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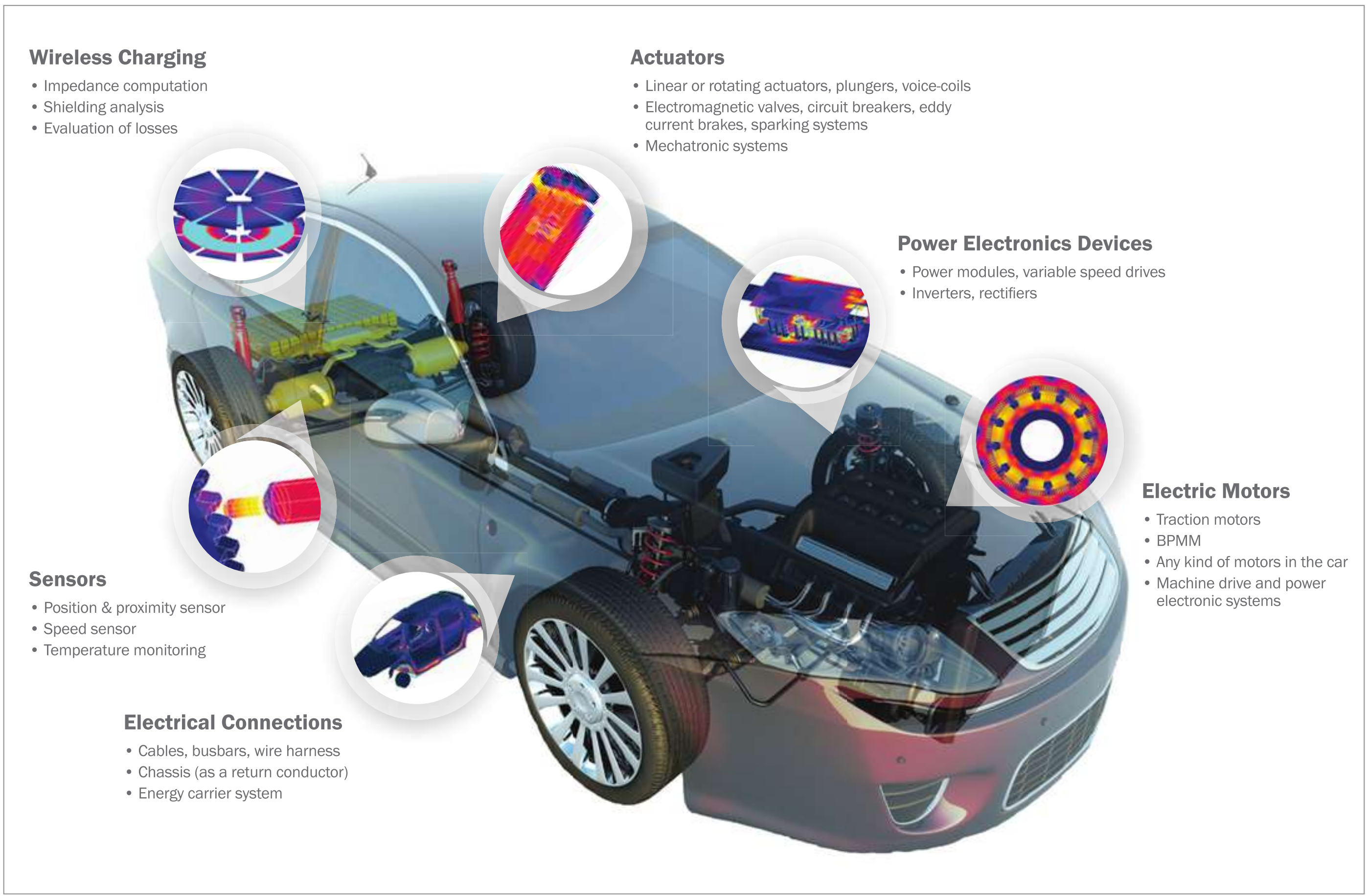

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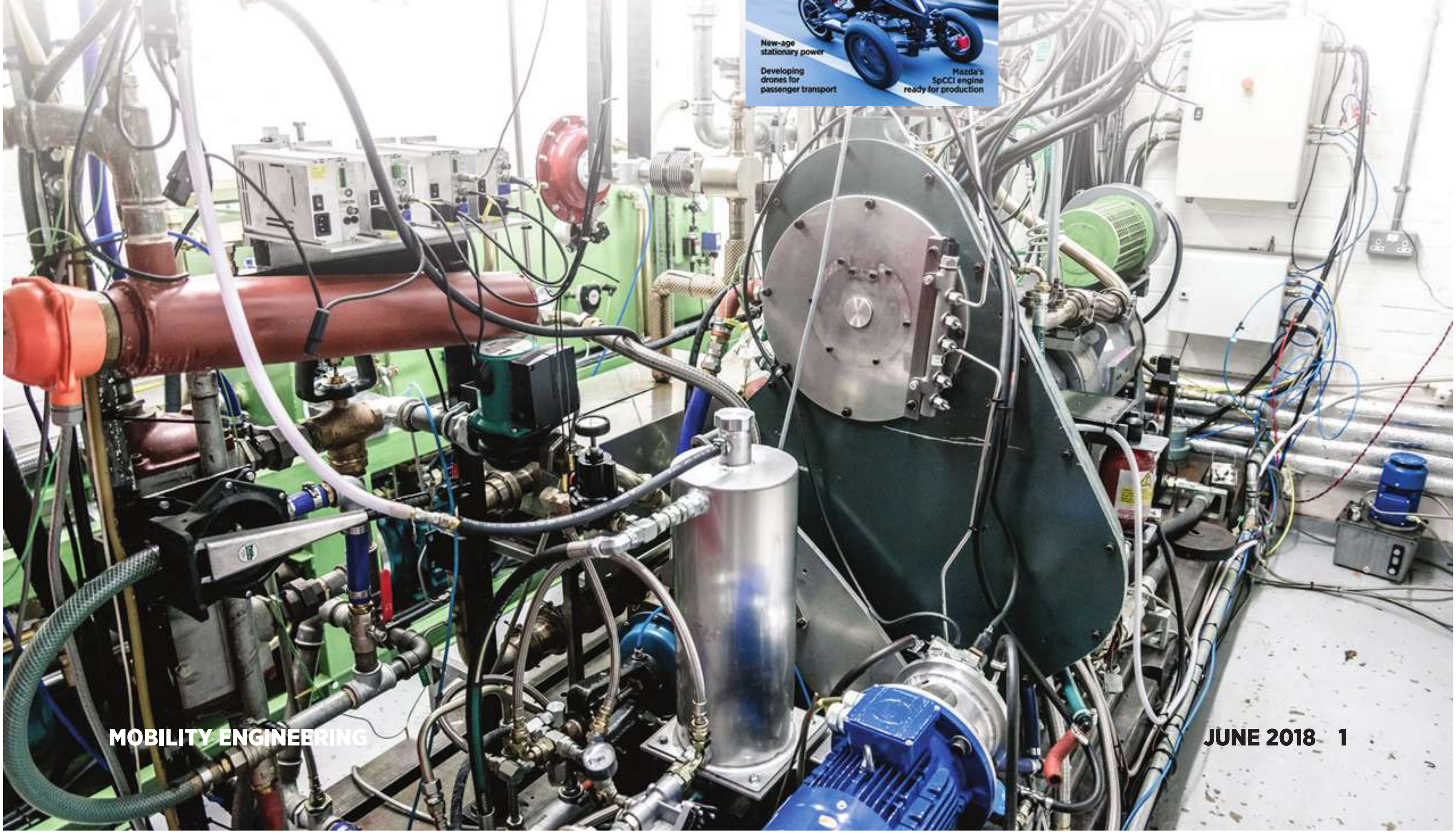
CONTENTS

Features

Cover

Sway Motorsports' three-wheeled electric motorcycle leans into a curve thanks to a suspension design developed in collaboration with engineering consultancy Motivo Engineering.



CONTENTS

Departments

SAEINDIA News

KRT competition on CAD, CAE – FEA & ED, 07th Jan, 18th Feb & 18th March 2018, Chennai

Group photo – KRT competition

SAEINDIA Southern Section (SAEISS) as a part of the engagement of the professional members had organized a KRT competition on Computer Aided Design (CAD), Computer Aided Engineering (CAE) - Finite Element Analysis (FEA) and Engineering Drawing (ED) on 7th January, 18th February & 18th March 2018 at Chennai. Nearly 40 teams from various Academia and Industries participated in all the 3 events.

CAD:
During the inaugural Function Mr. S. Sriraman, Chairman, SAEISS; Mr. S. Selvamani, Past Chairman, Mr. S. Shanmugam, Vice-Chairman, SAEISS and Mr. B. Srinivasan, KRT Champion took the stage. Mr. B. Srinivasan welcomed all the participants, volunteers and Judges for the CAD Competition. He informed all the participants about the rule book and evaluation criteria for the competition by giving the brief details about the event and requested Mr. S. Sriraman to give his Inaugural Address. Mr. S. Shanmugam then explained the need for the KRT Competition which can increase the design capabilities of members of SAEINDIA.

The 1st Place of the competition was shared by Mr. Rajesh Kumar and Mr. Ameer Malik Shaik both from Combat Vehicles Research & Development Establishment (CVRDE), Chennai who were they honoured with Certificate, memento and prize money of ₹ 50,000/- . Mr. S. Shanmugam thanked all the participants for their involvement and also requested their continuous support for all the programs organized by SAEISS.

CAE - FEA:
During the inaugural Function Dr.R.Rajendran, MC Member, SAEISS; Mr. Karthikeyan, Ucal Fuel Systems; Mr. Kumar, Professor, SRM Institute of Science and Technology took the stage. Dr. R. Rajendran gave the welcome address. He welcomed all the participants, volunteers and Judges for the CAE-FEA and gave the brief details about the event and invited Mr. Karthikeyan to make an enlightening Inaugural Address. After the designing process was completed then the Judges started their evaluation process of all teams.

During Valedictory function Mr. B. Srinivasan, KRT Champion, SAEISS thanked all the participants, Judges and Volunteers for making the event a grand success. The 1st Place of the competition was shared by Mr. S. Vivek and Mr. T. Sukumar both from WABCO INDIA Ltd, Chennai who were they honoured with Certificate, memento and prize money of ₹ 50,000/- . Mr. karthikeyan thanked all the participants for their involvement and also requested their continuous support for all the programs organized by SAEISS.

ED:
During the inaugural Dr. R. Rajendran, MC Member, SAEISS; Mr. S. Ganapathi, Ucal Fuel System Ltd and Dr. G. Nagarajan, Dy. Dean, SRM Institute of Science and Technology took the stage. Dr. R. Rajendran gave the welcome address.

He welcomed all the participants, volunteers and Judges for the CAE-FEA and gave the brief details about the event and invited Dr. G. Nagarajan, to make an enlightening Inaugural

SAEINDIA News

Address. After the designing process was completed then the Judges started their evaluation process of all teams.

Mr. S. Ganapathi informed all the participants about the rule book and evaluation criteria for the competition by giving the brief details about the event. The 1st Place of the competition was shared by Mr. T. Aravind Muthu Suthan and Mr. M.P. Jagadeesan from Ucal Fuel Systems Ltd, Chennai who were they honoured with Certificate, memento and prize money of ₹ 50,000/- . Mr. S. Ganapathi thanked all the participants for their involvement and also requested their continuous support for all the programs organized by SAEISS.

AWIM National Olympics, 20th – 22nd Jan 2018, Pune

Group photo – KRT competition

SAEINDIA in association with Eaton Technologies, Cummins, Mahindra & Mahindra, John Deere, Trim India, The Automotive Research Association of India (ARAI), Altair, Maruti Suzuki, Federal Mogul, IAC, Ansys, VGA Digital Printers and Hospitality Partner, Orchid Hotel, concluded the 10th edition of 'A World In Motion' (AWIM) National Olympics at Cummins India Office Campus (IOC), Balewadi, Pune from 20th to 22nd January 2018 starting with Inauguration ceremony on day 1 followed up the main competition and prize distribution ceremony on day 2 and finally a field trip to Science Park in Pune on the final day.

The event kicked off with a press conference held for a brief on the event, followed by Inauguration ceremony at Cummins IOC, Balewadi. Mr. Ketan Deshpande, CEO of Fuels Group NGO was the chief guest for Inauguration of the event. It saw music performance from Eaton's Beaton music club, magic show by a volunteer and speeches by the distinguished dignitaries.

This competition saw 80 teams from 30 Cities schools students work as a team, applying scientific design concepts and exploring the principles of laws of motion, inertia, force, momentum, friction, air resistance, jet propulsion, etc. to create moving vehicles like skimmer and balloon powered Jet-Toy cars.

The competition was divided into three main categories namely,

Toy Making: where the students were allotted two hours' time to make the toys and prepare their presentation. The teams comprised of four participants. Each participant had a specific role to play such as design engineer, test engineer etc. mimicking project teams in the Industry.

Track Events: The next step was for the team's toys to be evaluated on track for different parameters such as maximum distance, speed, accuracy, ability to carry weight

etc. 52 volunteers from Pimpri Chinchwad College of Engineering, Pradhikaran, Nigdi, Pimpri-Chinchwad contributed to managing the tracks for the event.

Presentation: This is the last leg of the competition which gave an opportunity to the students to extend their learnings of the toys to creatively come up with their own idea of toy. The ideas of toys were theme based from addressing cleanliness drives to entertainment each new idea was unique.

Throughout the competition participating students showed great sportsmanship and Innovative thought. It also included the students presenting their own idea of a functional toy. The competition was judged by a panel of eminent personalities from the automotive field. AWIM 10th National Olympics concluded with Dr. Anil Sahasrabudhe, Chairman, AICTE, Delhi, gracing the Valedictory function as a Chief Guest and give away the prizes to the winning teams.

Overall winners – Jet Toy & Skimmer

WINNING TEAMS OF SKIMMER (5TH STANDARD):

S. NO.	CATEGORY	NAME OF THE SCHOOL
1	Overall Winner	Shriman Gangadhar Govind Patwardhan English Medium School, Ratnagiri
2	Overall 1st Runners-up	G.P.H.S. Honnasandra, Bengaluru
3	Overall 2nd Runners-up	Valentine Circle English Medium School, Solapur

WINNING TEAMS OF JET TOY (6TH STANDARD):

S. NO.	CATEGORY	NAME OF THE SCHOOL
1	Overall Winner	Saupins School, Chandigarh
2	Overall 1st Runners-up	G Ashraya Neelbagh School, Bengaluru
3	Overall 2nd Runners-up	Pragati Madhyamik Vidyalaya, Nashik

International conference (ICDMT) 2018, 23rd & 24th February 2018, Mumbai

Thakur College of Engineering & Technology, Mumbai in association with SAEINDIA, McGraw-Hill Education and International Journal of Scientific and Engineering Research (IJSER) organised a two day event International Conference on Advances in Mechanical Design, Manufacturing and Thermal Engineering (ICDMT 2018) on 23rd & 24th February 2018 at Mumbai. The Conference aims to provide international forum and a vibrant platform for academicians, researchers and industry practitioners from mechanical and allied engineering to share their original research work, practical challenges, recent innovations, trends and to explore methods of application of research to the technological development leading to human welfare.

The program was composed of a multi-track agenda based on the areas as,

- Track-1: International Conference on Advances in Manufacturing (ICAM)
- Track-2: International Conference on Advances in Mechanical Design (ICAMD)
- Track-3: International Conference on Advances in Thermal Engineering (ICATE).

About 72 papers were received in all 3 areas and 65 of them were presented in the respective tracks.

Bird's eye view of the event

SAEINDIA News

Baja 2018, 24th to 30th January & 8th TO 11th March 2018, Indore & Ropar

Dr. Powen goenka, MD, M & M with committee members in action

One of the vehicle in action

One of the vehicle in action

Organising team @ iit - ropar

BAJA SAEINDIA is an educational pursuit for the engineering college students, an out-of-classroom-education system, where engineering students from all over India can participate as a team to design, analyse, fabricate and validate an all-terrain vehicle which gives them a pragmatic exposure to real world challenges as faced in the industry. This 11th edition of BAJA SAEINDIA 2018 is with the theme 'Ground to Glory' which celebrates the passion, hard work and perseverance of the budding engineers who start their journey from scratch and traverse throughout the year to turn their dreams into reality. From this year onwards the event will be held in two places as a move of increasing the participation opportunity of more teams. This 11th edition was held at both Indore & Ropar.

Indore:
This is the 1st leg of 11th edition which was held at the National Automotive Testing and Research & Development Infrastructure Project (NATRIP) facility at Pithampur near Indore, from 24th to 28th of January 2018 followed by HR meet on 29th & 30th January 2018. It is of two events namely mBAJA & eBAJA where the 1st is the conventional BAJA and the 2nd is the concept of electric driven BAJA ATVs to lay emphasis on "Electrical Mobility". About 388 entries were received for BAJA SAEINDIA 2018, out of which 180 teams were shortlisted for conventional BAJA and 41 teams for eBAJA. In both the cases the teams have to undergo Technical Inspection, Static Evaluation such as Design, Cost & Sales Presentation and Dynamic Events such as Acceleration, Sled Pull, Suspension & Traction and Manoeuvrability in sequence. Finally the endurance round which will be of 2 hours for eBAJA and 4 hours for mBAJA events on the final day followed by prize distribution on the valedictory function. The results are,

CATEGORY	EVENT	NAME OF THE TEAM, COLLEGE & WEIGHT
Light Vehicle	mBAJA	Team Nemesis, College of Engg., Pune & 126.2 Kgs
	eBAJA	Team Stallion, Smt. Kashibai Navale College of Engg., Pune & 206.5 Kgs
Overall Winner	mBAJA	Team Nemesis, College of Engg., Pune & Team Durgayans, Dr. DY Patil Inst. of Tech., Pune
	eBAJA	Smt. Kashibai Navale College of Engg., Pune

Ropar:
This is the 2nd leg of the 11th edition which was held at Indian Institute of Technology (IIT), Ropar from 08th to 11th of March 2018. The event had only mBAJA where the ATVs run on 10 HP Briggs & Stratton (B&S) Gasoline Engine whereas eBAJA vehicles will run on electricity, propelled by an electric motor and powered by a rechargeable lithium-ion battery pack.

