, Ex **LG Chem**, USA; Michael Kellar, **Charin EV**, AG (VW Group); Mr. Chaitan Maini, **Sun Mobility**; Mr. A. A. Deshpande, ARAI and Mr. Katsuya Inoue, **Honda** R&D.

The members of the panel discussion:

- Mr. Sumantra B. Barooah, Executive Editor, *Auto Car Professional* (Moderator),
- Dr. Prabhakr Patil, Ex CEO, LG Chem, USA
- Mr. Greg Harris, Head Commercial – Strategic Projects & New technologies, Horiba MIRA

SAEINDIA News

- Mr. Anup Sable, CTO, KPIT
- Dr. Tapan Sahoo, Sr. Vice President, Maruti Suzuki India
- Dr. Rahul Walawalkar, Executive Director, India Energy Storage Alliance
- Mrs. Rashmi Urdhwareshe, Director, ARAI
- Dr. B B Ahuja, Director – College of Engineering Pune (COEP)

The event was sponsored by prominent organisations such as AVL, Horiba, **Maruti Suzuki**, **Bosch**, Siemens, **Honda Cars India**, **Tata Motors** Ltd., **Valeo**, **Mathworks**, **Mahindra Electric**, Toyota Kirloskar Motors Ltd, **ABB**, **Infineon**, KPIT, **Ansys** and **Mercedes-Benz**.

Companies exhibiting at the event include ABB, **Sunlectra Auto**, **Pako**, LDRA, **OPAL**-RT, **Hybridtronics**, **Altair**, **National Instruments**, **ACME**, **Madhura International**, **Map my India**, **Axiom**, Honda Cars India, **Arrow Electronics India** Pvt. Ltd., **Araymond**, **Ador**, **Asia Electric**, **Littelfuse Far East** Pte Ltd., **Tata Consultancy Services**, **Sinsil International**, **Greenfuel** and **Dynafusion**.

Electric vehicle ride: chief guest with ARAI Director.

During the valedictory function, Dr. Akshay Rathore, Chair, Technical Committee, iTEC INDIA 2017, summarized the three-day event. This was followed by the Inauguration of "E-Mobility—Center of Excellence (COE) of ARAI" by unveiling of the cornerstone by chief guest Shri. Anant Geete, Honorable Minister for Ministry of Heavy Industries & Public Enterprises, Govt. of India, followed by the valedictory address by the chief guest and Dr. A.K. Jindal, Vice President & Head Engineering (CVBU), Tata Motors. Mrs. Ujjwala Karle, Chair, Organising Committee iTEC INDIA 2017, proposed the vote of thanks, followed by a visit by the chief guest to the expo and vehicle-display area.

The next (3rd) edition of iTEC INDIA will be organized in 2019 in Bengaluru.

Automotive Engineering show, November in Chennai

SAEINDIA, along with ACMA, organised the 11th edition of the Automotive Engineering Show (AES) at the Chennai Trade Centre (CTC), Chennai from November 9-11, 2017. The show was spread across two halls of the CTC and included more than 75 exhibitors.

SAEINDIA display at AES 2017.

Thiru M.C. Sampath, Honorable Minister for Industries—Industries, Steel Control and Special Initiatives, Government of Tamil Nadu, inaugurated the event by saying, "It gives me great pleasure to be here Tamil Nadu is known for automobile manufacturing and is the earliest state to start car manufacturing. The city Chennai has emerged as the largest exporter of automobiles in India and today, it is one of the top 10 global auto hubs. This city has an installed capacity to produce 1.42 lakh cars and about 3.61 lakh commercial vehicles every year." He also announced a new law, "Business Facilitation Act & Rules 2017," enacted by the government of Tamil Nadu. This law will provide an investor-friendly environment to enable the potential investors to do business with ease.

This edition of AES showcased new and evolving technology trends which can be adapted to create an efficient working environment on factory shop floors. The three-day exhibition also hosted daily workshops on topics such as:

- Surface Engineering in Automotive Industry
- Opportunities for Indian Automotive Manufacturing
- An exclusive seminar on Post GST Implementation on the final day of the expo

The exhibition ended with more than 2500 total visitors.

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Army, Air Force issue RFP for HAL's new Light Combat Helicopter

Hindustan Aeronautics Limited (HAL) said that India's Air Force and Army issued a request for proposal (RFP) for 15 of HAL's new Light Combat Helicopter, an advanced rotary-wing aircraft that received its Initial Operational Clearance (IOC) last August in Bengaluru.

The company said the LCH was designed and developed in India and is derived from its Advanced Light Helicopter project, but is extensively modified to meet the **Indian Air Force** requirements for light helicopter attack/combat duty. Features that are unique to LCH include a narrow fuselage in which the pilot and co-pilot sit in tandem, tricycle landing gear that improves crashworthiness, self-sealing fuel tanks, armor protection and low-visibility features—all of which, HAL says, make the "LCH lethal, agile and survivable."

The Light Combat Helicopter demonstrates a countermeasure feature. (image: HAL)

The LCH is fitted with two Shakti turboshaft engines that jointly develop a maximum of 1032 kW and make the advanced aircraft the first attack helicopter to land in forward bases at Siachen, 5400 m above sea level. The helicopter's maximum takeoff weight is 5800 kg, its top speed is 268 km/h and oblique climb rate is 12 m/s. The LCH's service ceiling is 6.5 km and its range on internal fuel tanks is 550 km.

HAL lists several other distinguishing aspects of the LCH:

- Glass cockpit
- Crashworthy bottom structure
- Canted flat panels for low radar cross-section
- Integrated Dynamic System
- Hingeless main rotor and bearingless tail rotor
- Anti-Resonance Isolation System
- Integrated Architecture and Display System
- IR suppressor
- Countermeasure Dispensing System
- EO pod, helmet-mounted display system and EW suite
- 20-mm gun, 70-mm rockets and missiles
- Air-to-air missiles
- Air-to-ground missiles.

Late in 2017, HAL also announced that a technology demonstrator of the LCH underwent its first flight with an in-house designed-and-developed Automatic Flight Control System (AFCS). "The maiden flight was flawless and flew for 20 minutes with the engagement of the system throughout," HAL said in a press release.

The development of in-house-developed AFCS was a HAL-funded project, the company noted, saying it will replace a high-value imported system. The LCH's AFCS is a digital four-axis system capable of performing control and stability augmentation and auto-pilot functions. The indigenous development of the AFCS system hardware, software and control logic is a fully in-house effort of HAL R&D Centers, the company notes.

Netradyne launches advanced ADAS solution in India

Netradyne has launched an advanced driver-assistance systems (ADAS) solution trained for Indian road conditions as part of its Driveri platform. Driveri, a four-camera, vision-based system mounted on the vehicle windscreen, helps fleet managers recognize positive driver performance and enhance driver safety for commercial vehicles. Netradyne claims it is the first company to launch a vision-based ADAS solution specifically trained for Indian road conditions.

Studies have shown that inattention within three seconds of an event is a major cause of accidents. In fact, this inattention has been shown to lead to over 2000 fatalities in a report ("Distracted Driving in India: A Study on Mobile Phone Usage, Pattern & Behaviour") from SaveLIFE Foundation shared by the Government of India in 2015.

According to Netradyne, Driveri (ADAS) provides real-time audio alerts in a vehicle when a collision is imminent, which helps the driver to gauge and take preventive action before any accident happens. In addition, Driveri also monitors and alerts the driver for drowsiness or inattention, conditions that can potentially lead to a collision resulting in loss of life and property.

Netradyne's Driveri advanced driver-assistance system provides real-time audio alerts to the driver in a vehicle when a collision is imminent, which helps the driver to gauge and take preventive action before any accident happens. (image: Netradyne)

"India has a very poor road safety record with over four hundred thousand road accidents recorded last year. ADAS solutions specifically customized for the Indian road and driving conditions are the need of the hour and will play a significant role in making our roads safer," said Avneesh Agrawal, Founder and CEO of Netradyne, in a release from the company. "We believe that Driveri will immensely benefit the commercial vehicle segment in India. With the ADAS solution customized for the market we are able to provide valuable insights to commercial fleet operators on their most prized assets: drivers and fleet," he added.

Driveri consists of multiple features that are designed to assist drivers. Several of these features are being adopted across global markets and India is catching up to global standards of safety, according to the release. Rising global awareness of technological advancements has led to an upsurge in consumer demand for such innovative technologies that can enhance safety standards. In addition to accident prevention, Driveri's ADAS solution helps educate and improve driver behavior and habits through regular feedback and monitoring.

Equipped with Quad-HD cameras that provide a view of the road similar to the driver's perspective, Driveri uses **Nvidia**'s Jetson TX1 TeraFLOP processor. It is capable of one trillion calculations per second. Using Netradyne's proprietary deep learning algorithms for video processing and Nvidia's hardware, Driveri can provide real-time safety assistance to drivers and help avoid accidents.

"With GPU computing, Netradyne's ADAS solution will enable vehicles to perform extremely complex sensor fusion with a four-camera, vision-based system, leading to more accuracy and substantially reducing missed detections and false alarms. With Netradyne, we foresee to transform safety in all aspects for Indian roads," said Vishal Dhupar, Managing Director, Nvidia - South Asia, in a release statement.

In addition to ADAS, the Driveri platform provides the fleet managers with a comprehensive view of their driver's activity through a blend of positive driving notifications and best practice identification in real time. This helps the fleet managers in rewarding and providing proper guidance and coaching opportunities to the drivers.

Tata Motors introduces heavy-duty Tipper range with ULTIMAAX suspension

Tata Motors introduced six new vehicles from its Construck range at EXCON 2017 construction equipment exhibition held December 12-16, 2017 in Bengaluru. Among the new product launches, Tata Motors introduced what it says is the first of its kind 4th generation ULTIMAAX suspension system for the HCV heavy-duty tipper range. The ULTIMAAX suspension was developed jointly by Tata Motors Ltd., along with **Hendrickson** Inc. (a joint venture partner of **Tata AutoComp** Ltd.).

Tata Motors' new Construck range includes the PRIMA LX 3130.K 19 CuaM scoop tipper, the PRIMA LX 2525.K 16 CuM Box tipper with ULTIMAAX suspension, and the PRIMA LX 3125.K 23 CuM box tipper. (image: Tata Motors)

The new range of vehicles showcased included the PRIMA LX 3130.K 19 CuaM scoop tipper, PRIMA LX 2525.K 16 CuM Box tipper with ULTIMAAX suspension, PRIMA LX 3125.K 23 CuM box tipper, SIGNA 3718.TK 24 CuM box tipper, SIGNA 2518.K 7 CuM Transit Mixer with Bogie suspension, and SIGNA 4923.S 14X2 CuM sideways tip trailer.

"We at Tata Motors are delighted to showcase some of our new construction and mining vehicles for the first time at the EXCON 2017," said Rajesh Kaul, Head, Sales and Marketing, Medium & Heavy Commercial Vehicles, Tata Motors Ltd., commenting on the occasion in a press release. "This year, our focus is on mining and road construction industry as there is a positive movement in macro-economic indicators in these segments. The products on display will be equipped with globally renowned **Cummins** SCR technology, heavy duty ULTIMAAX Suspension System, factory-fitted comfortable AC Signa cabins and lightweight, but stronger tipper bodies. We are also working on various aggregates like engines, axles and suspension systems to reduce maintenance costs and provide a long-lasting trouble-free operation. We will shortly introduce two of our new vehicles in the market, designed to offer maximum vehicle uptime and enhanced driver comfort at a lowest cost of ownership."

The ULTIMAAX rear suspension consists of a heavy-duty beam with central pivot and combination of shear springs and progressive springs, which are the main load-carrying components and are made of special proprietary rubber material. Progressive main springs carry a greater portion of the load in the vehicle. Its stiffness increases as the load increases without causing an abrupt change in ride characteristics, thereby providing a unique balance of empty ride quality and loaded stability. According to Tata, the use of rubber bushes in the front and rear eliminates the need for periodic lubrication, thereby ensuring total peace of mind and no need for periodic visits to workshop or using expensive chassis greasing system. The unique design provides long service life and easy replacement of rubber springs to reduce downtime.

Key features of the ULTIMAAX include:

- Higher payload of 250 kg (551 lb)
- Advanced severe-duty rubber suspension
- "Outstanding" durability, according to Tata
- Ride comfort using progressive springs with roll stability
- Maximized mobility and traction
- Low lifecycle costs since lubrication is not required
- Progressive rate springs provide long service life and are easy to replace.

"For the first time in India, heavy-duty tipper applications have been developed with rubber bushings as against metal bushings used in the conventional suspension," said Dr. A.K.Jindal, Head–Electric Vehicles & Defence Vehicles, Commercial Vehicle Engineering, Tata Motors. "This will reduce road shocks and improve driver comfort thereby enhancing productivity. Additionally, the ULTIMAAX suspension system will offer advantage of higher payload of approximately 250 kg due to low weight of the system over standard bogie suspension. Taking into consideration customer feedback and expectations, our teams worked extensively to tailor this suspension for the Indian off-road terrains."

The Tata Construck range consists of tippers, transit mixers, truck mounted cranes and concrete boom pumps engineered to address tough conditions and endure heavy-duty cycles of the construction and mining industry, with higher productivity and profitability. The company says Tata Construck Tippers cater to the widest range of applications like road construction, irrigation, coal, iron ore, marble, stone mining, and bulk material handling at port, limestone, concrete mixture and municipal applications.

TECHNOLOGY Report

OFF-HIGHWAY ELECTRIFICATION

Komatsu building AI into construction sites

One of the key challenges that Komatsu and Nvidia face is monitoring real-time data of workers and heavy machinery on the job site. (image: Komatsu)

Construction sites remain one of the more dangerous workplaces due to the presence of heavy machinery, uneven terrain and continuous activity. To help alleviate some of these issues, **Komatsu**, one of the world's leading manufacturers of construction and mining equipment, is bringing artificial intelligence (AI) to the work site. The company is taking the next step in its SmartConstruction initiative to improve worker's safety along with increasing productivity.

To achieve these improvements, Komatsu has partnered with **Nvidia** to leverage their AI technologies in this new environment. Nvidia is well-known for its medical, robotics and automotive partnerships. However, the construction industry brings a new set of challenges for the tech company with its constantly changing terrain and heavy machine capabilities. AI is central to reducing these issues.

"Modern AI turns out to be a very flexible and adaptable technology that can be applied to many industries, even if the use cases are very different," said Jesse Clayton, Nvidia Senior Manager of Product for Intelligent Machines. "You can argue that occupational safety for construction and mining is somewhat similar to automotive, but the machines and the environments behave very differently."

The first implementation of these technologies will be in Japan. "Japan can stand to benefit from this because of workplace injury and the nation's severe labor shortage due to its aging population," continued Clayton. "However, construction and mining worldwide all face the same fundamental challenges in safety, efficiency and site management."

According to a spokesperson for Komatsu, the company will expand these technologies to other markets based on their experience with this initial deployment.

Komatsu will utilize the Nvidia Jetson platform for AI computing. Jetson works with Nvidia cloud technology to power a 360-degree view of a Komatsu construction site. The credit-card sized platform will be able to identify people and machines nearby to prevent collisions and accidents. Cameras in the Komatsu machines provide real-time data to update the driver on any rapidly changing operating condition—one of the key challenges of implementing this technology.

In addition to the platform technology, **SkyCatch** will provide drones to gather and map 3D images for visualizing the terrain. **OPTiM**, an IoT management-software company, will provide an application to identify individuals and machinery collected from the surveillance cameras. Both of these companies are members of Nvidia's Inception Program for AI startups.

"We'll start integrating Nvidia GPUs into our construction sites," said Yuichi Iwamoto, senior executive officer, chief technology officer at Komatsu. "By leveraging Nvidia's experience in image processing, virtualization and AI, we can further transform construction areas into jobsites of the future."

Komatsu is championing these new technologies as the next step in its SmartConstruction initiative for improved worksite safety and efficiency. The initiative encourages development of technologies that will improve worker safety along with improving operational efficiencies. Facets of the program include intelligent machine products, intelligent training services, worksite data solutions and jobsite setup services.

Matthew Borst

Cameras in the Komatsu machines provide real-time data to update the driver on any rapidly changing operating condition—one of the key challenges of implementing this technology. (image: Komatsu)

AUTOMOTIVE EMISSIONS

PEMS intros on-the-road emissions testing to U.S., Europe

Emissions Analytics has tested more than 500 vehicles in the U.S. via the tailpipe-attached PEMS equipment (shown). Most tests involve combustion-engine vehicles, but an increasing number of electrified and even fuel-cell vehicles are undergoing road tests to compare their electrical efficiencies. (image: Kami Buchholz)

A newly-launched North American database for the first time provides online users with vehicle-to-vehicle comparisons of greenhouse-gas emissions and real-world fuel economy.

As the largest industry database of real-world vehicle emissions and fuel consumption, **Emission Analytics**' new EQUA Index (http://usa.equaindex.com) is based on a standardized test regime for vehicles fitted with a Portable Emissions Measurement System (PEMS) at the tailpipe.

"The lab is great for doing defined, very repeatable tests. But lab-based tests don't measure the vehicle's real road experience and real-world driving provides vital performance metrics," Nick Molden, Founder and CEO of U.K.-based Emissions Analytics, said during a *Mobility Engineering* interview.

PEMS achieved a milestone in September 2017 as the testing method became a cornerstone of Europe's newly-enhanced vehicle-certification process. "In order to sell a new light-duty vehicle, you need to do the test-cell measurements, which has always been the case, as well as perform real-world, on-road emissions tests," said David Booker, Ph.D, Chief Technical Officer of Saline, MI-based **Sensors, Inc.**, a global PEMS supplier.

The **U.S. EPA** now uses PEMS and other tools to characterize in-use emissions and to screen for high off-cycle emissions that could indicate an emissions defeat device or other compliance concern, according to agency spokesperson Nancy Grantham. PEMS and real-world test tools are used with lab data for certification testing prior to issuing certificates of conformity.

The EPA isn't creating an in-use conformity factor for PEMS testing, Grantham added. It currently is using PEMS and other real-world test data to confirm that real-world emissions results are consistent with official lab-test results.

Repeatable and verifiable

Emissions Analytics has tested more than 1600 light-duty passenger vehicles over the past six years in Europe and the privately-owned company began its North American testing in 2013. A team of four drivers have tested more than 500 vehicles in the U.S., ranging from subcompact cars to one-ton pickup trucks, in Los Angeles and more recently in Detroit.

"The drivers are trained to drive in a manner that mimics 'average' driving. Because we're collecting second-by-second data, we can audit to determine if the drivers did in fact drive at average speeds, follow the designated route and perform typical braking and acceleration," said Molden.

Repeatable and verifiable driving routes are important to Emission Analytics' overall testing methodology. "We're using PEMS to create a real-world label," Molden explained. "The EQUA Index is not a certification. It's not policing of regulations. It's testing for grades of comparison rather than a pass or fail."

The index is being touted as a guide for consumers, legislators, and automakers. And on an over-arching basis, the index recognizes good engineering work.

"Vehicle makers should look at emissions and mpg testing as an environmental and fuel-saving benefit that goes beyond doing just the minimum required to achieve regulatory certification," Molden suggested.

Since its inception in 2011, Emissions Analytics has relied on PEMS for its on-road vehicle testing. Each vehicle test covers 100 miles (161 km) of city (55%) and highway (45%) driving in a specific temperature range between 5°C and 25°C. The Sensors, Inc.-supplied PEMS equipment has reduced in package size and weight, now at 220 lb (100 kg), in recent years.

"You can do your best to simulate real-world driving in a lab, but it isn't the same as real-world driving," said Molden. Any driving scenario that puts a load on an engine impacts mpg and emissions numbers—and artificially recreating various road conditions on a chassis dynamometer is a difficult undertaking, especially for simulating hill climbing.

There have been widespread instances in Europe of the rolling-resistance in lab testing being less than what it would be on a road, according to Molden. Less rolling resistance means better mpg and lower emissions. "What was being done was technically legal, but roller settings are the Achilles heel of lab testing," he noted.

GPS is a key

For Emissions Analytics tests, a vehicle is fitted with a PEMS that connects to the tailpipe, a GPS system and a mini-weather station to capture the air temperature, pressure, and humidity. "We're not relying on any of the onboard vehicle systems, not even for vehicle speed and acceleration, as we're using the GPS. The GPS also provides the altitude, so we can measure the gradient of the road," said Molden.

On-road testing adds a layer of protection from emissions cheating. "The **VW** defeat device is a good example of what can be done to 'game' predictable, known lab testing. It's much harder to defeat on-road testing," he said.

Fuel economy, as well as CO_2, CO, NO, and NO_2 numbers, are addressed via a testing process that covers many parameters, including the use of air conditioning (North America's index has a 50% longer A/C load during testing compared to European-tested vehicles).

For comparative purposes, the EQUA Index uses the same base methodology. Emissions Analytics also does specific studies, however, where the base methodology has an additional consideration, such as cold-weather testing and steep-gradient testing. Customized reports are possible with the PEMS-focused testing.

Knowing the instantaneous emissions and fuel burn as well as the vehicle speed, road grade and altitude enables engineers to model the dynamic characteristics of the vehicle. Those characteristics can be used to create emission maps. For instance, by showing speed on an x-axis and acceleration on a y-axis, a user can see the specific operation combinations that elicit emission peaks or fuel-burn peaks.

This EQUA Index label shows the CO_2 rating for a 2017 sedan. (image: Emissions Analytics)

The connection between fuel economy and GHG emissions is undeniable. By measuring the carbon gases at the tailpipe and knowing the chemical composition of the fuel in the tank, one can accurately calculate the gallons burned using the carbon-balance method. "That's how in our testing we calculate mpg without cutting into the fuel line or using the CAN bus," Molden said.

A tailpipe emissions analysis of a vehicle driven in the real world also can dissuade tampering attempts. Vehicles tested by VW during the infamous "Dieselgate" scandal had 10% higher mpg than if they'd been in compliance, with low CO_2 emissions, but at the price of very high NOx emissions.

"So unless you have all the numbers lined up side-by-side from the same test, on the same car, on the same day, you have a fragmented system that is weak for manipulation," Molden explained.

Kami Buchholz

A 'mini-weather station' is attached to an Emissions Analytics test car to provide air temperature, pressure, and humidity readings during on-road test drives. (image: Kami Buchholz)

AUTOMOTIVE MOBILITY

Who wants Afreecar?

Game-changing ideas come to engineers in countless places and circumstances. For Dr. Chris Borroni-Bird, it was in a tiny village in Mali. The year was 2009, and Dr. Borroni-Bird, then director of **GM**'s EN-V program for the 2010 Shanghai World Expo, was on a typical vacation: working on clean-power and clean-cooking initiatives in sub-Saharan Africa.

"I noticed some solar panels donated by **BP** which were being used by the village's resident entrepreneur to charge lead-acid batteries, the type used in cars," he recalled. "The guy would then lease the fully-charged batteries out to villagers who needed electricity."

During his ten days working in the village, Dr. Borroni-Bird witnessed three use cases for the batteries. One provided cheap LED lighting, enabling the local work day to be extended without using kerosene lamps. Another battery application was for grinding corn. A third use was to pump water from deep in the ground; the village's fetid-gray well water was undrinkable.

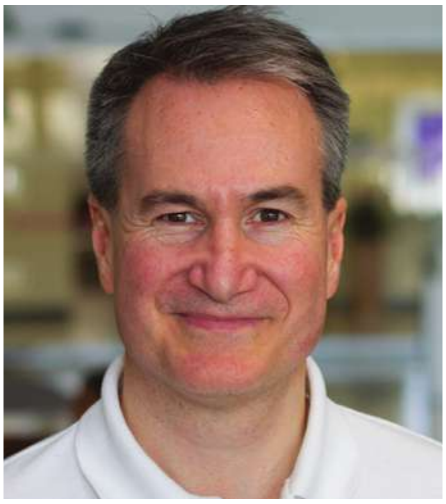
Another piece of the idea came while Dr. Borroni-Bird was walking 10 miles to the next village—a typical trip for millions who cannot afford powered vehicles. "Then it hit me—what might work here is a simple and cheap battery-powered vehicle that could be charged with solar panels, which are increasingly inexpensive. Such a vehicle could provide both transport and electric power to Africa's poor. Transport, no matter how humble, enables economic development," he said.

Personal mobility, mobile power

The incumbent means of personal mobility in sub-Saharan Africa are costly and inefficient. Walking is limited to distances of under 10 miles and a payload of about 10 kg. Oxen and other typical beasts of burden have greater capacity but can cost $200—and require food. Small motorcycles offer greater range and payload capability but can cost $2,000 to purchase and require regular fueling. So what sort of 'new' vehicle would work best?

A small electric 3- or 4-wheeled 'golf cart' might be too large, heavy and costly, he calculated. And it might lack the 5-to-10 miles (8 to 16 km) range

Simplicity and low-cost, robust construction are vital to the solar e-trailer/bike combo as a sustainable concept, as this rendering shows. The roof's angle of incidence is designed to be adjustable so that the solar cells can best optimize the sun's energy. (image: Chris Borroni-Bird)



Dr. Chris Borroni-Bird retired as Qualcomm's VP of Strategic Development in 2016 to focus on global sustainable-mobility solutions. At GM he led development of the EN-V, Autonomy and other advanced concepts. In the 1990s he led Chrysler's gasoline fuel-cell project. He holds over 40 patents, many on the 'skateboard' platform concept, and is co-author of ***Reinventing the Automobile: Personal Urban Mobility for the 21st Century***, with Dr. Larry Burns and the late Prof. Bill Mitchell, published by MIT Press.

The proof-of-concept e-trailer built by prototyping specialists Pratt & Miller. Marketable vehicles may be offered in both kit form and as ready-to-use fully assembled units. (image: Chris Borroni-Bird)

needed for a typical rural African duty cycle. But a small, lightweight trailer coupled to a bicycle, would combine the rider's pedal power with a battery and electric motor. This 'e-trailer' would have a roof covered with solar panels to charge the battery. The battery would power a small electric motor which would in turn drive the trailer wheels through a chain and sprockets.

The 3 kW·h of energy that 100 kg (220 lb) of lead-acid batteries can store on a solar-powered electric trailer can deliver a minimum 30 km (almost 19 mi) daily range to allow inter-village travel, Dr. Borroni-Bird calculates. He realizes that heavy lead-acid batteries will be most widely available and affordable until secondary use of lithium battery pack modules from EVs become a viable approach.

The solar e-trailer could be built from a kit that utilizes some 'repurposed' items—bicycle or scooter wheels, for example—and locally-harvested materials for the frame, axle and roof that supports the small solar-cell array. It would provide supplemental motive power to the bike rider when traveling up hills, and serve as a mobile electric-power unit for charging phones, pumping water, milling grain, running small refrigerators—and hauling.

During Africa's planting season, people can't easily access fertilizer. Villagers often walk up to 15 miles (24 km) per day to buy a 50-kg (110-lb) bag of fertilizer and carry it back home.

"Entrepreneurs with the bike-trailer system which I've dubbed 'Afreecar'—a play on the word Africa—could ride to the distribution center, pick up three bags of fertilizer," he envisioned. "They'd haul it back to their villages and get paid by the farmers. More food could thus be grown and it could be transported to market much, much easier."

Researchers at the **University of Michigan** who did early work with Dr. Borroni-Bird have modeled a typical rural-Africa duty cycle in which bike-and-solar-trailer rigs could deliver reasonable 50-100-mile (80-160 km) daily operation. He sees similar multi-use opportunities for the mobile power system in the cities of Africa and those of other continents.

With support from the university and automotive prototype specialists **Pratt & Miller**, he helped finance a proof-of-concept trailer developed and built by Pratt & Miller, as shown in the photo above. But a marketable unit needs to be lighter, less costly and more robust.