About 58 teams took part in the event. All the teams have to undergo the following test on this four-day event namely Technical Inspection, Static Evaluation such as Design, Cost & Sales Presentation and Dynamic Events such as Acceleration, Sled Pull, Suspension & Traction and Manoeuvrability in sequence finally to the endurance round on the final day. The results are,

CATEGORY	EVENT	NAME OF THE TEAM, COLLEGE & WEIGHT
Light Vehicle	mBAJA	Team Engines and Demons, Indian Institute of Tech., Indore & 138 Kgs
Overall Winner	mBAJA	Team Screwtenizers, Govt. college of Engg., Coimbatore & Team Aryans, Govt. College of Engg., Aurangabad

SAEINDIA News

Both the 1st and 2nd legs of 11th edition was supported by Mahindra who played a prominent role in slating the event since its inception under the able leadership of Dr. Pawan Goenka as the Chairman of the Steering committee of BAJA SAEINDIA. Since last 8 years Mahindra is the title sponsor and proudly continue to remain the same this year too, and others like ARAI, Altair, Anand Automotives, Ansys, ASDC, AVL, Bharat Petroleum, BKT, Bosch, Briggs & Stratton, Chitkara University, Continental, Cummins, Eleation, GM, IIT Ropar, iCAT, ITW Chemin, Lear, L&T, LNCT Indore, Math Works, Medanta Hospital, Mentor Graphics, M P Consulting, MYFM, NATRiP, OYO Rooms, Padmini Engineering, Polaris, Priya Events, PTC, Radisson Hotels, V J Productions, Varroc, Volvo and Wurth, SIAM, ACMA, ASDC & AICTE also proudly continuing their support towards the event.

Aero design challenge workshops, 17– 18 Feb, 2 – 3 & 16– 17 March 2018, Chennai

SAEINDIA Southern Section (SAEISS) conducted a series of 3 Aero Design Challenge (ADC) workshops in and around Chennai on 17th & 18th of February then on 2nd & 3rd and on 16th & 17th of March 2018. Student members of SAEINDIA about more than 35 teams each participated at all the 3 locations from various engineering Institutions across India. At all the 3 locations the event was graced by Dr. S. Senthil Kumar, Champion, ADC and Mr. T. Kasiraja, Treasurer, SAEISS where mostly the inauguration of the event and explaining the concepts to the students were made by them. After formal inauguration of the event at all locations the participants were given brief outline about the workshop and there was a talk about the importance of Unmanned Aerial Vehicle (UAV) and Aero Designing Challenge and their roles on societal applications.

They were also explained how the UAVs developed by MIT team are helpful in many real time practical situations for the Tamilnadu police department and National Disaster Response Force (NDRF) India. The participants were inspired after seeing the video taken with the help of UAVs during the flood situation in Chennai and how they saved many lives during that situation. They also emphasised the research opportunities in the field of UAV and its future challenges for constructive applications to the participants. After the explanation of the basics of the event the students were explained about the Engineering Design and Fabrication Process of UAV by the ADC Champions along with 9 Research associates from of Centre for Aerospace Research (CASR), MIT, Chennai.

On the 1st day the students were also taught about propulsion system, avionics systems and control surfaces of UAV.

Students preparing their UAV

Group photo - one of the event

All the participants learned the engineering concepts of aero design of UAV. The students received their kits for making UAV post lunch and started their work on design and fabrication of aero model as per the instruction given by the trainers. All the UAV models designed and fabricated by the teams have been gone through pre-check carried out by the trainers and flyers before the flight test in order to have proper stability requirements.

On the 2nd day all the teams who had completed fabrication of their own UAV models were asked to perform the flight test of their models successfully with the help of trainers and flyers at the designated places. The dynamic performances of the models were depending upon the accuracy in building the aero models. The students were happy as they could understand the fundamentals and design process of the UAV and all their models were flying successfully. They could also be able to understand and appreciate the importance of accuracy and role of each control surface for a successful flight of their models. The host institutions were given memento as a token of appreciation.

What the leaders look forward at FISITA 2018

The 37th edition of FISITA World Automotive is being held in Chennai, India from 2nd to 5th October 2018. This will be the first time that biennial FISITA World Automotive Congress is held in India. The event has aroused a great interest from the Indian automotive industry as this will be allowing them an opportunity to showcase their offering to the global audience at the event. The global leaders in automotive industry who want to reach out to the Indian market have also shown keen interest in participating at the congress. The event is being hosted by SAEINDIA along with support from FISITA. Approximately 350 technical papers are expected to be presented at the congress on the theme “Disruptive Technologies for Affordable and Sustainable Mobility”.

Mr. Arvind Balaji JMD of Lucas TVS has set out his expectation from this event “Disruptive ideas lead to technologies that aid in development of products and services that cater to the implied needs of customers. At TVS, with a large portfolio of products including in electronics and expertise in handling wide range of manufacturing processes due to our multi-product multi-location facilities, Design, Development & Testing capabilities in Automotive domain, we believe we are at an advantage. We are in a good position to understand Customer’s current and future, including electrification, requirements and can support in realizing products in a timely & cost effective manner.”

He further added “We have been practicing Shelf Engineering a method by which we anticipate the needs of the customers we serve and start developing the products before the same are demanded by them. We believe that FISITA 2018 will provide the right platform for TVS Group to identify the disruptors in Automotive Industry across the world and thereby feed us with enough inputs for our product development.”

Mr. Brain McMurray, Vice President – Engineering & Operations of General Motors Technical Centre India (GMTCI) says “We need to get ahead of tomorrow’s technologies today. That is the speed of innovation as we speak. Electrification for cars in India is just one small step of opportunity in this direction. Nevertheless, infinitely significant for our entire ecosystem here in India.

At General Motors, we are always exploring opportunities to enable our employees; encouraging them to become part of networking and technology groups. Our partnership with SAE in India and globally is one such enabler, aimed to foster continuous learning and strengthening the automotive eco-system at large.

GMTCI looks FISITA 2018 as an ideal platform to promote itself as a thought leader in mobility. Over 200 employees have submitted Technical Papers for FISITA 2018 making GMTCI as one of the largest contributors for the event.

The automotive sector is moving away from conventional powertrains and fast becoming the mobility solution space of the future. Tying in with this objective we have the Range Extended Electric Vehicle Competition (REEV) which will be the centerpiece of a national level student competition in India.

The premise of this competition is to help students at Universities put their skills to test, adopt learnings to breathe life into a product and make it commercially viable, all with a futuristic outlook. To help with this engagement, employees of GMTCI and partner companies have been working on a prototype which is set for launch at FISITA 2018. Along-with enabling our employees and partner companies to explore different paths themselves, the prototype will work as a benchmark for students to build their own vehicle.

General Motors is here and now propelling towards the future with an unflinching belief in the future of mobility –Zero Crashes, Zero Emissions and Zero Congestion; –the essence of the FISITA theme for 2018.”

Mr. Mathias Popp, Global VP Testing Services at SGS said “SGS globally serves the automotive industry with more than 6,000 employees. Many of these are members of one of the 37 FISITA member societies, contributing to society by advancing automotive engineering for achieving truly sustainable transportation. SGS’s participation in FISITA World Congress 2018 highlights our commitment to encourage employees to also get involved in automotive engineering research and share knowhow with the community to advance our industry. This year, SGS is a gold sponsor for the event and our engineers contribute two papers addressing current technology & regulatory challenges: 1) ADAS, new challenge for Homologation and Periodical Technical Inspection, 2) Data Mining Applications for Vehicle Testing and Development.

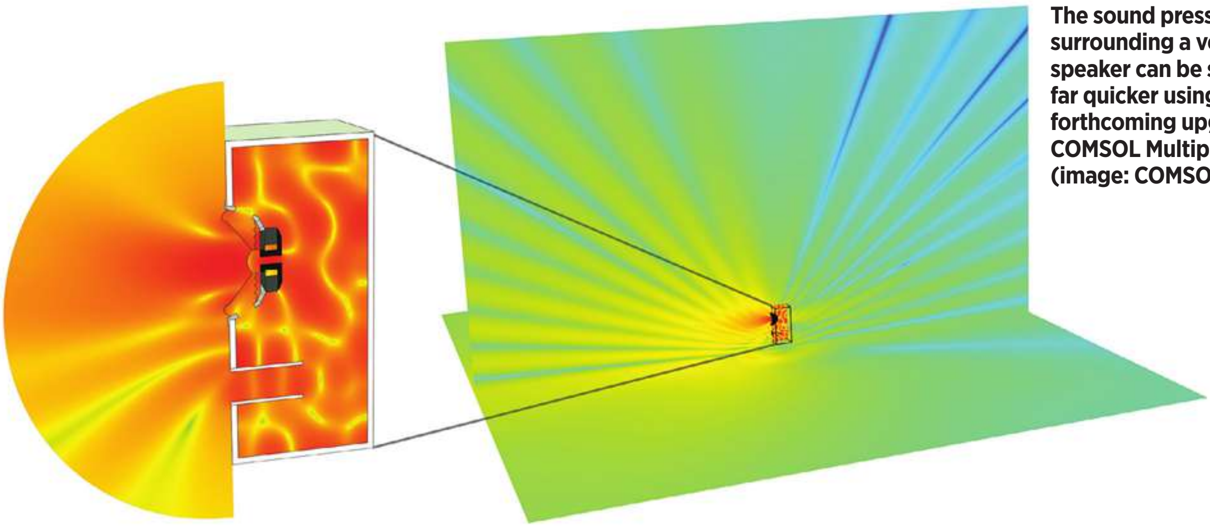
India as this year’s FISITA congress host, has played a major role in SGS’s international automotive testing services network for 10 years. Employing more than 125 engineers and technicians in our transportation laboratories in Chennai, Manesar and Pune, we support the Indian automotive industry with material and component testing and quality assurance services. Please feel free to meet our local and international representatives at Booth #2023.

SGS expects at FISITA Congress a lively discussion and presentation of possible solutions for pressing engineering topics like autonomous driving, data security, emissions control and sustainable automotive transport. Last but not least we expect to network and socialize with our global fellow automotive engineering colleagues.”

For further details on FISITA 2018 drop a mail to fisita2018@saeindia.org.

AUTOMOTIVE SIMULATION

Workhorse multiphysics tool gets upgrades



The sound pressure level surrounding a vented speaker can be simulated far quicker using the forthcoming upgrade of COMSOL Multiphysics. (image: COMSOL)

Engineers are now able to design with far higher precision, making materials thinner and lighter without sacrificing quality and durability. But as they press the limits of technology, engineers must often examine and understand subtle factors that might have been negligible in the past.

Often, these considerations involve multiple disciplines, which can make it difficult to see how changes in one technology will impact performance in other areas. **COMSOL** is finalizing a major upgrade of its Multiphysics multidisciplinary software tool, which let users see how changes in one field of physics impact other fields.

The enhancements come as the company faces increased competition from major CAE tool providers like **Dassault** and **Siemens** that are making acquisitions to build their multidisciplinary capabilities.

COMSOL previewed its Multiphysics 5.3a upgrade at the company's 2017 user conference in Boston. The upgrade, which shipped in late 2017, adds several features requested by users including increased speed. At the conference, CEO Svante Littmarck also spoke openly about bug fixes.

"Our enhancement request list was at 7,000 in 2014, now it's down to 400," Littmarck said. "Also in 2014, we had 4,000 bugs in our bug database. Today, that's down to 100. There are no critical bugs remaining, 90% of them are in corner cases so almost no one comes across them. We have 17 million lines of code."

BEM-FEM reduces run times

The company expanded modeling capabilities based on its hybrid boundary element-finite element (BEM-FEM) method. Magnetostatics was added, as was the ability to perform acoustics and acoustic-structure interactions using BEM-FEM. Given the increasing emphasis on high quality infotainment systems, the enhancement is seen as important for many automotive programs.

"Loudspeaker design involves many disciplines," marketing director Valerio Marra told *Automotive Engineering*. "One person will focus on shock, so they just need mechanical analysis. The next person will look at acoustics, someone else at electromagnetic parameters. It's nice if they can all start at the same point."

The enhanced BEM-FEM offering lets users analyze the full range of acoustic frequencies from the lowest bass notes to ultrasound efficiently, the company claims. Existing tools often focus on high and low frequency. The new offering aims to fill this gap, letting users model the middle ranges using far less computing power and time than alternative tools that don't examine different physics segments simultaneously.

Using BEM-FEM significantly reduces the processing workload, reducing run times. For example, a simulation of a speaker's sound pressure level used models with 125,000 finite elements, 20,000 boundary elements, and 250,000 degrees of freedom. By comparison, an FEM simulation would require 500 million finite elements for the same accuracy. That ability to quickly examine multiple physical elements at once is important in many different fields.

"For a muffler, you can run an acoustic analysis, but performance can change as very hot gases flow through it," Marra said. "If there's any structural deformation, acoustic performance can change. It's easier to analyze those parameters together using a single design tool to replicate what happens in the real world."

He noted that acoustics impact many elements of automotive design. For example, coupling mechanics and acoustics during transmission development lets engineers see how altering one piece of material in the transmission alters the sound. Version 5.3 also helps engineers analyze the performance of batteries.

"An estimation tutorial lets people understand the properties of a battery even if they don't know a lot about the chemistry in the battery," said COMSOL product specialist Rasmus Karlsson. "They can look at the internals of the battery while driving, the state of charge can be monitored for each cell and each electrode. Thermal modeling in 5.3 looks at cooling. If batteries have different temperature gradients, different parts of the battery pack will age at different rates. The program also makes it easier to determine performance with low-temperature starts."

New apps for design analysis

COMSOL, which has focused on multiphysics since 1986, now faces more competition from large engineering tool suppliers that are buying up companies to expand their blended offerings. Siemens spent $10 billion on automation and software companies in recent years, adding **Mentor Graphics** earlier this year. **PTC** and Dassault Systemes have each bought a dozen or more companies this decade.

Speed is a key factor for the multiphysics approach. Littmarck noted that the company's models can be run in far less time than is required by tools that aren't integrated from the outset of design. In Multiphysics 5.3a, performance improvements go up to 40% for algebraic multigrid meshes and 20% faster for geometric multigrid meshes, according to Bjorn Sjodin, Vice President of Product Management.

The Swedish company's cloud service also helps engineers do more analytical work by offloading simulations, the executives claim. Given the time needed for many simulations, that can be a major benefit.

"In the past, I ran simulations on my workstation and I couldn't do anything else while they ran," said Vasudevan Venkateshwaran, a Research Scientist at **W. L. Gore** and Assoc. "Now I put them on the cloud and forget about them until they're finished."

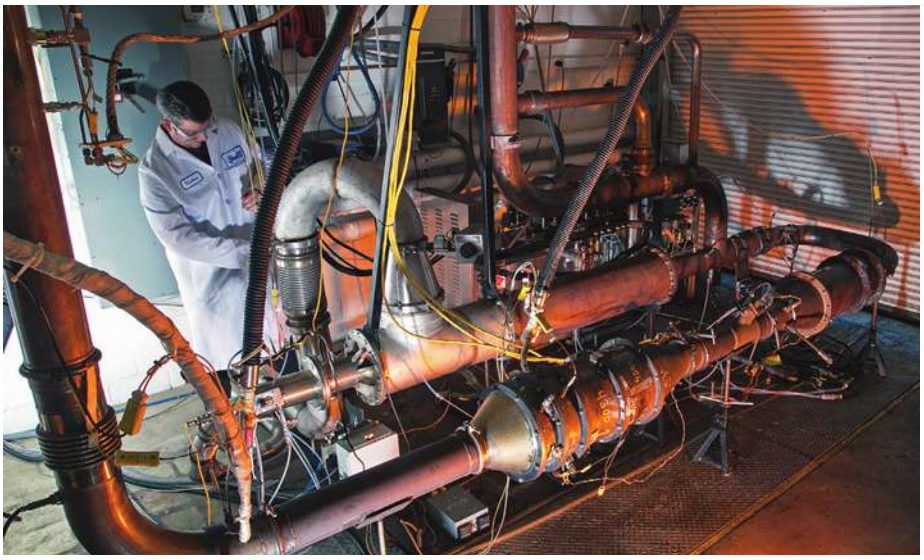
COMSOL is also expanding its offerings, with 150 new materials and 1,300 new material properties in the Material Library product. Shape-memory-alloy materials were added to simplify structural analysis along with more than 60 substrate material properties for RF and microwave analysis.

As designs get more sophisticated, design analysis is becoming so complex that it's common for only one or two engineers to fully understand some aspects of a design challenge. COMSOL has addressed this by letting the subject matter experts create apps that perform some aspects of design analysis. Less-skilled engineers can use these apps to examine tradeoffs in design.

Terry Costlow

COMMERCIAL VEHICLE EMISSIONS

SwRI's ECTO-Lab bridges gap in catalyst and aftertreatment development



ECTO-lab can evaluate the performance of complete aftertreatment systems, as well as individual components. (image: Southwest Research Institute)

Due to regulations requiring reduced pollutant emissions and fuel consumption, engines and emission control systems are becoming increasingly complex. At the same time, consumers are demanding reduced cost and increased product reliability and robustness. The combination of these challenges has vastly expanded the level of effort required to bring new engine systems to market. Product development cycles have increased, and so have the costs associated with them.

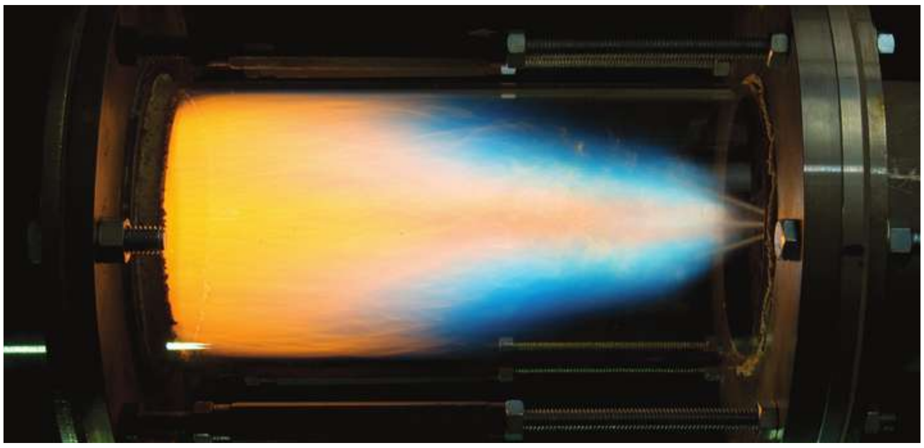
Southwest Research Institute's Powertrain Engineering Division is developing new tools and techniques that enable suppliers and OEMs to streamline development and evaluation of their powertrain solutions. SwRI's Exhaust Composition Transient Operation Laboratory (ECTO-Lab) is a computer-controlled, multi-fueled, burner-based continuous flow reactor system designed to duplicate the exhaust conditions from internal combustion engines. It is a transient, full-size reactor system. Unlike typical small-core gas reactor benches, which use bottled gas to simulate exhaust conditions, the ECTO-LAB produces a continuous exhaust flow through combustion of fuels and compounds, producing an exhaust gas composition that accurately and precisely duplicates the array of gaseous species created from the combustion of diesel fuel in an engine. The exhaust gas conditions are generated through independent, model-based control and allow any combination of mass flow, temperature, particulate mass (PM) emission, HC concentration and speciation, NOx, CO, H_2O and O_2 concentration within its window of operation.

ECTO-Lab accommodates full-sized catalysts from light-duty gasoline engines to large, heavy-duty diesel and natural gas engines. SwRI maintains several ECTO-Lab facilities at its San Antonio headquarters for contracted use, and the technology is also available for installation at client facilities.

Evaluating full-size aftertreatment systems

The ECTO-Lab system was created to fill a critical technical gap in the catalyst and aftertreatment development area. Prior to its development, OEMs and suppliers relied on small, pilot scale synthetic gas benches for fundamental catalyst testing. While these synthetic gas benches are useful since they provide full control over the gas stream composition (which enables the elucidation of fundamental catalyst behaviors and reaction mechanisms) they are limited by their ability to evaluate the performance of full-size after-

The ECTO-Lab combustor section is cooled using dilution air and nitrogen which controls gas temperature and exhaust oxygen concentration while also providing the cooling necessary to maintain integrity of the burner assembly. (image: Southwest Research Institute)



SwRI engineers utilized CFD simulation tools as well as combustion visualization techniques to optimize the combustion process for the ECTO-Lab system. (image: Southwest Research Institute)

treatment systems. The ability to quantify the performance of full-size components is necessary because of the three-dimensional impact of flow distribution and reductant distribution which exists in a full-size aftertreatment. In addition to the 3-D flow effects, synthetic gas benches are also limited by their ability to replicate the transient behavior of gas flows, system

The water-cooled ECTO-Lab system is capable of simulating the lean and rich operating environment encountered on light-duty applications which utilize three-way catalysts and lean NOx traps. (image: Southwest Research Institute)

warm-up, and heat transfer effects.

Due to these limitations, synthetic gas benches have typically been reserved for catalyst research and benchmarking, as well as quantifying mechanistic and kinetic behavior such as catalyst deactivation, poisoning, etc. The majority of catalyst and aftertreatment system development utilizes engine-based test stands to capture these 3-D and transient effects which are not possible with pilot scale synthetic gas benches. While these test stands are useful, they are constrained by practical limitations which require OEMs and suppliers to make judgment calls with incomplete datasets.

These practical limitations include: constrained exhaust gas temperature and flow rate, no independent control of NOx, PM, HC, etc.; reliability and durability issues associated with use of an engine, limited cold-start tests due to requirement of engine cool-down, high fuel cost for generation of exhaust gas, etc. Many of these practical limitations impede the development of fully optimized engine and emission control systems. The development of SwRI's ECTO-Lab system addresses many of these limitations, by making use of more than a dozen SwRI-held patents to allow for the evaluation of full-size aftertreatment components and emission control systems.

The ECTO-Lab system is a universal engine exhaust gas simulator in that it can control the exhaust gas composition for a variety of internal combustion engines. The current system is capable of simulating exhaust gas flow rates as low as 10 kg/hr and as high as 3250 kg/hr, which equates to engine displacements of approximately 1.5 L to 20 L. It also can replicate cold-start conditions down to room temperature, but can operate with exhaust gas temperatures more than 1100°C (2012°F) to rapidly accelerate hydrothermal aging of catalyst components. In addition, the system is capable of controlling O2 concentration from 0-15%, NOx emissions from 0-1200 ppm, and HC emissions from 0-10,000+ ppm.

One-of-a-kind burner system

The heart of the ECTO-Lab system is an in-house developed stoichiometric burner system which generates the thermal energy for catalyst evaluation. This burner has been refined over the past 20 years to provide controlled combustion of gasoline, diesel, natural gas, and propane fuels. The combustor provides primary control of the exhaust gas temperature and provides an intermediate level of control for exhaust gas components such as H_2O, CO, and O_2. Since the combustor is a stoichiometric, atmospheric combustor, it generates little to no NOx emissions—a benefit that allows more independent control of exhaust gas composition than an engine-based test system.

In addition to the combustion of HC fuels, the combustor system is also used to decompose nitrogen containing fuel components. It's the thermal decomposition/oxidation of these nitrogen-containing compounds that provide independent and controllable generation of NOx emissions. This independent control of NOx emissions is one of the most beneficial capabilities of the ECTO-Lab system for diesel and lean-burn aftertreatment system development. It can be operated as an engine exhaust simulator, or as a synthetic gas bench, therefore providing a technology which bridges the current gap in catalyst testing capability.

Two of the other critical items in the ECTO-Lab system are the water-to-air heat exchanger and dilution system. Both technologies enable independent control of temperature and O_2 concentration in the exhaust gas stream. The water-to-air heat exchanger system allows operation at stoichiometric or fuel rich operating conditions, while still being capable of independent temperature control. This capability is a necessity for aging and evaluation of aftertreatment components that are subject to stoichiometric or fuel rich exhaust streams, such as three-way catalysts (TWC) and lean NOx traps (LNT).

The dilution system, which provides fresh air and/or nitrogen to the exhaust gas stream, is used when the desired exhaust gas stream represents a lean-burn combustion application. The dilution system provides a means for independent control of O_2 concentration and exhaust gas temperature. The combination of both the water-to-air heat exchanger and the dilution system enable the ECTO-Lab to independently control the temperature of the exhaust gas stream and excess oxygen for both conventional spark-ignited stoichiometric engines and compression-ignited lean-burn engines.

HC speciation control a recent development

One of the most recent advancements on the ECTO-Lab system is the ability to control the concentration as well as speciation of HCs present in the exhaust gas stream. This capability is of increasing interest for light-duty applications, where HC emissions are as stringently regulated as NOx emissions. The control of the HC speciation profile is important because HC components have varying levels of reactivity depending on the specific structure of the HC. To accurately quantify the performance of emission control devices, it is imperative that the component or system be tested in an exhaust gas stream that represents the intended application.

In a synthetic gas bench, the HC mixture is simplified to one or two components because of practical limitations.

SwRI's newest ECTO-Lab system is capable of producing exhaust streams with flow rates of up to 3250 kg/hr. (image: Southwest Research Institute)

For the engine test bench, the HC mixture is complex, but is typically constrained by the choice of engine hardware and/or operating condition. With the ECTO-Lab system, complex HC mixtures are easily controlled so the impact of these complex profiles on catalyst performance can be quantified. The techniques used allow for speciation control with all HC fuels, including diesel and gasoline.

While these individual modules provide a significant level of capability for exhaust gas composition, the system would be of little use if these conditions were not controlled accurately and precisely. A robust control strategy is required to replicate the complex and highly transient emission profiles from internal combustion engines. To solve this challenge, SwRI engineers looked to their successes in the control of internal combustion engines and development of model-based sliding mode controllers for precise control of advanced combustion modes. Given the similarities in the control requirements for the ECTO-Lab system, this model-based controller was adopted for this purpose. The result is a highly transient, highly reproducible system which can replicate the exhaust gas conditions for many different engines.

The greatest benefit of using the sliding mode control system is the ability to replicate the emission profiles of engines operated in highly transient drive cycles like those encountered for the light-duty and heavy-duty federal transient protocol (FTP-75 and HD-FTP). The transient capability allows the ECTO-Lab to be more than just a full-size synthetic gas bench. With this transient capability, the system can be used not just for fundamental full-size aftertreatment testing, but also for the development of aftertreatment system controls.

One of the biggest challenges encountered with increasing stringency of emission regulations is emission control system cold-start strategy development. With a conventional engine-based test cell, the engine and aftertreatment system must be cold-soaked for eight hours prior to a cold-start test. With the ECTO-Lab system, there is no engine, which means only the aftertreatment system must cool down. SwRI has developed rapid cool-down strategies, which allow for a cold-start test to be conducted every hour. This allows for an increase of calibration throughput by a factor of eight, leading to reduced development timelines and/or improved controls.

Cary Henry, Ph.D., Assistant Director of Diesel Engine and Emissions R&D at Southwest Research Institute, wrote this article for *Truck & Off-Highway Engineering.*

COMMERCIAL VEHICLE CYBERSECURITY

Hackers aim to exploit vulnerabilities in CVs, pushing security to the forefront

Encryption and firewalls are some of the techniques TTControl builds into its controllers. (image: TTControl)

Commercial vehicles are coming into the sights of hackers who have succeeded in attacking governments and corporations. Cyber-criminals hope to exploit vulnerabilities in connected trucks and off-highway vehicles with the aim of wreaking havoc or extorting funds from vehicle owners or equipment makers.

Now that most commercial vehicles are connected, protecting them from attackers with multiple layers to provide defense in depth is becoming a necessity. On the bright side, system developers and OEMs who haven't had to worry about cyber attacks until recently can leverage the efforts of industries that have been battling hackers for years.

Those efforts are widespread. SAE International focused on best practices in its SAE J3061 standard. Groups like the National Science Foundation have sponsored a number of projects. Microsoft recently joined other companies calling for the U.S. to establish a single national cybersecurity agency.

These efforts are augmented by security-related developments from a diverse group of companies including Harman, Blackberry and Argus Cyber Security, which was purchased by Continental last year.

Most experts note that security needs to be designed in at every level, from semiconductors up to complete vehicles. That will provide defense in depth, which helps prevent hackers from penetrating deeply enough to take control of a system or vehicle.

"Security is a supply chain problem," said Peter Brown, Chief Automotive Architect at Wind River Systems. "Companies have to have a layered architecture. If somebody breaks through one layer, they find that they have to break through another, then another."

Those layers span a range of technologies. Most experts feel that security needs to be designed in from the start of a project. It's more difficult to add complex, multifaceted security techniques to existing vehicle designs. That's because many hardware and software layers come from a range of suppliers, addressing many levels of vehicle design.

"Attacks must be prevented by strong encryption technology in the communication links," said Jose Ogara, Product Manager at TTControl. "Additionally, connections should not transverse public internet using private access point names. At the vehicle level the gateway should never open ports or services to the internet, and a firewall should always be present. Security is an architectural issue at the vehicle level, and additional measures such as signed codes should also be considered."

Many security specialists note that the need for a broad-based security architecture requires support from the CEO level down through design and manufacturing personnel. If not, security's likely to be pushed aside when harried developers try to avoid cost overruns or missed deadlines.

"Leadership must lead," said Bryson Bort, CEO at Scythe, a data-security startup. "If there's not a focus on security

VisionLink analyzes data and creates reports based on user preferences. The software allows password log-in and provides secure access to the customer. (image: Caterpillar)

coming from the top of the company, nothing's going to change."

Some connected vehicles have been protected because connections were largely proprietary, so hackers ignored them to attack easier targets. But the shift to join the Internet of Things and leverage existing communications tools and technologies has changed that. Connected vehicles usually have hardware and software produced by a range of Tier 1s and other suppliers, so open architectures are becoming the norm.

"We see the need for open platforms," said Sanjay Ravi, Managing Director Automotive at Microsoft Cloud Services. "Open application programming interfaces make it possible to include several players, from startups to very large automotive companies."

The move toward openness extends to development tools. Many design teams gravitate toward open source software like Linux. Software modules found in these libraries have been tested by scores of engineers, so many of their vulnerabilities have been discovered and fixed.

"Open source initiatives could give a positive contribution to security thanks to a shared collaborative framework and wide-open review process," said Maddelena Brattoli, Software Design Manager at STMicroelectronics. "Platform security is generally designed independently from the operating system. This approach guarantees the availability of the fundamental hardware building blocks like true random number generators, cryptographic hardware, physical isolation, secure boot process that customers can leverage in the operating system or application with a limited effort and via standard API."

Once all these plans have been put in place, equipment operators may be asked to join in the security effort. Owners can decide if they want to use passwords or other schemes that identify who's logging in. This step prevents unauthorized use and lets companies set different levels of access for operators and maintenance technicians.

"Who can access the data and how they access the data are important," said Jason Hurdis, Global Market Professional, Caterpillar Inc. "VisionLink software allows password log-in and provides secure access to the customer."

Terry Costlow

AUTOMOTIVE INTERIORS

Autonomous vehicle cabins depart from traditional interior designs

As in-vehicle connectivity and electrified powertrains usher in the autonomous driving age, designers envision new looks for vehicle interiors.

The stage-setter for cabin makeovers is the automotive industry's rapid acceleration toward an electrified-vehicle portfolio. As more battery-electric vehicles enter the marketplace with the rechargeable battery packs housed underneath the cabin floor, the door opens to a new era of interiors.

"A flat cabin floor will give us a lot more leeway to do more creative things within the car space," Richard Chung, Vice President of Innovation & Design for Adient, an independent company after a 2016 spinoff from Johnson Controls. Chung spoke with *Automotive Engineering* at the 2018 North American International Auto Show (NAIAS) in Detroit.

While internal combustion engine-powered cars won't disappear from mainstream offerings anytime soon, electrified vehicles are charging automakers' long-term plans. In the same month as the 2018 NAIAS, Ford and Nissan had major announcements about their electrified vehicle product plans.

Ford will extend its electrified vehicle line-up to 40 vehicles globally, including 16 full battery vehicles by 2022 as part of an $11 billion-plus electrification investment. Nissan's luxury brand Infiniti will offer electrified powertrains starting in 2021, including the launch of the brand's first pure electric vehicle that same year. Electrified vehicles will comprise more than half of **Infiniti**'s global sales by 2025.

Infiniti's Q Inspiration concept, unveiled at 2018 NAIAS, features the automaker's production-ready variable compression ratio engine and the Nissan-developed ProPILOT semi-autonomous driving system. The minimalist design of the concept's interior provides roominess with a punctuation on the occupants' experience, according to Alfonso Albaisa, Senior Vice President of Global Design, Nissan Motor Co., Ltd.. Albaisa said designers have a wide latitude to express their "artistry in the age of autonomy, connectivity, and break-

Adient's latest AI18 concept interior aimed at autonomous vehicles shown in 'lounge mode' (top) and 'conversation mode.' (image: Adient)

through powertrains."

With the progression toward shift-by-wire and steer-by-wire technologies, interior planners will no longer have to design around the powertrain tunnel. In short, a flat cabin floor devoid of a powertrain hump will bring about re-configured interior environments.

Adient's newest interior concept, the AI18, features five different seating modes for SAE Level 3 and 4 autonomous driving. The seat supplier developed the AI18 based on findings from its proprietary studies of customers' seating needs for 2030 and beyond.

AI18's family mode is the closest to today's conventional vehicle cabin with two forward-facing front seats and a rear bench seat. In the baby-plus mode, front seats rotate 180-degrees from the driving direction so parents can engage with their children while traveling. An integrated ISOFIX restraint system attaches a child seat to the rear seat.

In the AI18's cargo mode, the rear seat cushion retracts into the cargo bay via an electric mechanism to provide additional stow space behind the front seats. In the communication mode, front seats rotate toward each other. To accomplish this seat movement, Adient engineers are developing a seating platform that lifts, enabling the seats to turn within a compact interior space. This innovative upward kinematics movement of the

The concept Q Inspiration's cabin is packaged within a sedan that has coupe-like proportions. (image: Infiniti)

seating platform occurs with the person in the seat, which Adient claims is an industry-first.

Lounge mode accents comfort as the front seats anthropometric pivot enables a recline beyond today's normal range. The seat's headrest, integrated armrests and leg support are synchronized to move with the occupant. Front-row seatbelts are part of the seat structure instead of being integrated into the B-pillar, as is today's practice.

"What we see in the future is that the seating is going to be the center of everything," Chung said, stressing the importance of offering easily modified seating modes in a driverless vehicle. "The term 'driver' will eventually disappear. Everybody will be a rider, all equal," he said.

In future ride-sharing autonomous driving scenarios, a vehicle's cabin materials probably won't be vastly different from today's touchstones. Metal-based and petroleum-based materials are expected to retain heavy usage, but some of the usage locales will differ from today's interior landscape

"On Adient's AI17 concept last year, we used a plastic mesh to replace the seat foam," Chung said. The plastic pad reduced the seat thickness by approximately 3 in (76 mm) and saved weight. Plastic is a realistic alternative to foam, according to Chung, as it provides elasticity and structural integrity. "We're probably the biggest supplier of foam pad for seat makers, but we also realize that we have to think about the next step," said Chung.

While today's vehicles have occupants of all sizes and shapes repeatedly getting into and out of seats, an era flush with autonomously driven vehicles raises the durability bar. "We foresee stronger materials being needed, especially in the ride-sharing scenarios," Chung said, pointing to the AI18's unique seat cover, Monofil. "It's very similar to a fishing line's durability and strength, but it's actually a woven fabric," Chang said of the under-development material.

Beyond the comfort and durability aspects, seats in a self-driving vehicle will have multiple functions. "The key thing is the connectivity that can happen through the seat, such as telehealth," Chung said. AI18's seats contain sensors that capture a person's body position and pressure points, and that information forms the basis of an intelligent comfort assistant. Seat-concealed sensors could also be used to monitor an occupant's vital signs, such as pulse and heart rates.

"We're showing the vision of a telehealth scenario because we view it as something that's completely viable in-vehicle in the future," Chung said.

From a safety standpoint, each seat inside an autonomously driven vehicle likely will be linked to all vehicle safety systems. Adient and automotive safety supplier **Autoliv** recently announced a strategic partnership to develop solutions for passenger safety regardless of the seat's position.

Kami Buchholz

AUTOMOTIVE PROPULSION

Cadillac unveils all-new V8

In the latest signal that automakers aren't shutting off investment in internal-combustion just yet, General Motors' Cadillac premium-vehicle brand unwrapped an all-new V8 roughly four years in the making. Cadillac will begin with exclusive use of the twin-turbocharged 4.2-L DOHC V8 starting in the first half of 2019 with a high-performance V-Sport variant of the CT6 flagship sedan—but it's easy to speculate the V8 could be earmarked for future use by at least one other important GM model.

Revealing the new V8 architecture to a small media group, Jordan Lee, chief engineer for Cadillac V8 engines, said the engine is intended to underscore the Cadillac brand's exclusivity and performance heritage and deliver an appropriate blend of high performance and refinement. The updated 2019 CT6 lineup will offer two variants of the new V8: a high-output version for the V-Sport model that generates an estimated 550 hp at 5,700 rpm and peak torque of 627 lb·ft (850 N·m) from 3,200-4,000 rpm.