Locally sourced components

To achieve favorable economics that stimulate local manufacture, the solar e-trailer solution must be very low cost and robust to generate profit. When integrated with a cellphone, which are ubiquitous in Africa, the Afreecar concept becomes "a low-cost, locally made 'hub' that can transform lives and create a vibrant manufacturing and service economy," he said.

The vehicle or hub might be owned and operated by the same company that makes or distributes it, or by an entrepreneur who buys or leases the vehicle from the company. In either case, the operator generates revenue by providing mobility, electric power and wireless communications—and perhaps by monetizing data generated by the service.

"The cell phone is an important tool in the solar e-trailer concept," Dr. Borroni-Bird explained. "Besides providing direct operator communications, the phone's GPS map would provide route information, battery monitoring, and even inform the rider of the optimum angle to set the solar-panel roof in relation to the sun at any given time of day. It could offer predictive maintenance and data analytics."

Readers who admire Dr. Borroni-Bird's idea will ask, "What's to keep this idea from being co-opted by others?" He concedes that "there is no competitive advantage in the hardware—it has to become a commodity if the vision is to be realized."

More detailed analysis and planning is required for creating a sustainable business model. "Local communities around the world could take the standardized electrical kit, produced in scale perhaps in Taiwan or China, and provided by company or foundation for integration into whatever version of the vehicle is developed locally. Let those communities figure that out, using a reference design and specifications," he said.

Dr. Borroni-Bird also believes "it would be a good idea to provide complete vehicles, but the foundation is the electric system. Some [local operators] may make the solar trailer for bikes; others may cut up a motorbike and make a 3-wheeler or golf cart," he surmised.

Versions of the solar e-trailer for developed markets might also include a low speed autonomy kit, such as for **MIT Media Lab**'s Persuasive Electric Vehicle (https://www.media.mit.edu/galleries/persuasive-electric-vehicle/).

What are the next steps? Dr. Borroni-Bird now has a half-time appointment at MIT Media Lab in the City Science Group, directed by Kent Larson.

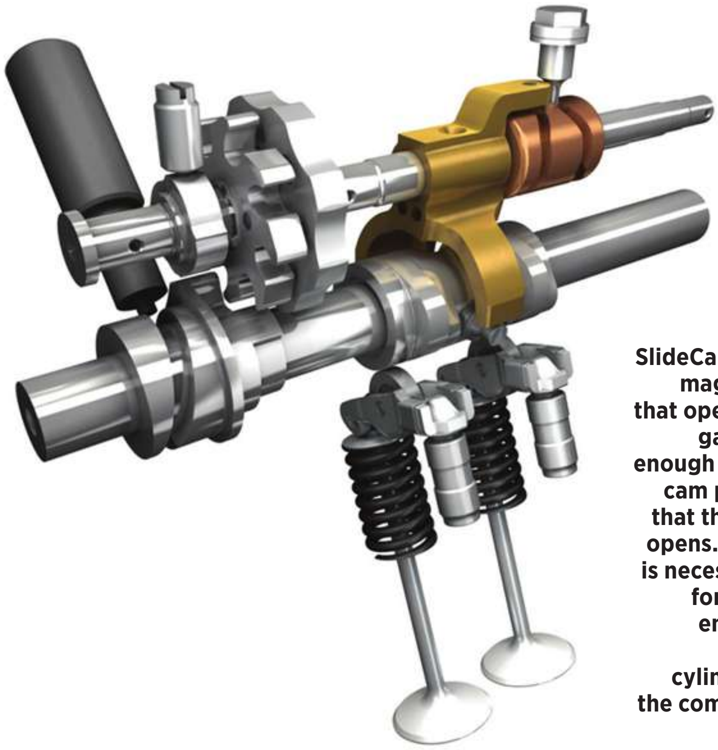
At MIT, Chris is keen to study community needs and to develop a rugged "solar e-trailer" prototype that pulls all these ideas together. He hopes to secure support to build the electric kit consisting of the battery, motor, controller and solar panel.

Those interested in collaborating can contact Dr. Borroni-Bird at MIT Media Lab. There also was an exhibit at January's 2018 North American International Auto Show.

Lindsay Brooke

COMMERCIAL VEHICLE PROPULSION

IAV brings variable valvetrains to heavy duty



SlideCam works through a magnetic pin actuator that operates on a shifting gate. It engages fast enough to switch between cam profiles in the time that the valve closes and opens. Only one actuator is necessary per camshaft for all cylinders of an engine, whether it is three, four, or six cylinders, according to the company. (image IAV)

Variable valve actuation, especially timing, has been readily available for light passenger engines for years. Problems in introducing the technology to heavy-duty diesel engines include the vastly different thermodynamics at play and the durability required. With already high compression ratios, clearance between the piston and valve in diesels can be an issue. Since a diesel is typically unthrottled, it is more difficult to improve efficiency compared to a gasoline engine. Constant switching in engines that run continuously means building reliable gadgets that can run for thousands of hours.

However, with the continued push for both fuel efficiency and criterion emissions control, IAV thinks it is time for heavy-duty applications to consider it. An engine with a fixed valve lift and timing must balance high-speed engine performance and low-speed fuel economy. Low speed and cold start exhaust temperatures also affect aftertreatment devices, especially important as regulatory pressures continue.

The **IAV** SlideCam system, available under licensing agreement from the company, toggles between two cam lobes, according to Robert Dolan, Director, Commercial Vehicle and Government Programs, which can vary timing or lift or both. "It is a switchable system, with two settings on the hot side and two settings on the cold side," he explained. "That allows, for example, a Miller cycle and a retarder function."

One device produces two benefits. Using it to produce a Miller cycle operation makes combustion more efficient, meaning better fuel economy. The other is improving aftertreatment.

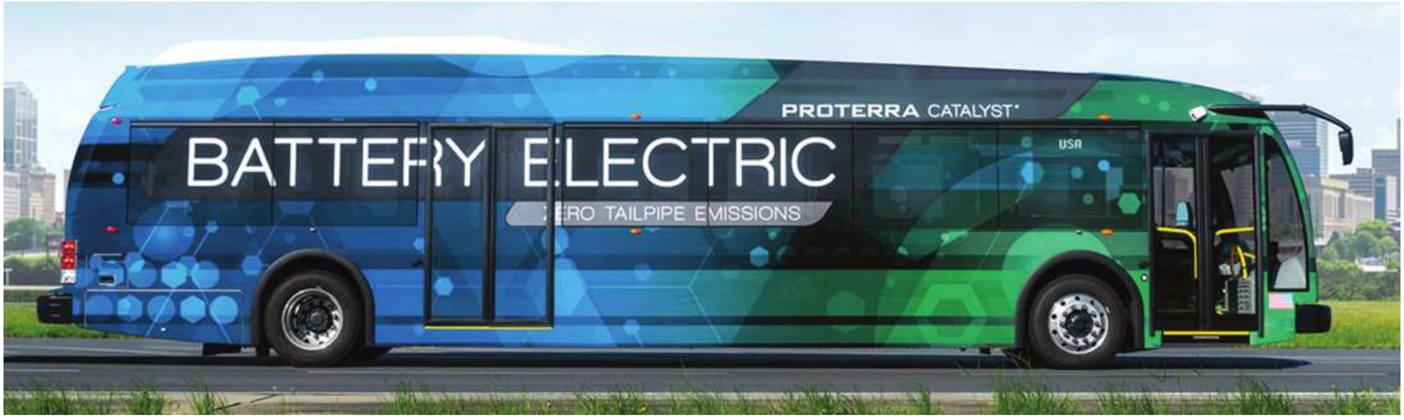
SlideCam's ability to open the exhaust valve earlier when needed means it can hold the temperature of the aftertreatment devices at a higher temperature without lowering combustion process efficiency. Standard techniques with fixed cams include post-injection of fuel during low load operation, which can entrain fuel and lead to more frequent oil changes, as well as impacting fuel efficiency.

Dolan reports that IAV is currently working with an on-highway OEM to transfer the technology through a patent arrangement. "It could also see off-highway utility as well," he said.

Bruce Morey

COMMERCIAL VEHICLE PROPULSION

Making the case for battery-electric fleet power



The Proterra Catalyst E2 max set a world record of 1,101.2 miles on a single charge with 660 kW·h of energy storage. That September 2017 feat occurred at the Navistar Proving Grounds in New Carlisle, IN. In an urban setting with passengers and the HVAC system operating, the E2 achieves approximately 200 miles per charge. (image: Proterra)

Battery-electric power is drawing more and more applications to commercial and heavy-duty fleets as the zero-emission technology edges closer to a tipping point.

"We're not at critical mass in any market yet with battery-electric," said Rick Herndon, Chief Executive Officer of **Voltabox of Texas** Inc., a manufacturer of Li-ion battery systems.

One market undergoing dramatic change is commuter buses. "All the big players recognize they have to have electric, especially for municipal applications," he said. Herndon and other technology experts spoke with *Mobility Engineering* during The Battery Show and Electric & Hybrid Vehicle Technology conferences in Novi, MI.

Navitas Systems' Starlifter 48-V Li-ion battery that's used for sit-down forklift applications and the counterweight (in green). The counterweight is necessary so the Li-ion battery's weight is akin to that of the heavier lead-acid battery it replaces. (image: Navitas Systems)

Electrifying transit buses

While electric public transportation buses still reflect relatively small numbers, substantial growth is projected around the world.

In India, for example, the goal is to have 300,000 electric transit buses by 2030. "India's electric mass transit wants are driven by a government initiative aimed at reducing fossil fuel consumption," said Adrian Schaffer, Senior Vice President of Sales and Business Development for Longmont, CO-based **UQM Technologies**. "There are opportunities in India and other regions; I think the key is to start thinking about how we create partnerships to grow the battery-electric market."

More than 800 electric transit buses are in-service or on-order throughout the U.S. as of September 2017, according to Fred Silver, Vice President of **CALSTART**, a non-profit organization headquartered in Pasadena, CA.

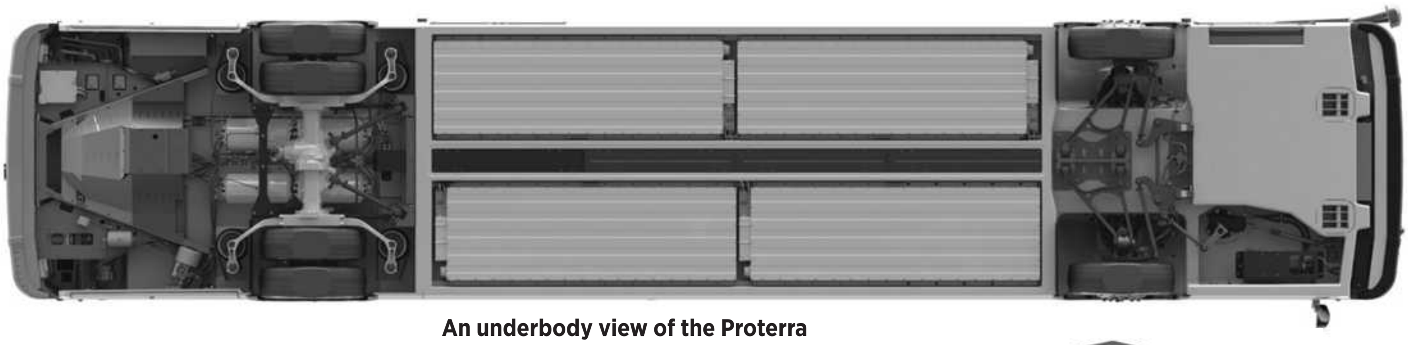
"We're pretty much covering the waterfront when it comes to the different kinds of bus platforms available in the U.S.," said Silver, noting that the electric products range from microbus to double-decker transit buses.

Proterra's Catalyst portfolio—the FC, XR and E2 Series—of 40-ft (12-m) electric buses reflects different curb weights and driving ranges. "The innovative part is that all of our Catalyst buses use the same physical space for the battery packs, so there's not a unique underbody for each bus," said Dr. Gary Horvat, Chief Technology Officer for Burlingame, CA-based Proterra.

As the newest bus in the product lineup, the Catalyst E2 claims the longest driving range of any electric transit bus, the company claims. The vehicle's **LG Chem** developed Li-ion cells are housed in a liquid-cooled battery pack with an energy density of 160 W·h/kg and 260 W·h/L, regarded as the highest in the heavy-duty industry. E2's energy storage system accounts for approximately 20% of the vehicle's curb weight: 29,850 to 33,060 lb (13,540 to 15,000 kg).

"Because of where our battery packs are packaged, there's a low center of gravity. That means improved performance. The bus has better handling for the driver because the battery pack weight is in the center, under floor between the axles, rather than in the rear of the bus," Horvat said.

A Starlifter battery pack in-use on a Toyota forklift. (image: Navitas Systems)



An underbody view of the Proterra E2 shows the battery packs. (image: Proterra)

XALT Energy's modular sub-pack is configurable from 7.1 to 11.4 kW·h. (image: XALT Energy)

XALT Energy's modular battery packs in a 7-series string, 80 kW·h total energy, can be used for electric transit bus applications. (image: XALT Energy)

Battery pack modularity

Battery pack modularity is viewed as an essential element to accommodate the inevitable changes in technology, according to Martin Klein, Vice President of Engineering for Midland, MI-based **XALT Energy**.

"Heavy-duty fleet managers want to know year-over-year that the same base product can be updated," said Klein. "The ability for an operator to upgrade as soon as new technology, including cell and controls, comes online is very important."

XALT Energy's battery sub-pack provides an easy-to-install solution for its customer base, which includes heavy-duty trucks, construction vehicles, and transit buses. "Our sub-pack has a cast aluminum enclosure, and that's important as the large format batteries are undergoing heavy usage with some buses on 18-hour drive cycle schedules on a daily basis," Klein said.

The cast-aluminum enclosure enables bolt-on features, reducing the overall parts count. Inside-the-pack considerations include cell tabs welded to the bus bars, and direct liquid cooling of the cell face. "We don't use passive cooling plates because that would add mass to the pack and such plates are much less efficient," said Klein.

Depending on the type of cell, the energy storage in the 90-V battery sub-pack ranges from 7104 to 11,482 kW·h.

"If an operator wants to change from a short-run bus with frequent stops to a long-range bus, it's just a swap out of the battery core. We update the voltage, the curves, and the calibrations and the pack is ready to go with the same cables, same connectors, same mounting locations, same battery management system," said Klein, noting that the pack is designed to last for 12 years.

XALT's available remote monitoring system can detect problems during in-vehicle operation. "In one example, we noticed that a customer's cell string was down. We called them before they knew of the problem," Klein said, citing a loose vehicle connector as the culprit. "Real-time monitoring can pinpoint issues quickly and that's important, especially for new entrants into the electric vehicle market."

Forklifts ripe for Li-ion

For electric forklift applications, lead-acid batteries remain the popular choice, according to Mil Ovan, President and Chief Marketing Officer of Woodridge, IL-headquartered **Navitas Systems**. "The forklift market is the largest non-automotive market by dollar volume for lead-acid batteries, representing about $2 billion a year in North America," said Ovan.

It's a meaty market of opportunity that Ovan and others say is ripe for Li-ion battery technology.

"As the temperature plummets, the ability for lead-acid chemistry to react and provide energy slows down. So as the temperature falls, like in a food distribution warehouse, there's more runtime available with a Li-ion battery-powered forklift," Ovan said.

In a "sit-down" Class 1 forklift application, a lead-acid battery can weigh up to 4000 lb (1814 kg), about double that of Li-ion batteries. Lead-acid batteries also require about eight hours of charging time, much longer than the fast-charging time for Li-ion. It also takes about eight hours for lead-acid batteries to cool down before a return to service. In short, the drawbacks associated with lead-acid have opened the door for Li-ion batteries.

"Eventually you'll see the forklift manufacturers take advantage of the fact that a Li-ion battery is smaller and lighter weight," said Ovan, noting that a change in battery chemistry can elicit new forklift designs that reduce the possibility of tipping, rolling, and other vehicle instabilities. "You can lower the center of gravity if you've relaxed the lead-acid battery box constraint because you can put the energy storage where you want," he said.

Proponents of battery-electric applications say the technology is absolutely ready. "So now the discussion needs to be about commercial viability to determine where the value proposition is within the market segments around the globe," said Herndon.

Kami Buchholz

TECHNOLOGY Report

AEROSPACE MANUFACTURING

Improving the surface finish of additive manufactured parts

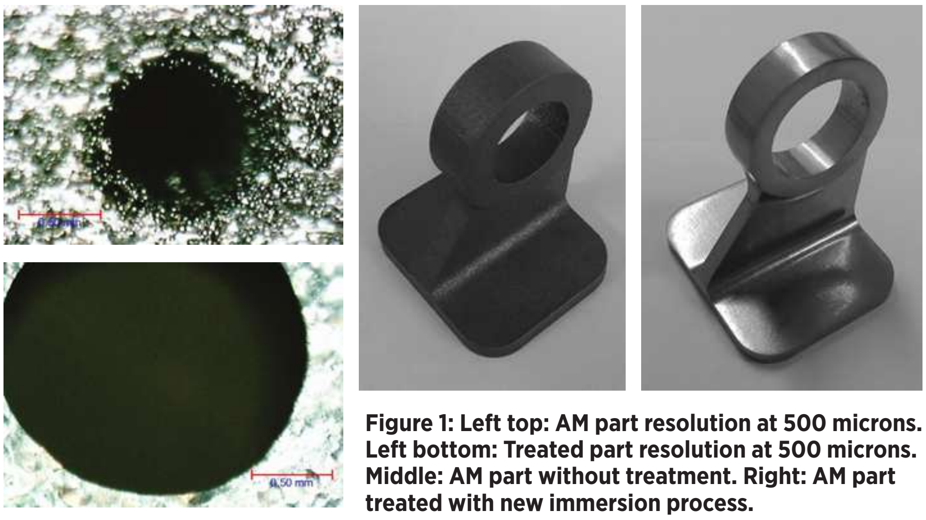


Figure 1: Left top: AM part resolution at 500 microns. Left bottom: Treated part resolution at 500 microns. Middle: AM part without treatment. Right: AM part treated with new immersion process.

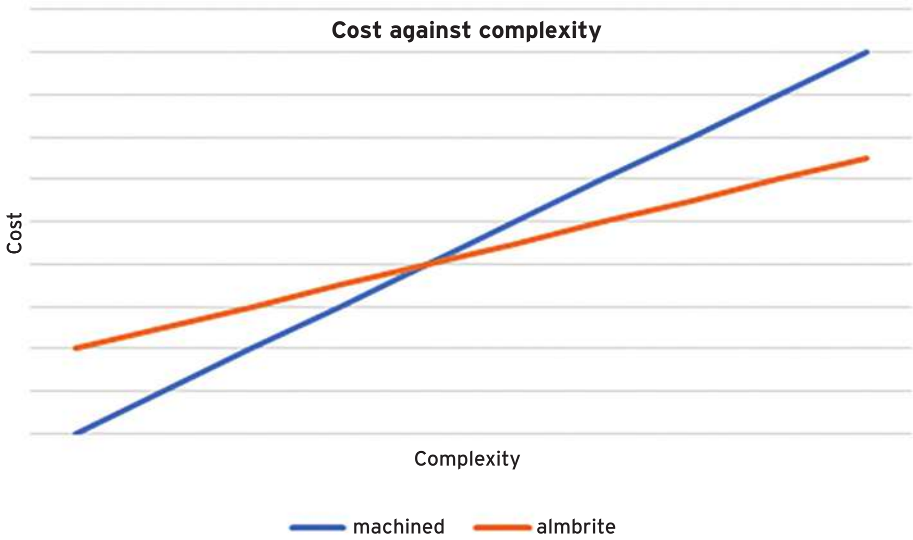


Figure 2: Improved performance.

South West Metal Finishing has been working on an additive manufacturing surface treatment process for the last three years and believes it could be the future choice of aircraft manufacturers around the world, such as the likes of **Safran**, **UTC Aerospace** and **Airbus**.

Almbrite™ is a chemical immersion process designed to modify and enhance the surface of additive manufactured (AM) parts by removing foreign object debris whilst smoothing and brightening the surface of a part, as illustrated in Figure 1.

Aerospace and defense manufacturers have been searching for a surface treatment solution since additive manufacturing started to be used. One of the challenges regularly encountered is the poor finish of AM components. They are often rough or porous, with semi-melted powder particles. That can obviously affect the performance of the component, which is detrimental when you're making an aircraft.

AM uses various techniques to construct a three-dimensional object including direct energy deposition and powder bed fusion processes. AM is a process in which a component is built up in discreet layers by using a high-energy heat source to fuse powders. The processes are driven by data from computer aided designs (CAD) which are then sliced into individual layers. In some cases, fine metal powders are deposited on top of a build platform and the energy beam is used to melt the shape of the design. The build then proceeds with a new layer of metal powder which is then melted, such that the component is built up in a layer by layer fashion.

This layer manufacturing approach means that more complex parts can be produced compared with traditional processes. One of the benefits of AM for manufacturers is that increased complexity generally doesn't have a detrimental impact on the cost of the process. Parts treated with the new technology are more cost-effective than machined parts as they can increase in geometric complexity without increasing the cost of build (Figure 2).

AM allows component designers to have greater design freedom, knowing that the end result will be more representative of the final design than is possible with traditional processes.

The use of AM is on the rise in every sector, including medical and automotive, because of the versatility of creating bespoke designs, one-off prototypes, or complex components that cannot be machined. But without the correct finish, these components may fail at the early assessment stage in an industry that tests and re-tests to the breaking point.

The aerospace and defense industry has adopted AM, though it needed time to collate data and carry out stringent tests before it was confident the components could withstand the operating conditions they would be subjected to. Everything had to be tried and tested and then tested again. Now the processes are considered safe enough, they must make sure the finish of these components fulfills the necessary requirements.

The highly skilled team developing this technology knows the testing, time and effort it takes to achieve approval certificates in aerospace and are fully accredited with NADCAP, ISO 9100, ISO9001 and ISO14001, holding approvals for all the major UK tier one suppliers. AM surface treatment is being taken to the next level and many of the issues currently facing those using additive manufacturing in the aerospace industry are being addressed. This innovative surface treatment pro-

Figure 3: No geometric constraints. Sheffield University's Formula 1 team optimised rocker arms for their vehicle's suspension system, treated with the new technology for optimum performance.

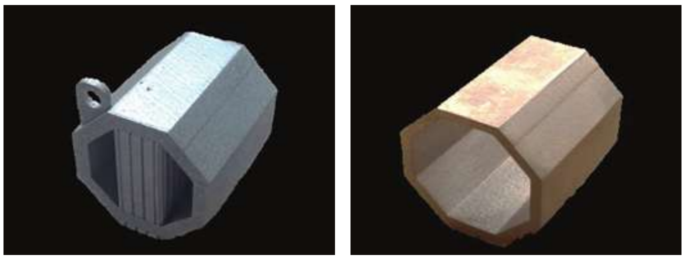


Figure 4: Support structure removal.

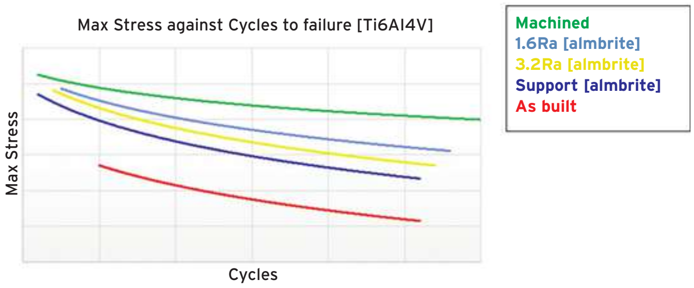


Figure 5: Max stress tested against cycles to failure comparing machined parts and treated parts' performance.

cess greatly improves the finish of components made using additive manufacturing, by chemically removing material from each surface to achieve the final condition required.

Research and development began on the AM treatment project in 2014. It has taken a long time to fully develop, but there was significant demand for this type of post processing. Large aerospace manufacturers using additive manufacturing presented the need for a more refined and enhanced surface finish on their AM parts. Both commercial and technical challenges were overcome before launching Almbrite as a production capable finishing solution. This is a fantastic opportunity for the aerospace industry to really push the quality and finish of AM parts being used to build aircraft in the market today and going forward.

So, how exactly does it work? The surface treatment process essentially refines the surface of the component by chemically removing material from each surface to achieve a surface roughness of below 3.2 microns, whilst enhancing edge and feature definition.

For reference, metal AM parts tend to have an average roughness between 10 to 30 microns depending upon the AM process used. This means that the technology can reduce the roughness of an AM part by up to 88%. It could also be argued that the innovative surface treatment could almost increase the quality of AM aerospace components ten-fold.

Almbrite can enhance surface quality regardless of the complexity of a component's geometry (Figure 3). This complements AM designed components, which use either traditional or topology optimized approaches, where conventional treatments are unable or too costly to be used.

An AM part's topology describes the way in which its geometrical properties and measurements are interrelated and arranged. As AM is increasingly adopted by big players in the aerospace and defense industry, the complimentary and innovative treatment similarly has the potential to generate substantial interest among top manufacturers.

Almbrite is a chemical immersion process; the immersion bath used during the treatment is changed, or refreshed, depending on throughput. If many AM parts need their surfaces treated in a certain period to a high level of material removal, the bath will need to be replenished regularly. The level of material removal during the ALM surface treatment process is controlled using a combination of process parameters. The immersion times required during the treatment process are the same regardless of component size; however they do vary depending upon materials.

This technology is currently being used to finish components made of titanium alloys whilst applications on polyether ether keytone (PEEK), a thermoplastic polymer used widely in engineering, as well as aluminium alloys are in development. The surface treatment process is also being looked at for application on nickel-based alloys in the future.

Titanium and aluminium alloys are the primary metallics used for manufacturing in the aerospace and defense industry currently. Aircrafts are also made up of a huge range of polymers; high performance polymer PEEK is highly valued in aerospace manufacturing. Nickel-based alloys are primarily used in the engines and mechanical systems of aircraft, and this is where the technology is branching out to in the future.

The material on which Almbrite is being used does impact the treatment's chemical compositions, however, the process requires a chemical reaction to occur when treating either Titanium or PEEK thermoplastic polymers, which removes the unwanted material from the component surface.

In metal additive manufacturing, support structures are used to help transfer heat away from the part as new fused powder layers are added whilst helping to hold the part's shape as it forms. Until now, metal AM has lacked an efficient way to remove supports after the build is complete. In fact, supports have often been removed with hand tools—e.g., hammer and chisel—

which is a bit primitive considering the advanced technology involved in the aerospace industry.

However, the new surface treatment process dissolves supports used in the AM process, removing the need to machine away or manually remove support structures, as illustrated in Figure 4. This is hugely beneficial as manually removing supports constrains the geometric freedom of the part, restricting the design possibilities of aerospace components.

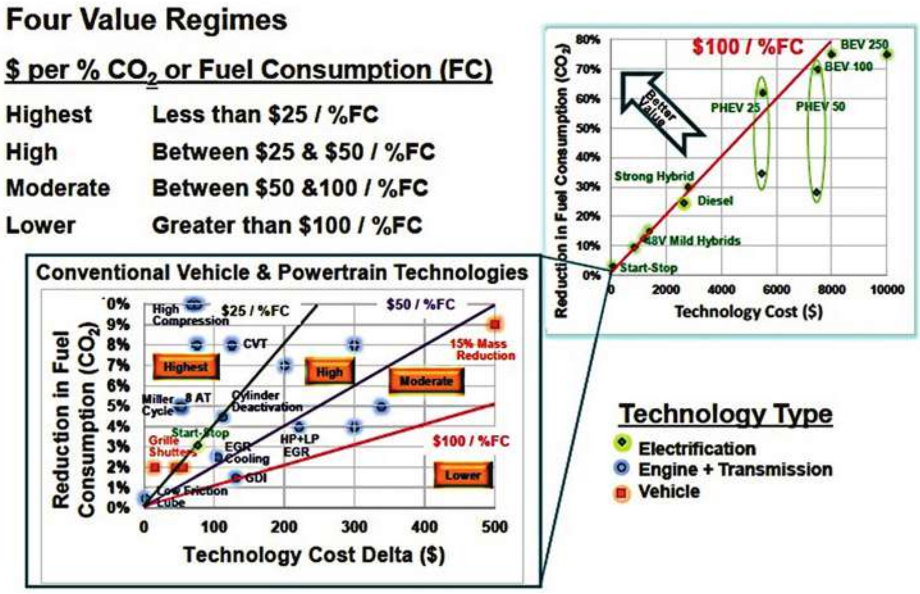
Further advantages include improving surface related material properties such as fatigue strength (Figure 5) and fracture toughness, whilst offering a controlled, cost efficient and repeatable treatment. The process can be used for any type of part, but a significant advantage is that it is also suitable for internal surfaces where a high-quality finish can be achieved. The surface treatment technology is currently being used on hydraulic aerospace components such as pumps, gears, pipes and filters whilst development of application on more complex mechanical parts is underway. Additionally, the shiny, bright, aesthetically pleasing finish that is produced means that it is being used on interiors such as gear sticks and dashboards. There is a broad scope of diverse applications in the future of AM surface treatment.