The standard variant of the all-aluminum V8 is projected to produce 500 hp at 5,000-5,200 rpm and 553 lb·ft (700 N·m) from 2,600-4,600 rpm. Assistant chief engineer John Rydzewski said premium-unleaded fuel is required to achieve those output figures. The direct injection system operates at 5,076-psi (345-bar) and compression ratio is 9.8:1. Engineers told *Automotive Engineering* that the comparatively high pressure of the DI system meant they could forego the current trend of coupling direct- and port-injection fueling systems.

The "Hot V" difference

Perhaps the new 4.2-L V8's signature design feature is "reverse" porting that sees the exhaust ports on the inside of the engine's 90-degree vee, with intake charge entering the cylinders from ports on the outside of the vee.

This is not a first for production-vehicle V8s, but the Cadillac engine takes the concept to a new extreme, locating not only both twin-scroll turbochargers in the engine vee (as integral parts of each exhaust manifold), but also the single-volume catalytic converters, bringing a new

Cadillac unveils an all-new 4.2-L V8 for the 2019 CT6 lineup. The twin-turbocharged DOHC V8 develops an SAE-rated 550 hp and 627 lb·ft for the performance-oriented V-Sport version of the CT6. (image: GM)

definition to the term "close-coupled" in relation to the catalysts. The catalytic converters, drilled for inclusion of an oxygen sensor, literally sit atop the engine and all but inside its valley. Once the exhaust leaves the converter, there are no other components or restrictions on the route to the dual exhaust tips at the rear bumper.

Rydzewski said the "Hot V" design is "the most effective way to optimize the turbo responsiveness of the system."

The compact twin-scroll turbochargers are supplied by Mitsubishi Heavy Industries (MHI) and feature electronic wastegate control; the titanium-aluminide turbines can spin at up to 170,000 rpm and are half the weight of a similar design in Inconel material, GM said. Maximum boost pressure is 20 psi (1.4 bar) and the air-to-liquid intercooler design can reject up to 20 kW of heat per cylinder bank, dropping intake-charge temperature by as much as 130°F (74°C), Cadillac said.

Extracting the immense heat developed in the engine vee was one of the most challenging aspects of the new V8's development, added Lee. He said the clean-sheet design allowed new thermal-management solutions to assure the V8 maintains acceptable temperatures, particularly after the engine is shut down and the turbochargers and catalysts retain immense amounts of heat. Lee said the single front cooling fan continues to circulate ambient air over and around the engine, while the variable-flow water pump also circulates coolant for whatever time is required after engine shut-down.

Compact packaging

With cylinder bores just 10 mm (0.4 in) apart, Cadillac's new V8 packages its 4.2 liters of displacement in a footprint that's about 50 mm (2 in) shorter than usual, said Lee. Bore is 86 mm and stroke is 90.2 mm; Lee said the tight spacing between bores did not dictate a limitation on bore size.

The V8's 6-bolt main-bearing cylinder block is A319 alloy with pressed-in iron liners. The cylinder heads are Rotocast-supplied 356 aluminum, with 36 mm intake valves and sodium-filled 29-mm exhaust valves. The crankshaft is forged steel, as are the connecting rods.

Fuel-saving measures

Performance and refinement were paramount design targets for the 4.2-L V8, but the architecture includes several fuel-saving technologies.

Most significant is Active Fuel Management in its first use for a GM-made DOHC V8. The setup operates the engine in 4-cyl. mode when appropriate, shutting down the outboard two cylinders of one bank and the inner two cylinders of the other engine bank. The variable valve timing allows for 55 deg of authority for exhaust valves and 70 deg of authority for intake. This and other engine-operating parameters are governed by a new E86 engine-management controller.

The new engine also incorporates start-stop for increased fuel saving, although Lee said it remains too early to

The new Cadillac V8's signature design feature is its "Hot V" configuration that sees exhaust exiting the cylinders on the inside of the engine "valley" and driving directly into a close-coupled turbocharger and emissions catalyst for each cylinder bank. (image: GM)

Cutaway of all-new Cadillac V8 shows unique packaging of close-coupled catalytic converter in the engine vee area. (image: Bill Visnic)

release projected fuel-economy figures.

For the 2019 CT6, either variant of the new V8 will be coupled with the GM Hydra-Matic 10-speed automatic transmission with GM's Performance Algorithm Shifting/Performance Algorithm Liftfoot (PAS/PAL) and steering-wheel paddle shift control. An electronic console selector frees interior space by eliminating mechanical linkages.

Additionally, the CT6 applications will include all-wheel-drive as standard fitment with the new V8. The AWD transfer case is mounted integrally with the engine's cast-aluminum oil pan.

Hand-made in Kentucky

Cadillac's new 4.2-L V8 will be hand-assembled at GM's Performance Build Center in Bowling Green, Kentucky. This is the site of assembly for **Chevrolet**'s Corvette and certain hand-built engines for that model.

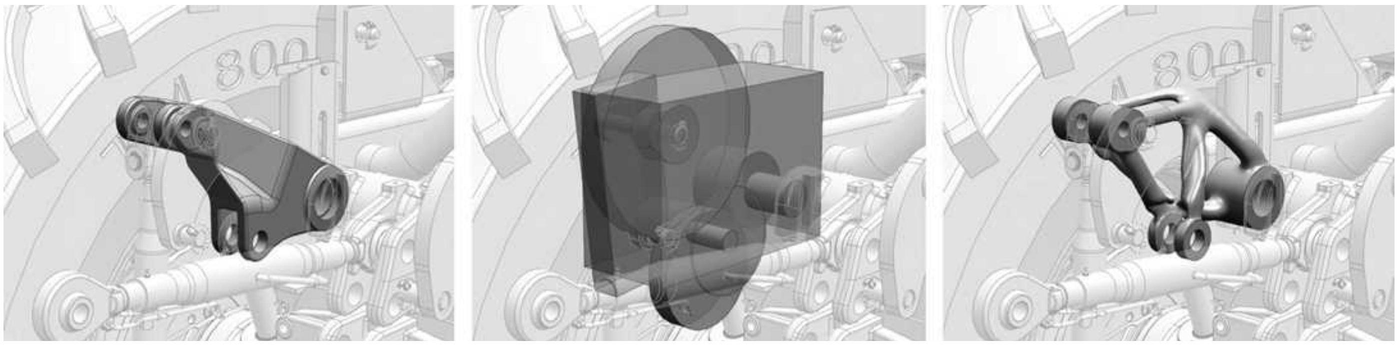
It has long been alleged that the next-generation Corvette could be powered by a new V8 engine—other than its longstanding small-block OHV V8—in addition to the possibility of either adding or wholly moving to an advanced mid-engine vehicle architecture. With the obvious power and torque "headroom" of the new Cadillac V8 and its new assembly location in the same plant where the Corvette and special Corvette engines are built, many will find it logical to speculate that Cadillac's new V8 architecture is foreshadowing its eventual use for the Corvette—or other Cadillac models.

The company's powertrain engineers of course aren't directly addressing that speculation, but Lee didn't exactly throw cold water when telling the media that the new Cadillac V8 "could be the basis for a lot of other things going forward."

Bill Visnic

COMMERCIAL VEHICLE SIMULATION

Generative design software exploits AI to change how new vehicles, equipment are designed



Siemens NX Topology Optimization for Designers creates design alternatives for an agriculture machine component. The originally designed component (left) is replaced with a set of volumes that define the design space. Functional loads and constraints are defined including design for manufacture such as 3D printing, casting or machining. Additional design goals are set such as mass material reduction to arrive at an optimum form (right) that suits the various requirements. (image: Siemens PLM)

What if a computer program could create a design for you?

As computers get more powerful and algorithms more clever, design software is now generating potential solutions rather than simply evaluating designs proposed by humans. In fact, today's generative design tools can offer hundreds, even thousands, of alternatives for a human engineer to evaluate.

Aids to design efficiency are becoming increasingly critical. The set of constraints and requirements for off-highway equipment, heavy-duty trucks, and light vehicles is growing enormously. Requirements are often conflicting, forcing engineers to think of trade-offs between say, fuel economy and safety. Cabin comfort and mass. Design complexity versus manufacturing cost. It is becoming more than a human can handle.

"Generative design for us is a way to use the power of computing algorithms to evaluate and iterate on these often-conflicting requirements. Requirements that often span not only engineering, but materials and manufacturing requirements as well," explained Tod Parrella, NX Design Product Manager for **Siemens PLM**.

Level of focus – systems vs. parts

Tools that Siemens offers iterate on designs to explore all possible solutions, according to Parrella, based on requirements and constraints. The human engineer then chooses the most optimal design. "The engineer becomes more the requirements driver, and the algorithms and software help derive the optimum product form based on those inputs and requirements," he said.

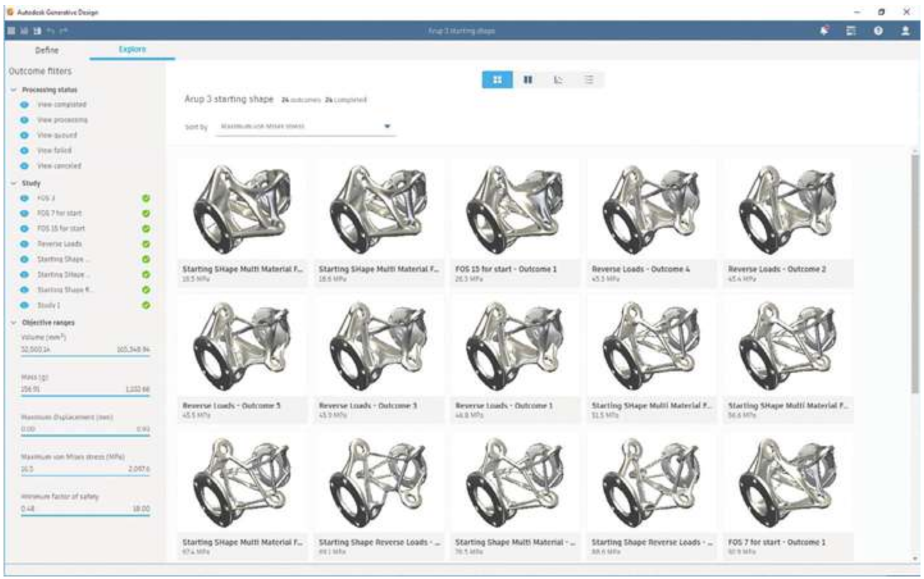
In the briefest of summaries, generative design tools rely on CAE simulation to evaluate successive designs against performance requirements. There are many variations on that theme, two of which Siemens offers—Topology Optimization and Multivariate Design Optimization.

Topology Optimization tries to find the best shape for a part, typically to minimize stress and strain hot spots in response to loads, while also minimizing weight and mass. Brackets, door hinges, or crane booms are examples of parts designed through topology optimization, often resulting in organic looking designs. While noting that this technique is especially useful in designing parts for additive manufacturing, it is just as useful for traditional manufacturing techniques. According to Parrella, Siemens can accept manufacturing constraints as well to ensure a design is say, castable or machineable.

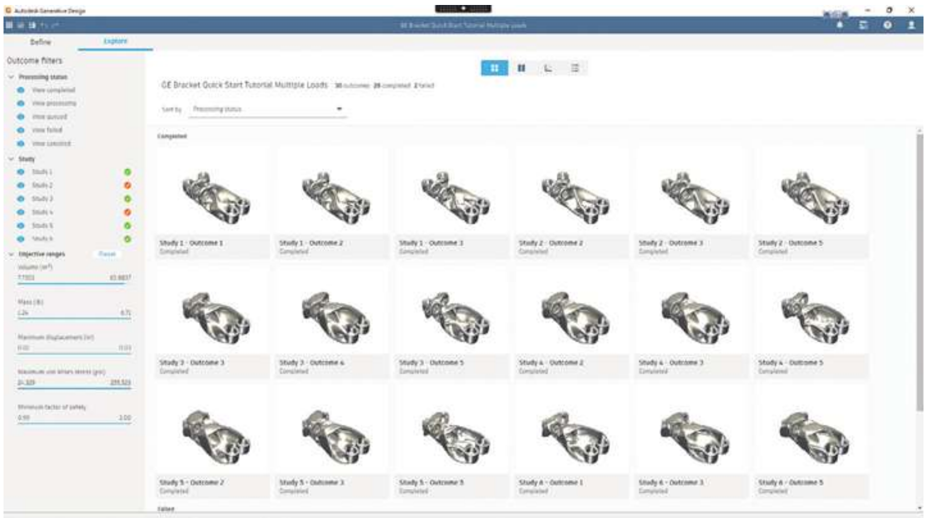
"We offer two versions of this, one for the designer or engineer who needs tools that are well integrated into the CAD environment and another for more advanced uses. The advanced is integrated into the simulation environment offering much more flexibility and analysis types," he said.

Multivariate Design Optimization explores a design space that includes many different variables. It is much broader than topology optimization and can holistically derive system solutions even up to and including vehicles. Siemens offers its HEEDS platform multivariate design simulation, which provides solutions using any number of

Convergent Modeling from Siemens makes it possible to reuse the mesh generated result from Topology Optimization in the context of the design without reverse engineering. Feature modeling operations that further refine and detail the design are easily incorporated. (image: Siemens PLM)



Autodesk Generative Design runs artificial intelligence-based algorithms to produce a wide range of design alternatives, many more than a human engineer can produce economically. (image: autodesk)



Complex load-bearing parts, including but not limited to brackets and supports as shown here, are especially ripe for Generative Design techniques. (image: autodesk)

simulation tools, including third-party simulations or a customer's own.

A typical use in the commercial-vehicle domain is using these tools to optimize the design of large chassis components. "They are not necessarily optimizing for the lightest weight design, but want to minimize mass and material, while maximizing strength," he said. "Generative design is making possible the ability to realize new designs that would never have been imagined without it."

According to Parrella, it is making possible the ability to evaluate many more design alternatives than humanly possible, offering more complete designs that account for multi-disciplinary requirements and constraints.

Artificial intelligence and cloud data storage

Autodesk is another company advancing new tools for generative design. It offers two tools of special interest to off-highway and vehicle designers: Fusion 360 for general topology optimization, and Netfabb for lattice and surface optimization, especially tuned for the needs of additive manufacturing designers.

"While we offer those tools, it is important to note that generative design is not just topology optimization," stressed Doug Kenik, product manager for Autodesk. "It is software that helps designers solve problems in balancing requirements for both business and performance, as well as materials and process."

That is where Autodesk Generative Design enters the picture. It runs artificial intelligence-based algorithms to produce a wide range of design alternatives, according to Kenik.

"It is currently in a beta release and we are getting feedback on it right now," he said. Without revealing too many specifics, he did share that AI techniques like Deep Learning, and possibly Convolutional Neural Nets, can be leveraged in such a system.

But, according to Kenik, the algorithms are not as important as the data. Importantly, he ties AI design with cloud data storage. "Data is the key, that is when AI becomes feasible," he stated. "Generative design techniques can now produce tremendous amounts of data, which you can store in the Cloud."

Autodesk Generative Design alone could generate thousands of design options, based on a single set of requirements and constraints. That is why Autodesk is keen on cloud computing and data storage, since it is fast becoming the lowest-cost option for many companies.

The advent of cloud computing and generative design is an unstoppable force, according to Kenik. It needs attention from the engineering community. AI is currently making itself known as applied to social issues, like identifying human faces and interpreting natural language.

"There is so much opportunity there to make the engineering process and design process go so much smoother," he said.

AI could jumpstart a paradigm shift in design, changing how engineers interact with computers and design software. "Instead of simply acting as a repository for easy access to designs, let the system work with us in generating these designs," he said.

He offers cautions for the future: "If you're not looking at it right now from an engineering and design standpoint, there could come a time—perhaps soon—when your competition, using these tools, will have a leg up on you."

Bruce Morey

AUTOMOTIVE PROPULSION

Achates Power OP engine begins real-world test phase

Achates Power's 2.7-L opposed-piston engine installed in an F-150 demonstrator on display at the 2018 NAIAS. (image: Matt Borst)

The Achates 3-cylinder OP engine features two crankshafts. Each cylinder set employs two pistons, sharing a common combustion chamber. A turbocharger and supercharger combine to create the pressure differential in the cylinder. (image: Matt Borst)

In 2016, Achates Power received a $9 million award from the U.S. Dept. of Energy's ARPA-E program to develop its opposed-piston gasoline compression ignition (OPGCI) engine. Through Achates' recently-announced partnership with Aramco, the engine has entered the in-vehicle development phase and is now fitted to Ford F-150 demonstrators, revealed at the 2018 North American International Auto Show.

The OP design aims to achieve fuel economy levels beyond regulatory requirements with lower emissions and cost, compared with current production engines.

The 2.7-L, 3-cylinder engine (see February 2017 AE cover story: http://www.nxtbook.com/nxtbooks/sae/17AUTP02/index.php#/0) has undergone minor updates in recent months to make it more production-ready. The combustion chamber was further refined, through partnerships with Delphi and Argonne National Laboratory, and compression ratio was increased from 16:1 to 18.5:1 to achieve indicated thermal efficiencies (ITE) above 50%.

"We chose to demonstrate our ultra-clean, ultra-efficient OP engine in a full-size light-duty pickup truck because of the significant need and opportunity for improvement in this segment," said David Johnson, president and CEO of the San Diego-based company. "These trucks are driven more miles, sold in higher volume, consume more fuel and emit more CO_2 than other light duty vehicles."

In the F-150, the Achates engine is expected to achieve a combined 37 mpg on pump gasoline—4 mpg better than the proposed 2025 CAFE regulations—and deliver 270 hp (201 kW) and 480 lb·ft (650 N·m). Those fuel economy, power and torque numbers are superior to those produced by Ford's new 3.0-L V6 diesel that will be available in the 2018 F-150.

Energy giant Aramco, which has analyzed dozens of engine/fuel technologies at its Novi, Michigan, research and test facility since 2015, saw great potential in the Achates engine for demonstrating real-world engine efficiency improvements, noted David Cleary, the Research Center Leader. "We are big believers of testing engines on dynos and looking at the numbers," he told *Automotive Engineering*, "but we are even bigger believers in getting in the car and driving them."

The GCI engine has true compression ignition; there is no spark-plug assistance like that employed in Mazda's SpCCI system (see October 2017 *AE* cover story, http://www.nxtbook.com/nxtbooks/sae/17AUTP10/index.php#/). The Achates OPGCI injects fuel early in the compression cycle for a lean mixture, with incoming air and residual exhaust that is purposefully left in the cylinder. Then, ignition is initiated by injection of the gas just like on a diesel engine. The turbocharger and supercharger provide the pressure differential in the cylinder.

With this higher combustion efficiency comes reduced engine-out emissions, reduced aftertreatment requirements and improved cold-start-emissions, the engineers claim. Johnson and his team believe that along with an average 60% reduction in overall bill-of-material, their GCI engine achieves a 10% cost savings over a comparable supercharged V-6.

Achates Power is currently putting its OP-engine demo vehicles in customer hands. Watch *Automotive Engineering* for program updates and an on-road driving report later this year.

Matthew Borst

AUTOMOTIVE MATERIALS

GM turns to carbon fiber for 2019 GMC Sierra pickup bed

Exploded image shows the materials mix used in GM's new carbon fiber composite cargo bed on the 2019 GMC Sierra Denali.

Steel truck beds. Aluminum truck beds. The battle to create the lightest, strongest pickup cargo bed intensifies yet again, as carbon fiber debuts as the bed material for the 2019 GMC Sierra Denali.

"This is a revolutionary application on the next-generation Sierra," said Mark Voss, General Motors' engineering group manager for pickup boxes. Voss and others involved with the industry-first carbon fiber truck box spoke with Automotive Engineering at the new Sierra Denali's recent global debut in Detroit.

The carbon-fiber composite material, developed by GM and Continental Structural Plastics, offers superior dent, scratch and corrosion resistance, according to Tim Herrick, the 2019 Sierra's chief engineer. Compared to the Sierra's standard steel truck bed, the carbon fiber bed is 62 lb (28 kg) lighter. Because of the material's formability, the sides of the carbon fiber box are pushed further outward—increasing the bed's total volume by a cubic foot.

The carbon-fiber bed will be available for the GMC Sierra Denali in short-bed configuration. This 5-ft 9-in short box is 1 in (25 mm) longer and 2 in (50 mm) taller than that of the previous generation Sierra.

"We didn't start out saying, 'Let's create a carbon-fiber truck box'," Herrick said, pointing out that other carbon fiber applications, including some under the body, were considered before the cargo-bed program got the green light.

Making a carbon-fiber truck bed a production reality began with creating the material chemistry. "The decision to go with a carbon-fiber thermoplastic (nylon 6) allows for reusing and recycling the material," noted Voss. "There are actually two parts on this cargo bed that are made from 100% of the recycled material that's created during the production process," he said, referencing the right- and left-side front stake pocket reinforcements.

Rather than opting for woven carbon fiber, the material is in a "chopped" form. "We really want to use every ounce of fiber—and with the chopped fiber we're able to do that," Voss explained.

The production process requires the joining of two layers, according to Herrick. "With sheetmetal, you'd spot-weld the layers together. But with this, we're using a structural adhesive and a mechanical fastener at the beginning of the bond to prevent the susceptibility of peeling," he said.

Akio Nakaishi, general manager of the composites business unit for the Teijin Group, parent company of Continental Structural Plastics, said the molding of parts has a one-minute takt time. "That is very innovative and it makes us able to produce this part on a large scale," Nakaishi noted.

To confirm the cargo bed's durability, the GM team loaded and unloaded objects that included snowmobiles with carbide-steel runners. They also flagrantly dumped in bricks, rocks, firewood and other material. Said Voss, "We tested many, many different scenarios of how the truck bed could be used and abused."

Production versions of the carbon fiber truck bed will differ in one significant fashion from the prototype version shown to media at the vehicle's debut. "A special production tool will be used that will make the top of the corrugations have a sandpaper-like grip," said Voss. "The lower portion of the corrugation is made from a smoother grain, making it easy to wash out sand, dirt and mud."

Workers at Continental Structural Plastics plant in Huntington, IN, will mold and form the carbon-fiber bed, which will then be trimmed out at GM's Fort Wayne, assembly plant. The 2019 GMC Sierra Denali goes on sale this fall.

Kami Buchholz

AUTOMOTIVE SAFETY

Soft tests for autonomous vehicles

A graphic example of soft target benefits. (image: AB Dynamics)

AB Dynamics has developed a new platform to propel a range of variable road-user targets. (image: AB Dynamics)

There is enormous pressure on the entire mobility industry to achieve and demonstrate unprecedented levels of validation to gain and maintain public confidence in the safety of autonomous vehicles.

Statistics may point to human fallibility being the cause of almost all road accidents, but the switch to a connected robotic environment must ultimately deliver every nano-second of every day on the promise of a guaranteed near-total safety highway environment. Today's grudging acceptance by the global public of the inevitability of deaths and injuries on the road will not continue in a driverless environment.

But moving towards that state has not necessitated a totally clean technology slate. Many OEMs, universities, automotive consultancies and government-backed programs have been edging towards it for decades.

An example is advanced testing and measurement systems' specialist AB Dynamics. In the 1990s, it developed "driving robots," not autonomous devices but systems that were pre-programed path-following controllers that established a technology and expertise basis for future driverless vehicle testing.

Applying specific, already-proven robot-driver hardware to a conventional existing vehicle, provides the ability to short-cut the early development processes and concentrate on what really matters—software and sensors that can (absolutely reliably) deliver total CAVs (Connected Autonomous Vehicles) that can drive themselves while monitoring and reacting to other vehicles and road situations.

All this has generated the need for test methods to validate CAVs not just by computer but by some physical testing. This can be costly and involve impacts, so the rapid growth in proving ground use of "soft target" testing has become increasingly important.

At AB Dynamics, Commercial Manager Jeremy Ash, explained: "Soft targets are now protecting valuable development vehicles from damage in the event of a collision. CAVs can interact with soft targets that look like other vehicles but are actually a photo-realistic vinyl skin stretched over foam panels. These are mounted on a very low platform that can pass underneath the test vehicle as the foam panels separate during an impact."

The aerodynamically stable soft target vehicles are self-propelled using electric motors powered by on-board batteries and can reach speeds up to 80km/h. Their interaction with other vehicles is synchronized by telemetry using AB Dynamics' Synchro software package designed to ensure accurate and timely positioning such as offset head-on impacts.

The company works closely with Euro NCAP and NHTSA, both of whom have adopted the Soft Car 360 vehicle target as the Global Vehicle Target for harmonized ADAS testing.

CAVs have to interact with all types of vehicle but also other road users, including pedestrians, cyclists and motorcyclists. In order to enable testing with these more vulnerable groups a new, compact, motorized platform called LaunchPad has been developed by AB Dynamics, which can carry a range of different VRU (vulnerable road user) targets and is robust enough to be driven over by a test vehicle.

Ash said that unlike belt-driven platforms which can only travel in straight lines, LaunchPad can follow complex paths and uses AB Dynamics' Synchro package to synchronize its motion with that of other vehicles.

AB Dynamics claims to be the only company capable of synching a VRU, soft car target, and real car in an on-track test scenario, enabling all the mobile architecture in a test to be controlled. The company is also exploring the addition of controlled fixed street furniture, such as traffic lights.

Through liaison with bodies such as Euro NCAP, NHTSA and China's CATARC, Ash is aware of both the diversity and the efforts being made to harmonize CAV testing: "Tests such as NCAP, aimed at providing consumer information, have a different focus to government agency tests, which may concentrate on ensuring the relevance or validity of a particular test type.

"Being realistic, you cannot test all the possible scenarios; the skill is in identifying the best sub-set of test scenarios, based on the worst cases, and demonstrating that these are sufficiently wide-ranging to reasonably represent all likely events."

Stuart Birch

COMMERCIAL VEHICLE ELECTRIFICATION

ChemSEI-Linker extends lithium battery life, increases EV range

New technologies continue to push the boundaries of battery technology. As electrification becomes more prevalent in the heavy-duty and off-highway industries, battery capabilities continue to be a vital link in what new, advanced powertrains are able to accomplish. The Industrial Technology Research Institute (ITRI), Taiwan's largest technology R&D institution, has announced a new material designed to increase cycle life and improve recyclability of lithium batteries.

Over time, the battery discharge/charge process creates microcracks that degrade its performance. ITRI has created ChemSEI-Linker to extend the number of cycles by 70% and increase vehicle range by 15%. This material covers the lithium battery electrodes and protects them from a solid electrolyte interface (SEI) layer that forms on electrodes during the discharge/charge process. Increasing battery life and range could also allow manufacturers the ability to reduce battery pack sizes, lowering an expense that can make up to 40% of a vehicle's cost.

Because ChemSEI-Linker creates a layer over the active electrode material, recycling becomes a simpler and effective procedure, ITRI claims. A battery manufacturer can extract the electrode directly for reuse rather than having to transform it into lithium carbonate and various metals by intermediate physical and metallurgical recycling processes. This allows for streamlined recycling operations and reduced costs for reusing the lithium materials. The ChemSEI-Linker layer also improves battery safety by passing the nail-penetration tests.

"Nations worldwide are actively developing industries and products related to electric vehicles, such as safe, high-capacity, high-power, long-life, and low-cost lithium-ion batteries," said Dr. Jing-Pin Pan, Chief Technology Officer of ITRI's Material and Chemical Research Laboratories, in a statement. "Service life, energy density, power density, capacity, and safety are the most crucial technological challenges for practical batteries. ITRI developed ChemSEI-Linker to address environmental concerns and improve the performance, recyclability, and safety of lithium batteries."

ChemSEI-Linker is an artificial nanoscale solid electrolyte interface that stabilizes lithium battery electrodes using a unique composition and structure. The material includes a self-forming chemical solid electrolyte interface modification technology (ChemSEI) and an electrode paste with a linker (Chemlinkbat paste) integrated into a multifunctional architecture. It combines in-situ organic hyperbranched polymer material with silane-type linkers, electro-conductive additives (graphite, carbon nanotubes, metallic flakes or fibers) and conductive metallic ion inorganic structural materials.

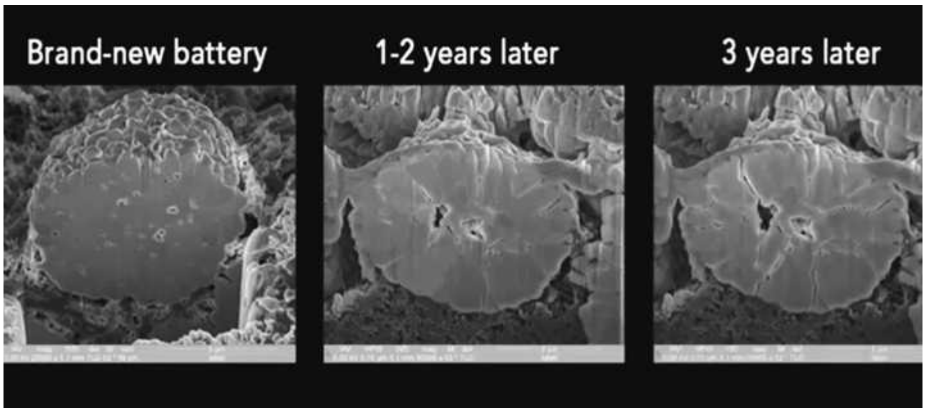
A protective film forms on the surface of the active electrode cathode and anode materials during the mixing of the Chemlinkbat electrode paste. This film provides stress buffering and functional protection for the interfaces between the active electrode materials, electro-conductive additives, and binders of the electrode paste. Chemlinkbat paste can be applied with two-sided precision coating and baking to manufacture ChemSEI-Linker electrodes.

Lithium batteries present the latest electrification capabilities available for advanced vehicle propulsion. ITRI has developed a material critical to the performance, security and reusability of this technology. ChemSEI-Linker offers the possibility to use lithium batteries longer and safer, over and over again.

Matthew Borst

ITRI has created ChemSEI-Linker to extend the number of cycles by 70% and increase vehicle range by 15% (image: ITRI)

ChemSEI-Linker is added to the cathode to create a layer protecting the battery from degradation during the cycling process. (image: ITRI)



This new material covers the lithium battery electrodes and protects them from a solid electrolyte interface (SEI) layer that forms on electrodes during the discharge/charge process. (image: ITRI)

COMMERCIAL VEHICLE AUTOMATION

Paccar reveals new and future tech

Although 2018 marked its first-ever presence at the enormously influential Consumer Electronics Show (CES), Paccar made sure it fit right in with the show's technology- and transportation-sector veterans by unveiling a pair of big-rig demonstrators that show the way the multi-faceted OEM plans to address expanding interest in autonomous driving and more environmentally-conscious operations.

Some CES visitors may have thought it incongruous to see tractor-trailer rigs touting their high-technology credentials, but this year's show in fact was bursting with commercial and off-highway vehicles, service companies and other affiliated businesses as it becomes increasingly apparent that many autonomy innovations, in particular, may be first deployed in commercial environments.

For Paccar's first-ever presence at the influential Consumer Electronics Show (CES), the company joined the show groove by displaying a Peterbilt 579 model modified for SAE Level 4 autonomous driving capability. (image: Paccar)

Peterbilt autonomous development tractor

Based on Peterbilt's 579 model, an aerodynamics-optimized on-highway platform, the autonomous development tractor incorporates a phalanx of cameras and radars and lidar sensors to deliver the potential for extended hands-off driving.

"Our main focus is on [SAE] Level 4 ADAS [advanced driver-assistance systems] trucks," Wesley Slavin, Peterbilt's marketing manager, on-highway, told *Truck & Off-Highway Engineering* during CES 2018. "Our expectation is to still have an active driver in the seat, but to give the driver a reasonable amount of break time," he added.

Peterbilt is convinced Level 4 autonomy is ideal for over-the-road trucking, Slavin said, because it can reduce the burden of operating a vehicle for extended periods—but perhaps equally important, Level 4 autonomy has the potential to significantly decrease vehicle downtime, as the truck can continue traveling while the driver rests. Level 4 autonomy will mean regulators will be faced with examining and potentially modifying current laws regarding mandated driver rest periods—including the definition of what constitutes "rest," Slavin said.

"When regulators and the environment adjust, we'll be ready to go," he said.

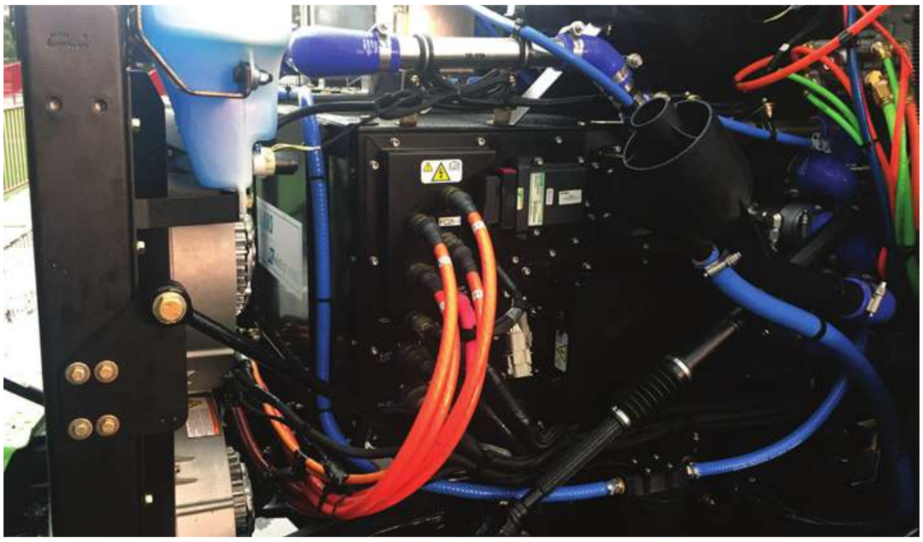
Peterbilt's autonomous development tractor features a sensor suite of three Velodyne lidar sensors—one in the middle of the windshield's "visor" and one on each side mirror—three forward-looking cameras, a camera on either side of the rig, two side-looking radar sensors and front-facing radar.

Collating the input from the 11 sensors is an Nvidia P2 processor. Another critical part of the hardware equation is a ZF-supplied ReAX torque-overlay electric steering assist. Slavin said Peterbilt did all the hardware-integration work internally at its laboratory in Denton, Texas.

For now, the company intends to use the vehicle strictly as a demonstrator, but Nvidia intends to test it, Slavin added.

The next phase for Peterbilt will be to leverage the development of the autonomous demonstrator to provide new ADAS functions, such as accident-avoidance and lane-centering

Kenworth R&D Manager Brian Lindgren at the rainy CES showing of the company's fuel cell-powered T680 day cab that has 150 miles of electric driving range and zero emissions. (image: Bill Visnic)



Ballard-made fuel cell for the electric Kenworth T680 generates 85 kW. (image: Bill Visnic)

Well-integrated into the space behind the driver's compartment are the electric T680's hydrogen storage tanks, holding enough H_2 for an approximate 150-mile driving range. (image: Bill Visnic)

capability, for production models. But an on-the-road pilot program for Level 4 autonomy is "probably a couple years out," according to Slavin.

"I think the technology [for Level 4 capability] is there," he added. "There are some algorithms and scenarios to work through. Our goal is to make sure the operator is safe—but everybody around is safe, too."

"Technology is reshaping the commercial vehicle industry, and we have to be sure Peterbilt is on the front line of those developments," said Kyle Quinn, General Manager, Peterbilt Motors Company, in a statement. "CES is a melting pot of companies making breakthroughs and pushing the envelope in a wide variety of industries, trucking included. This opportunity to showcase Peterbilt's work is exciting."

Kenworth zero-emission T680

Paccar's Kenworth unit displayed at CES 2018 an electrically-driven T680 day cab developed and built to take part in the Zero Emission Cargo Transport (ZECT) demonstration project managed through Southern California's South Coast Air Quality Management District (SCAQMD). Electricity is derived from a fuel cell supplied with compressed hydrogen from onboard storage tanks—and there are no direct noxious emissions.

The truck's dual-rotor traction motor develops 565 hp, making the truck capable of carrying the legal GCWR of a Class 8 tractor. Brian Lindgren, Kenworth's R&D Manager, told *TOHE* that the Ballard-made fuel cell generates up to 85 kW and its fully-charged 100-kW·h lithium-ion battery pack has enough charged capacity for about 30 mi (48 km) of driving range. After that, the fuel cell begins supplying electricity for tractive drive and to recharge the battery pack if load permits.

With a full load of hydrogen, total driving range is about 150 mi (240 km), Kenworth said, "making it ideal for short-haul and port operations."

Lindgren told *TOHE* the fuel-cell truck will go into service late in the first quarter of 2018 in real-world drayage testing with Total Transportation Services Inc. (TTSI) at the ports of Los Angeles and Long Beach in southern California. A follow-on project, he added, will involve another four vehicles—and Kenworth is working on a second project to develop a T680 day cab using a near-zero-emissions natural gas engine and generator to extend the battery range.