The application possibilities of this innovative surface treatment technology are endless. With high-level skill and precision engineering experience, AM is now being used to produce a vast range of components. These are usually small scale, mechanical parts due to the stage at which AM is at in its technological development. Aerospace manufacturers are looking at building larger structural aircraft parts with AM such as stringers or wing sections as the capabilities expand. It's key that AM can replace manufacturing processes for components that are already in use, to speed up production time and optimize performance without having to redesign the parts. Whilst AM took its time to be adopted by the aerospace industry due to the strenuous testing involved, Almbrite is already being rapidly accepted by aerospace and defense manufacturers.

This article was written by James Bradbury, Lead Researcher, South West Metal Finishing (Exeter, UK). For more information, visit http://info.hotims.com/65858-503

AUTOMOTIVE THERMAL MANAGEMENT

Thermal management plucks CAFE's low-hanging fruit



Thermal upgrades' estimated effect on fuel economy and cost per 1% improvement. (image: ITB Group)

Thermal management systems may offer the most "bang for the buck" in the quest to improve vehicle efficiency and thus meet stringent U.S. Corporate Average Fuel Economy standards. Although some of the "low-hanging fruit" in this area has been picked, opportunities still exist to further improve thermal management before engineers must shift to more costly investments.

This was the widely-expressed belief by speakers at the 2017 **SAE** Thermal Management Systems Symposium, led by a keynote from Sean Osborne, director of the **ITB Group**, a consulting firm specializing in the subject.

The need for improvement becomes urgent in 2018. That's because when the 2019 model year begins, the **NHTSA** raises the penalty for missing the CAFE target, from the present $5.50 per 0.1 mpg shortfall. Initially the new penalty was set at $14 per 0.1 mpg, but the industry was granted a review, based on claims of negative economic impact and objection to the way an inflationary adjustment to CAFE was applied. Environmental groups are fighting the review delay.

Market shift to trucks, SUVs an issue

To date, automakers have met the CAFE standards, but the shifting of the market from passenger cars to light trucks and SUVs has tightened the margins, and forced high use of retained and/or purchased CAFE credits. Fines paid by OEMs during the 2010-14 period include $46.2 million by **Jaguar Land Rover**; $28.2 million by **Daimler**; $17.4 million, **Volvo**; $4.8 million, **Porsche**, and $3.6 million **Fiat Chrysler** (FCA).

FCA, with its 2015 sales concentrated in **Jeep** and **Ram** trucks, also used 33.4 million credits and was projected to use 62.0 million for 2016. The amounts it spent to accumulate the needed credits is confidential.

Cost of installing new technology has to be balanced against buying credits. FCA was the first U.S. maker to go across the board with R-1234yf, a low-global-warming refrigerant that when used carries significant credits (13.8 g CO_2 for cars, 17.2 g for trucks).

To stimulate sales, the **Chrysler** Pacifica plug-in hybrid (PHEV) is cheaper in transaction prices than the gasoline-only model for the most popular configurations. FCA has yet to install direct fuel injection on its high-volume 3.6-L V6, but it has a system fully engineered and ready to deploy when its use is more cost-effective.

Flow valves, heat recovery

For conventional powertrains the lowest-hanging "fruit" to date, according to ITB's Osborne, consists of such features as high compression ratio, liquid-cooled EGR, idle stop-start, low-friction lubricants and active grill shutters. Of the energy produced by the engine, 26% is diverted to the cooling system and 32% to the exhaust, according to Jaguar Land Rover estimates based on the NEDC—New European Drive Cycle. Other opportunities in the thermal management area are focuses of attention.

BMW has been using a duty-cycle-controlled electric water pump for more energy-efficient cooling on its gasoline engines for several years. But coolant flow valves may be a less-expensive alternative for engines with complex coolant flow patterns based on temperatures in the cylinder block vs. head(s) and ambient temperatures.

Further, recent research by **Bosch**, in its TMSS presentation, indicated a flow valve system also could contribute to range extension in battery electric vehicles (BEVs). Using the GT Suite from **Gamma Technologies**, a Bosch team projected that recovering heat from electronics, along with a heat pump, could increase BEV range by perhaps 25 km (16 mi) by avoiding re-use of a battery heater to enhance battery capacity. This approach also was seen as less expensive than adding battery kW·h capacity in cold ambient.

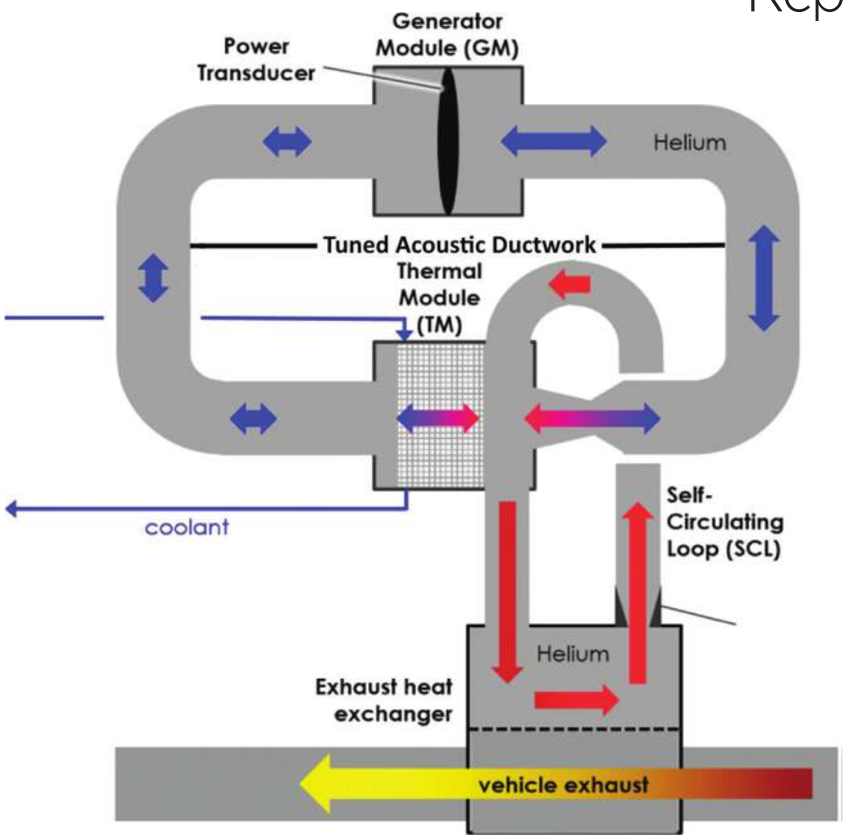
Although exhaust heat recovery seems likely to be among the higher-cost systems available, two already are in use on U.S. market **Toyota** Prius and **Hyundai** Ioniq/**Kia** Niro hybrids. They're basic systems, with a heat exchanger in the exhaust transferring heat to engine coolant for faster warmup.

In the Niro/Ioniq split system, early heating of the block reduces engine friction, increasing use of the all-electric mode. So fuel economy in the EPA city cycle was increased up to 7%, claims Kia for the Niro. This is much more than 1% estimated for such a system by a **Tenneco**/**Computational Science Experts Group** (CSEG) research team led by Tenneco's Dr. Dipanka Sahoo. It indicates selection of the right application is key.

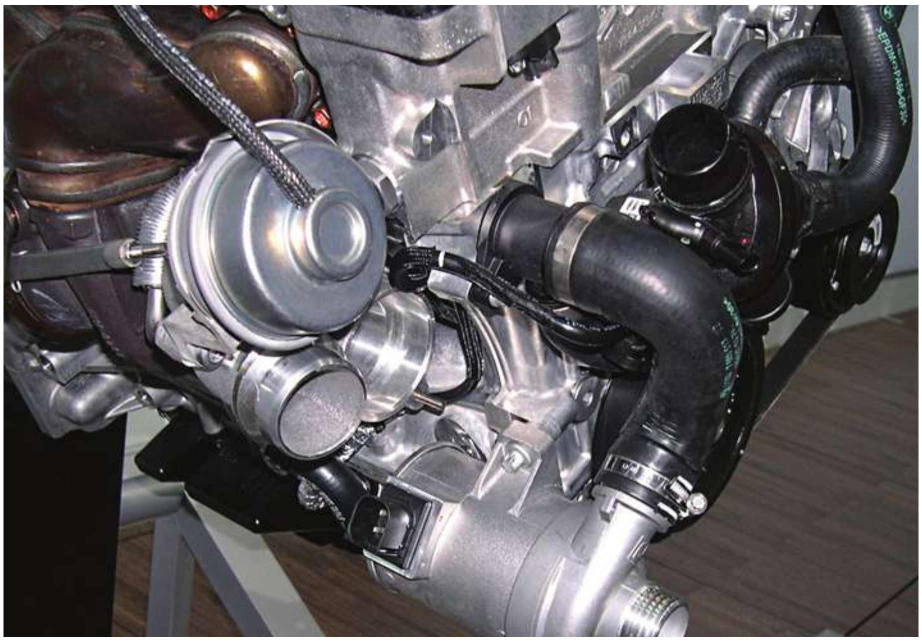
The Tenneco/CSEG estimate is based on 85% effectiveness in the first 250 s of warmup and an average of 19% heat capture over the entire cycle.

Other systems the Tenneco team also evaluated converting exhaust heat into mechanical work or electricity, which can reduce alternator load and/or serve as hybrid assist devices.

One is the "TEG" (thermo-electric generator), which uses exhaust heat to provide the high temperature of a temperature differential that produces electricity from a solid-state device that is



Thermo-acoustic system uses helium as the working fluid. A tuned acoustic ductwork carries amplified thermally-generated heat waves to the generator module to produce work. (image: Tenneco/CSEG)



BMW's electric water pump provides energy-efficient cooling on four-cylinder gasoline engines. (image: Paul Weissler) the reverse of the Peltier effect used for cooled-heated seats. The thermo-electric materials are rare-earth type, not inexpensive (particularly those with higher efficiency). However, work in nanotechnology could improve efficiency and minimize need for rare-earth substances, both in TEG and Peltier applications, the Tenneco team believes. Fuel economy improvement was projected at 0.7%.

Thermo-acoustic potential evaluated

The thermo-acoustic traveling wave system also was evaluated. It uses a pair of heat exchangers (one hot from absorbing exhaust heat, one cold). A porous medium called the regenerator, in between, establishes a temperature gradient between the two, using helium as a working fluid. This results in an oscillating gas flow, generating sound (acoustic) waves that are amplified and flow through a tuned duct into a mechanical device (a generator/power transducer) to produce useful mechanical work or convert to electricity.

The device can be compact and requires no rare earth or other exotic materials. In itself it has no moving parts. And although its fuel economy improvement was calculated at just 0.45% on an EPA city cycle, the TA device develops high power on the highway cycle, and including that the improvement was 2.7%.

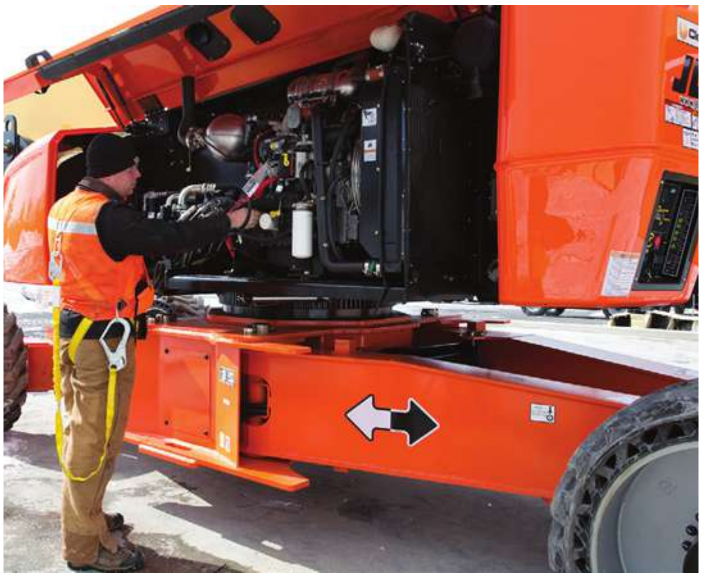
Organic Rankine cycle was cited as another choice, but because it results in larger-size systems the Tenneco group said it had more likely application in trucks. It's somewhat akin to an A/C system, using an evaporator to capture heat and build pressure on a working fluid (a refrigerant). Then it releases the pressure through an expansion device that performs mechanical work. Residual heat is rejected through a condenser.

Available data led the Tenneco researchers to develop fuel economy numbers modeling a Class 8 truck, in which three steady-state operating conditions were investigated. Heat recoveries were 56%, 59% and 64%, accumulations of 67.7 kW, 84.9 kW and 121.9 kW of energy, with conversion efficiencies of 11-13%, and fuel economy improvements of 3.6-4.1%.

Paul Weissler

OFF-HIGHWAY THERMAL MANAGEMENT

Assessing a vehicle's cooling system performance



JLG relies on CFD analyses when developing new engine bay installations, including that for the JLG 1500AJP Ultra Boom, shown. (image: JLG Industries)

Off-highway OEMs historically have utilized simple 1-Dimensional analyses (either themselves or through their cooling system suppliers) to predict the cooling performance of each vehicle's engine system. These analyses produce a low accuracy rate, which often results in late design changes leading to delays in the overall project.

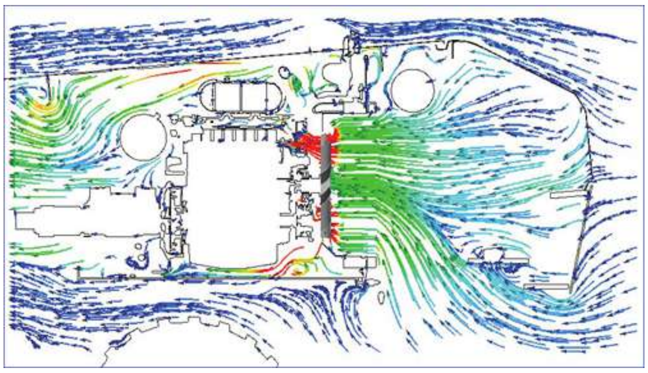
To improve this situation, manufacturers have a tool at their disposal in computational fluid dynamics (CFD). Using inputs of temperatures, flows, restrictions, heat transfer ability of coolers, and 3-Dimensional models of vehicle architecture, a 3D prediction of the cooling performance can be achieved. The 3D prediction results in an overall systems design with a higher success rate during validation.

JLG has been routinely using CFD software tools from industry-leading suppliers for more than five years, when developing new engine bay installations. The introduction of so many new engine variants, including hybrid drives and global emissions legislation variants, has driven the need to get it right the first time while managing even more variables.

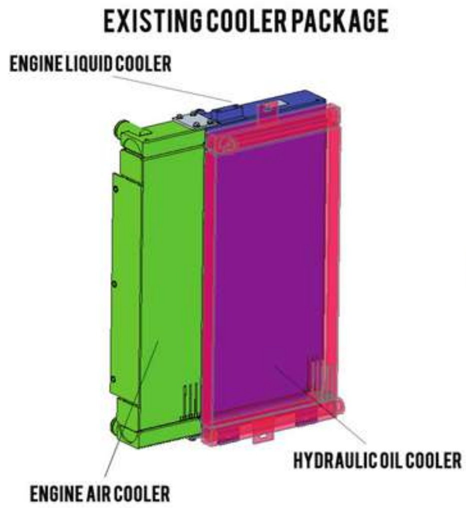
The example described here is an extract from the analysis performed on a JLG 1500AJP Ultra Boom, launched in 2016.

CFD reveals design inefficiencies

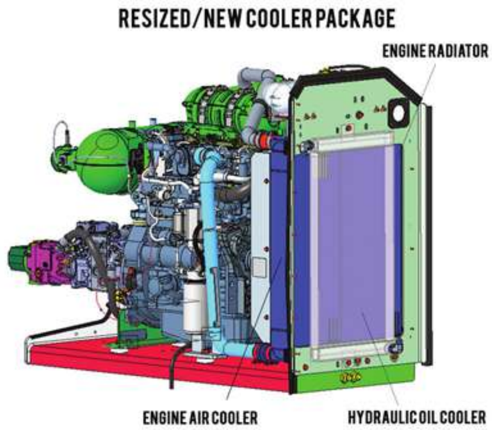
There are often multiple coolers that make up a system. Each of these coolers must work together to provide the required level of performance for each part of the system. By making sure that each cooler is balanced with the proper airflow, preheat temperatures and more, the desired performance of the system will be achieved.



Previous predictions from 1D analyses provided a less-than-desirable first-test success rate, closer to 70% on average. CFD has jumped that average rate up to 90%. (image: JLG Industries)



For the initial cooling system design, two of the systems were performing optimally but the engine charge air cooler was below the requirement. (image: JLG Industries)



Engineers determined via CFD that the engine liquid cooler needed to be made smaller while the engine charge air cooler needed to be larger. Also, the location of the hydraulic oil cooler was changed to balance the airflow correctly. (image: JLG Industries)

By utilizing CFD in the early stages of the design process, engineers can iterate in a soft environment to achieve the desired performance. By doing so, the team can avoid changes in the validation portion of the design cycle which are common when using 1D analyses.

Once an initial design of the cooling system has been created, it is time to use the CFD tool to analyze the efficiency of each individual cooler. In this specific case, the internal temperatures and cooler flows (constants, liquids and air) versus the heat exchanger efficiencies (constants) are mapped as a heat rejection from the system to the vehicle's environment based on the external cooler flows (air), which the CFD tool is simulating.

CFD revealed the following about the initial design of the cooling system:

- Engine liquid coolant was being cooled to 110% of the requirement
- Engine charge air was being cooled to only 75% of the requirement
- Vehicle hydraulics were being cooled to 109% of the requirement.

While two of the systems were performing optimally, the engine charge air cooler was below the requirement. Based on the design, it was determined that the engine liquid cooler needed to be made smaller while the engine charge air cooler needed to be larger. Even though the hydraulic oil cooler was performing above the requirement, the size did not need to be changed. However, its location in front of the other two coolers was changed to balance the airflow correctly.

Once each of the changes was finalized, a second run-through using the CFD tool was completed. It resulted in the following:

- Engine liquid coolant was being cooled to 101% of the requirement
- Engine charge air was being cooled to 109% of the requirement
- Vehicle hydraulics were being cooled to 110% of the requirement.

Each of the cooling systems were shown to be sufficient and able to perform to the requirements of the vehicle's overall system. With this information from the simulation, the project continued. Later, an actual vehicle validation confirmed the positive results from this simulation.

Future challenges and opportunities

CFD is not a replacement for the physical testing of applications. In the access industry, it is certainly an improvement to the original 1D analyses that were being provided. Previous predictions provided a less-than-desirable first-test success rate, closer to 70% on average. Typically the errors occurred in overall airflow, air inlet and outlet orifices and the split between hydraulic, engine coolant and transmission oil in the cooler stack. CFD has jumped that average success rate up to 90%. Despite this drastic increase in success, vehicle validation needs to be completed to confirm the results of the CFD simulation and analysis and all aspects of a vehicle's cooling system.

At JLG, the use of CFD to ensure optimized cooling performance will continue to evolve, with Stage V engine legislation introducing new components with distinct thermal requirements, such as diesel particulate filters (DPFs). Also evolving are the varieties of power systems, such as hybrid drives and their associated components, such as clutches, electronic controllers and charging systems.

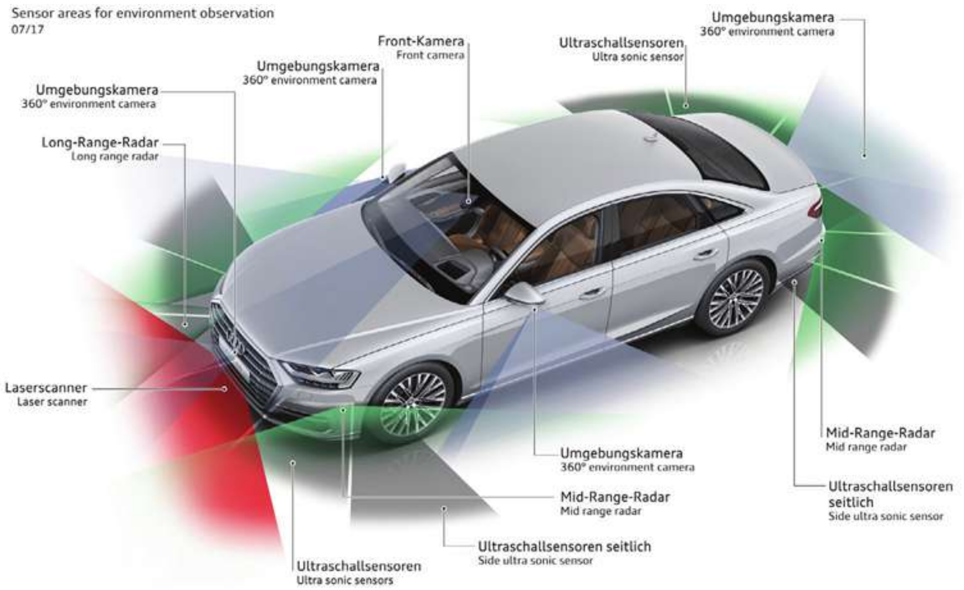
In conjunction with the continued development in power systems are related analyses such as noise and vibration, where the analysis of energy, airflows and pressures can be simulated and analyzed. In the future, new manufacturing processes, such as additive manufacturing and 3D printing, provide new opportunities to optimize components' forms for fluid flow characteristics.

Brian Barkley, Senior Chief Engineer, JLG Industries, Inc., wrote this article for *SAE's Truck & Off-Highway Engineering*.

Cooling system performance on the JLG 1500AJP Ultra Boom was significantly improved through the use of CFD software tools. (image: JLG Industries)

AUTOMOTIVE ELECTRONICS

Reconfigurable chip usage ramps up as ADAS advances



Audi uses a number of sensors in its zFAS piloted driving system on the new A8, so FPGAs are used to make it easier to configure connections. (image: Audi)

Reconfigurable processors have seen growing use in rapidly-changing infotainment systems and are expanding into advanced driver assistance systems (ADAS). The role of field-programmable gate arrays (FPGAs) and other customizable processors is expected to develop further with the emergence of autonomy, where the vagaries of artificial intelligence makes customization more important.

As vehicle OEMs make software more of a differentiator, devices that make it simple to alter hardware to match changes in algorithms and software are becoming more practical. In a growing number of systems, changes in software can improve performance significantly. Sometimes, performance can be further improved by altering the programming structure.

"Algorithms change rapidly, researchers can find 2% better performance, but they can't do that if they can't change the hardware," said Steve Roddy, Senior Group Director, Tensilica Marketing at **Cadence**. "They need a programmable solution that has the computing horsepower they need."

The 2018 **Audi** A8's zFAS piloted driving highlights the growing role of reconfigurable hardware, as well as the demanding computing requirements of electronic controls that make life or death driving decisions. An **Intel** Cyclone V FPGA that has dual ARM cores augments Audi's control module, which also employs an **Nvidia** GPU, a **Mobileye** vision processor and a basic CPU.

"Audi is our first adoption in an ADAS system with a heterogenous approach," said Michael Hendricks, Senior Director of Intel's Automotive Programable Solutions Group. "ADAS and autonomy are moving so rapidly, there's a major breakthrough every three months. It's difficult for an ASIC developer to hit the bulls eye. FPGAs bring a lot of assets and give developers more flexibility to adapt."

Expectations of strong growth is attracting other FPGA suppliers like **Xilinx**. Reconfigurable devices make it simpler for design teams to alter hardware late in development cycles while also letting them configure control modules that can be used in various models. For example, some ADAS systems may have more sensors than others.

"With an FPGA, you can tailor the I/O, setting the right number of LVDS and CAN connections, for example," Hendricks noted. "FPGAs offer a sea of logic gates so both hardware and software can be programmed so algorithms and hardware are optimized."

Customizable hardware was once used primarily for development, with ASICs or specialized processors used in production. But that limitation faded as radios transformed into infotainment systems. These devices are seeing more widespread usage in infotainment as users demand more features and functions. In large vehicles, customized processors will help foster communications between humans.

"In a big SUV, smart microphones in the headliner can figure out who's talking and send their voice through the speakers," Roddy said. "These chips let them layer in this level of functionality."

Safety and infotainment are primary drivers behind expectations of continued solid growth for automotive ICs. **IHS Markit** expects the automotive semiconductor market from $32.1 billion in 2016 to $34.4 billion in 2017, slightly outpacing 7% growth from 2015 to 2016.

Long-term expectations are fueling major changes in the automotive chip world. Intel acquired **Altera**, which makes FPGAs. It also acquired Mobileye, maker of vision processors. **Qualcomm** is in the process of acquiring **NXP Semiconductors**, which last year purchased **Freescale** Semiconductors. **Citigroup** predicts that Nvidia, once a small player in vehicles, will hit $1 billion in automotive in fiscal 2018 after seeing revenue rise 52% in fiscal 2017.

Though newer companies like Nvidia and Cadence are focusing on automotive applications, traditional suppliers have maintained the bulk of the market. NXP, **Infineon**, **Renesas**, **STMicroelectronics** and **Texas Instruments** were the largest automotive suppliers in 2016, according to **Semicast** Research. **Robert Bosch**, **On Semiconductor, Microchip Technology**, **Toshiba** and **Rohm Semiconductor** rounded out the top 10.

Terry Costlow

Advancing toward driverless cars

Autonomous-driving technology is set to revolutionize the auto industry. But getting to a true "driverless" future will be an iterative process based on merging numerous individual innovations.

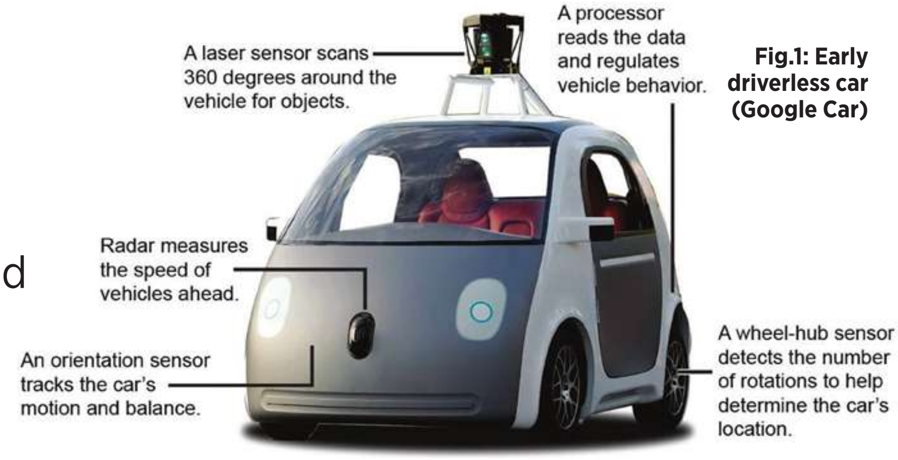


Fig.1: Early driverless car (Google Car)

Introduction

One of the most prominent recent developments in the automotive industry is the introduction of autonomous "driverless" technology, which is sure to create a revolution in the transportation sector. Although it remains early in the development and commercialization process, several factors can be identified for consideration before adopting driverless technology.

An autonomous vehicle (widely referred to as a "driverless" vehicle, "self-driving" vehicle or "robotic" or "robo" vehicle) can sense its environment and navigate without human input. Many types of autonomous vehicles are being developed by nearly every major automaker, but as of early 2017, automated cars permitted on public roads were not yet fully autonomous: they all require a human driver at the wheel who is ready at a moment's notice to take control of the vehicle.

Autonomous vehicles employ a variety of techniques and technologies to detect their surroundings, including radar, lidar, global-positioning system (GPS) odometry and machine vision. Advanced control systems interpret the sensory information to identify appropriate navigation paths, as well as obstacles and relevant signage. Autonomous vehicles have high-powered processing systems that can analyse sensory data to distinguish between vehicles using the road, which is very useful in planning a path to the desired destination.

Technologies in autonomous vehicles

Currently, auto manufacturers are focused on advanced driver-assistance systems (ADAS) features that expect a driver to take charge when "self-driving" is not appropriate. The intent is to enhance the driving experience in the automobile and remove the "stress" aspect of driving—but only during limited conditions and situations. Mapping of the terrain in which the car drives is done in real time, as opposed to using the "delta" approach **Google** initiated, starting with pre-mapped routes and terrain information. The following sections cover some innovative autonomous-vehicle technologies and illustrates auto manufacturers' incremental approach to developing self-driving vehicles.

Lane-change assist: This driver-assistance system typically consists of two radar units invisibly mounted in the corners of the rear bumper. One sensor operates as system master, the second unit is configured as slave. Using an onboard data link, the input signal of both radars is combined in a data-fusion tracking algorithm. This feature has been in volume production since 2006 and is used by nearly every major automaker.

Parking assist: Fully-assisted parking-aid technology now is available from **Ford** and many other manufacturers. It can automatically park vehicles in tight spaces and park in both perpendicular and angled parking spaces, which is particularly useful in tightly-congested streets and parking areas in Europe and Asia.

This technology uses ultrasonic sensors to scan for an open parking space at speeds as high as 19 mph. When the system identifies a suitable parking place, it alerts the driver, who can stay in the car or get out and use a remote to finish the parking job. The car then backs itself into the parking space.

Adaptive cruise control: Adaptive cruise control (ACC) is an "intelligent" form of cruise control that automatically adjusts vehicle speed to keep pace with the vehicle in front. A small radar unit behind the grille or behind the front bumper measures the distance to leading traffic and maintains a preselected following distance. If not using radar, some ACC systems employ a laser and others use an optical system based on stereoscopic cameras. ACC is ideal for stop-and-go traffic and congesting commuting situations that can swing abruptly from 60 mph cruising to a standstill. Regardless of the technology, ACC works in any light conditions, but its abilities can be hampered by heavy rain, fog or snow. In an autonomous vehicle, ACC needs to track not only the vehicle directly in front, but also the vehicles in adjacent lanes in the event a lane change becomes necessary.

Vehicle-to-vehicle (V2V) communication: In 2014, the Obama Administration announced that it planned to actively advance V2V communications technology. With V2V, vehicles exchange information with other vehicles, transferring data and alerting drivers to potential collisions and other hazards. Vehicles also "talk" to infrastructure of all manner: sensors on signs, stoplights and even sensors embedded in the roads to get traffic updates and rerouting alerts. The system will permit the vehicle to communicate with homes, offices and smart devices, acting as a digital assistant, gathering information needed throughout the day.

Vehicle-to-vehicle communications data includes speed, location, and direction of travel, braking and loss of stability. The mode of wireless transmission could be dedicated short-range communications (DSRC), a standard set forth by bodies like FCC and ISO, a cellular communications network such as upcoming 5G or satellite-based.

Sometimes DSRC is described as a Wi-Fi network because one of the possible frequency of 5.9GHz, the same frequency used by Wi-Fi. But it is more accurate to say that DSRC is "Wi-Fi-like." The range is up to 300 meters for about ten seconds at highway speeds (not three seconds as some reports say). The V@V concept is envisioned as a mesh network, meaning every node (vehicle, smart traffic signal, etc.) could send, capture and retransmit signals. Five to ten "hops" on the network could gather traffic conditions from a mile ahead—enough time for even the most distracted driver to react.

Benefits of Autonomous Cars

Safety: Of all transportation problems, safety issues have the most serious impact on daily life. Traffic accidents also have colossal negative effects on economy. Vehicular travel currently is the most deadly form of transportation, with more than a million annual deaths worldwide. Implementation of autonomous vehicles is projected to greatly reduce the number of crashes, since 90% of traffic accidents are caused by human error. Intelligent safety systems currently in use already have proven their success in helping drivers avoid accidents.

Traffic congestion: With the introduction of fully autonomous vehicles, traffic flow theoretically would be drastically altered. In the early stages of implementation to the highway system, there would be a combination of autonomously-driven vehicles and human-controlled vehicles and this could cause some confusion and problems concerning motorists' reaction to driverless vehicles and how well the autonomous vehicles can integrate into traffic flow. The autonomous vehicles presumably would be programmed to strictly follow all traffic laws, while human drivers have the choice to break the law.

As time progresses and autonomous vehicles become more common, traffic would become far less congested; vehicles should be able to seamlessly merge into moving traffic and then exit the highway just as easily. With the reduction of traffic, there is a chance that there could be economic improvements. Also, with less stop-and-go traffic, average fuel economy would be improved.

Fuel economy: Autonomous vehicles will eliminate ineffective braking and acceleration, operating at an optimum performance level in order to achieve best-possible fuel efficiency. If the fuel efficiency gain from autonomous vehicles were even 1% better, the result would be billions of dollars of savings. It also is possible to obtain increased fuel efficiency from the implementation of autonomous safety systems.

Time Costs: The phrase "time is money" is true for most situations in modern life and the monetary value of time is increasing every day. Using automated vehicles could save a considerable amount of time in an individual's life, particularly if the person resides in a busy city. Even if the time savings were not considered as having monetary value, having more time for leisure activities would improve quality of life. Reducing the amount time lost on the road also will enable people to be on time and with more energy, resulting in a significant improvement in work efficiency.

Autonomy applications

Defense: Automated navigation systems with real-time decision-making capability makes autonomous capability attractive for warfield and other military applications.

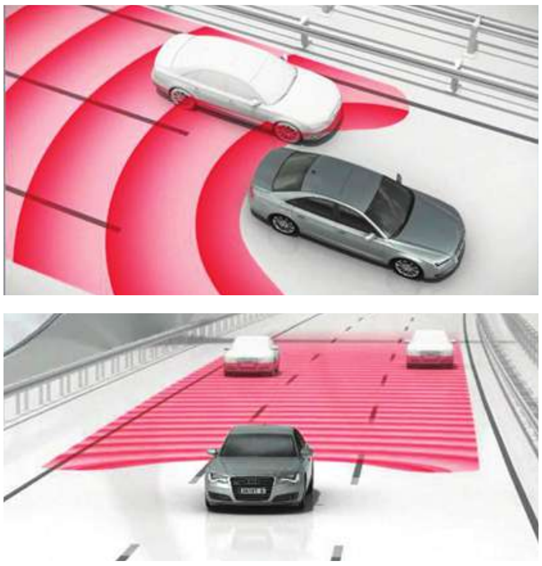


Fig. 2: Lane assistance.

Shipping: Autonomous vehicles will have a huge impact on the land-shipping industry. A primary transport mode for goods on land is by freight trucks; currently, all of trucks are driven by an employee of a trucking company. If the trucks were driverless, a person to move the vehicle from one point to another is no longer needed and the truck can drive to the destination without having to stop for anything other than fuel. Full autonomy theoretically would save trucking companies an enormous amount of money, but it also would put thousands out of jobs. These people would have to find and learn a new profession.

Taxi services: Another sector that would be strongly affected by autonomous driving is taxi services. The business is based solely on driving someone who does not have a vehicle or does not want to drive. This type of service could reduce the number of vehicles on the road because not everyone would have to own a car and an autonomous vehicle could be requested only when needed.

Taxis also drive around cities and wait in busy areas for a request for transportation. A taxi service comprised completely of autonomous vehicles could address many inefficiencies of the current system. Autonomous taxis could wait in designated areas, reducing urban congestion. The need for a human in the service goes away completely and is another example of a potential large degree of unemployment attributed to autonomous vehicles.

Public transportation: In most forms of public transportation, a human is at the controls Whether it is on a bus, in a train, subway, streetcar, or shuttle, there is a person sitting in the driver's seat, controlling the vehicle's actions. For rail-based transportation, "driving" is a simpler process more involved with accelerating and decelerating the train from and into stops; there is no concern over keeping in a lane or avoiding other vehicles. However, driving a bus, for example, is a more-complex task,

Fig. 3: Parking assistance for parallel parking.

watch the actions of other drivers and pedestrians making critical judgements at every stop.

The early stages of autonomy implementation for most modes of public transportation most likely would keep the driver behind the wheel as a safeguard in case there is a problem with the system. The driver also would be needed in the adoption phase to instill public trust.

Intelligent transportation: Intelligent transport systems vary in technologies applied, from basic management systems such as vehicle navigation, traffic signal control systems, container-management systems, variable message signs, automatic license-plate recognition or speed cameras to monitor and to more advanced applications that integrate live data and feedback from a number of other sources, such as parking guidance, weather information bridge de-icing systems. Additionally, predictive techniques being developed to allow advanced modelling and comparison with historical baseline data; this technology will be a revolutionary step in intelligent transportation.

Challenges for self-driving vehicles

- The equipment and technologies used are costly
- Safe use of complex artificial intelligence software as the "brain" of the driverless vehicle
- Changing road conditions and infrastructure will require instantaneous decisions from the autonomous system
- Professional drivers will become unemployed
- Consumer concern about the safety of driverless vehicles
- Software reliability
- Limitations of artificial intelligence in chaotic environments
- Susceptibility of the vehicle's sensing and navigation systems to different types of weather or deliberate interference, including jamming and cyber-attack.
- Autonomous vehicles likely will require very high-quality, specialised maps to operate properly

Future scope

The transition to an automated transportation structure will address many current problems

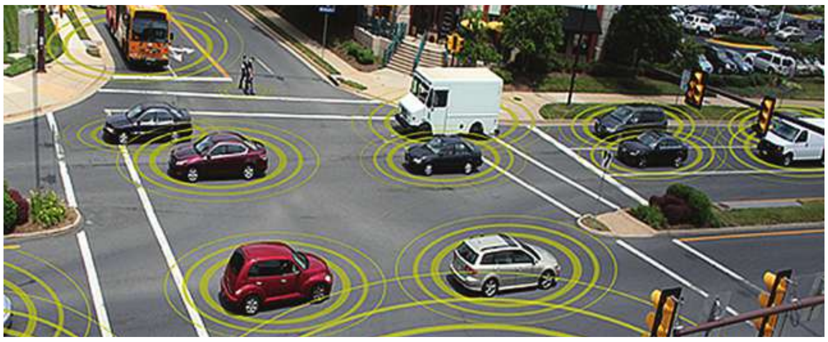


Fig. 4: Vehicle-to-vehicle communication.

caused by traffic congestion. Implementation of autonomous cars will allow vehicles to be able to use the roads more efficiently, thus saving space and time. Factors such as narrow lanes will no longer be an issue—and most traffic problems will be avoided to a great extent by the help of this new technology.

Smooth traffic flow is at the top of the wish list for countless transportation officials and research indicates that traffic patterns will be more predictable and less problematic with the integration of autonomous vehicles. Auto manufacturers already are using various driver-assist systems and the trend is expanding. As a result, these early "co-pilot" ADAS systems are expected to gradually evolve to autopilots.

All developments indicate that one day, the intelligent vehicle will be a part of our daily lives, but it is difficult to predict when. The most important factor is whether the public sector will be proactive in taking advantage of this capability, determining if the benefits will come sooner rather than later. Since current ADAS technologies are quite similar to the systems that are used in autonomous-vehicle prototypes, they are regarded as the transition elements on the way to the implementation of fully autonomous vehicles.

Conclusion

Currently, various technologies can assist in creating autonomous vehicle systems. Items such as GPS, automated cruise control and lane-keeping assistance are available to consumers right now. The combination of these technologies and other systems such as camera-based lane analysis, automated steering and brake-actuation systems and the hardware and software necessary to control all of the components will comprise what becomes a fully autonomous system.

An overriding issue: winning an individual's trust to allow a computer to drive the vehicle. To address this, there must be extensive and robust research and testing to assure a near-foolproof final product. The product will not be accepted instantly, but will over time as the systems become more widely used and the benefits become clear. The implementation of autonomous vehicles also presents the problem of replacing humans with machines that can do the work for them. There will not be an instant change, but it will become more prevalent as autonomous vehicles are integrated into society.

Author: Mr. Kishore Rangarajan, Assistant Professor in the Dept. of Automobile Engineering, Kumaraguru College of Technology, Coimbatore, Tamilnadu.

Overcoming the challenges of HCCI COMBUSTION

Homogenous-charge compression ignition (HCCI) holds considerable promise to unlock new IC-engine efficiencies. But HCCI's advantages bring engineering obstacles, particularly emissions control.

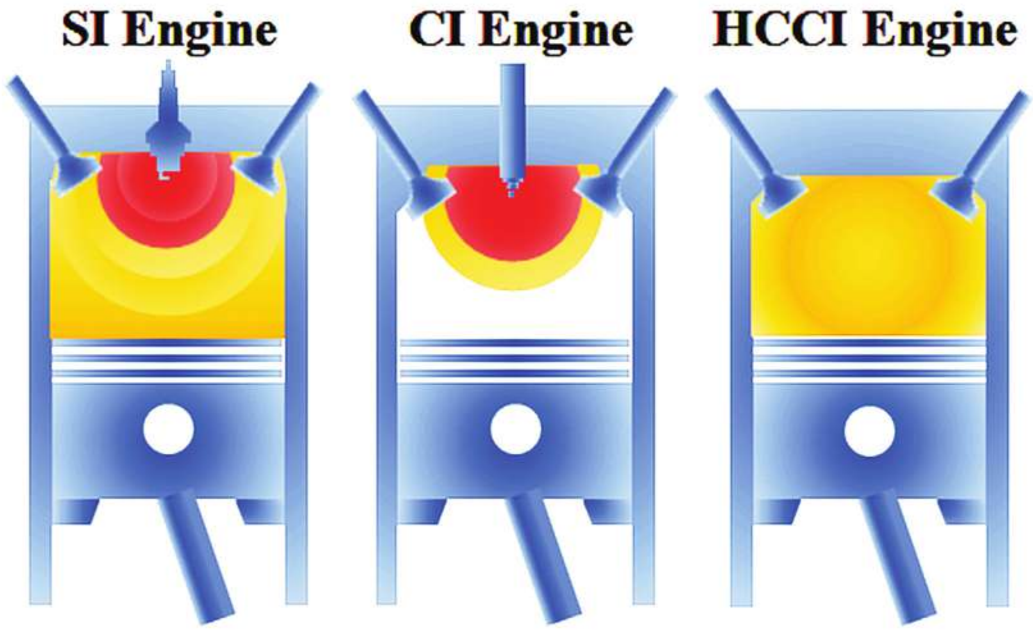


Fig. 1: Comparison of SI, CI and HCCI combustion.

The internal-combustion (IC) engine, as a prime mover in the industrial, power and transportation sectors, has simplified the lifestyle of humans. It has revolutionized the automotive sector and the subsequent exponential growth of the automotive population helped create wealth—but also caused pollution-related issues.

The environmental impact of harmful tailpipe emissions and ever-tightening emission regulations is enticing researchers and auto manufacturers to develop engines that would significantly reduce emissions—without a performance compromise. Over the years, researchers have tackled these issues by adopting alternative fuels, advanced aftertreatment devices or modifications in engine design.

In terms of engine design, homogeneous-charge compression-ignition engines (HCCI) give hope to researchers as an advanced combustion technology to meet the stringent emission norms. HCCI engines combine the best features of spark ignition (SI) and compression ignition (CI) engines. Recently, studies are concentrated on realizing HCCI's potential while addressing its challenges for production-vehicle applications.

In HCCI engines, once a conducive environment prevails inside the combustion chamber, the mixture burns volumetrically in the absence of spark. Research revealed that HCCI reduces both NOx and Particulate Matter (PM) emissions simultaneously and researchers are focusing on experimental as well as computational methods to make HCCI a viable option for future engines.

The HCCI concept, however, is not a modern finding. In the late nineteenth century, "hot bulb" engines operated with HCCI-like combustion.

HCCI engines use homogeneous fuel and air mixture—as in the SI engines—and employ high compression ratios to allow the mixture to auto-ignite, as does a diesel engine. HCCI combustion involves the auto ignition, by compression, of the homogeneous air-fuel mixture that is prepared either inside the combustion chamber or inducted into it. Essentially, an HCCI engine works on the principle of having a dilute, premixed charge that reacts and burns volumetrically, without the aid of spark, throughout the cylinder as it is compressed by the piston; this particular characteristic of an HCCI engine facilitates its operation with lean mixtures at low temperatures.

This lean-mixture operating capability reduces the Indicated Specific Fuel Consumption (ISFC) to a considerable extent, while low-temperature combustion is responsible for very low NOx (a roughly 90-98% reduction). Meanwhile, brake thermal efficiency for an HCCI engine is comparable to that of conventional CI engines and much superior to SI engines.

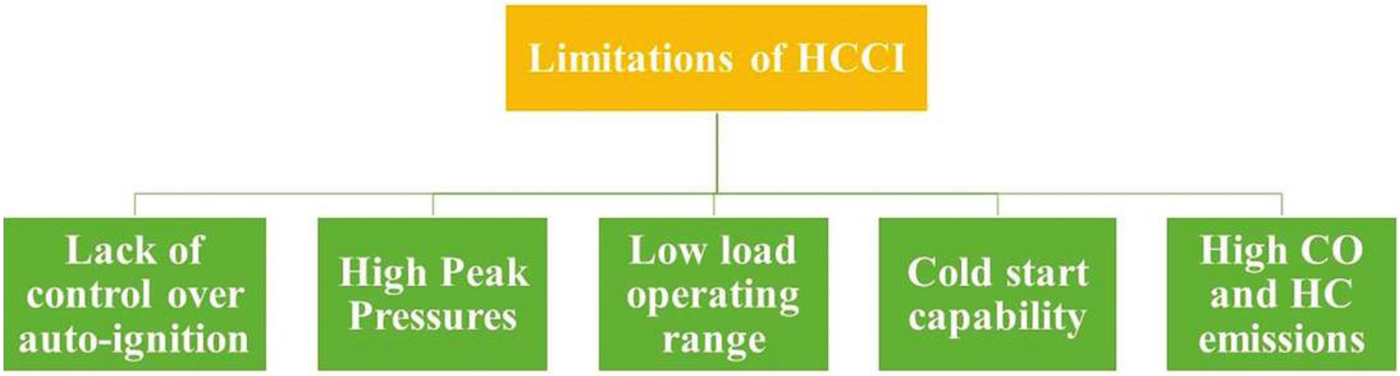


Fig. 2: Limitations of HCCI engine.

Challenges associated with HCCI engines

Though HCCI engines have many attractive features, they also suffer from some limitations. Many researchers have reported the challenges/limitations of HCCI engines as shown in Fig. 2.

It is observed that researchers have adopted different methods to achieve HCCI combustion and the resultant low soot and NOx emissions. It appears there are two methods to enable an engine run in HCCI mode through premix and injection techniques.

The classification of methods to achieve HCCI mode of combustion can be seen in Fig. 3.

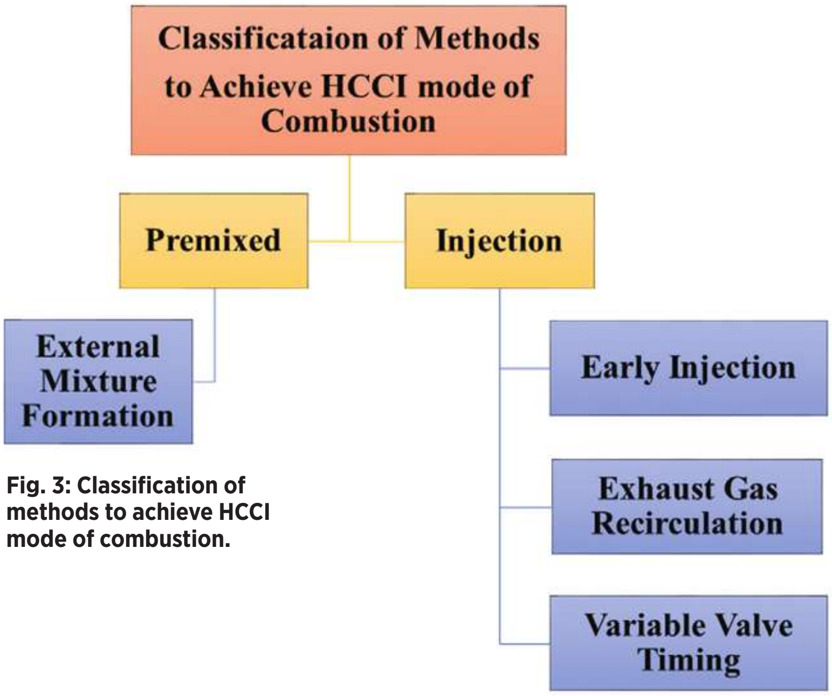


Fig. 3: Classification of methods to achieve HCCI mode of combustion.

Many researchers opt for the injection mode, as it requires nominal modifications to existing engines. But there are questions about this method, as it is difficult to determine if the charge inside the combustion chamber is completely homogeneous under different conditions. For high-speed engines, this method is not suitable. Generally, ideal homogenous conditions cannot be achieved with this method.

Some researchers advance the injection timing—called early injection—to inject the fuel much sooner than would be normal, encouraging the fuel to mix completely with the intake air. The early injection of fuel also provides more time for the air-fuel mixture formation process before it is auto-ignited. The extra time gained by fuel and air promotes better homogeneous mixture formation than in conventional engines. This method ensures homogeneous mixture formation under low and moderate speeds, but at higher engine speeds this method will not serve the purpose of developing a homogeneous mixture, while improper early injection timing leads to overloading of bearings; incomplete combustion will be a result.

Exhaust Gas Recirculation (EGR) is one technique incorporated by various researchers to help achieve HCCI combustion. With this process, some proportion of exhaust gas is retained in the combustion chamber itself, using the heat energy associated with the retained (i.e. recirculated) exhaust gasses to vaporize the fuel injected in to the combustion chamber. This fuel vaporization facilitates the homogeneous mixture formation desired for homogeneous combustion; EGR can be classified as "external" or "internal."

By controlling the EGR and backpressure exhaust valve, external EGR can be achieved. By altering the valve overlap period, internal EGR can be generated. Control of NOx emission ignition timing and burn rates also can be achieved with EGR techniques.

The effects of EGR on HCCI combustion are a preheating effect—an increase in the temperature of the inlet charge with the EGR addition; a dilution effect—substantial reduction in oxygen concentration; a heat-capacity effect—higher heat capacity of CO_2 and H_2O vapor obtained with the introduction of hot EGR that increases the total heat capacity of the air-fuel mixture and EGR leading to a temperature depression of gas at the end of compression stroke; and a chemical effect—participation of constituents of EGR in the chemical reactions during combustion, affecting the reaction rates in the combustion chamber.

Despite the advantages of low NOx emissions, low specific fuel

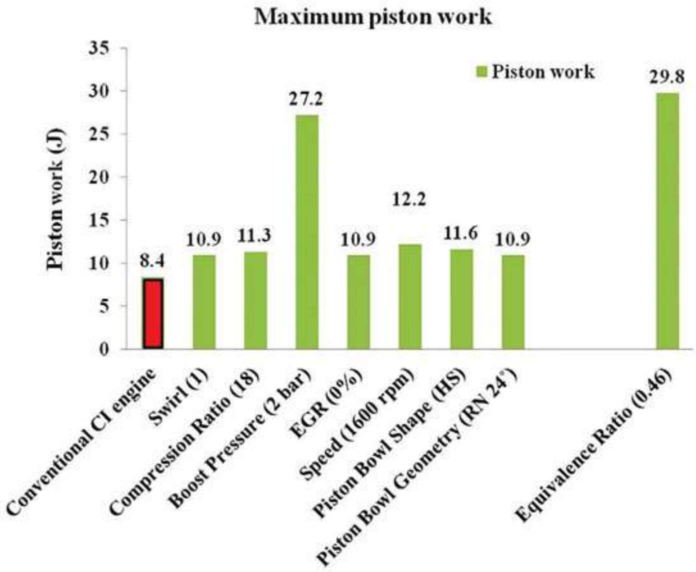


Fig. 4: Comparison of maximum piston work obtained by conventional CI and HCCI modes with swirl ratio 1.

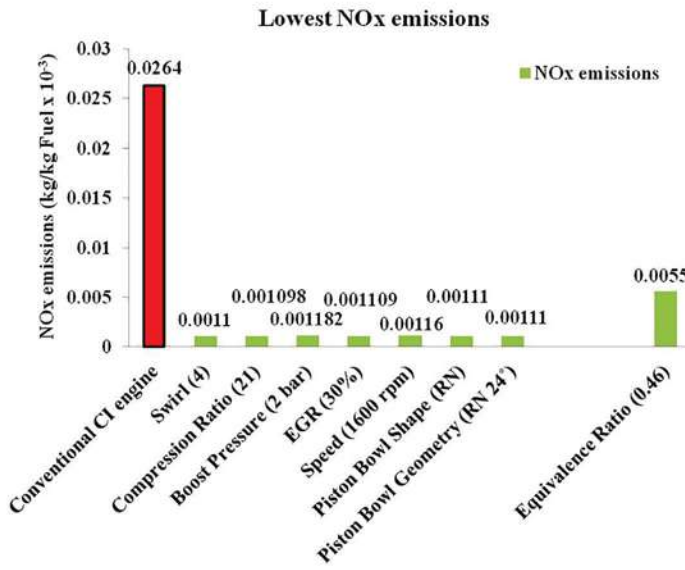


Fig. 5: Comparison of lowest NOx emissions obtained by conventional CI and HCCI modes with swirl ratio 4.

consumption and high engine efficiencies, HCCI engines suffer from the problem of combustion phasing control at high loads and high engine speeds. In IC engines, variable valve timing (VVT) is nothing but adjusting the valve lift timing event to improve engine performance and reduce fuel usage or emissions; control of combustion phasing and emissions in HCCI engines also can be realized with the application of VVT.

The compression ratio of the engine can be altered without any modifications to the engine geometry by incorporating the VVT technique of late intake valve closure (IVC) times. Late Intake Valve Closing (LIVC) helps decrease temperatures during compression and delay ignition, thus increasing the high-load capacity of the HCCI engine. Negative valve overlapping is a widely-used recompression valve strategy employing negative valve overlap (NVO) to trap varying amounts of hot residual gasses, providing an indirect form of ignition and combustion phasing control.

There are typical techniques of valve timing adjustments and each has its own range of effects on the performance of the engine, as well as on CO, UHC, and NOx emissions.

The premixed method is gaining the attention of researchers as a way to achieve ideal HCCI combustion under all engine running conditions. The premixed mode of HCCI combustion is achieved via external mixture-formation in which a fuel vaporizer is used to vaporize the fuel; the mixture of fuel vapor and air then enters the combustion chamber, where it is compressed. As there is no sparkplug, the design is such that the temperatures attained because of compression lead to auto-ignition of the charge, much like a diesel engine. Thus HCCI engines attain the advantages of both SI and CI engines.