"We don't know what powertrain's going to 'win' for developing electricity," said Lindgren, who said the fuel-cell powertrain, including batteries, weighs roughly 7000 lb (3175 kg) more than the standard T680 day cab model.

"Our testing shows that this truck performs equally as well, if not better than, current diesel trucks on the market," said Stephan Olsen, Kenworth director of product planning, in a statement. "There is a lot of promise, and we see the day where Kenworth's zero and near-zero emission trucks could be a common sight in regional operations. Kenworth is heavily focused on the evaluation and development of both zero and near-zero emission solutions for the trucking industry."

Lindgren said Kenworth is particularly interested in using the demonstration program to study the coupling of electrification with ancillaries such as steering and braking, which use systems that traditionally rely on power from the truck's combustion engine. Both the power steering and brake air compressor for the fuel-cell demonstration trucks are electrified.

"We think this [zero-emissions capability] is going to be a necessity in California," said Lindgren, "and applicable elsewhere." California has a long-standing initiative to improve air quality around its heavily-congested ports; development for Kenworth's fuel-cell truck was supported by $2.8 million in funding under a larger grant from the U.S. Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy (EERE), with SCAQMD being the prime applicant, Kenworth said.

Apart from the demonstration projects, "Right now, we don't have any firm production plans," said Lindgren, who said the company is examining the possibilities for limited-quantity series production in 2021-22.

Bill Visnic

AUTOMOTIVE AERODYNAMICS

Magna's new active airdam boosts 2019 Ram fuel efficiency

2019 Ram 1500 shows active airdam deployed. The collaboration with Magna included development of validation requirements including bench testing. (image: FCA)

For the all-new 2019 Ram 1500 pickup, FCA engineers again surprised their industry competitors with an impressive array of integrated technologies aimed at improving the pickup's fuel efficiency. The list of segment 'firsts' includes 48-V hybridization, a heated/cooled rear drive axle and an active front airdam to optimize the truck's aerodynamics.

Developed in collaboration with Magna International (which also designed the Ram's active grille shutters), the new active airdam is designed to deploy at 35 mph (56 km/h) and retract at 15 mph (24 km/h). It is responsible for 40% of the new pickup's total 9% aerodynamic improvement over the outgoing model, noted Mike Raymond, the Ram's chief engineer.

"We got a few [aero] counts out of the new cab's roof design and the taller tailgate, but the active airdam really brought us significant gains in both Cd and Cd(A), which is big for our highway fuel-economy numbers," he told *Automotive Engineering*. Improving Ram's Cd from 0.393 in 2018 to 0.357 in 2019 represents a 36-counts drag reduction—worth 1 mpg in highway operation, Raymond said.

Active aerodynamic systems qualify for the "off-cycle" credits that automakers can earn in their federal fleet fuel efficiency compliance. The current U.S. CAFE rules require average pickup truck economy to increase from 29.6 mpg in 2018 to 39.3 mpg by 2025.

System development began in 2014, after FCA's DT program (2019 Ram) engineers had established some base geometries, including what the overall deployed height of the air dam should be. Then came some early wind-tunnel work.

"FCA came to us with a rough concept and we handed our Exteriors team 'the reins' to develop the product part," explained Tony Povinelli, Magna's Global Product Line Engineering Director. "The program included development of new test and validation requirements, including bench testing," he added.

As a fullsize pickup, the new Ram offered adequate space between the front frame crossmember and the front lower fascia in which to package the airdam module. It's a compact unit, consisting primarily of the airfoil and actuator assembly. Povinelli noted that the module's control electronics communicate with the truck's active grille-shutter system via LIN (Local Interconnect Network), the serial network protocol used for subsystems communication in the vehicle.

The composite airfoil is constructed using a 'two-shot' molding process using glass-filled nylon to create the blade's spine, which then is overmolded with nylon/rubber 'soft shot' to provide a durable exterior.

The airdam's actuator includes an electric motor, declutching mechanism and a controller. The system requires a 12-V power supply (48-V hybrid Ram trucks incorporate a DC-DC converter between their 48-V and 12-V networks). Magna's Closures group developed the cam-type clutch mounted on the actuator output shaft, according to Povinelli. The clutch plays a vital role in ensuring that the deployed airdam can retract to avoid breaking if the underside of the truck's front end impacts road debris.

"This is a very robust system," Raymond asserted, "with the actuator designed for life-of-vehicle service." He praised the Magna team as being "great to work with."

With U.S. fullsize pickups and SUVs facing considerable regulatory pressure to increase overall fuel efficiency, Povinelli expects Magna's active-airdam business to expand steadily, mirroring its 10 million active grille shutters currently on the road. The company is also developing active underbodies, active wheel deflectors and active rear diffusers, which can be applied across all passenger and commercial vehicles.

Lindsay Brooke

Roadmap for future Indian passenger DRONE SECTOR

Fig 1. Airbus concept car with drone capabilities

India UAV market

Autonomisation of Artificial Intelligence (AI) in ground vehicle is rewriting the history of automobile industry. AI has also started to conquer aviation through aerial robotics and commercial Unmanned Aerial Vehicles (UAV) market. Research and application of drone technologies towards human transportations are even being carried out by startups to big commercial players like Boeing and Airbus.As per UAV regulations, UAV traffic and role of Air Traffic Control over commercial UAVs are still being a big bottle neck, passenger drones and their market will have to travel a long way for its establishment and sustainable survival.

Earliest recorded use of UAV dates back to August 1849, when Austria launched an unmanned balloon bomb attack against Venice. During World War-I in 1918, small biplane aerial torpedo guided by gyroscopes, a barometer, and a mechanical computer called as 'Kettering bug' was developed by US Army. But they were never used in combat. UAVs are widely used for military purpose during midlevel and recent times of the past century. Those periods the main purpose of UAVs was to enter enemy region safely without jeopardizing the life of pilot.

In 1999, India's defense and intelligence failed to spot and prevent incursion of Pakistan across Line of Control (LoC) and resulting Kargil war. In addition, Indian army had lack of training and experience in mountain warfare. Indian owned Indian Air Force (IAF) reconnaissance aircraft Canberra PR57 was shot down by a Chinese made missile. These incidents exposed limitation of India in Photo Reconnaissance. Hence India first used UAVs in Kargil war in 1999 for surveillance and reconnaissance.

In late 90s Israeli army had experience of dealing with counter-terrorism and border-control. Israel became one of the few countries to help India directly in this war. Israel speeded up the delivery of the Indian order of arms including Unmanned Aerial Vehicles, Israel Aerospace Industry (IAI) Searcher and IAI Heron that had been placed before development of Kargil war.

At present, Indian arsenal consists of IAI Harpy, IAI Harop, IAI Heron, IAI searcher produced by IAI. And also, Indian manufactured DRDO Nishant, DRDO Lakshya, Rustom-I and Rustom-II.Long Range UAVs (High Altitude-Long Endurance) segment is in developing stage which is likely to enter in the India market by 2021. Due to high cost concern, India is targeting more towards domestic manufacturing under "Make in India" initiative. Rustom-H is most likely to be the first long range UAV in the country. Rustom-H is expected to enter in the market by earliest 2021. In terms of end user application, military application market held major share in the overall market.

However Indian commercial UAV market growth is buoyed by security concerns, predominantly, terrorist threats, border intrusion, and rise in domestic crime rate; India recorded over crime 3 million incidences in 2016, growing from 2.2 million incidences in 2015. Indian commercial market also faced ups and down due to lack of regulations and governance.

Regulations on commercial applications of UAVs in India

Indian Aviation ministry on 1st Nov'17, unveiled the rules on the commercial usage of drones in India. According to Directorate General of Civil Aviation (DGCA), Government of India, Drones are classified into 5 categories based on their weight namely,

1. Nano drones that weigh 250 gm and
2. Micro drones, that weigh 250 gm to 2 kg,
3. Mini drones that are from 2 kg to 25 kg in weight,
4. Small drones that weigh something between 25 kg to 150 kg and finally
5. Large drones that weigh 150 kg or above.

Fig 2. Ehang 184 – Passenger Drone

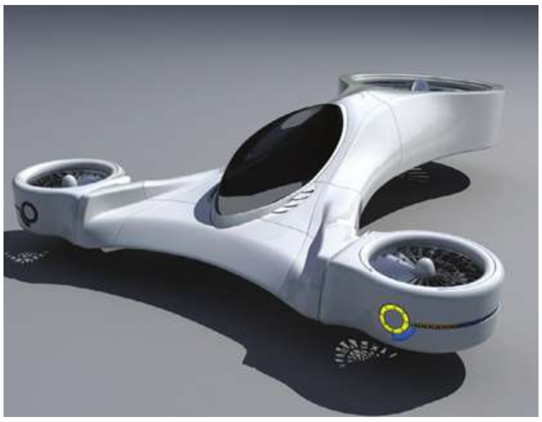


Fig 3. A passenger drone model

Nano drones are not capable of flying more than 50 ft from the ground and would need no permission. Drones up to 2 kg that cannot fly more than 200 ft would need police permission, while anything more than 2 kg will need to apply for permission, a license and a flight plan. Moreover, over the coming years, with upcoming clarification on DGCA regulation for commercial usage, the market is likely to register higher adoption in India.

Commercial use of UAVs in India

With these regulations, Companies such as Amazon and Flipkart will soon be able to use drones to deliver packages in India. In the US, firms such as Amazon is experimenting with delivering packages with the help of drones.

In India, e-commerce delivery companies create thousands of jobs in the process. Related to this, a CEO of Indian UAV manufacturing firm once mentioned that "Pizza delivery and apparel delivery from Amazon will not work here because the traffic management will become a big mess and this will create chaos and DGCA will not be able to handle this. There are 50,000 deliveries made by e-commerce companies like Amazon, Flipkart, Dominos in Delhi alone every day. We need to prepare more for this".

The rules will certainly benefit medical industry for blood delivery, organ transportation, first aid kit delivery as also for providing food packets during disaster management but more preparation is still needed.

Few Indian UAV technology start-ups

Some of the key players in Indian UAV market include- Hindustan Aeronautics, Israel Aerospace Industries, Bharat Electronics, TATA Advanced Systems, Dynamatic Technologies and Larsen & Toubro.

Few notable startup contributors like AirPix does aerial photography; Garuda Robotics a Singapore-based Robotics, sells software and services for the UAV industry; Edall Systemsstarted with providing service to National Aerospace Laboratories (NAL) and followed by training on Aerospace design during 2011 in Bangalore.IdeaForge has developed Netra UAV in collaboration with DRDO. Police forces of at least three states along with Central Reserve Police Force (CRPF), and the Uttar Pradesh Special Task Force are its customers.

Possible future challenges faced by UAVs in airspace

UAV market in India is presently growing at a significant rate; wherein, in terms of volume, mini-UAV segment acquired major share of the market, followed by, medium, and long range UAVs. With regulations on operations of UAVs, India has legalized the use of UAVs in airspace. With this legalization India can experience boom in the commercial UAV industry.

But before bringing UAVs into commercial use, still there are few challenges which have to be considered. Need of collision avoidance system, UAV tracking system and lost link system are some of them. One more challenge will be protecting civilians from possible UAV crashes.

Land mapping, Aerial Photography and Crop spraying are few most common commercial applications of UAVs. But such applications can sabotage the privacy of the Indian civilians. As with the use of UAVs one can easily collect the data without the knowledge of the target. Prior to integration of UAVs in airspace, adequate infrastructure is necessary.

Framing commercial UAV regulations, improving air traffic through technological development and resolving the above mentioned practical hurdles are equally important issues to be addressed before moving on to passenger drones. Research on these areas will aid for the drone technology application over commercial transportation. By resolving the technological challenges, the growth of current commercial UAV sector will lead us to the next era of aviation.

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INTERNET OF VEHICLES: Connected Vehicles & Data - Driven Solutions

1. Introduction

'ACES' of automobiles is considered as the framework of future mobility. 'ACES' stands for Autonomous, Connected, Electric & Shared. Digital disruption is attributed to be a key driver in shaping the future of mobility. Adaptation of high-end electronics and integration of the same with the conventional mechanical systems of vehicles has substantially improved vehicle efficiency, affordability, safety, and easiness. Further to that exponential increase in computation power of processors, advancement in electronics and connectivity to the cloud opened a new era of connected solutions in vehicles, pet named 'Internet of Vehicles'.

2. Connected Vehicles

Connected vehicles are now considered as a critical node in the emerging IoT (Internet of Things) ecosystem. Vehicles in the connected ecosystem generate large amount of data from the onboard sensors. Over and above the functional sensor data, vehicle's peripheral sensor outputs can be improvised to generate information about the road, traffic and weather condition. Overall connected vehicle's data composes of vehicle internal sensors and other peripheral parameters such as:

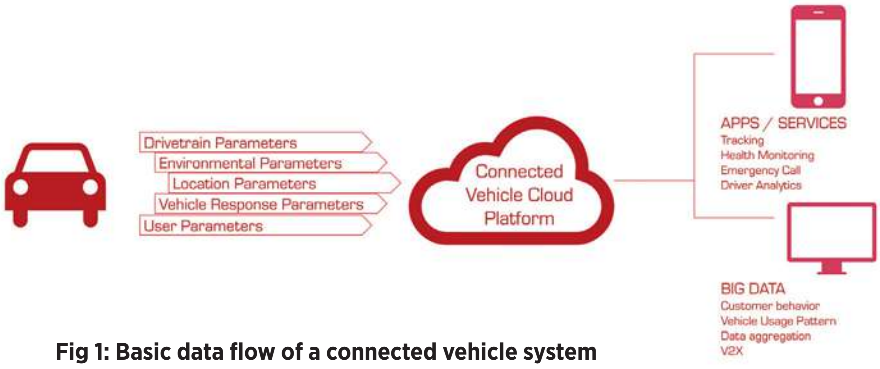

Fig 1: Basic data flow of a connected vehicle system

DATA TYPES	PARAMETERS
Drivetrain	Engine RPM, load, temperature, fuel level, driver inputs (acceleration, braking, gear shift) and diagnostic trouble code
Environmental	Cabin interior/exterior temperature, rain condition, humidity, pressure and ambient light condition
Location	GPS coordinates, altitude, GPS based speed and direction of travel
Vehicle Response	Roll, pitch & yaw rate from the gyro, vertical, horizontal & lateral acceleration from Accelerometer, visual data from camera and audio data from microphones
Non- vehicle	Data from Smartphone, fitness bands, other wearables, infotainment and social media

3. Machine learning & data Analytics

The huge amount of data available needs to be processed and converted into useful insights. This information can directly benefit vehicle owners as well as manufactures. Humungous data along with computing power (eg: cloud computing, GPU - Graphics Processing Unit) to process that, brings machine learning to the automotive industry, like every other industry today. Before mentioning the details of machine learning, one should understand what is the difference between a general program or algorithm versus machine learning. An algorithm is a set of logically written instructions that converts data to useful and meaningful output based on the needs that algorithm is made. Whereas, in machine learning, data will be analyzed and processed with respect to the output to build a program that can be used to predict output based on the new set of data. This output program is typically called as machine learning model. This machine learning model can be used for making predictions or decision-making tasks.

4. Machine learning definition

Machine learning process is learning from the available observations or data without relying on rules-based programming. Machine Learning is a preferred approach, where a lot of parameters are involved and it is difficult to create rules for every desired output. As per Tom Mitchell's definition: Machine learning is a computer program learn from experience 'E' with respect to some class of task 'T' and some performance measure 'P', if its performance on 'T', as measured by 'P', improves with experience 'E'. For example, travel time between two places (task 'T') can be predicted using past traffic and weather patterns (experience 'E'). If the learning is successful, a better prediction of travel time can be obtained (performance measure 'P'). Primarily machine learning is classified as supervised and unsupervised. In supervised machine learning, for every instance of input data, there is output available for learning, this data is called labeled data. In unsupervised learning, no labeled data is available. The machine learning model understands the interactions or underlying structure of data and can be used for grouping or making a prediction.

5. Data driven solution development

Let's consider a connected vehicle problem statement to 'detect the vehicle running gear position of all the connected vehicles on road form the cloud data available'.

5.1 Non-machine learning

Non-machine learning can be called as a rule-based approach since every output is obtained by certain fixed rule. In rule-based approach, the gear position can be detected based on the known ratio of vehicle speed and engine speed. In this case, metadata of the vehicle's gear ratios should be known upfront. An algorithm can be written fixing the boundary conditions to required output.

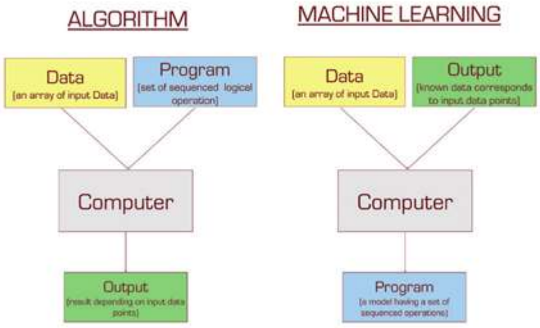

Fig 2. Difference between an algorithm vs machine learning

5.2 Supervised machine learning

Supervised Machine Learning can be applied when; there are about 10% of vehicles in the connected vehicle fleet are of high-end variant and those having additional sensors for recording gear position in real time. These 10% vehicles are sending vehicle speed, engine speed and gear position to cloud. Typically, this labeled gear position data can be used to train a machine learning model. Take vehicle speed and engine speed as input features and available gear position data as output variable to build a supervised machine learning model. This model from the 10% vehicle data can be can be used to classify gear positions of vehicles which have only vehicle speed and engine speed data available. Most of the current machine learning exercises in connected vehicles are supervised machine learning.

Supervised machine learning is of two types depending on the prediction variable type. First is called classification problem, where the output variable to be predicted is a category or a discrete value, such as "Gear Position 1" or "Gear Position 2". Classification models can be applied for grouping of drivers as 'risky' or 'non-risky' category. Advance levels of driver classification are difficult in rule-based approach since it involves high dimensions of data and complexity in rule creation.

The second type of supervised learning is called regression, where the output variable or prediction is a real or continuous value, such as the value of "speed" or "fuel quantity". The classification model can be used for driver risk ranking, where driving behavior parameters like acceleration, deceleration, ABC pedal usages are considered as input features. Vehicle parts useful life prediction based on vehicle usage pattern is one of the applications for regression models. This approach takes historical usage pattern of the vehicle and failure mileage data as an input variable to build a machine learning models. This machine learning model can give better results than traditional reliability methods like MTTF (Mean time to failure) & MTBF (Mean time between Failure) since it can be customized to adapt randomness and diversity of input variables.