The use of high compression ratios facilitates use of very lean mixtures—thereby low Indicated Specific Fuel Consumption (ISFCs) are possible with HCCI engines. The use of a very lean premixed charge leads to low-temperature volumetric combustion and low NOx and soot emissions.

These lower temperatures also are responsible for high CO and HC emissions because they inhibit the oxidation of CO and HC. There also are problems associated with external mixture formation techniques: ISFC is higher compared with conventional engines and there are increased HC emissions. A few researchers have achieved HCCI combustion using the external-mixture strategy. But many researchers have tried to achieve HCCI and its resultant low NOx and soot emissions, but have encountered high HC and CO emissions. Engine performance can be improved by varying geometrical and operating parameters and emissions can be mitigated by utilizing these adjustments, as well as adopting EGR, swirl and other operating methods.

The authors did use the premixed mode to achieve HCCI combustion and did extensive numerical analysis. The present work deals with a development of an in-house model in C Object-Oriented Programming Language (C++) to achieve near-HCCI conditions by varying injection timing and EGR. Though the model could well predict the in-cylinder pressures and temperatures, it could not account for parameters such as the simultaneous effect of swirl, turbulent kinetic energy, piston bowl geometry and other variables.

As HCCI combustion is volumetric in nature, to analyze the effect of these parameters it is quite essential to adopt a multidimensional model. For this purpose, Extended Coherent Flame Model having three Zones (ECFM-3Z) combustion model developed in Solver for Turbulent flow in Arbitrary Regions – Computational Dynamics (STAR-CD) is employed. Thus, a systematic computational study was carried out by employing a premixed-charge concept for achieving HCCI and

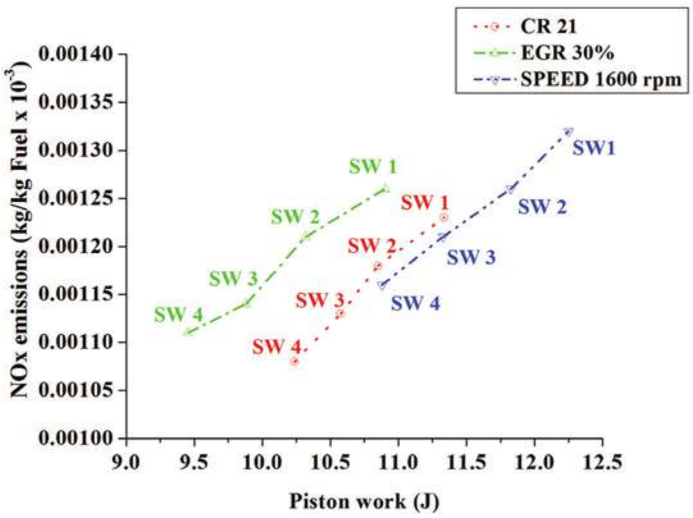


Fig. 6: Optimum tradeoff achieved between NOx emissions and piston work for different parameters -1.

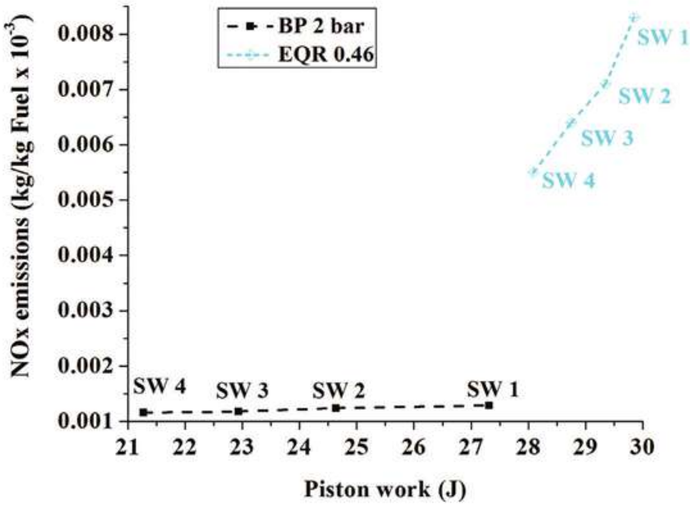


Fig. 7: Optimum tradeoff achieved between NOx emissions and piston work for different parameters –2.

for examining the effect of compression ratio (CR), swirl, combustion chamber geometry, boost pressure, ignition quality of fuel and other parameters on the performance as well as emissions of an HCCI engine.

The model is validated with the data of two different engines available in literature. It is observed that ECFM-3Z combustion model, with modifications incorporated, has well predicted the characteristics of HCCI engine. Moreover, the modified model is found to be insensitive to engine geometry.

Also, the computational study established that the combination of swirl and any other parameter would overcome certain challenges associated with realization of HCCI.

Extensive numerical experiments were conducted and performance is predicted in terms of piston work, turbulent kinetic energy, Velocity Magnitude (VM) and emissions NOx, HC, CO, CO_2 for the chosen engine configuration. Simulation results revealed that induction-induced swirl motion has significant effect on HCCI engine performance and emissions as Turbulent Kinetic Energy (TKE) and VM increased with increase in swirl intensity. Decrease in piston work, in-cylinder pressures and temperatures, CO_2 and NOx emissions were obtained with increase in swirl ratio. With increase in swirl ratio, an increase in wall heat transfer losses and CO emissions also developed. Efficient, effective combustion and reduction of emissions were observed by enhancing the air motion inside the combustion chamber with optimized piston-bowl shape and geometry.

It was observed that the combined effect of swirl and other input parameters subdue the difficulties such as emissions increase, a decrease in piston work and poor load-bearing capacity and auto-ignition. The combined influence of equivalence ratio and swirl improved the engine performance and reduced emissions to a considerable extent. Load-bearing capability was improved by employing boost pressure. An increase of 151.00% in piston work was observed with increase in boost pressure from 1 bar to 2 bar with swirl ratio 1. A total of 11.12% reduction in NOx emissions with swirl ratio 4 and 42.59% increase in CO emissions with swirl ratio 1 have resulted with increase in boost pressure from 1 bar to 2 bar.

See Fig. 4 for a comparison of maximum piston work obtained by conventional CI and HCCI modes with swirl ratio 1.

It was found that low compression ratio with high swirl for an equivalence ratio of 0.46 and reentrant angle of 24° is found to be optimal among the different parameters studied. For swirl ratio beyond 4, it resulted in combustion irregularities and enhanced wall-heat transfer losses.

The premixed technique is effective in achieving HCCI with induction-induced swirl. By adopting the strategy, it resulted in low HC and CO emissions and low NOx emissions. The study revealed that there exists a tradeoff between NOx emissions and piston work and Figures 6 and 7 show the tradeoff curves for different input parameters at an optimum value for the swirl ratios 1 to 4. ■



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SIMULATION FOR TRACTOR CABIN VIBROACOUSTIC OPTIMIZATION

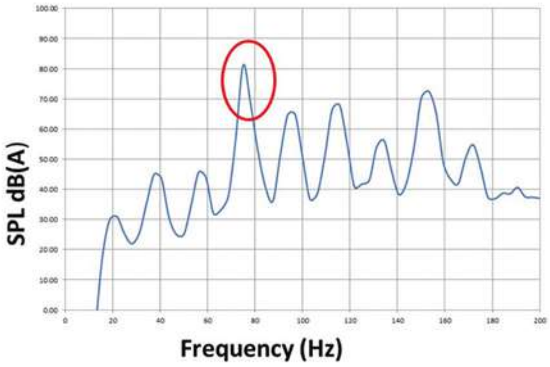


Figure 1: Measured driver-perceived noise level, left side.

Figure 2: Noise-generation sources.

Abstract

In recent years, tractor operators have indicated a preference to drive more comfortable tractors. The high noise and vibration levels to which drivers of agricultural tractors often are exposed for long periods have a significant role in driver fatigue and also may lead to substantial hearing impairment and other health problems.

Therefore, it is essential for an optimal cabin design to have time- and cost-effective analysis tools for the assessment of the noise and vibration characteristics of various design alternatives at both the early design stages and the prototype testing phase. Engine excitation is transferred through the cabin suspension to the body and then resonates with the body structural mode. According to analysis of the body panel contribution, the biggest contributor to booming is the floor. If the floor is modified, the stiffness at the interface is increased and the coupling between the floor mode and engine excitation frequency is avoided—and interior booming is significantly reduced.

Introduction

The automobile body, as a carrier of many other systems and components, consists of beams, pillars and various panels. The body is subjected to various dynamic loads such as engine excitation and road excitation. These excitations transfer energy to the body panels (such as front and rear windshields, roof, floor, etc.) through the body beams and pillars. The excited panels radiate sound to the passenger compartment or are coupled with the body acoustic cavity modes, inducing interior booming. This booming is a low-frequency noise that typically makes occupants uncomfortable. Therefore, in the early stage of the body development, the booming attenuation should be identified and verified as early as possible in the body design to avoid design change in late stages of the project development; otherwise, cost is high and timing is very tight to incorporate the required structure modification.

The aim of this study in the field of noise and vibration is to develop a simulation methodology for predicting in-cabin booming noise and to correlate with experimental results. The established process will be used for any new projects to aid in reducing development time.

Problem Description

Interior booming was identified in a prototype vehicle in stationary condition and at certain vehicle speeds. Figure 1 shows the tested interior noises. The booming peaks appear at 75 Hz, and the sound pressure level at the driver ear is 12 dB (A) higher than the target. Through considerable testing and analysis, the structure-borne sound is confirmed as the major contributor to booming.

The frequency spectrum is measured in the driver's left ear, as shown in Figure 1.

From the frequency data in Figure 1, the peak can be seen at 75 Hz. To study the causes and mechanism of the booming, the "source-transfer path-response" method is used, including BIW (Body-In-White) modal analysis, noise transfer function testing and analysis, acoustic cavity modal, panel vibration contribution, etc.

Booming noise source-path-receiver identification: With any NVH problem, booming noise can be represented by a source-path-receiver model reads as

$$Y(f) = H1(f) * F1(f)$$

Where Y (f) stands for the cab sound response, H1 (f) is the transfer function between the Sound Pressure Level (SPL) acquisition locations and the cab frame, F1 (f) is the force generated from the engine, exhaust, transmission, etc.

Where Y (f) stands for the cab sound response, H1 (f) is the transfer function between the Sound Pressure Level (SPL) acquisition locations and the cab frame, F1 (f) is the force generated from the engine, exhaust, transmission, etc.

Root-cause analysis

Analysis of excitation sources: To identify the excitation sources that generate booming, interior sounds are tested at different vehicle speeds, with the corresponding engine speeds and second-order excitations recorded simultaneously. When the vehicle is stationary, the engine speed

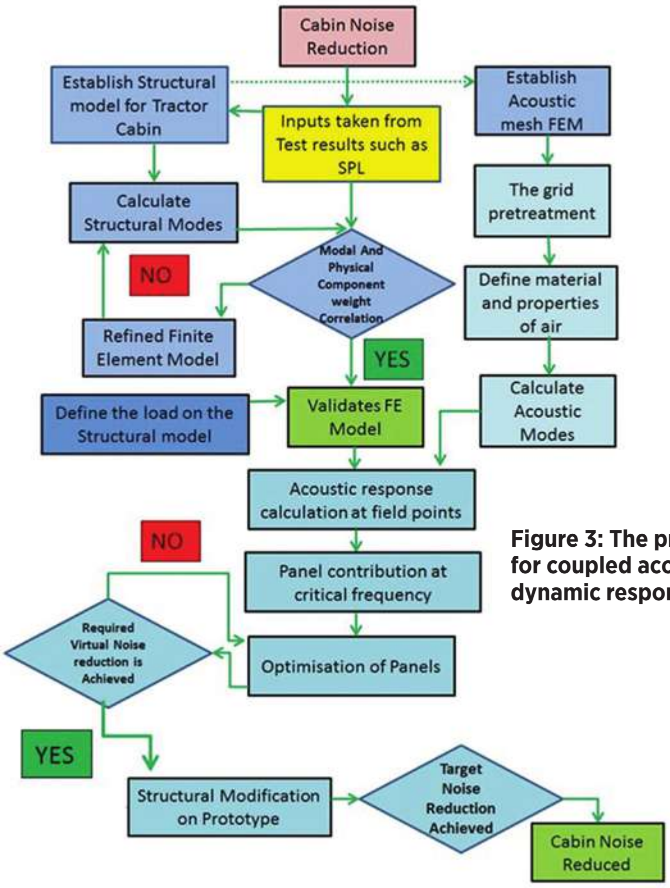


Figure 3: The procedure for coupled acoustic field dynamic response analysis.

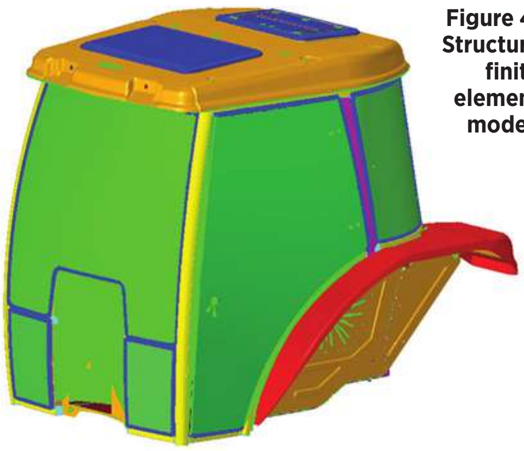


Figure 4: Structure finite element model.

is 2250 rpm and the corresponding second-order excitation frequency is 75 Hz, which matches the booming frequency; the engine excitation is generating the booming.

The road excitation frequency can be calculated as:

$$f = N\frac{V}{3.6L}$$

Where N is an integer 1, 2, 3 ..., V is the vehicle speed, L is the gap between the road surface excitation strips. The road excitation frequency is typically between 20Hz and 100Hz. The gap of the tested road is 0.3m, so the 1st order road excitation frequencies corresponding to the speed of min 15 km/h and max 60 km/h are 13.8 Hz and 55.5 Hz. So, road excitation frequency is not the root cause of booming at 75 Hz. From the above testing results and analysis, the booming can be confirmed to be from engine excitation rather than road excitation.

Coupled acoustic dynamic response analysis method: It is vital to understand the acoustic prediction from the structure vibration analysis. The coupled methods used to predict the interior noise of tractor cabin are FEM-FEM. The fundamental purpose for the below method is to develop the ability to predict the numerical solutions of sound power and sound pressure of a structure model. The procedure for coupled acoustic filed dynamic response analysis is illustrated in Figure 3.

Modeling and modal analysis for the tractor cabin

Structure finite element model: To predict the interior noise of a tractor cabin, a finite element model (FEM) of a full tractor cabin was established based on finite element method. In this model, solid and shell were used as element types. The structure finite element model is shown in Figure 4.

Structure model analysis: To guarantee the accuracy of the structure model, after determining the element types and identifying material properties, modal analysis was performed in the frequency range between 0 and 200 Hz. The cabin structure mode shapes are shown in Figure 5. The modal shape at 61.2 Hz has relatively high amplitude for the front glass and modal shape at 75.6 Hz has high amplitude at the floor, as shown in Figure 5.

The body structural dynamic characteristics, including resonant frequencies and vibration modes, can be obtained by BIW modal test and analysis. The engine excitation frequency 75 Hz is very close to the body modal frequency of 75.6Hz, so the excitation easily induces the body to vibrate. A comparison of modal frequency between the simulation result and the experimental result was performed to verify the accuracy of the model. Table 1 shows that the modal frequency of simulation is similar with the result of experiment. The comparison proves the mass, inertia and stiffness matrices of the established structure finite element model are consistent with the actual tractor cabin.

Cavity model analysis: For the cavity model established by FEM, the material of the acoustic medium is air with a density of 1.225 kg/m3, a sound velocity of 340 m/s. After defining the fluid material and the property of acoustic model, the modal analysis was performed in the frequency range of 0-500 Hz. The results show that the cavity modal has a total of 6 orders before 200 Hz. Considering the first and second harmonics of the engine (2250 rpm/4 cylinders) firing frequency, which were calculated as 75 Hz and 150 Hz, this result confirms they do not coincide with acoustic modes of the cabin.

Body-panel contribution analysis: From the above analysis, the body panel modes at 75 Hz being excited by the engine excitation can be confirmed as the cause for the interior booming. In order to identify each panel's contribution, the panel contribution must be processed.

Simulation		Experiment		Modal Error	
Mode order	Frequency A	Mode order	Frequency B	$\left\|\frac{B-A}{B}\right\|$ (%)	The Main Vibration part
1	37.6 Hz	1	38.2 Hz	1.57	Rear Fender
2	44.5 Hz	2	45.1 Hz	1.33	Roof 1st mode
6	61.2 Hz	6	62.9 Hz	2.71	Front Glass
8	75.6 Hz	8	75.4 Hz	1.11	Front, Side glass &Floor mode

Table 1. The comparison of modal frequency between simulation result and experimental result.

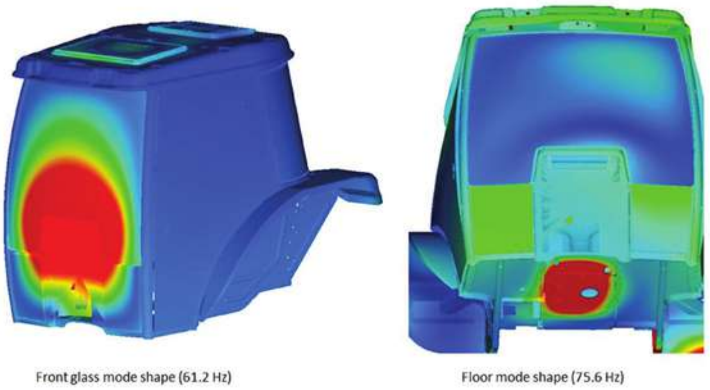


Figure 5. Structure mode shapes of cabin.

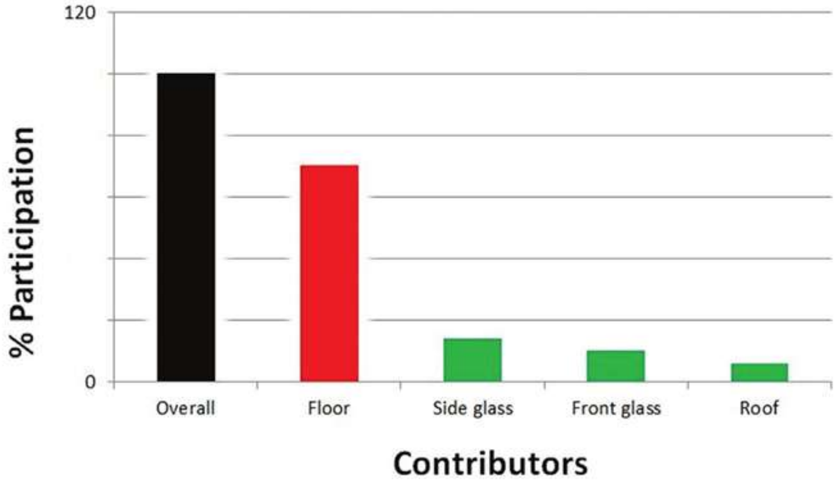


Figure 6: Result of panel contribution analysis at 75 Hz.

The interior sound pressure is related to each panel's vibration and its sound radiation. For a particular booming frequency, the panel contribution analysis can be used to find the contribution of each panel to the interior sound pressure. Figure 6 shows the relevant panels' contribution relating to the 75 Hz interior booming. The major contribution panel is the front floor panel, followed by side glass and front glass. So, floor is the major noise contributor at 75 Hz. The structural modifications need to be done to shift the frequency.

Cab structural simulation and solution evaluation: FEA based structural modal analysis was performed on the cab. The floor panel mode at 75.6 Hz matches well with the mode at 75.4 Hz from modal test. One easy way to stiffen the floor is to add ribs and to add more welding locations; FEA results show that adding beads and additional welds stiffened the floor and increased the floor mode frequency from 75.6Hz to 102.5 Hz. The floor mode vibration amplitude is reduced and not matching engine excitation and acoustic cavity modes.

Booming noise reduction solutions and results: For preliminary countermeasure test and FE analysis, ribs are added to the floor panel and increased welding locations on the floor. There is also recommendation to change the side and front window glasses to thicker laminated glasses and increase welding points on the roof to fully bond the two roof layers also was proposed. After these changes were made in FEA, the tractor cabin was simulated and the result is shown in Figure 7. Clearly, the simple and low-cost changes on the cab structure eliminated the booming noise and lowered the sound pressure levels by 8~10dB at the booming frequencies.

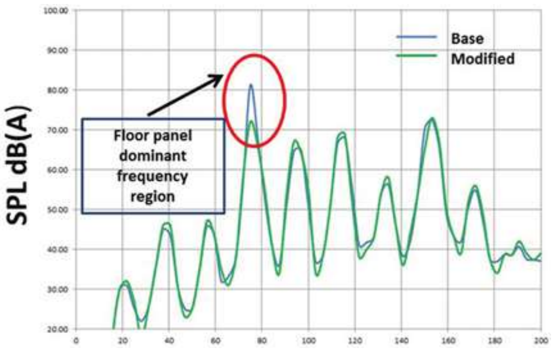


Figure 7. SPL comparison for base and modified model in cabin

Summary

Both experimental and FE structural modal techniques were leveraged to identify the root causes of the booming noise of a cabin and evaluate the potential solutions before the prototype was produced. Modal techniques were convenient to apply and useful to identify the structural/acoustical natural frequencies of a tractor cabin. The tests results were used to identify potential structural problems and validate FE models, which were then used to evaluate potential solutions and gain insight to the test results.

This article is adapted from SAE technical paper 2017-01-1847, authored by Shaik Mohammad Asif Basha (Senior Member), V. Ravindran (Principal Member), and P. Nageshwar Rao (Chief Technology Officer) of Tractor and Farm Equipment Limited (TAFE), Chennai. He received Master's degree in Automotive Engineering from Coventry University, UK. The key responsibility is to develop new process and techniques in NVH Simulation and handle critical advance engineering projects. Automotive NVH professional with more than 7 years of experience and gained expertise in Finite Element Analysis for CAE NVH Simulations and hands on experience in NVH Testing in automotive industry.

Method of identifying and stopping an electronically controlled diesel engine in RUNAWAY MODE

Abstract

A diesel engine is said to be in runaway mode when it runs out of control using an external fuel source and the operator cannot shut down the engine using conventional methods. During runaway, the engine damage can range from minor to catastrophic and this can cause enormous damage to the environment due to a lack of emissions control under these circumstances. In addition, an organization can incur financial losses due to loss of an entire engine and/or engine components.

In engine applications such as power generation in an oil refinery, oil mist can enter the intake stream of the engine and cause an engine runaway. In some OHW (Off-Highway) and CV applications, the oil separator is connected to the intake system to have closed-loop crankcase breathing system where in the engine oil may enter the combustion chamber through intake and the engine enters runaway mode. In scenarios where the turbocharger piston rings fail due to high pressure difference, the oil used for lubrication of the turbocharger bearings enters the intake through the turbo compressor, resulting in engine runaway until the oil in the crankcase sump is completely consumed.

In literature, one of the methods to detect a runaway condition is to check if the engine speed reaches unsafe values. It is also possible to detect a runaway condition based on current acceleration time and compare the same with the safe thresholds. Both these methods are not fast enough for runaway detection as they need to wait for a threshold violation to determine a runaway mode. In this paper, a method is proposed to improve the response time of the runaway detection system in electronically controlled engine applications.

The intention of the proposed method is to ensure very fast detection of the runaway condition and shutting off the engine using electronically-controlled actuators, thereby saving the engine and engine components.

Introduction

Safety in diesel engine control is given the highest priority to avoid both damage to equipment as well as death or injury to operating personnel. The need is for precise control of the diesel fuel and intake air to ensure that the energy released from the fuel is safe and identify when the energy released is potentially unsafe.

A vast number of diesel engines are used in the petrochemical and oil and gas industry for day-to-day operations. In such industries, there is a possibility of leak of flammable hydrocarbons and this will pose a serious hazard to both the diesel engine and personnel. A diesel engine runaway can be described as a situation where the engine runs out of control from an external fuel source (such as oil mist in the charge air) and the engine cannot be shut down using conventional methods (i.e. turning off the engine ignition switch or fuel system, injection cut-off from the ECU, disengaging engine load, etc). Consequences of engine runaway can range from minor engine damage to engine explosion, causing catastrophic damage to the equipment and surrounding facilities and/or death or injuries to personnel.

Fig. 1: Runaway locomotive engine at Kansas (courtesy RailPictures.Net - Image Copyright © Zach Pumphrey).

Diesel	210°C
Lube Oil	365°C
Methane	580°C
Propane	470°C
Butane	405°C

Table 1: Auto-ignition temperature of various fuels.

The causes of runaway on a modern diesel engine:

- Suction of engine lubrication oil via the crankcase breathers due to excess oil in the oil sump
- Leak of engine lubrication oil into the cylinder due to wearing out of oil seal rings on the turbocharger and/or piston rings
- Sufficient concentration of flammable gas such as butane, propane, etc. available in the air.

To address the issue of diesel engine runaway, several international standards have been put into place. EN 1834 - 1971 requires that all vehicular and stationary diesel engines working in a hazardous area must have an air intake shut-off valve to prevent the engine runaway condition. ISO 3046-6:1990 standard requires that an over-speed protection device be installed on engine to prevent engine runaway. EEMUA-107 requires the use of air intake shutdown valve with flame arrestor for diesel engines operating in potentially flammable atmosphere.

Method of identifying and stopping an electronically controlled diesel engine in RUNAWAY MODE

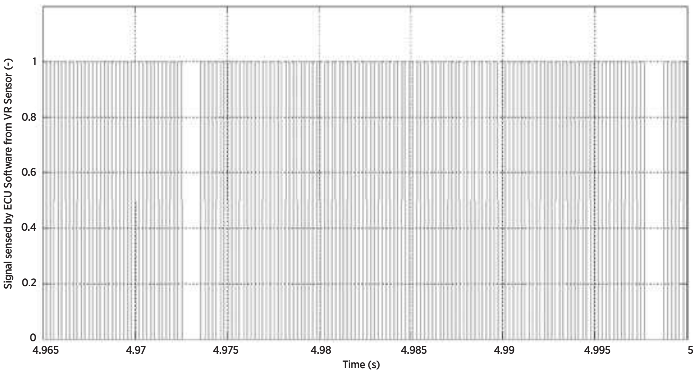


Fig. 2: Typical engine speed signal sensed by the ECU.

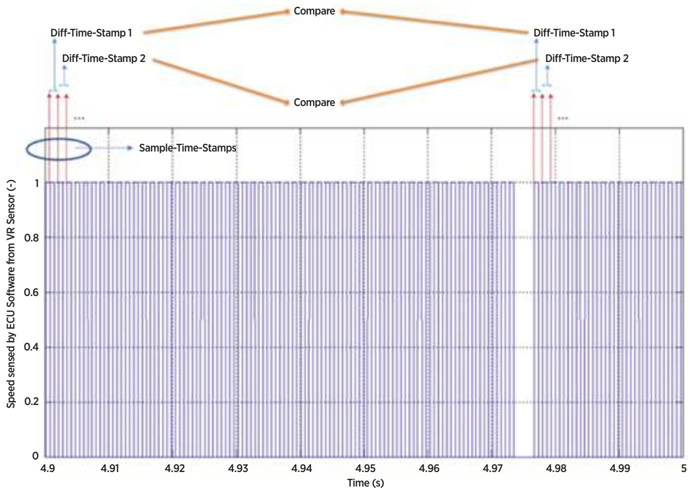


Fig. 3: Computation of Diff-Time-Stamp and comparison with previous 360° values.