5.3 Unsupervised machine learning

Unsupervised Learning can be applied to more complex scenarios. Where only available data is vehicle speed and engine speed from the fleet, gear information unavailable. Generally, unsupervised machine learning can become handy to create models if labeled data is not available. Unsupervised learning can learn the relation between input features and give a better output prediction or grouping. Primary class of unsupervised machine learning is clustering. In clustering, the input variable is appropriately grouped based on a distance function between each observation or data points. It can be based on the nearest neighbors of the data points in its feature space. Unsupervised model efficiency and accuracy are dependent on the distance function's tuning. In gear position detection problem, a number of clusters can be obtained based in combinations of vehicles speed and engine speed, this clusters can be identified as different gear positions.

Data analytics tools & resources

In the process of development of developing a data-driven solution, there are different tools required.

Python & R are the widely used open source programming languages for data analytics and machine learning. A lot of open source libraries supports both languages, to do every process in machine learning from data gathering to deployment of the model. Example libraries in python are; for data processing Pandas and Numpy, for machine learning model building Scikit-Learn and tensorflow etc. A lot of MOOCs (Massive Open Online Courses) are supporting for learning machine learning and data analytics like, Udacity, Udemy, Coursera, and Edx. Data science communities like Kaggle, Analyticsvidhya are some good resources to start learning as well as participate in data analytics challenges.

Conclusion

Machine learning and data science are getting popularity in the automotive industry as same as industries like healthcare, marketing, trading, consumer electronics etc. In India and globally Internet of Vehicles comes with a set of challenges, ranging from personal data security, poor internet connectivity and coverage, hardware and software reliability etc. Penetration of 4G/5G and changes in customer attitude towards the overall connected ecosystem will advent internet of vehicles and improve the adaptation.

Internet of Vehicles and Data analytics have potential to solve several problems in the automotive domain. This can be achieved by the best combination of experts from the automotive domain and data science. The automotive domain expert is vital in selecting the input features for specific problems. On the other hand, an experienced data scientist can play a key role in selecting proper algorithms and testing the algorithm performance. A collaborative organization framework teaming up automotive domain experts and data scientists with people from marketing, manufacturing, information technology, and electronics can bring substantial business advantages leveraging the digital ecosystem. ■

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Development and verification of electronic braking system ECU software for commercial vehicle

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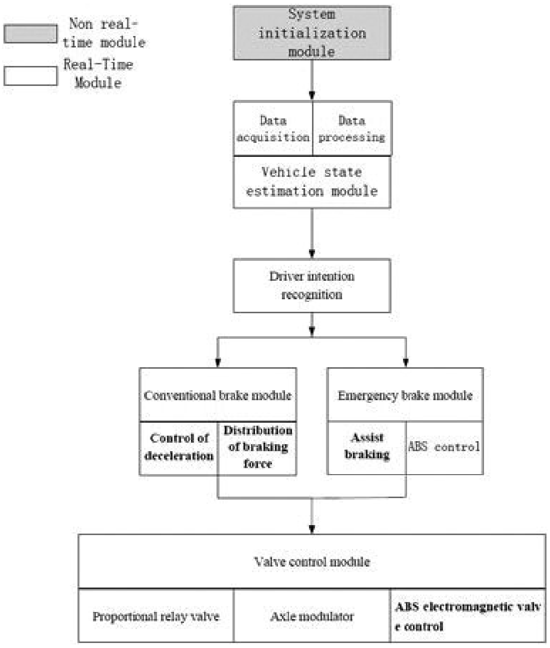


Fig 1. The overall software frame of EBS

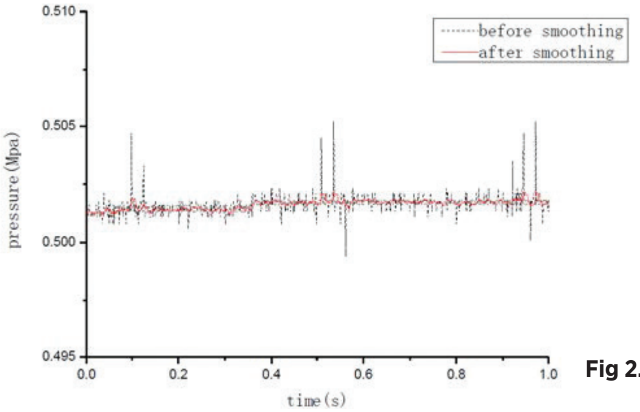


Fig 2. Smoothing

ABSTRACT

Electronic braking system (EBS) of commercial vehicle is developed from ABS to enhance the brake performance. Based on the early development of controller hardware, this paper starts with an analysis of the definition of EBS. It aims at the software design of electronic control unit, and makes it compiled into the controller in the form of C language by the in-depth study about control strategy of EBS in different braking conditions. Designed controller software is divided into two layers. The upper control strategy includes the recognition algorithm of driver's braking intention, estimation algorithm of the vehicle state, conventional braking strategy which consists of the algorithm of deceleration control and braking force distribution, and emergency braking strategy which consists of the algorithm of brake assist control and ABS control. Lower control strategy includes feed-forward compensation and PID control of proportional relay valve, on-off control of axle modulator, on-off control of axle modulator of ABS solenoid valve and the design of CAN communication. Based on the hardware-in-the-loop simulation test-bed, this paper conducts EBS hardware-in- the-loop simulation tests in different conditions. The test conditions consist of loaded conventional brake, unloaded conventional brake, loaded emergency brake, unloaded emergency brake. The test results show that the control strategy in different conditions can achieve the expected result. Experimental work confirms that the designed software can be used as the basis of the product development.

INTRODUCTION

The brake system is the most important components to ensure the vehicle safety. During the brake process, the brake system must maintain excellent handling ability. Meanwhile, ensure that the vehicle stop within a safe distance. For commercial vehicles which transport the goods or passengers, the performance of brake system is an important indicator to evaluate the safety performance. Electronic braking system (EBS) of the commercial vehicle is developed from ABS to enhance the brake performance.

In China, the study of EBS is in its infancy and only a few universities carried out the study of control algorithm, simulation platform and CAN communication. Domestic colleges and universities mainly focus on the control algorithm.

This paper topics from the National Natural Science Foundation "based on the heavy-duty semi-trailer model predicts the kinetic stability of multi-objective control study" (Project No. 51075176). Based on the early development of controller hardware, which includes the selection of the microcontroller, the minimum circuit design, the design of the external driver circuit, the design of the signal processing circuit, CAN communication design, this paper is mainly aimed at the software design of the controller for Electronic Braking System (EBS), as well as the closed loop test [1]. The test results show that the control strategy in different conditions can achieve the expected result.

THE SOFTWARE DESIGN OF EBS

The software design of EBS is based on the design principles of ECU software which also includes the compatibility of software and hardware. This paper uses a modular method to design the software in order to increase readability and manageability of the software. The Controller of EBS collects a large amount of information in the process of working and the operand is big. So the program needs to meet the requirements of real-time, accuracy, reliability, easy modify and portability. The controller of EBS makes real time scheduling according to the priority level. The entire software includes the module of system

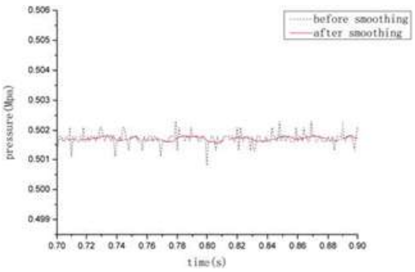


Fig 3. Partial enlarged detail

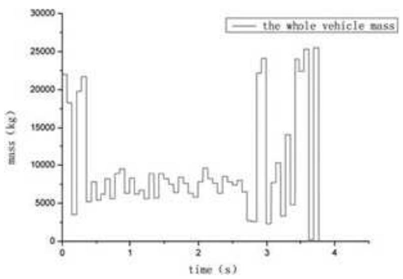


Fig 4. Mass estimation curve

initialization, vehicle state estimation, driver intention recognition, conventional brake, emergency brake, valve control and CAN communication. Local variables should be used in algorithms of various modules for a superior portability.

Date number	1	2	3	4	5
Rate of change of braking pedal	592.78	715.36	722.93	651.24	826.38
Date number	6	7	8	9	10
Rate of change of braking pedal	755.70	635.89	812.58	866.20	276.53
Date number	11	12	13	14	15
Rate of change of braking pedal	624.32	605.89	723.77	655.64	702.62

Table 1. Rate of change of braking pedal in emergency braking condition

System Initialization Module

Data Smoothing Process

Glitches may appear in the signal of wheel speed because of the influence of electromagnetic interference. So, the process of smoothing is necessary for the software applications. This paper uses the moving average to smooth the data in every 10 sampling points. As the following figures, Figure 2 shows the curve after smoothing. Figure 3 is the enlarged partial detail.

Vehicle State Estimation Module

The Estimation of Speed and Deceleration

Considering the characteristic of compiling C language into the single chip microcomputer and the feasibility of the control algorithm, this thesis adopts taking the maximum speed of the wheel as the speed of the vehicle as the evaluation method. The method of getting maximum speed of the wheel is shown as the following formulas:

$$V_{ref}(t) = \max(u_{11}(t), u_{21}(t), u_{12}(t), u_{22}(t)) \tag{1}$$

In it, the V_{ref} is the estimated speed of the vehicle, u_{11} is the speed of left front-wheel, u_{21} is the speed of right front- wheel, u_{22} is the speed of left rear-wheel, is the speed of right rear-wheel. We can get the deceleration when we deliver the speed of vehicle in two machine cycle:

$$a_x = \frac{V_{ref2} - V_{ref1}}{\Delta t} \tag{2}$$

In the formula, a_x is the evaluation of the deceleration of vehicle body, V_{ref2} is the evaluation of the speed of vehicle body, V_{ref1} is the evaluation of the vehicle body in last time, Δt is the time between two machine cycle.

The Estimation of The Mass of The Vehicle

As the mass of the vehicle will not change during it is running, so we can evaluate the mass of the vehicle according to the braking process before, and store it into the ECU.

We can get the braking force of the wheel according to the pressure signal of the four wheels. In the initial stage of braking process, the wheel is pure rolling, so the force of the brake is equal to the braking force of the ground. We can get the whole mass by further calculation.

$$F_b = P_{11} \cdot \gamma_{11} + P_{21} \cdot \gamma_{21} + P_{12} \cdot \gamma_{12} + P_{22} \cdot \gamma_{22} \tag{3}$$

$$F_x = F_b \tag{4}$$

$$m_e = \frac{F_x}{a_x} \tag{5}$$

In it, F_b is the braking force, P_{11} is the pressure of the air chamber in the left front-wheel brake, P_{21} is the pressure of the air chamber in the right front-wheel brake, P_{12} is the pressure of the air chamber in the left rear-wheel brake, P_{22} is the pressure of the air chamber in the right rear-wheel brake, γ_{11} is the conversion ratio between the pressure of the air chamber in the left front-wheel brake and the braking force, γ_{21} is the conversion ratio between the pressure of the air chamber in the right front-wheel brake and the braking force, γ_{12} is the conversion ratio between the pressure of the air chamber in the left rear-wheel brake and the braking force, γ_{22} is the conversion ratio between the pressure of the air chamber in the right rear-wheel brake and the braking force, F_x is the conversion ratio between the pressure of the air chamber in the right rear-wheel brake and the braking force, m_e is the whole mass of the vehicle, a_x is the deceleration of the vehicle.

Fig 4 is the estimation mass of the whole vehicle, because the braking pressure and wheel speed in the initial phase of braking in the visible part of the curve fluctuate obviously. So the calculation error of the whole mass is relatively large; in the end of the

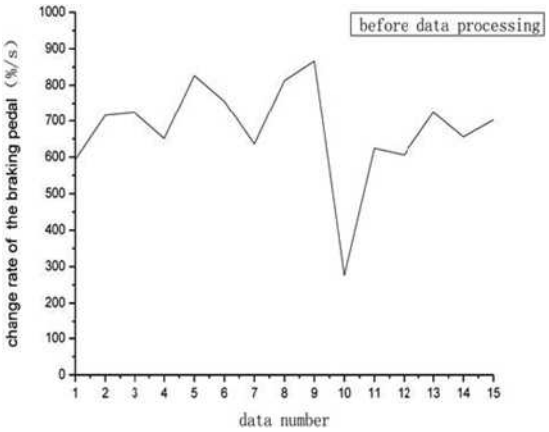


Fig 5. The change rate of the braking pedal before data processing

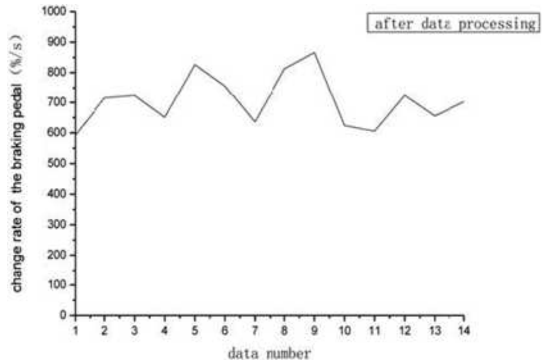


Fig 6. The change rate of the braking pedal after data processing

Road surface	peak adhesion coefficient	sliding adhesion coefficient	Road surface	peak adhesion coefficient	Sliding adhesion coefficient
Pitch (dry)	0.8~0.9	0.75	Unsurfaced road (dry)	0.68	0.65
Pitch (wet)	0.5~0.7	0.45~0.6	Unsurfaced road (wet)	0.55	0.4~0.5
Snow (compressed)	0.2	0.15	Ice	0.1	0.07

Table 2. The adhesion coefficient on various kinds of road surface

curve, because the speed is less than 20km/h, the amount of calculation error of the speed is relatively large, leading to the amount of calculation error of whole vehicle mass is relatively large. The date in the middle of the figure is stable. By calculating the average value, we can get the mass of the vehicle is 7329.63kg, comparing to the actual date 7690kg. The margin of error is 4.7%.

The Recognition Module of Driver's Braking Intention

The recognition of driver's braking intention is that, at the beginning phase, deducing the intention of the driver according to his particular action and choosing taking conventional braking strategy or emergency braking strategy. Considering the characteristic of compliance C language and its effect, this thesis takes the control strategy of threshold value to recognize the driver's intention. Thinking that different drivers have different driving habitat and the randomness and error are coming from the process of measuring. This thesis uses fifteen dates gotten from three drivers as the threshold value in the process of recognizing the braking intention of drivers.

Due to the misoperation, we need to handle the date above to get rid of abnormal dates (big errors).

Firstly we calculate the average value $\bar{x}$ and standard deviation s; $\bar{x} = 677.86$, $S = 133.47$. According to the statistical results of calculation, we take the date 276.53 which have the biggest difference to the average value as doubtful value. We calculate G by Grubbs test statistics:

$$G = \frac{X_{10} - \bar{x}}{s} = \frac{276.53 - 677.86}{133.47} = 3.01 \quad (6)$$

Adopting the level of significance $\alpha = 0.05$, according to the inspection threshold gotten from the critical value table of Mrs Grubbs $\lambda(\alpha, n)$, we can get the critical value G(15) is 2.409. Because the statistic G is bigger than the critical value G(15), we take the value 276.53 as abnormal value and get rid of it. Then we calculate the rest 14 dates according to the above process and test whether they are malformed. According to the test, there is no aberrant value in it. After dealing with the 14 dates, we can set the threshold value of pedal's rate in the recognition module, in which the time change from 0% to 100% is less than 140ms. Fig 5 and Fig 6 respectively show the change rate of the braking pedal before and after getting rid of the anomalous dates.

Module of Conventional Braking

Control of Deceleration

The deceleration control module takes the deceleration of the vehicle as the control objective, adopting the desired deceleration according to the opening of the pedal. When the module of EBS makes sure of that the opening of pedal is 100% when the vehicle gets the biggest braking deceleration, we can get the desired braking deceleration with the corresponding opening of pedal according to the opening of pedal and deceleration.

In every working conditions, we can use the following formula to calculate the biggest braking deceleration [2][3]:

To the vehicle with ABS:

$$a_{max} = \varphi_p g \quad (7)$$

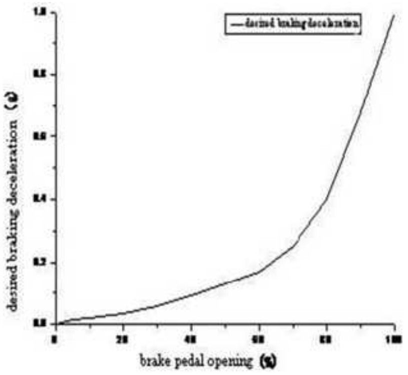


Fig 7. The curve of desired braking deceleration and brake pedal opening

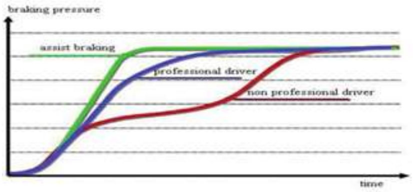


Fig 9. The distinction between non-professional drivers, professional drivers and ABS in emergency braking

To the vehicle without ABS:

$$a_{\max} = \varphi_s g \tag{8}$$

In it, φ_P is the peak adhesion coefficient, φ_s is the sliding adhesion coefficient. When choosing the biggest braking deceleration, we must take the road which can provide the peak adhesion coefficient as the target to make sure the vehicle can make the most use of the braking force of the ground. The adhesion coefficient on various kinds of road surface is shown as the Tab 2[4].

As fig 7. desired braking deceleration and the slope of the curve of the opening of pedal is changing with the braking force.

Distribution of Braking Force

During the braking of the vehicle, the equitable distribution of braking force between front and rear axle can ensure the shortest distance. At the same time it can give the vehicle the better maneuverability and direction stability [5][6]. Due to the transmission of the axle load during the braking, we need to distribute the braking force in real time by the axle load.

Defining the ratio of braking force of axle and their dynamic axle load as traction coefficient is shown as the following formula:

$$\mu_i = \frac{F_{xi}}{F_{zi}} \tag{9}$$

In this formulas above, μ_i is the traction coefficient of axle i, F_{xi} is the braking force of axle i from the ground, F_{zi} is the dynamic axle load of axle i.