The well-known and accepted procedure to shut down an engine in runaway is to provide effective charge-air control. Several manufacturers provide different types of charge air intake shut-off valves with local, remote and automatic shut-down capability. While it is known how to shut down a runaway engine, the real problem with an engine in runaway is that there is no way of knowing how fast the engine will run and how close one can get to it to shut it down. For automatic control, it is imperative that the engine control unit, or ECU, is able to correctly identify a runaway condition in the shortest possible time and take necessary action to prevent runaway.

For an engine running in a constant-speed mode, it is very easy to identify a runaway condition. If the engine speed were to increase beyond a certain threshold over its desired speed, the over-speed protection valve can be closed and shut down the engine. However, there have been several recently-reported incidents in which vehicular engines entered a runaway condition. In fact, it has been reported that in the drilling industry, 75% of explosions involved a vehicular engine. A vehicular engine is not running in a constant-speed mode and is designed for all manner of engine transients; the control logic normally used for stationary engines is not applicable.

In this paper, we propose a control logic to identify a vehicular engine runaway. The logic can be very easily realized using the existing sensors on the engine, the throttle valve and the ECU. It will be shown that within two-three engine rotations, it will be possible to detect a runaway condition.

Runaway identification

The auto-ignition temperature of the various fuels is indicated in table 1. As seen from that table, it is clear that combustion of diesel will cause ignition of the second fuel in the combustion chamber. As the second fuel has less oxygen available, combustion of the same would result in the production of a large quantity of unburned hydrocarbons or soot. A typical engine under runaway is shown in Fig. 1.

Delay in identification of runaway by an operator would be sufficient to destroy the components of the engine and the engine itself. For the ECU software to detect and take necessary actions, at present there exists no control logic for vehicular engines. The normally-adopted engine monitoring strategy in vehicular engines is to determine the fuel injected and thereby calculate the estimated operating engine speed and the current accelerator pedal position. If the engine speed deviates beyond a certain threshold then injections are cut-off. However, in the runaway case, injection cut-off will not stop the engine. In addition, before injections are cut, it is possible that engine components have been damaged.

Engine speed determination

The ECUs used for engine control make use of the variable reluctance sensor and a toothed wheel (also referred to as crank wheel) to determine the speed of the engine. The wheel generally used comprises of (60-2) teeth which are spaced 6° apart. The wheel is normally mounted on the engine crankshaft. As the wheel rotates, it changes the reluctance experienced by the sensor. This varying reluctance, produces a voltage which when sampled and filtered by the ECU would appear as shown in Fig. 2. Each pulse on the ECU signal is a representation of the tooth on the crank wheel.

For computing the engine speed, the normal procedure adopted by the ECU is to sample each rising and/or falling edge of the signal and determine from the time at sampling the angle of rotation of the wheel. From the rate of change of the angle, the engine speed is computed.

Time-stamp processing

As the crankshaft rotates, the timer value at each rising and/or falling edge can be stored. For simplicity, only the rising edge is considered here. Since there are 58 rising edges before the gap (two missing teeth), an array of size 58 can be used to store all the 58 timer values. This information is critical for identification of a runaway condition.

At a speed of 4000 rpm, for example, there is one revolution every 15 ms. At this speed, we are getting a timer value input into the array every 250 µs. Once all the 58 timer samples have been entered, the operating system (OS) can be notified via an interrupt to process the data. This will typically happen once every 15 ms, which is not

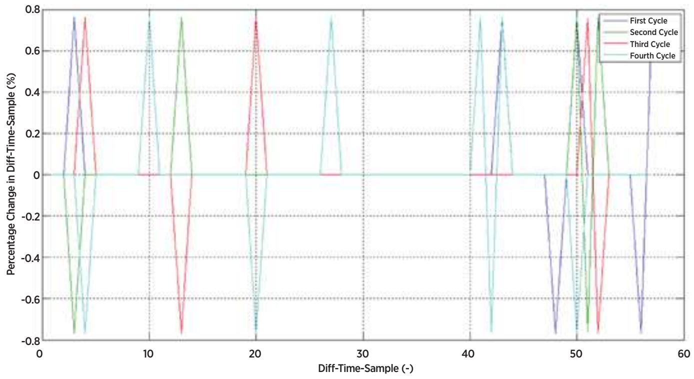


Fig. 4: Diff-Time-Stamp comparison at idle speed.

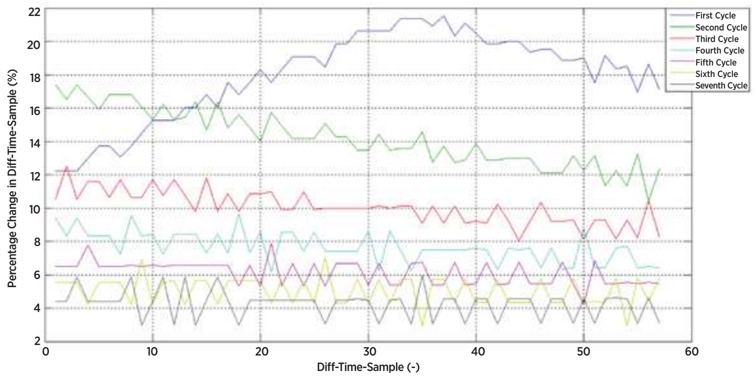


Fig. 6: Diff-Time-Stamps during acceleration of a common-rail diesel engine.

demanding on the processor. The storage of these sample-time stamps is shown in Fig. 3.

Once all the 58 sample time stamps are available, the OS can compute the difference in time stamps between successive teeth. This time value is indicated as Diff-Time-Stamp in Fig. 3. These timer values can be compared with the timer values from the previous rotation as shown.

If the engine were to be running at a constant speed of 765 rpm (idle speed), then the difference in time stamps per rotation when compared to the previous rotation would be as shown in Fig. 4.

Current speed-governors for modern common-rail diesel engines can hold the engine speed with an accuracy of ± 10 rpm. The data in figure 4 was processed at an engine speed that was varying. Even with constant fluctuation in engine speed, it is observed that Diff-Time-Stamp does not change by a large percentage for a fixed engine speed.

If the engine were to be accelerating, then the variation in Diff-Time-Stamps between successive rotations (per engine cycle) is shown in Fig. 6. As one can see, the first cycle has the maximum change in the diff-time stamp and by the time the seventh cycle is reached, the change is almost a straight line approaching zero as steady-state engine speed is being reached.

Now considering the case where just as the engine accelerates, it starts burning the "rogue" fuel. Again, the first cycle has the maximum change and by seventh cycle the change is almost a straight line. In the runaway case, in the seventh cycle, the engine speed is nearly 20% than that in the normal case. In both cases, same fueling quantity was injected in the engine. Both cases were studied for 0.4 seconds from the instant of acceleration.

If a comparison now is made between the normal case and runaway case in terms of diff-time stamp per cycle, then it would appear as shown in Fig. 8 and 9 (not included in this article).

In the runaway case, it is observed that for the first cycle the Diff-Time-Stamps are over 20% (by average) above the normal case and by cycle four it is about 14% above the normal case.

Using the Diff-Time-Stamps, it is possible to clearly distinguish between a runaway engine and an engine under normal operation.

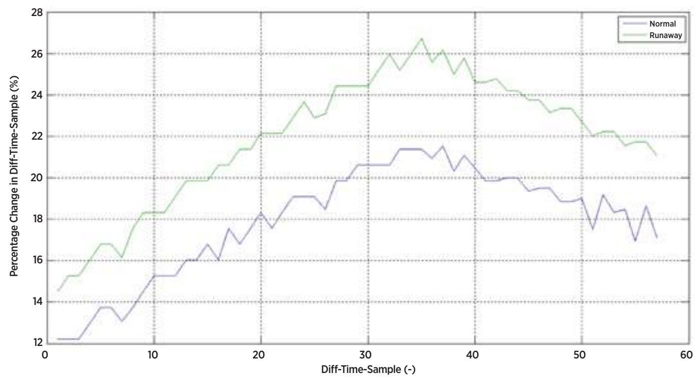


Fig. 8: Comparison of Diff-Time-Stamps between normal and runaway case for the first two rotations during acceleration.

Control logic

From Fig. 6, a calibratable map (2-D table) can be developed with one axis as injected fuel quantity. The average value of Diff-Time-Stamps per cycle can be stored up seven engine rotations. When an increase in fuel quantity is detected by the software, it can compute the diff-time stamps for each cycle. The computed values can be compared with the calibrated values and checked if the values are above the limits specified by calibration. If the values are greater than the limits and they have exceeded the threshold specified, then a signal can be sent to over-speed protection valve to close the intake. Using this approach, it is possible to shut down the engine in the case of a runaway scenario within two to three engine rotations.

Summary/Conclusions

From the above control logic, it can be observed that it is possible to detect runaway mode of an electronically-controlled diesel engine within three engine rotations and stop the engine by either closing the intake or exhaust flap, thus saving the engine and its vital components from a potential damage.

Hence, the authors claim that this method can be deployed to all diesel engine applications, both vehicular and large diesel engines in the oil and gas industry and other stationary applications.

This article was adapted from SAE technical paper 2013-01-2735, authored by Niranjan Mariyanna DGM and Rohit Chakravarthy of the Technical Engineering Section - Powertrain Customer Projects, Robert Bosch Engineering and Business Solutions Limited.

ELECTRIFICATION not a one-size-fits-all solution

The 988K XE, the first wheel loader from Caterpillar with a high-efficiency electric drive system, offers a range of bucket capacities from 6.2 to 17 yd^3 (4.7 to 13 m^3). Rated standard and high lift payload for the loader reaches 12.5 tons (11.3 tonnes) when working with face material and 16 tons (14.5 tonnes) with loose material. (image: Caterpillar)

Efforts in the off-highway industry have been under way for decades, but the technology still faces implementation challenges.

by Jennifer Shuttleworth

Some electrification efforts in the off-highway industry have been quite successful, yet others still need either time to catch on or may just flat-out not be suited for electrification. It is not an across-the-board solution, nor does it necessarily need to be one.

Talking with several industry experts, they generally agree: the movement to electrification in off-highway equipment is driven by several factors and there are different considerations. Emissions regulations, air quality concerns, performance, cost and economics. There are also different value propositions to consider for the various segments of the industry.

Government mandates are forcing changes. "But, underlying these are three big drivers—environmental needs, costs and performance," **Oerlikon Fairfield**'s Robert Kress, business development director, told *Mobility Engineering*. The relative importance and influence of each in off-highway applications is dependent of the operating conditions encountered by the machines.

According to Darren Almond, **John Deere Power Systems**' (JDPS) manager of drivetrain product planning, each segment of the off-highway market presents different value propositions for vehicle hybrid or full electrification solutions. Take, for instance, the underground hard rock mining market. This segment may turn to electrification to eliminate all engine exhaust, avoiding the costly process of ventilating mines.

"Other segments, like vehicles that move containers at ports, may be motivated by emissions regulations and zero-emissions zones to pursue electrification," Almond said.

Cummins Inc.'s Vinoo Thomas, director of electrification business development, agrees. "One of the main drivers to electrification of off-highway equipment is carbon emissions and general air-quality concerns in urban areas and attainment zones near ports; green initiatives are driving early adoption of electric vehicles," he said.

Economics is another driver. "Battery costs are beginning to drop as demand increases," Thomas said. "However, incentives/subsidies to offset vehicle and infrastructure costs are likely to be needed to continue to drive adoption."

"Overall, the established on-highway benefit of improved fuel economy from hybrid solutions also applies to the off-highway market to a degree," Almond said.

As far as cost considerations are concerned, the price of gas or diesel is often compared to what is touted as the low operating costs of electric. "But, I also believe the manufacturers ultimately hope to lower costs by simplifying the vehicle designs, for example, by removing many components found in traditional IC vehicles," Kress said.

There also is the short-term potential to hybridize some vehicles, allowing for smaller internal combustion (IC) engines that fall below the threshold where additional expenses for emission controls are avoided.

Kress opined that performance can be a factor that probably gets the least consideration. "But, in certain situations, electric vehicles have a better performance 'feel.' Elon Musk has already demonstrated that electric passenger vehicles, and now trucks, offer impressive acceleration," he said. With off-highway equipment, some hybrid designs can supplement the energy needs during peak duty cycles to create a better performance.

A compact electric drive system

At Agritechnica 2017 in November, Oerlikon Fairfield introduced a new electric drive system for off-highway vehicles. The company worked on the system with **Ashwoods Electric Motors**, a company in which OF has a minority investment. The system integrates an Oerlikon Fairfield Torque Hub planetary drive with the Ashwoods-produced interior permanent magnet (IPM) motor to create an ultra-compact drive.

"With the battery-operated vehicle marketplace, certainly efficiency is king; everyone is looking to do more with less," Kress said. "The two real sweet spots of this motor are greater efficiency and smaller package size."

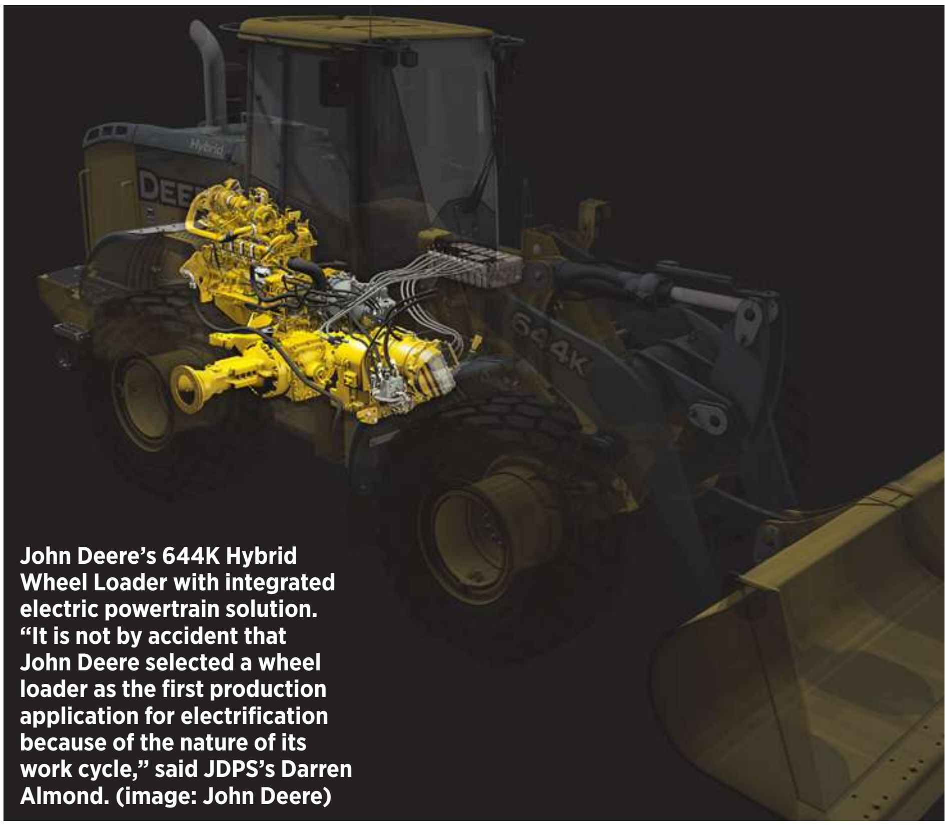
With the IPM motor's smaller size, it is also lighter. It is one-third the weight of a typical incumbent induction motor for the same rated output. Depending on the application, "that can be a very big deal to OEMs as they're trying to build their battery-operated vehicles," he said. It offers about two-thirds more motor space.

The company claims the unit is so compact that it enables vehicle manufacturers to provide a steerable four-wheel-drive configuration where previously there was not enough space to offer this possibility.

The complete unit can deliver 4000 N·m (2950 lb·ft) of drive torque and 5600 N·m (4130 lb·ft) of braking torque, yet the motor is up to 30% smaller and lighter than current production solutions that use larger brushed DC or induction motors coupled to a planetary gearbox. The Oerlikon Fairfield/Ashwoods Electric Motors solution provides a triple planetary ratio in the length of the standard double-planetary design.

Combining the two technologies with an integrated electric parking brake has enabled the elimination of several duplicated or redundant components. For example, a common shaft can be used for motor, brake and transmission, saving weight, cost and package space.

"Smaller product envelopes free the equipment designers to utilize space more efficiently," Kress said. Areas reserved formerly to contain the motors/drives can now be utilized more productively for other purposes—e.g., cabling, controllers, etc.



John Deere's 644K Hybrid Wheel Loader with integrated electric powertrain solution. "It is not by accident that John Deere selected a wheel loader as the first production application for electrification because of the nature of its work cycle," said JDPS's Darren Almond. (image: John Deere)

"There's an opportunity to create customized electrification solutions for individual segments, resulting in a wide variety of solution types."

- Darren Almond, JDPS

Hurdles to electrification

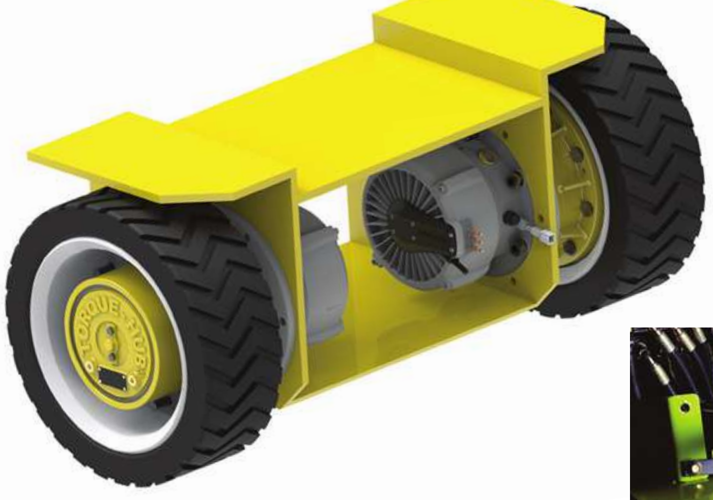
Electrification has been successfully used in material handling applications, as the industry experts *Mobility Engineering* talked with detailed. The nature of the work lends itself to electrification: the enclosed environment with a limited range and manageable infrastructure.

Implementation of the technology faces challenges in other off-highway equipment due to issues such as battery technology, cost and weight of electrification, getting the market to accept something new, as well as electrical system component costs.

"Additionally, the price of the equipment has to offer acceptable ROI," Cummins' Thomas said. "Without subsidies it could be challenging to implement electrified equipment economically." Companies interested in moving toward electrified equipment will need to be able to identify available subsidies and be able to apply for and be awarded them.

According to JDPS' Almond, components and systems for the off-road implementation of electrification are in their early stages. On-highway electrification solutions don't require as much power or durability than what is needed for off-highway applications—the requirements and value propositions of which are so varied that developing a singular solution becomes very challenging.

"Because of this, there is an opportunity to create customized electrification solutions for individual segments, resulting in a wide variety of solution types. This is what makes electrification very exciting right now," Almond said.



Oerlikon Fairfield's interior permanent magnet (IPM) motor produced by Ashwoods Electric Motors (left) is one-third the size and weight of induction motors, providing a large increase in available space in this materials handling application (below), at basically the same price point. (images: Oerlikon Fairfield)

Overcoming hurdles

Battery technology has and will continue to advance. Supply chains will gradually reduce their price points, "but it may take another 10-15 years," Kress offered.

According to Thomas, lithium-ion battery prices need to continue to drop to a level that allows for reasonable payback without the use of incentives.

"There are various market studies that predict that the turning point for electric-vehicle adoption will occur when batteries are equal or better than diesel engines in terms of cost, and estimates show that could be anywhere from 5 to 10 years out," he said.

According to Almond, one of the keys to success in overcoming these hurdles is to account for the entire system solution. "John Deere seeks to offer integrated solutions that address the interfaces between the electrical generator and/or motors, power electronics and mechanical interfaces. Because we have already done the development work to manage these interfaces, the end users can have confidence in the fact that all this new technology on their machines will simply work," he said.

"Furthermore, advances in battery, power electronic, generator and motor, and drivetrain technology are being made every week," he offered.

Promising candidates

Material handling applications have a long history of use of electrification. Lift trucks have been battery powered since the late 1960s. "Since then other applications of material handling have adopted electrification," Thomas told *Mobility Engineering*. "Most of the sites are static or have a limited (fixed) range. In other words, the equipment doesn't have to go outside of its normal ecosystem."

However, Thomas says it is becoming apparent that many different types of applications are experimenting with electrification. "Many OEMs are seeing the high level of interest in electrified equipment and want to be seen as an early adopter—or, at least, be viewed as evaluating it," he said. Acceptance of electric applications will be different by customer and region depending on their initiatives.

One of the unique advantages of an electric system is the ability to recycle braking energy. Thus, applications that tend to change direction or repeatedly go through a stop/start cycle are the ones acting as early adopters of electrification.

"This is why the first applications of electric hybrid technology in John Deere equipment is for wheel loaders," Almond said. The braking energy in the wheel loader cycle often occurs precisely when hydraulics are required. The hybrid system allows for the transfer of that braking energy to hydraulic energy via the electric drive components.

"Other applications are continually being investigated to meet our customer's needs," Almond said.

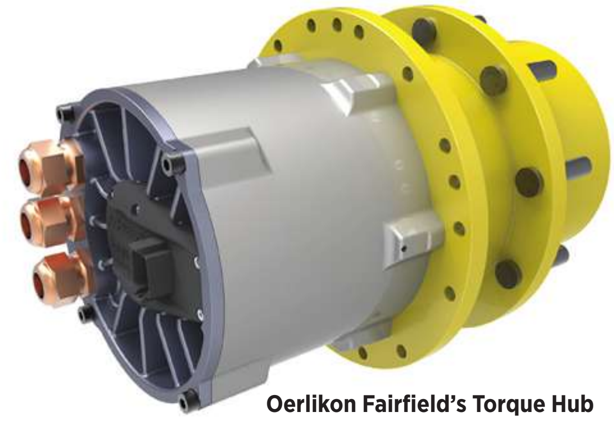
New electric-drive wheel loader

At a recent press event, **Caterpillar** revealed its first electric drive wheel loader. The new 988K XE offers 25% greater overall efficiency and up to 10% more productivity in load-and-carry applications than the standard Cat 988K loader. It is also up to 49% more efficient for truck loading.

The 988K XE, which is a new addition to the 50-ton (45-tonne) loader lineup, is 90% identical to the 988K. Featuring switched reluctance and more than four years of testing in a range of applications, the C18 ACERT engine, mechanical dropbox, driveline and axles from the 988K remain in the electric drive machine.

"We still leveraged the C18 engine that we have on the 988K, but we took the generator, inverter and motor for our powertrain. So the torque inverter and transmission came out," Todd Tuntland, Caterpillar product application specialist, told media at the press event in Peoria, IL. He explained that effectively this is a transmission replacement.

The XE is said to be easier to operate. It has a



Oerlikon Fairfield's Torque Hub planetary drive integrates with the IPM motor produced by Ashwoods Electric Motor to create an ultra-compact drive solution. (image: Oerlikon Fairfield)

variable speed motor and no longer has gears. Directional changes are very smooth. Operators can control ground speed with virtual gears. "You don't have to pull clutches to shift anymore," Tuntland said. "So when you're operating this machine, compared to the mechanical drive, it's much quicker and it's very smooth."

Headed to production in March at Cat's Decatur, IL plant, the 988K XE is targeted for applications such as haulage fleet up to 70-ton (64-tonne) trucks, truck loading (shot rock) up to 840 tons (760 tonnes), and load-and-carry up to 660 tons (600 tonnes).

The electric-drive wheel loader uses 40% less powertrain oil and offers extended oil change intervals of 2000 hours (1000 more than the 988K).

"We are going to target applications likely north of 2500 hours; that's because the payback on the XE will be very attractive for customers," Tuntland said. "They need the production and they're conscious about the efficiency—the tons per gallon."

Tuntland claimed that for 2500 hours "at current fuel prices, depending on where you're at in the world, you would be in that two- to four-year payback. The 2500 is hours per year for the end user, so obviously the more you run it, the higher the fuel price, the bigger the payback."

Caterpillar claims greenhouse gas (GHG) reductions on the 988K XE are equivalent to one year of electricity use for nearly 10 homes and equivalent to 13.5 passenger cars driven for one year.

Whether Caterpillar will bring the electric drive to other classes or machines remains to be seen. "We're always evaluating ways to reduce cost-per-ton for our customers." Tuntland said. "So it's certainly something for us to consider going forward."

Cummins revealed the Aeos 1, the fully electric Class 7 Urban Hauler electric vehicle concept truck, in August 2017. (image: Cummins Inc.)

Hybrids best?

Despite the electrification movement in the off-highway market, don't dismiss the IC engine's value particularly when coupled with an integrated hybrid system.

"I believe it is important to recognize that the IC engine is not going away anytime soon," Kress told *ME*. "There is still a lot of room to improve the efficiency of these engines, and these advances will slow the adoption of electric-only systems in some off-highway applications."

That said, operating conditions for the application probably have the greatest influence on the type of electric system.

"As an example, with a road construction site, unless operators have the ability to charge machines in remote locations, fully electric vehicles are difficult to operate effectively due to charging dependency," Thomas said. "But, a hybrid application could work well in these undeveloped locations or work sites."

Thomas explained that diesel will play a strong role in many of Cummins' markets for years to come, and the company will continue to invest in those technologies accordingly. "With that in mind, we continue to invest in a variety of technologies to provide our customers with a broad portfolio of powertrain solutions that meet their needs," he said. Having invested in electrification technologies for more than 10 years, Cummins has produced several hybrid and fully-electric demonstration vehicles. In August 2017, the company unveiled the Aeos 1 fully electric Class 7 Urban Hauler EV concept truck.

"Duty cycle plays a big role in determining the electric system, as it forces the vehicle manufacturer to think more about how the vehicle works within the larger production system. This is especially true when considering battery technology, as the total energy usage of a daily work cycle needs to be considered," Almond said.

"If a vehicle can work for eight hours, then sit around for 16 and can be plugged into a wall—that may influence the type of technology," Almond detailed. "If it has to run 24/7—how you're dealing with the energy management really has an influence on what type of electric system needs to be employed."

700 MILES, hands-free!

Super Cruise is a significant step forward in making customers comfortable with hands-free highway driving under limited operating conditions. Note green lighted bar on upper wheel rim. (image: GM)

GM's Super Cruise turns Cadillac drivers into passengers in a well-engineered first step toward greater vehicle autonomy.

by Lindsay Brooke

Two sunny days in late September, a state-of-the-art luxury sedan, and good company make for a potentially great road trip. But this one was special.

"Pretty remarkable that we've already driven about 500 miles without either of us touching the steering wheel; I'm impressed," I noted to co-driver Sam Abuelsamid, as we headed southbound from Chicago, on Interstate 57 in Illinois.

Sam, a former electronic systems engineer-turned-journalist, analyst and magazine columnist, concurred. "It appears this is the vehicle to have if you want to reduce the driving workload over long distances," he offered.

We covered another 200 miles (321 km) of hands-free operation before re-taking the wheel of the 2018 **Cadillac** CT6 as we neared our Memphis, Tennessee destination. Of the 900 miles (1450 km) we'd traveled since leaving Cleveland, Ohio the previous day, more than 75% were handled by **GM**'s new Super Cruise technology. In terms of the **SAE** automated-driving levels, Super Cruise operates at Level 2, or "partial automation." This means the CT6 drove itself under human supervision most of the way, handing off to us to pilot when required.

GM's flagship sedan is the first to feature Super Cruise, best described as an automated driver-assistance package. Demonstrated five years ago, the system was slated for 2016 launch. But GM wisely pushed the "pause" button after the company's tragic, multi-billion-dollar ignition switch recall and a traffic fatality involving **Tesla**'s erroneously named Autopilot. Various YouTube videos of ludicrous Tesla drivers climbing into their cars' back seats during Autopilot operation also caused GM engineers and safety experts to move Super Cruise forward more cautiously.

By summer 2017 the system had been fully

Super Cruise-equipped CT6s incorporate three cameras and five radar sensors, in addition to map data and significant data-fusion capability. (image: GM)

developed and validated and was readied for the CT6 application. To demonstrate its confidence in Super Cruise, GM invited media to drive a small fleet of CT6s from New York to Los Angeles, in three waves of roughly 1,000 miles each. Sam and I chose the second wave on the Cleveland-Chicago-Memphis leg. Most of our journey was on U.S. interstate highways and multi-lane divided state freeways because currently they are the only types of roads for which Super Cruise is operationally mapped.

Benchmark driver monitoring

GM engineers and human-machine interface designers created a system that is easy and intuitive to operate. Press a marked button on the left steering wheel spoke, center the vehicle in the lane, and an icon will appear in the cluster signaling that the system is ready for use. Press the button again and the icon turns green, as does a light bar inset into the upper radius of the steering wheel—Super Cruise is thus engaged and the CT6 steers itself along the highway at speeds up to an “official” 80 mph (129 km/h), although a few journos said they saw 90 mph (145 km/h) while in Super Cruise mode.

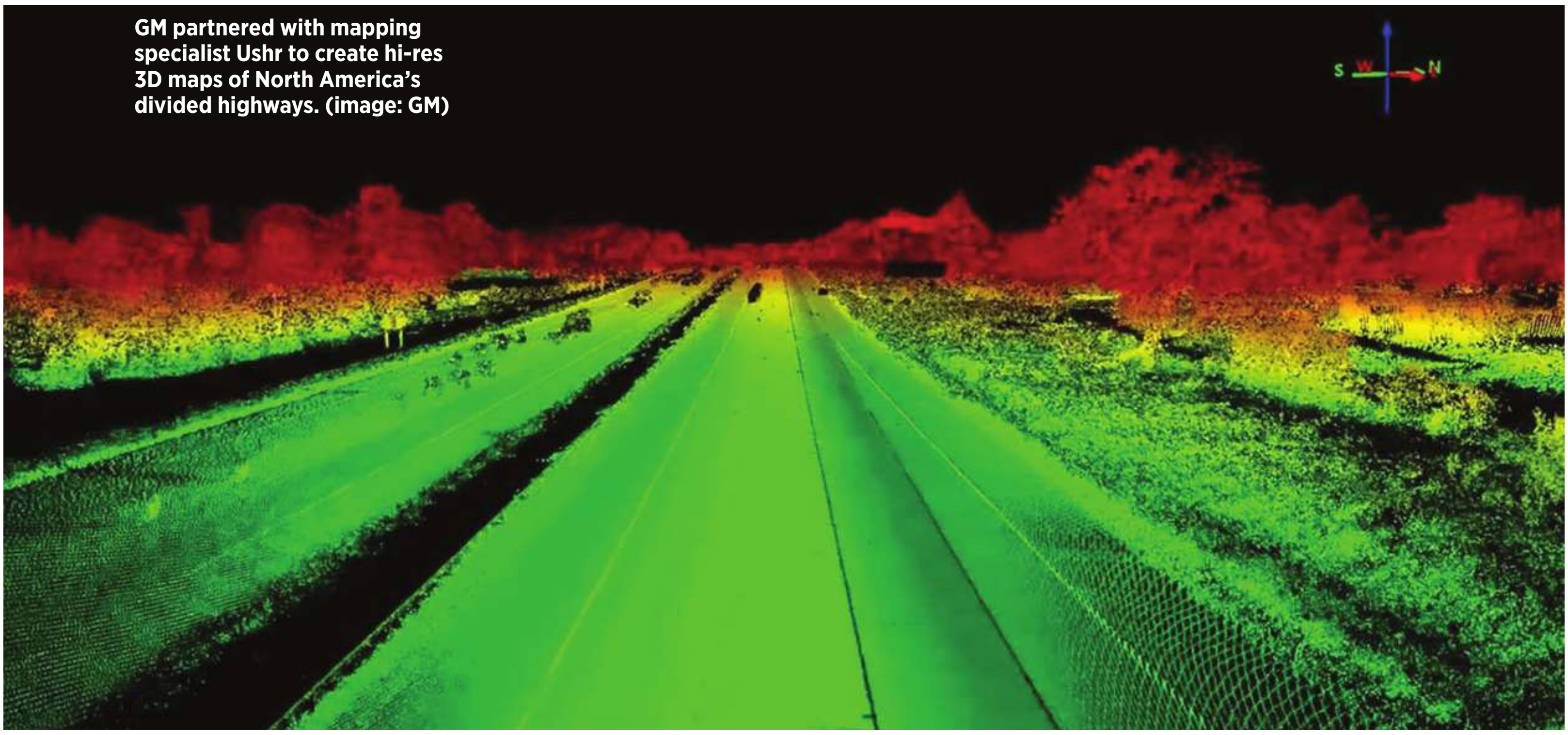
With the driver’s hands off the wheel, the vehicle consistently follows lane markings and stays centered, even when the lines are faded and non-existent, such as on fresh asphalt. Sam and I each “drove” for intervals of an hour or more without touching the steering wheel. Passing other vehicles does require the driver to press the throttle pedal but Super Cruise then resumes operation when the pedal returns. Pressing the button after manual braking also re-engages the system.

Primary hardware includes three exterior cameras; one is forward-looking and mounted in the rearview-mirror module. The other two are located on the exterior mirror housings. There are also five radar sensors, one a forward-looking long-range unit and the others short range/side-looking, mounted in the front and rear corners. After entering a tunnel, Super Cruise remains engaged for up to 0.6 mi (1 km) at which point dead reckoning takes over.

Another vital element is Super Cruise’s Driver Attention Monitor. Its performance is benchmark: Infrared emitters in the light bar within the steering wheel rim project thousands of invisible points of light onto the driver’s face, which are then captured by a small, almost unnoticed camera located on the steering column. The system monitors position and movement of the driver’s head, face and eyes—are you looking forward and attentive to the road ahead? Are your eyes closing due to sleepiness? Behind our dark sunglasses, Sam and I each tried to “trick” the system by fluttering our eyelids and rolling our eyes but it was never fooled.

Super Cruise will require some CT6 owners to adapt. The time it permits

700 MILES, hands-free!



GM partnered with mapping specialist Ushr to create hi-res 3D maps of North America's divided highways. (image: GM)

the driver to scan the mirrors or select an HVAC setting is mere seconds, and is speed-dependent. It won't let you ogle that **Ferrari** passing in the opposite lanes or check out that cool old barn along the roadside before it starts to escalate driver intervention, as explained below.

Sam and I agreed that the overall quality of GM's sensor fusion and calibrations, based on our perception of how smoothly Super Cruise keeps lane, handles curves and brakes itself, is superior to any SAE Level 1 vehicle we've tested to date.

Maximum sensing-distance capability is 2500 m (1.5 mi), noted Robb Bolio, the Vehicle Performance Manager who accompanied our media wave. He said the sensor array and the system controller are all sourced from GM's regular ADAS component vendors. System software was developed in house and **Trimble** supplied Super Cruise's GPS that's accurate to 2 m (6.5 ft).

There is no lidar; GM enlisted Atlanta-based **Ushr** (formerly part of **GeoDigital**) to digitally

Super Cruise 'invention on the critical path'

Before leaving Chicago in the CT6 on Day 2 of our 900-mile Super Cruise test, *Mobility Engineering* spoke with Vehicle Performance Manager Robb Bolio about the program:

Q: Why did GM decide to rethink the initial Super Cruise program and err on the side of conservative functionality?
Obviously there's the safety piece and that includes validating our mapping to ensure the system is right. We want Super Cruise to be available to the driver all the time, but to be a robust and safe system we recognized it can't be available all the time.

This is new invention on the critical path. It's how GM is doing business now. The integration piece is dear to my heart; my team did the first-gen **Chevrolet** Volt, the Spark EV and the Bolt EV. They were all critical-path programs in which we had to be comfortable with moving fast and making late changes.

Super Cruise as a system is made up of many pieces—adaptive cruise control, lane-centering control, the driver monitoring system, the 'virtual path' the car follows that is a very complex set of algorithms. It's a whole new ballgame of integration and sensor fusion. So we took the extra development time, and GM leadership supported us, to get it totally right.


Super Cruise Vehicle Performance Manager Robb Bolio is a veteran of GM's fast-paced hybrid and EV programs. (image: Lindsay Brooke)

We did the software—every algorithm was created by our team at GM. We want to own this technology. We work with suppliers on the sensors and processors but we drove the process and we want to own the IP, the software. The way it's tied together on these key technologies is very important to us.

Q: When the program began, did you approach it from a cohesive systems-integration perspective, even though it's more complicated to define all the pieces from the start?
Yes. When you work with suppliers the specs change as you go. We're learning on the fly; we may have a set of requirements that are defined but two months later we decide to change it. Owning the software allows us to iterate quickly without driving a lot of cost. It's difficult when you're inventing to know what the car's going to be like when you're done.

LB

map more than 160,000 miles (257,500 km) of divided highways in the U.S. and Canada. The resulting precise, high-definition 3D maps are the heart of the Super Cruise software.

"It 'geofences' the highway," Bolio noted. "No back-road, town or urban capability at this point." The map data "provide accurate details of road curvature, trajectory and annotations," he said, and will be over-the-air updated for customers at Cadillac dealers initially. During the 900-mi trek, our car remained consistently centered and faithful in most cases where lanes merge or end; a few times it did attempt to exit a couple off-ramps for a split second before snapping back into the intended lane.

Here, you take the wheel

If you've been distracted for five seconds, the driver monitor begins a steady and rapid warning escalation to regain your attention. The green Super Cruise icon on the cluster and the light bar on the wheel begin flashing and audible chimes in. There's also a driver-select haptic seat "buzz" pioneered by Cadillac that's quite effective in jogging your attention. Less than five seconds later, if the driver hasn't responded the flashing lights turn red and the audible and haptics heighten.

Another five seconds without driver response (the car must "feel" driver contact via capacitive sensors in the steering wheel rim) and Super Cruise begins to slow the car's speed toward a stop—which it will also do, smack dab in the lane. Bolio explained that GM research concluded that stopping in the road is safer than on the shoulder, which often doesn't exist. As the car decelerates, it also shuts off the Super Cruise function until the next time the driver cycles the ignition switch. During a full vehicle stop, the system calls OnStar for help and alerts first responders if emergency medical care is required.

By design, GM's Super Cruise as employed in the 2018 CT6 has what some may consider to be limitations. Others, however, including me, will applaud them as well-reasoned conservative steps toward the "higher" levels of SAE autonomy. That the five-second limit requires driver attention and minimal head and eye movement proved not to be relaxing on a 900-mile journey. In fact, I found my typical sense of highway-driving alertness to be heightened considerably. The driver must be prepared to take back control at any time.

Super Cruise currently will not change lanes—that's a manual task left to the human.

Tiny camera mounted on the CT6 steering column provides a precise view of the driver's head and eye movements for Super Cruise operation. Note green 'steering wheel' icon in cluster signifying system is engaged. (image: Lindsay Brooke)

It also doesn't read speed-limit signs like the **Mercedes-Benz** system in the E-Class, nor will it transit through a cordon of Jersey barriers in construction zones. In at least one hands-free situation with me behind the wheel, our CT6 handed control back to me abruptly a few feet after entering a single-lane-with-concrete-barriers construction zone.

And we media types on the second-wave drive complained that the system stubbornly would not engage as we departed Cleveland, when the bright morning sun was behind us. Bolio was aware of this issue, explaining that infrared wavelengths contained in the sunlight entering the car at specific angles can foil the emitters in the driver-monitoring system. The monitoring camera then cannot "see" the driver's face and so will not engage Super Cruise until the sun rays entering the car diminish.

As a system, Super Cruise by my estimate may cost GM $400, a figure Cadillac will easily recoup in its $5000 option pricing. The system is standard on Premium-trim CT6 models. Dealer sales staff are advised to give test-drives only when the sun is high in the sky.

Competitors, however, are already lined up at Cadillac dealers to order Super Cruise-equipped cars for their teardown and analysis. ■

Toyota rethinks the flagship

2018 Lexus LS500 F Sport in profile shows new GA-L platform stance on 123-in wheebase. Overall length is 206.1-in. (image: Ron Sessions)

Black-out treatment on F Sport models plays down the massiveness of the new LS500 grill. (image: Ron Sessions)

Toyota has engineered a complete road-to-roof redo of its flagship **Lexus** LS sedan, dropping the V8 engine in favor of a twin-turbo V6, adding **Aisin**'s new 10-speed planetary automatic and retaining a hybrid-electric powertrain option—and that's just the beginning. The 2018 model marks the fifth generation of the luxury sedan that rocked the luxury-sedan establishment almost 30 years ago. While the LS has represented less than 2% of the brand's U.S. sales in recent years, its significance to Toyota exceeds its sheer numbers.

Chief Engineer Toshio Asahi and his team began work on the new LS500 and hybrid LS500h in late 2011. One key goal was to attract a younger buyer with what Asahi calls "Brave Design," picking up the Lexus family 'spindle' grille theme and developing a longer, more muscular exterior form. Lowering the hood by 1.2 in (30.5 mm), the decklid by 1.6 in (40.6 mm) and dropping the roof 0.6 in (15 mm) versus the 2017 LS helps the new version look more ground-hugging as well.

The 2018 LS500 shares Toyota's new GA-L global luxury platform with the recently-launched LC coupe. There's now just one wheelbase (123.0 in/3124 mm) offered and the new car's 206.1-in (5232-mm) overall length exceeds by an inch (25.4 mm) that of last year's long-wheelbase LS460L. Among competitors, the new LS is sized between the slightly more-abbreviated **Cadillac** CT6 and fractionally longer **Mercedes-Benz** S-Class. The LS's front wheels are pushed forward for the desired longer dash-to-front-axle aesthetic and the rears moved back for a gain of 2.2 in (56 mm) more rear-seat legroom.

New HMI, lower H-point

Sumptuous interiors have been a pillar of the Lexus luxury reputation and the new LS offers a lot to catch the eye. But there's also plenty of technology. A standard 8-in driver information display and a 12.3-in-wide (312-mm) infotainment screen are arrayed across the center of the dash, with a 24-in-wide head-up display optional. Images shown in the HUD include vehicle speed, gear selected, road signs, safety system notifications for such things as front cross traffic warnings and pedestrian alerts as well as navigation information about upcoming turns.

Between driver and shifter is the new remote-touch interface. It now works less like a computer mouse and more like a smartphone with swipe and pinch control. Standard Lexus Enform Wi-Fi ushers in-car internet connectivity to up to five devices courtesy of **Verizon** 4G LTE service and an optional 23-speaker **Mark Levinson** surround-sound system brings 16 channels and 2400 watts of auditory immersion.

But the most striking aspect of the new LS is its craftsmanship and attention to detail, or *takumi*, something Asahi-san feels is central to Lexus "moving from a luxury car brand to a luxury lifestyle brand." Interior occupants are cocooned with soft-touch surfaces and generously-padded contact points. The sides of the console and armchair-caliber door armrests are backlit with small LEDs and appear to be free standing from the doors. Available interior upgrades in the Executive Package include door trim with handmade origami-like cloth pleats and interior trim-panel pieces fashioned from hand-cut flame- or herringbone-pattern wood. Intricate laser-cut and polished Kiriko glass is also available.

Nestle into one of the highly-supportive and all-day comfortable multi-adjustable front buckets and you may notice a lower H-point than in the previous model. The seats impart a lower center-of-gravity perception that's central to

Toyota's latest large car body structure remains steel-intensive. (image: Lexus)

Sport-tuned air suspension of the LS500 F Sport features active front and rear stabilizers, active rear suspension. (image: Lexus)

the new LS's sportier feel. A new access mode (available with the optional air suspension) raises the car 30 mm (1.2 in) for ingress and 10 mm (.39 in) for egress—part of the *Omotenashi* tradition of Japanese hospitality, Lexus says.

An F Sport for the LS

According to Asahi, Lexus studies discovered a change in the priorities of LS buyers. Previous owners were focused on status, whereas new customers were seeking something more experiential. In short, make the LS more of a driver's car, beginning with a stiffer body structure. Engineers greatly increased use of high-strength steel in combination with aluminum fenders and door, hood and decklid outer panels, as well as cast-aluminum strut towers. There's also extensive application of structural adhesives—something Toyota was late to adopt—and laser screw welding for increased panel joint rigidity. The new car is about 430 lb/195 kg heavier than the 4277-lb/1940-kg model it replaces.

Steering accuracy is improved courtesy of double ball-jointed upper and lower control arms in the front suspension. Toe-control links in the rear add lateral stiffness for greater linearity in response to steering input, Asahi noted. Standard on the new LS is an adaptive variable suspension (multilink front, 5-link rear with optional air springs) featuring active damping. The system's linear-solenoid actuators have 650 different settings to respond to inputs from G-force, yaw-rate and vehicle-speed sensors. As a result, body control proved exemplary over swells, sharp dips and bumpy sections of road during *Mobility Engineering*'s test drive.

And despite exclusive use of run-flat tires on 19- or 20-in alloy wheels, impact harshness over rough stretches of pavement meets expectations of this segment. All but one wheel design has a hollow-chamber rim section to absorb road noise.

Cluster details on the 2018 LS500. (image: Lexus)

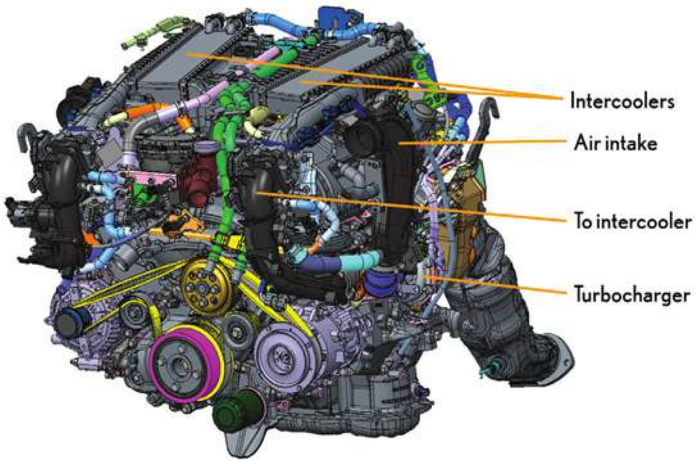
Also new for 2018 is an F Sport package which adds larger front and rear brake rotors, more-powerful calipers (six pistons front, four rear) plus optional summer tires. The active rear steering, an LS feature since 2012, provides greater high-speed stability and improved low- and mid-speed steering response, engineers said.

New powertrain, hybrid

The 2018 model is the first Lexus LS without a V8 under the hood. In its place is Toyota's all-new long-stroke (100 mm) V35A-FTS twin-turbocharged 3.5-L DOHC V6 that shares nothing with the 3.5-L V6 Lexus used for years in other models. Along with the pair of turbos integrated into the exhaust manifolds there is much new technology here: electronic wastegates, dual VVTi intelligent variable valve timing, **Denso** 4ST direct fuel injection combined with port injection and high-flow, laser-clad intake valve seats first detailed by Toyota in a 1992 **SAE** Technical paper (http://papers.sae.org/920571/).

The 416 hp (310 kW) of the new V6—rated on 95 RON premium unleaded fuel—tops that of last year's 4.6-L V8 by 30 hp (22 kW), and there's an extra 75 lb·ft (102 N·m) available from 1600 to 4800 rpm. For rear-drive models, 0-to-60 mph acceleration improves to a claimed 4.6 s, about


LS500 cockpit. (image: Lexus)



CAD view of the new V35A-FTS V6 highlighting intercooler and turbo packaging. (image: Lexus)

1.5 s quicker than the 2017 car. Turbo lag is practically nil and midrange part-throttle tip-in delivers satisfying thrust that minimizes downshifting. A high-flow exhaust adds some voice, while active noise control works through the car's audio speakers to quell unwanted low-frequency booming when cruising at low rpm.

Augmenting the V6 is a new wide-ratio version of Aisin's AWR10L65 10-speed 'Direct Shift' planetary automatic shared with the LC500 coupe. (See http://papers.sae.org/2017-01-1099/.) It's fitted with a lower first gear for quicker acceleration and taller top gears for relaxed cruising and improved highway fuel economy. Standard steering-wheel paddle shifters enable manual shift control; except for aggressive back-road blasts or steep mountain downgrades the 10-speed automatic's programming predicts what gear is needed for a given situation so well that the driver can concentrate on steering, accelerating and braking.

Available all-wheel drive makes the LS usable year-round in cold climates. Its **Torsen** limited-slip differential can send as much as 48% of drive torque to the front wheels. On dry roads, it can send up to 69% of torque to the rear wheels. Lexus expects as much as 35% of LS sales will be AWD models.

Being a Toyota product, of course there's a hybrid version. The LS500h offers a combined output of 354 hp (264 kW) produced by the 3.5-L Atkinson cycle V6 (8GR-FXS) and two electric motors. The system now is a "multi-stage" design with powerflow working through a CVT and 4-speed planetary gearset. The result is a more natural step-shift feel and no real "rubber band" sensation during brisk acceleration. And because the 2018 LS500h uses a more compact lithium-ion battery, it offers considerably more trunk space than last year's LS600h with NiMH battery.

A plug-in hybrid is not available yet; Toyota feels the U.S. charging infrastructure remains insufficient. Rear-drive models get a 25 mpg city/33 mpg highway EPA label with a 600-mile (966 km) range; AWD hybrids drop 2-3 mpg from that.

The new LS goes on sale in February 2018. Base price in the U.S. had not been announced as this article went to press, due to exchange-rate variables. But Lexus expects to bring the Tahara-built flagship in at around $75,000 USD. Fully optioned examples are anticipated to top $100,000.

Ron Sessions

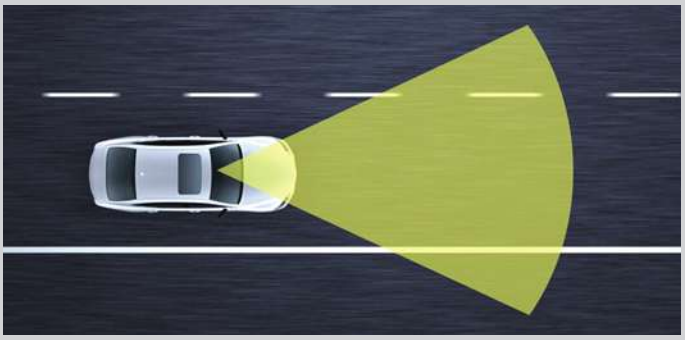
LS safety and semi-autonomous driving

Toyota engineers define the automated driving capabilities in the latest Lexus LS as an extension of its safety systems, not a liberating **SAE** Level 2 semi-autonomous experience. The standard 2018 Safety Suite + uses a 77-GHz forward-facing radar and a monocular camera that enables all-speed dynamic cruise control with full stop.

The system includes Pre-Collision with pedestrian detection and emergency braking, lane-departure alert and lane-keeping. The latter does a decent job of keeping the vehicle from wandering over brightly painted and well-maintained lane markers, as long as the road isn't too curvy, and imparts not-too-aggressive correcting torque to the steering wheel. But lane-keeping still wants hands on the wheel every few seconds or it signs off after flashing a visible warning and sounding a chime.

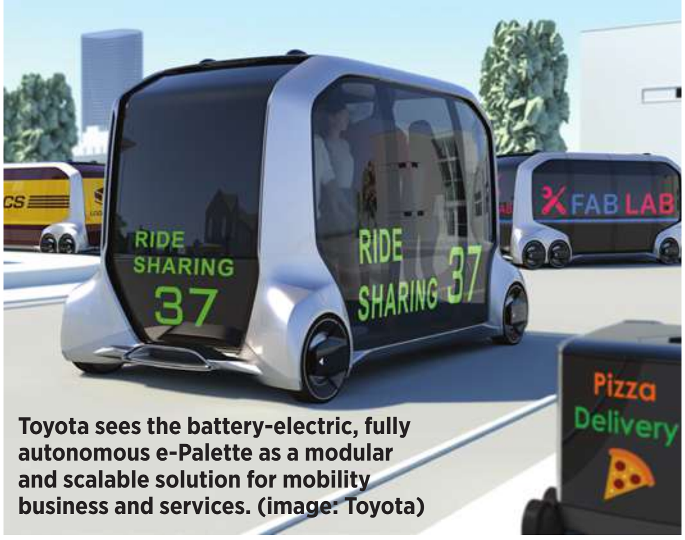
Moving the LS a bit further into the semi-autonomous driving arena is an optional Advanced Safety Package with stereo front-facing cameras, side-scanning forward radar and a vehicle follow capability that Lexus says works up to a speed of 110 mph (177 km/h). The side-scanning front radar operates up to 164 ft (50 m) in both directions to help prevent or mitigate collisions at intersections. A Lane Trace Assist feature can "trace" the path of the vehicle driving ahead and even follow mild curves in the road when white or yellow lines are not present.

Chief Engineer Asahi is most enthusiastic about the new Active Steering Assist component. In this, the stereo cameras can detect the direction a pedestrian is moving and will attempt to steer around the person if the car can't be braked in time—but only if it can stay within the lane. However, ASA doesn't work for larger objects, such as a truck backing into a traffic lane.

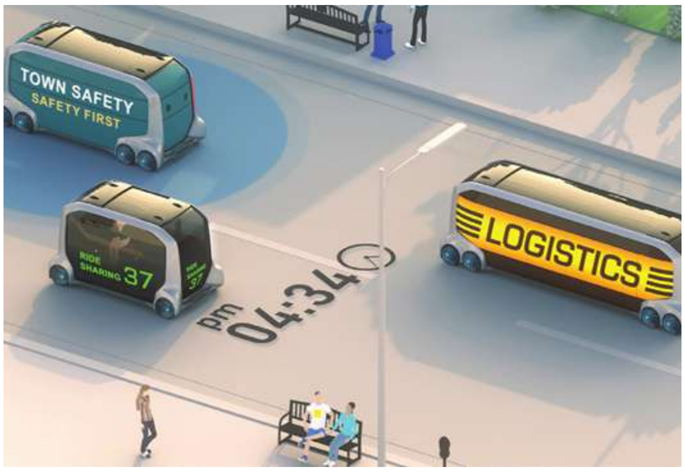

The Lane Trace Assist feature can "trace" the path of the vehicle driving ahead and follow mild curves in the road when lines are not present. (image: Lexus)

RS

Toyota unveils autonomous e-commerce concept vehicle, development alliance



Toyota sees the battery-electric, fully autonomous e-Palette as a modular and scalable solution for mobility business and services. (image: Toyota)



Three sizes of e-Palette are intended to provide flexibility for potential purchasers or lessees. (image: Toyota)

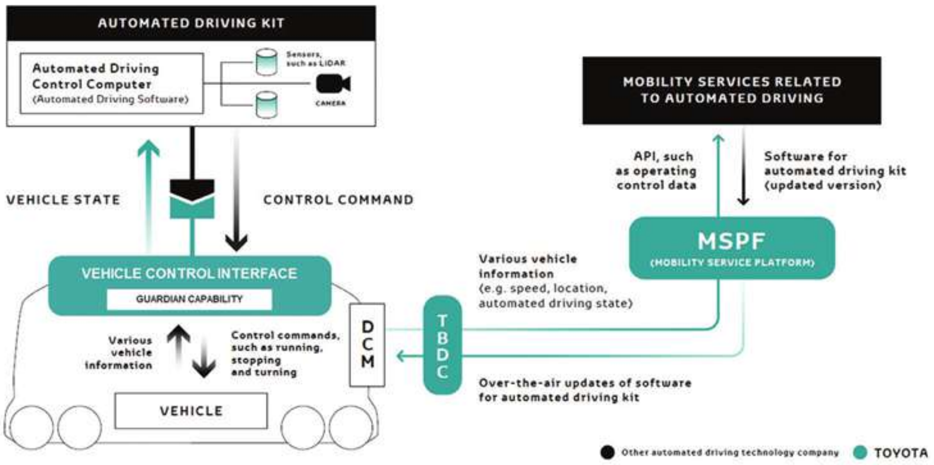
Toyota used the 2018 Consumer Electronics Show (CES) to reveal an all-new, battery-electric commercial vehicle targeted for emerging e-commerce and mobility business applications. The pod-like e-Palette vehicle is designed to employ certain Toyota-developed foundation technologies but to also be flexible enough to allow companies purchasing or leasing the vehicle to apply their own or a preferred automated-driving system.

In addition, the e-Palette, which is intended to be built in three different sizes, also is the centerpiece of a new mobility-as-a-service (MaaS) development alliance Toyota formed with initial partners **Amazon**, **Didi**, **Mazda**, **Pizza Hut** and **Uber**. Toyota said the e-Palette Alliance launch partners "will collaborate on vehicle planning, application concepts and vehicle verification activities."

Toyota is developing the e-Palette because it intends to be a key supplier of mobility hardware and services, including collection and distribution of the "big data" widely expected to be a key revenue stream for MaaS companies. Toyota president and member of the board of directors Akio Toyoda indicated the e-Palette and its accompanying development alliance mark a watershed for the company's automaking business:

"This announcement marks a major step forward in our evolution towards sustainable mobility," Toyoda said in release issued during the CES 2018 unveiling, "demonstrating our continued expansion beyond traditional cars and trucks to the creation of new values—including services—for customers."

Toyota said it plans to conduct feasibility testing of the e-Palette Concept in various places around the world, including the United States, starting in "the early 2020s." But the company apparently intends to showcase functional e-Palette vehicles at the 2020 Olympic and Paralympic Games in Tokyo.



The e-Palette's controls design employs the company's Guardian safety architecture but allows flexibility for the end-user to overlay Guardian with a preferred automated-driving control system. (image: Toyota)

Three sizes, spectrum of potential uses

The electric e-Palette concept revealed at CES 2018 is the largest of what is envisioned as a three-size lineup of autonomous vehicles with lengths varying from 4 m (13.1 ft) to 7 m (23 ft). The e-Palette Concept revealed at CES was 4800 mm long, 2000 mm wide and 2250 mm high. The company said e-Palette's flat and barrier-free interior and low floor mean almost any imaginable interior configuration could be fitted, such as a passenger-carrying ride-share layout or a mobile hotel room. The design also is intended to enable quick transition between interior layouts.

Equally important, Toyota said that although the vehicle's "foundation" controls incorporate the company's "Guardian" safety-oriented architecture, it designed the e-Palette to allow potential customers to use their preferred automated-driving controls, with the

The e-Palette design is intended to provide flexibility for a variety of potential uses, as well as quick transition between interior configurations. (image: Toyota)

Guardian system acting "as a safety net to help ensure appropriate operation."

Gil Pratt, who leads the Toyota Research Institute (TRI) where much of the company's autonomous-vehicle development takes place, told reporters immediately following the e-Palette's CES introduction, "At TRI, we are unafraid of competition. If somebody wants to use a certain (automated driving-controls) suite, they can still use e-Palette."

Services emphasis

An equally intriguing calling card for e-Palette is Toyota's Mobility Services Platform (MSPF) to advance a suite of connected-vehicle services and data logging for e-Palette users: "The new alliance will create a broad-based ecosystem of hardware and software support designed to help a range of companies utilize advanced mobility technology to better serve customers," Toyota said in a release.

Zach Hicks, CEO and president of Toyota Connected, told reporters, "That's why we brought in a variety of partners – to help us develop it."

Launched in 2016, the MSPF is Toyota's framework for connected-vehicle applications, providing a full suite of services to support MaaS, ranging from vehicle leasing and insurance to fleet and big-data management.

Apart from the planned deployment at the 2020 Olympics, Toyota officials provided no definitive timeline for when e-Palette vehicles might be in series production or which, if any, of the existing development partners would deploy the vehicles in public use.

Bill Visnic

Case IH Quadtrac CVX the first high-hp articulated tracked tractor to offer a CVT

The Case IH Quadtrac and Steiger CVX range are the first high-horsepower articulated tracked tractors available with CVT technology. The flagship 540 CVX is shown in action. (image: Case IH)

The most significant upgrade to **Case IH**'s Quadtrac and Steiger articulated tracked tractors for 2018 is a new CVXDrive transmission supplied by **ZF**, the first such application of a continuously-variable transmission (CVT) in the segment, the company claims. CVT development for Case IH's mid-power tractors dates back 17 years; the company decided that now is the right time to bring the technology and its benefits to the top end of the tractor market.

A range of three Case IH Quadtrac CVX models—470, 500 and 540 CVX—will complement the existing line of five models with the standard powershift transmission. The CVT—a ZF ECCOM 6.0 transmission—is also available on five Steiger models: the 370, 420, 470, 500 and 540. The new machines had a prominent spot in Case IH's booth at the recent Agritechnica event in Hanover, Germany.

"At 613 peak horsepower, the 540 CVX, which is the flagship in the Quadtrac CVX range, offers the highest available power of any CVT tractor," Vincent Hazenberg, product marketing director for Case IH in Europe, Middle East and Africa, said during a pre-Agritechnica demonstration for media of the tractor's performance on a farm in Slovakia.

Quadtrac CVX tractors are powered by an electronically-controlled 12.9-L Cursor 13 six-cylinder engine from sister company **FPT Industrial**, with a single-stage turbocharger on the two smaller tractors and a two-stage turbocharger in the 540 model. On the 540 CVX, the smaller turbocharger delivers low-rpm responsiveness, while the second, larger unit provides maximum boost at high rpm. Each turbocharger has its own cooling system to provide 30% faster response under load.

Maximum power is achieved at 1900 rpm, and maximum torque of 2607 N·m (1923 lb·ft) at 1400 rpm. The tractor has a diesel capacity of 1230 L (325 gal) and a DEF (AdBlue) tank that holds 322 L (85 gal).

The Quadtrac 470 CVX and 500 CVX have respective maximum power outputs of 525 hp and 558 hp.

The FPT engineering team adapts the engine setting to suit the CVT's attributes, said Diego Rotti, product marketing manager for off-road engines at FPT Industrial. "There is some tailoring in the engine, and it depends on the application," he explained. "The matching of engine performance with CVT's gear management is optimized, because torque output needs to be adapted compared to the standard stepped transmission."

The engines meet Stage IV/Tier 4 Final emissions legislation through the use of the Hi-eSCR system, which is a maintenance-free SCR-only solution. To meet Stage V limits, coming in 2019 or 2020 depending on power range, FPT Industrial decided not to just add a diesel particulate filter (DPF) to its current solution. Instead, its second-generation Hi-eSCR2 will integrate a particulate filter into the SCR unit with no change in layout or volume,

The ZF ECCOM 6.0 CVT, suitable for large tractors up to 650 hp, features four mechanical ranges, with automated range-changing under full draft load. (image: ZF)

according to Rotti. Moreover, the system will still be for life and regeneration-free, as with the current Stage IV/Tier 4 Final technology, he added.

On the Quadtrac and Steiger tractors, there is "basically no difference" between EU and U.S. market products, according to Hans-Werner Eder, Quadtrac product marketing manager. The only differences for Europe are road lights, decals and signs are according to EU law, he said.

CVT details

The CVXDrive transmission in the Quadtrac 470, 500 and 540 CVX models offers a number of benefits that result in increased productivity with faster cycle times and maximum fuel efficiency, according to Hazenberg. Ease-of-use particularly for inexperienced operators is one of those benefits, as is reduced operator fatigue. Performance enhancements include faster acceleration to field or road speed, full power availability at low ground speeds for special applications/implements, and full hydraulic flow availability at low ground speeds, for applications such as drilling/planting.

Providing stepless travel from standstill up to 40 km/h (25 mph), and 0-18 km/h (11 mph) in reverse, CVXDrive allows three target speeds to be stored, adjustable via the thumbwheel and buttons on the armrest-mounted Multicontroller. The transmission incorporates a kick-down feature that ensures maximum acceleration, and 40 km/h is achieved at just 1640 rpm.

The CVT features four mechanical ranges, with automated range-changing under full draft load. The first time 100% mechanical power transfer takes place is below 10 km/h (6 mph), matching heavy draft application requirements. Four multi-plate wet clutch packs, mounted on the four planetary gear sets, change the ranges without power interruption, with equal clutch speeds guaranteeing smooth shifting without clutch wear.

The hydrostatic pump and hydrostatic motor are a single unit, with no high-pressure pipes between pump and motor. A variable swash plate on the pump creates different speeds and allows the fixed hydrostatic motor to be operated in both directions. An example of this is the Active Hold Control (AHC) feature, where the hydrostatic motor eliminates the input speed from the engine. AHC allows the tractor to remain static when stopped on a hill, without the operator applying the foot or hand brake. The park brake is automatically applied after 45 seconds.

In place of the foot throttle found on tractors with the powershift transmission, Quadtrac CVX models are fitted with a drive pedal that controls the tractor's ground speed when in automatic mode. In manual mode, the foot pedal acts as a conventional foot throttle. The Multicontroller also incorporates a power shuttle switch, which

"CVX can bring a wide range of engine, fuel and work advantages to Quadtrac owners' businesses," said Hans-Werner Eder. (image: Ryan Gehm)

Quadtrac CVX models feature a revised Multicontroller armrest that incorporates the dual throttle for minimum/maximum speed settings, and a slightly different Multicontroller joystick more suited to CVT operation. (image: Ryan Gehm)

works in parallel with the shuttle lever on the left of the steering column, for direction changes without releasing the steering wheel. The Eco Drive dual-hand throttle allows the setting of minimum and maximum engine speeds to minimize fuel use, and the engine droop function, which determines the engine speed down to which the rpm can drop under load.

"CVX can bring a wide range of engine, fuel and work advantages to Quadtrac owners' businesses," said Eder. "They include reduced engine speed to optimize fuel efficiency, and, for those operating PTO-powered equipment, enhanced operation through the achievement of uninterrupted peak power via stepless speed progression."

Operating systems and in-cab updates

One of the key operating systems for Quadtrac CVX tractors is Automatic Productivity Management (APM), which is designed to ensure the most efficient operation of the machine, whether the operator or owner's target is minimum fuel use or maximum output.

APM coordinates the engine and transmission with the Multicontroller and drive pedal, automatically reducing engine speed to the minimum required

The FPT Industrial team did some "tailoring" to the Cursor 13 engine to better match it to the CVT, said FPT's Diego Rotti. (image: Ryan Gehm)

for the tractor's workload. The tractor can also be operated in manual mode, without APM, with the transmission controlled via the Multicontroller and the engine speed via the foot or hand throttle.

The variable-displacement pump that supplies the key hydraulic requirements is a pressure- and flow-compensating type, providing 216 L/min (57 gal/min) of oil flow (with 428 L/min [113 gal/min] an option). The system operates at a pressure of 210 bar (3045 psi), supplying up to eight remote valves. The valves and the 8949-kg-capacity rear linkage are controlled electronically via the Multicontroller armrest.

Introduction of the CVXDrive transmission prompted a few new features to be added to the established Surveyor cab. The slightly-revised Multicontroller armrest incorporates the dual throttle for minimum/maximum speed settings, and a slightly different Multicontroller joystick is better suited to the operation of the CVT.

Information is still displayed in Case IH's pillar display in the right-hand A-post. This shows engine speed, transmission forward and reverse target speeds, currently-engaged target speed, actual ground speed, a park brake/neutral/forward/reverse indicator, and which speed will be selected if the direction is reversed. Also shown on the display are the fuel and DEF tank levels.

Ryan Gehm

Honda 2018 Accord: antidote for crossover fever

The 2018 Honda Accord's overall length is slightly reduced but wheelbase is extended by 2.16 in. (image: Honda)

Honda engineers aren't saying it in so many words, but one could construe the tenth-generation 2018 Accord sedan as being purposely developed as the "anti-crossover." At a time when most of the developed world is indicating a preference for the high-seating-position, high-center-of-gravity handling of crossovers and SUVs, the all-new Accord is lower, situates its driver lower and has a new, stiffer chassis that's oriented towards increased driver involvement.

In other words, attributes that *aren't* strong points for most current mainstream crossovers, the body style that for several years has nibbled at the midsize sedan segment's longtime dominance. So as if to reward those who continue to choose a midsize car—still roughly two million buyers in the U.S. last year—the new Accord seems deliberately designed to be everything an SUV isn't.

You can get the most-powerful variant of the car with a manual transmission, for heaven's sake.

The 2018 Accord is, declared American Honda's Ray Mikicuik, assistant vice president, Honda auto sales, "the most radical re-imagining of the Accord—ever."

Chances for success seem promising, even if the sedan market is "losing" to crossovers: not only is the tenth-generation Accord as resolved a package as can be remembered for this nameplate, the primary competitive set is shrinking, as the domestic automakers scurry to blanket the truck and SUV segments at the expense of sedan body styles.

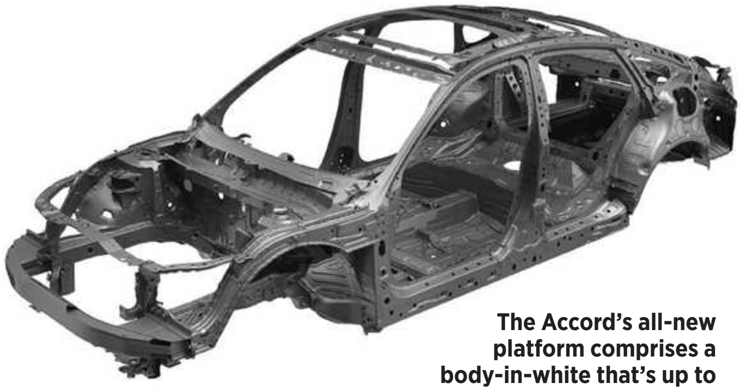
One fly in the ointment: Accord's chief rival, the **Toyota** Camry, also is all-new for 2018 and also happens to be quite good. But the latest Camry doesn't offer turbocharged engines—and certainly not a manual transmission.

Man-maximum, machine-minimum

Drop into the new Accord and that's practically the first thing you notice—it's a drop. The new hip point is about 1 in (25 mm) lower than before and overall height also is down by 0.6 in (15 mm)—all part of Honda's current "man-maximum, machine-minimum" design brief that sees the car's overall length slightly reduced while the wheelbase is hiked by 2.16 in (55 mm) and interior volume plumped by 2.5 ft^3.

Factor in the quite noticeably thin A-pillars (about 20% narrower) moved rearward by an almost-remarkable 4 in (100 mm) and you're left with the perception the new Accord has a longer hood and occupants sit further back. The effect "gives more of a rear-drive proportion impression," said chief engineer and Global Development Leader Junji Yamano—even if 60% of the new

The 2018 Accord's architecture incorporates new front and rear suspension design. (image: Honda)



The Accord's all-new platform comprises a body-in-white that's up to 5% lighter and has improved rigidity. (image: Honda)

Accord's weight still resides on the front driven axles.

Rear-seat legroom is where occupants will enjoy most of the wheelbase expansion, where there's now 2 in (50 mm) more legroom. Trunk space is up almost 1 ft^3 for the conventionally-propelled 2018 Accords and a full 3.2 ft^3 for the Accord Hybrid, where trunk space now is identical to the non-hybrid models thanks to the new platform's repositioning of the lithium-ion battery pack under the rear seat.

"The biggest thing we wanted to do" with the Accord's new architecture, Yamano told *Mobility Engineering*, "was extend the wheelbase." But without a reduction in overall length, "it would have gotten really big for a D-segment vehicle." So the front overhang was reduced and the A-pillars moved rearward by that whopping 4 in.

The A-pillars were able to be made so thin by using high-strength steel with a unique cross-section, said Yamano; 29% of the body-in-white now is ultra-high-strength steel, the most ever for a mass-produced Honda. And well more than half of the new body structure is high-strength steel of 440 MPa or better. The secondary benefit of all this HSS is weight reduction: Honda said the 2018 Accord is 110 to 176 lb (50 to 80 kg) lighter, depending on trim level.

Honda's also begun slapping around more body adhesive than ever before and it's helped the new Accord increase bending and torsional rigidity by a respective 24% and 32%.

Underpinning the body structure is a new Macpherson strut front suspension mounted to a solidly-mounted aluminum front subframe. Rear suspension is a multi-link design attached by an isolated subframe. Yamano and Tetsuya Miyahara, chief engineer, body and chassis, said the front suspension's new L-arm design markedly improves resistance to lateral forces coming from the tires when cornering. The new rear-suspension layout now attaches the trailing arm to the body rather than the subframe—delivering a pleasing and dynamics-enhancing "passive self-steer" according to Miyahara, while simultaneously improving ride comfort.

An optional new adaptive-damper system—a segment first—can adjust damping force every 1/500 s.

No V6, no problem

Long a holdout regarding turbocharging, Honda's been all-in with recent model launches and the 2018 Accord follows the trend with two turbocharged and direct-injected 4-cylinder gasoline engines that displace either 1.5-L or 2.0-L; the Accord

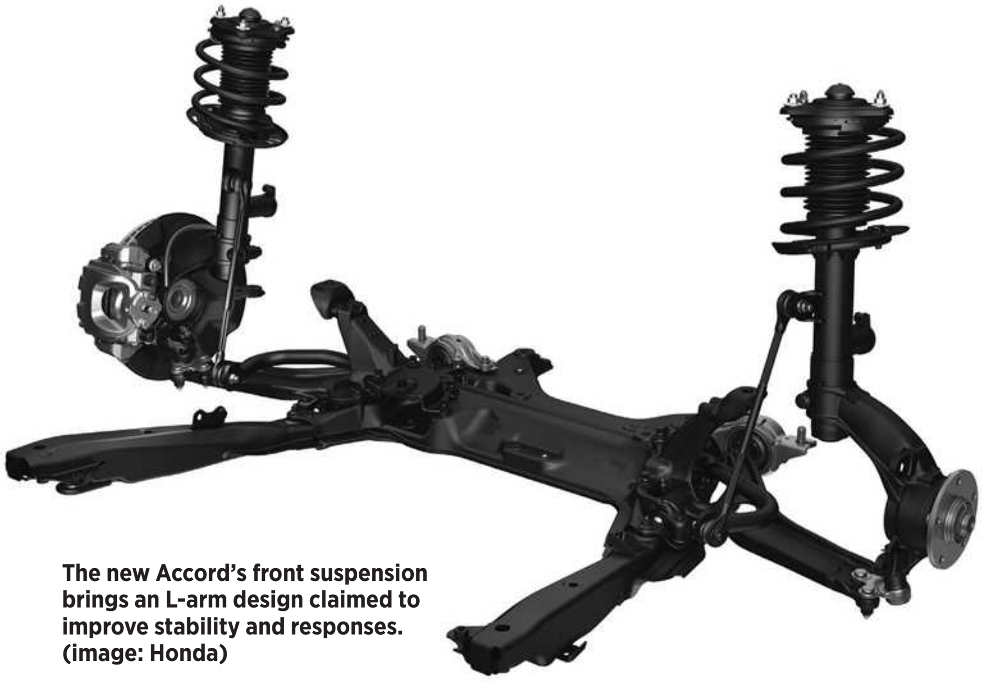
The 2.0-L turbocharged 4-cyl. generates 252 hp and replaces Honda's 3.5-L V6 as the Accord's upgrade engine. (image: Honda)

Hybrid employs Honda's effective and efficient 2-motor setup.

The 1.5-L 4-cylinder has dual Variable Timing Control valvegear, SAE rated at 192 hp (143 kW) at 5500 rpm and 192 lb·ft (260 N·m) from 1500 to 5000 rpm. It replaces the base Accord's normally-aspirated 2.4-L and by comparison is a distinct upgrade in general liveliness and urge. As with most small-displacement turbocharged engines, that urge tapers at higher road speeds, but it's a small price to pay for the 30 mpg city/38 mpg highway rating achieved in this spacious sedan.

Generating an SAE-rated 252 hp (188 kW) at 6500 rpm and 273 lb·ft (370 N·m) from 1500 to 4000 rpm, the 2.0-L is an eye-opener from a standstill and pulls majestically in nearly every situation. Yamano smiled when asked if V6s are relics—even if the chief competition retains a V6 in the lineup for its newly-redesigned midsize sedan.

"I don't want to disrespect the V6," he said. "We still use it in various models. I think there are 'best solutions' in all categories.


The new Accord's front suspension brings an L-arm design claimed to improve stability and responses. (image: Honda)

There still is a place for high-displacement V6s" in larger vehicles, he contends, but "I really think the low-end torque of turbo engines contributes a lot to the acceleration experience."

Another contributor to the 2018 Accord's acceleration experience is the keen choice of transmissions. Yes, Virginia, Honda still believes in manuals and both of the Accord's new turbo engines can be coupled with a 6-speed manual transmission. The 2.0-L gets the same crisp and willing short-throw job used in the new Civic Type R.

Manual-gearbox midsize sedans are a last gasp of fresh air when the world can't talk of anything other than cars driving themselves—but the reality is that nearly everyone will choose an automatic. Honda's new 10-speed planetary automatic (a front-drive sedan first, Honda asserts) is paired with 2.0-L engine and its superb performance and general deportment are alone enough to convince a buyer to choose the Accord's upgrade engine. The 10-speed has a 68% wider ratio spread, including a 43% lower first gear and 17% taller top gear, compared to the outgoing Accord's 6-speed automatic—and it manages all the ratios with stunning effectiveness.

Honda's redesigned continuously-variable transmission (CVT) is the automatic that comes with the 1.5-L engine; it offers an 11% lower ratio compared to the outgoing unit for improved launch performance. It's one of the best-operating, least-cantankerous CVTs in volume production and is far from a medieval torture device, but the 10-speed automatic is equally efficiency-enhancing and its refinement is so advanced that one wonders how far the variable-cost of the 10AT would need to be cut to justify obsoleting the otherwise-commendable CVT. For now, however, it's worth noting that Honda's early projections see the CVT generating nearly 10% better fuel economy than the 6-speed manual.


Chief engineer and Global Development Leader Junji Yamano with the all-new 2018 Accord. (image: Bill Visnic)

Meanwhile, the new hybrid powertrain brings no such issues. Under its hood is a 2.0-L Atkinson-cycle 4-cyl. that Honda said surpasses 40% thermal efficiency; the engine works in conjunction with the dual electric motors, the first for any production hybrid to use non-rare-earth magnets. A new twist is a driver-selectable choice of regenerative-braking intensity via steering-wheel paddles.

Superior interior

The tenth-generation Accord cockpit seems to mirror much of the design intent of the exterior: there's deliberately more than meets the eye, as the simple and sweeping dashboard lines and streamlined instrument-panel and controls dispel any perception of feature overload. The Honda Sensing driver-assist suite (lane-keeping assist, adaptive cruise control, automatic braking road-departure mitigation and, for the new Accord, traffic-sign recognition) now is standard, as is a slick new information display for it all.

The all-new HMI incorporates a 7-inch TFT driver's meter and 8-inch touchscreen infotainment interface that's augmented by actual volume and tuning rotary knobs. Both 1.5-L and 2.0-L Touring models feature a new 6-in driver's HUD (head-up display) with selectable information, including speed, engine rpm, turn-by-turn navigation, and traffic-sign recognition. Available connected-car technologies include wireless device charging, automatic Bluetooth phone pairing with Near Field Communication (NFC) technology, 4G LTE in-car Wi-Fi, and Wi-Fi-enabled over-the-air system updates.

Honda says it is the first OEM to include NFC capability in a production model. The NFC chip enables the user of Android and Apple smartphones to tap the small NFC tag—marked by an oddly distracting "N" scrawled on the passenger-side dash—to instantly pair the phone with the Accord's Bluetooth connection.

Honda invested $267 million to upgrade its assembly plant in Marysville, Ohio, to build the 2018 Accord, a figure that included several new production processes incidental to the car's new architecture. The 1.5-L and 2.0-L models hit showrooms by the end of November, and the Accord Hybrid goes on sale in early 2018.

Bill Visnic

COMPANIES MENTIONED

AD INDEX

Prof. David Greenwood says of future battery development: “We are going to need new alternatives to deliver a step-change.”

Addressing the ‘grand challenge’ of battery research

Research universities are playing an increasingly vital role in advanced automotive battery R&D and manufacturing capability. Among several new partnerships in Europe is the British government’s investment in the multi-faceted Faraday Battery Challenge, which provides links between leading universities and the auto industry.

Helping to meet that Challenge is the recently announced **Faraday Battery Institution**, created to co-ordinate U.K. academic research in partnership with industry. The Institution brings together seven U.K. universities to accelerate fundamental research in the development of battery technologies, including the **University of Warwick**, **Imperial College**, London; **University College London**; **University of Cambridge**; **University of Oxford**; **Newcastle University**; and the **University of Southampton**.

David Greenwood, Professor of Advanced Propulsion Systems at the University of Warwick’s Manufacturing Group, recently spoke with SAE European editor Stuart Birch about the new organization.

The Institution is set to explore “novel approaches” to battery development; what are these likely to be and which would be the salient areas?

The central principle of the Faraday Institution is ‘application-inspired fundamental research’. This means the right science and technology experts working together on the future advances that are going to drive innovation towards commercial application.

The initial focus for this investment is the automotive industry, which has an urgent need for low carbon solutions, but other sectors, such as grid, marine, and aerospace, are likely to grow.

The Faraday Institution will work on research programs developed from grand challenges set by industry, so a focus will be on the biggest research issues that are inhibiting progress. The first tranche of research areas covered will be battery degradation, multi-scale modelling, solid-state batteries and recycling/circular economy.

From a public perspective, lack of energy density, high cost, excessive weight and recharging time remain the negative aspects of electric-vehicle use; are you confident that these can all be successfully and satisfactorily addressed?

We are continually seeing rapid improvements in lithium-ion battery technologies which are used in electric vehicles today. For example, volumetric energy density has doubled in the last 15 years, and costs have fallen by a factor of four within the last 5-10 years.

The challenge is that new technologies, which are emerging at a ‘proof-of-concept’ stage, will take at least eight to ten years to make it to the commercial market as fully-validated, industrially-manufactured products. The chemistries we are using in electric vehicles today were developed in labs in previous decades. Commercial batteries are the result of a long-term development process to optimize and validate them for industrial scale manufacturing for specific applications.

Does lithium-ion technology have the development potential to solve near- to medium-term battery challenges—and what of the fuel cell?

Lithium-ion batteries are broadly accepted to be the automotive chemistry of choice for the next eight to ten years due to existing production maturity and the R&D needs of other future alternatives.

There is still much we can do to optimize lithium-ion for automotive applications, such as new formats and structures of cells, new material additions such as silicon composites, or improved prediction of how batteries age and degrade over time. However, again, the cell materials are only part of this story.

If lithium-ion cannot meet the industry’s long term EV needs, what battery high energy density alternatives could be developed in the medium to long term?

Lithium-sulfur is demonstrating high gravimetric energy density in some applications today, but retains issues with safety, cycle life and volumetric energy density.

Solid-state batteries are also being investigated and could offer improved safety and energy density but currently, manufacturing methods would prove too expensive for most applications.

It is important to note that alternatives will need to offer more than an improvement in energy density. There are some alternatives, such as lithium air, which demonstrate very high energy density, but may not have the power density which is going to be required for automotive applications.

We may see a situation where different solutions are developed for different automotive markets, depending on whether they are aimed at premium or low cost, or whether range is a defining factor. Sodium-ion is an example of another chemistry which is already being demonstrated in market applications. It offers a lower cost alternative to lithium-ion. It could be an ideal solution for some applications where this is the primary factor as opposed to maximized energy density, e.g. very low-cost or light-duty vehicles.

Published by K.Venkataraj. Printed by S.Arumugam on behalf of SAEINDIA. Printed at Hitech Offset (P) Ltd, 11, Srinivasa Nagar Main Road, Koyambedu, Chennai – 600 107. Published from SAEINDIA, 1/17, 3rd Cross, Kasturba Nagar, Adyar, Chennai – 600 020. Editor K.Venkataraj.

RNI No. TNENG/2014/55684