In any conditions of deceleration, the best distribution method of braking force is to ensure the traction coefficient equal between front and rear axle until the two axles reach the adhesion limit [7][8], as this:

$$\frac{F_{x1}}{F_{x2}} = \frac{u_1 \cdot F_{z1}}{u_2 \cdot F_{z2}} = \frac{F_{z1}}{F_{z2}} \tag{10}$$

In this formula above, F_{z1} is the dynamic axle load of front axle, F_{z2} is the dynamic axle load of rear axle, F_{z1} can be gotten from the sensor of front axle load, F_{z2} can be calculated by the estimation of all the vehicle

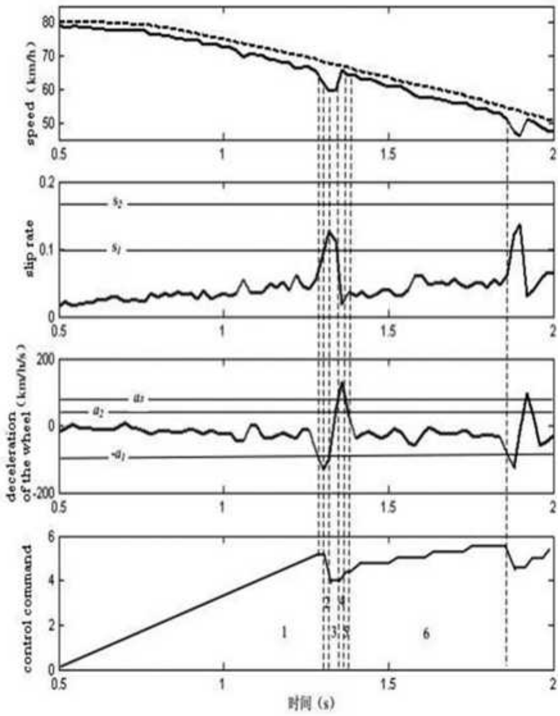


Fig 10. The process of ABS control

mass subtracting the load of front axle.

According to the desired braking deceleration and the curve of the opening of braking pedal, we can get the desired braking deceleration in the certain opening of pedal, together with the mass of vehicle, we can get the summational braking force from the ground. According to formula (10), the braking force of every axle can be expressed as:

$$F_{x1} = m_e \cdot a_{aim} \cdot \frac{F_{z1}}{F_{z1} + F_{z2}} \tag{11}$$

$$F_{x2} = m_e \cdot a_{aim} \cdot \frac{F_{z2}}{F_{z1} + F_{z2}} \tag{12}$$

In that above, m_e is the whole mass of the vehicle, a_{aim} is the desired deceleration of the vehicle, F_{z1} is the dynamic axle load of the front axle, F_{z2} is the dynamic axle load of the rear axle.

Because the wheel is pure rolling, every braking force of axle from brake is equal to the braking force from ground:

$$F_{b1} = F_{x1} = m_e \cdot a_{aim} \cdot \frac{F_{z1}}{F_{z1} + F_{z2}} \tag{13}$$

$$F_{b2} = F_{x2} = m_e \cdot a_{aim} \cdot \frac{F_{z2}}{F_{z1} + F_{z2}} \tag{14}$$

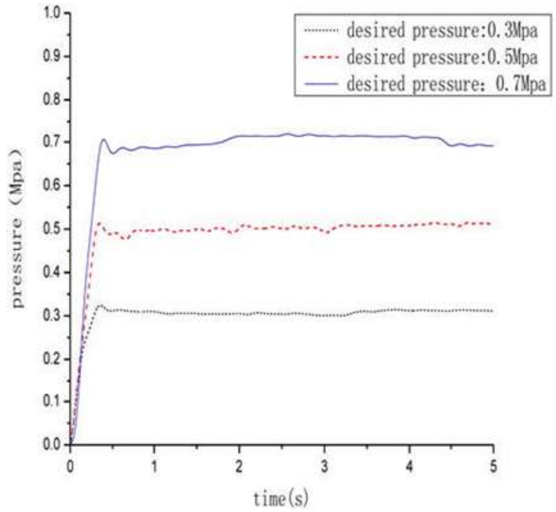


Fig 11. The curve of proportional relay valve control

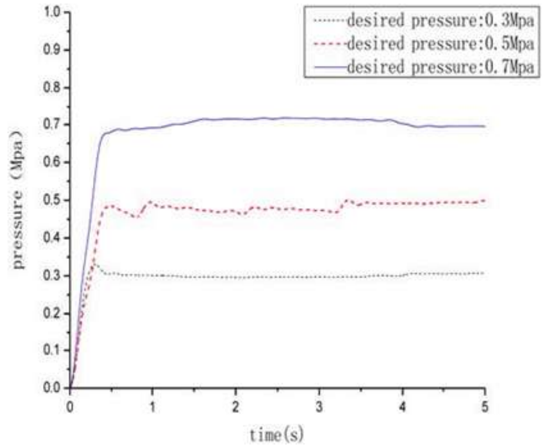


Fig 12. The pressure curve of the axle modulator

In the formula above, m_e is the whole mass of the vehicle, a_{aim} is the target deceleration of vehicle, F_{z1} is the dynamic axle load of the front axle, F_{z2} is the dynamic axle load of the rear axle.

Module of Emergency Braking

Assist Braking Control

When it is the emergency braking, the driver may touch the brake not decisively or not give enough force to the pedal which will not trigger the function of ABS and lead to the addition of braking length and the decline of safety. Throughout the experimental study of 114 drivers, the researchers find that 50% of the drivers failed to give sufficient force to the pedal to trigger the function of ABS, this will add much time before the vehicle get the biggest braking deceleration.

Assist braking system can give abundant force to trigger the function of ABS in short time after recognizing emergency working condition to make up the time the drivers waste on response lag and brake hesitation and shorten the braking length [9]. Fig 9 shows us the distinction between non- professional drivers, professional drivers and ABS in emergency braking [10].

I-frame Type	Parameter Name	Byte	Resolution Ratio	Physical Quantity Range
Estimate on vehicle state 0x555	Pedal Aperture	8、7	0.1 / bit	0.0% ~ 100.0%
	Vehicle Quality	6、5	1 / bit	0.0kg ~15000.0kg
	Vehicle Speed	4、3	0.1 / bit	0.0km/h ~ 100.0km/h
	Lessened Speed	2、1	0.01 / bit	0.00m/s2 ~ 10.00m/s2
Target Pressure 0x2AA	Ration Relay Valve	8	0.01 / bit	0.00Mpa ~ 1.00Mpa
	Left Air Chamber Of Axle modulator	7	0.01 / bit	0.00Mpa ~ 1.00Mpa
	Right Air Chamber Of Axle modulator	6	0.01 / bit	0.00Mpa ~ 1.00Mpa

Table 3. Part of the definition on information frame data domain

EBS judges that whether it is emergency braking by the result gotten from the recognition of driver's braking intention module. If it is the emergency braking condition, the assist braking module control the aperture of the proportional relay valve and axle modulator to make all the axles get maximum braking force to trigger the ABS module to get the shortest braking length and improve the safety of.

ABS Control

ABS will be triggered when the vehicle is fully braked by the auxiliary braking functional module. Given the complexity of the real vehicle braking operating condition and the stability of the electronic control system, presently, the combination of threshold control and slip rate control is the most widely used control strategy on the actual vehicle. This paper adopts the threshold of wheel lessened speed as the main control parameter and the slip rate as auxiliary control parameter.

Figure 10 is the wheel anti-lock adjustment process. Thereinto, $-a_1$ is the threshold of wheel lessened speed; a_2 is the down threshold of wheel accelerated speed; a_3 is the up threshold of wheel accelerated speed; s_1 is the down threshold of slip rate; s_2 is the up threshold of wheel slip rate. 1 stands for boosting and transient pressure phase; 2 stands for decompression phase; 3 stands for pressure maintaining phase; 4 stand for repressurizing phase; 5 stands for pressure maintaining phase; 6 stands for staircase pressurization phase. Anlysis of the wheel anti-lock adjustment process is as follows:

At the beginning of the emergency brake, the ground braking force and the arrester braking torque enlarge at the same time. When the wheel slip rate exceeds the optimal slip ratio corresponding to the ground, the growth of ground braking force is less than the growth of arrester braking torquerate. According to the wheel dynamics, the absolute value of wheel lessened speed is larger at this moment, and it will swiftly come to the $-a_1$, threshold of wheel lessened speed.

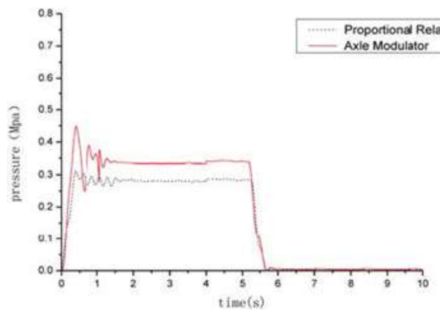


Fig 13. The pressure curve of loaded conventional brake

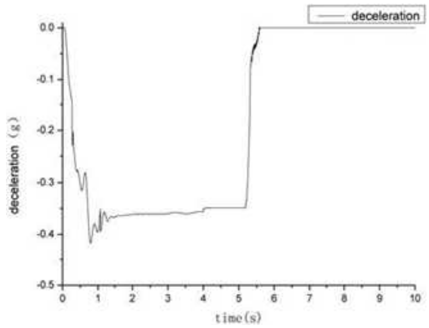


Fig 15. The deceleration curve of loaded conventional brake

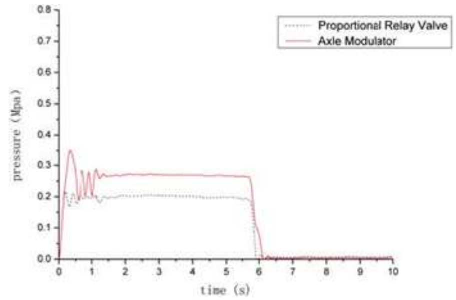


Fig 16. The pressure curve of unload conventional brake

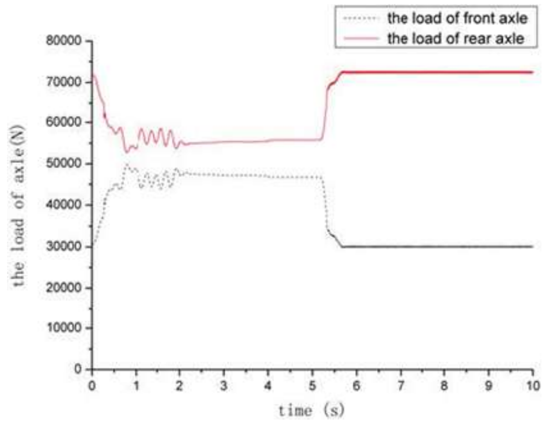


Fig 14. The load curve of loaded conventional brake

However, the wheel slip rate is less than the assigned s_1, the down threshold of slip rate. Therefore, it should maintain brake pressure temporarily. When the wheel slip rate is bigger than s_1, it enters decompression phase. There is a certain lag in the ABS machine-atmospheric pressure system, the arrester braking torque will be kept awhile and decreased. Consequently, the wheel speed and the wheel lessened speed will constantly decrease for some time. Hereafter, the wheel lessened speed begins to increase. Wheel speed is picked up momently. When the wheel lessened speed is larger than $-a_1$ threshold, ABS enters the pressure maintaining phase. When the wheel accelerated speed surpasses a_3, up threshold of wheel accelerated speed. Brake pressure will be increased to ensure it is under the wheel accelerated speed. Then, it come back to the pressure of maintaining again. When the wheel accelerated speed is less than a_2, down threshold of wheel accelerated speed, ABS carries out staircase pressurization control to make wheel stay at a stable area as long as possible. The adding of staircase pressure will make the wheel slip rate increase at a relatively stable area. When the wheel lessened speed reduces to $-a_1$, threshold of wheel lessened speed, it gets into the next ABS control loop. S_2, up threshold of wheel slip rate, is utilized for preventing wheel locking when suddenly transition of the vehicle to low adhering road out of control.

Valve Body Control Module

Proportional Relay Valve Control

The front axle proportional relay valve adopts combination control, including feedforward compensation control and PID control. If the target pressure becomes larger, then step-up hysteresis curve can be used to confirm the initial value of PWM duty ratio, soon afterwards PID will be used to regulate; If the target pressure becomes smaller, then step-down hysteresis curve can be used to confirm the initial value of PWM duty ratio then, and PID will be used to regulate. Feedforward compensation control can make the pressure of the front axle ratio approach the target pressure quickly, and the following PID adjustment can make the actual pressure stabilize around the target pressure.

Figure 11 shows pressure curve of proportional relay valve, which adopts combination control, including feedforward compensation control and PID control. Target pressures are 0.3Mpa, 0.5Mpa, 0.7Mpa respectively. And arrived time of target pressures is 0.153s, 0.227s, 0.259s respectively.

Axle Modulator Control

Axle modulator control employs a loop-locked switch control method. When the controller does not operate, acquiescent status of bride control valve is a closed admission valve and an open air evacuation valve. If the actual pressure is lower than the 95% of the target pressure, the duty ratio of the admission valve of controller is 100%, and the duty ratio of open air evacuation valve is 0%. Axle modulator pressurize; If the actual pressure is larger than the 105% of the target pressure, the duty ratio of the admission valve of controller is 0%, and the duty ratio of open air evacuation valve is 100%. Axle modulator decompress; If the error of actual pressure and target pressure is not beyond ±5%, the duty ratio of the admission valve of controller is 0%, and the duty ratio of open air evacuation valve is 0%. Axle modulator maintains pressure.

Figure 12 shows the pressure curve of the axle modulator, which adopts loop-locked switch control method for controlling. Target pressure is 0.3Mpa, 0.5Mpa, 0.7Mpa respectively. And arrived time of 75% of target pressures is 0.151s, 0.307s, 0.283s respectively.

ABS Electromagnetic Valve Control

The ABS electromagnetic value control envoys on-off control method. If the deceleration of the wheel and the slip rate surpass the threshold to operate pressure adjustment, acquiescently, the admission valve of ABS

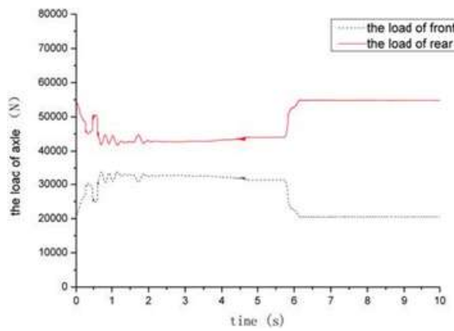


Fig 17. The load curve of unload conventional brake

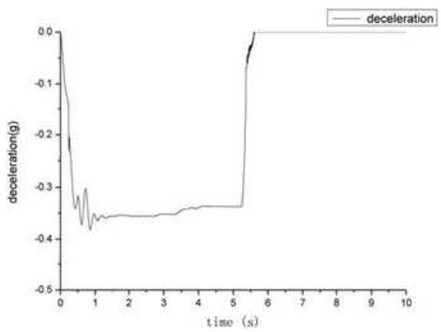


Fig 18. The deceleration of unload conventional brake

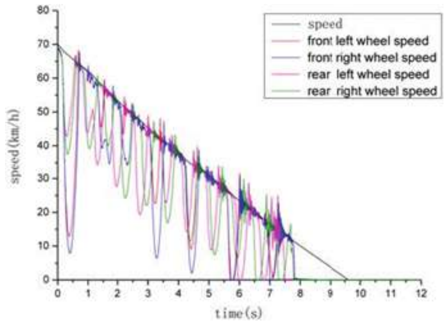


Fig 19. The wheel speed curve of loaded conventional brake

electromagnetic valve is open and the air evacuation valve is closed. During the process of pressurizing, the admission valve is open and the air evacuation valve is closed; during the process of decompression, the admission valve is closed and the air evacuation valve is open; during the process of pressure maintaining, the admission valve is closed and the air evacuation valve is closed.

CAN Communication Module

In this paper, the main designing purpose of the CAN module of EBS is to import information into IPC (Industrial Personal Computer) to carry forward the parameters on-line debugging of pre-software program and confirmation of control strategy, including pedal aperture, vehicle quality, vehicle speed, lessened speed, target pressure calculated by ECU. CAN communication adopts 11 bit identifier standard frame, and the identifier is consisted of ID18 to ID 28[11]. The numeric field of CAN module sends 8 bytes data to IPC at every turn. Each byte can represent a number ranges from 0 to 255. The protocol of CAN communication is defined by itself. Given the limit of numeric range representing in each byte, whether the transinformation can satisfy the physical quantity resolution ratio should be taken into consideration. Part of the definition on information from the data domain is shown in the table 3.

EBS HARDWARE-IN-THE-LOOP

The development of EBS controller involves many aspects, including atmospheric pressure, electricity, and machinery, the structure of EBS controller is very complicated, and there are a large number of non-linear links. If only theoretical analysis and model offline simulation is used for development, then actual circumstances vary greatly, it will cause a poor adaptability on EBS controller; If the traditional vehicle test is adopted to test and verify the development method, then the development cycle will be longer, even some minor modifications on controller will take a lot of tests in the process, and it is hazardous in the braking condition, so tests on emergency braking is inadvisable. The hardware, based on the accurate vehicle dynamics model in the loop simulation test-bed, installs some components and parts vehicle into the test-bed, connecting the software via the interface of computer for real-time simulation. The hardware in the loop simulation test-bed is very suitable for the software debugging and modification during the initial stages progress of controller. There are numerous advantages such as low development cost, good repeatability, short development cycle, ability of working on dangerous condition. Thus, the hardware in the loop simulation is rather essential for EBS controller progress.

Analysis the Result of Hardware-in-the- Loop

Test conditions are loaded conventional brake, unloaded conventional brake, loaded emergency brake, unloaded emergency brake. The ground which the conventional braking happened has good adhesive coefficient and the emergency braking has bad adhesive coefficient.

The attitude of experiment for conventional braking working condition is: checking whether the control algorithm can ensure the proportional relation of braking deceleration and the opening of pedal has nothing to do with load and other thing; whether the braking force can prorate in front and rear axle. So, conventional text needs to ensure the same open degree.

The attitude of experiment for emergency braking working condition is checking whether the control algorithm can assist the braking and making the braking force runs up and whether the ABS can assure the wheel not lock when braking takes large use of the ground adhesion. So that emergency text needs to ensure the 100% open degree.

Loaded Conventional Brake

The open degree is 74.2% when loaded conventional braking, at the beginning of the braking the speed is 70km/h, the adhesion coefficient of the ground is 0.77. The result of the simulation is shown as the figure. At the beginning of the braking, the load of front and rear axle change largely. Proportional relay valve and axle modulator need to follow the pressure currently, so it changed rapidly. After the load is stable, the real pressure of front and rear axle is close to the target pressure. its value is pro rate to the axle load.

Unload Conventional Brake

The opening degree is 76.5% when unload conventional braking. At the beginning of the braking the speed is 70km/h, the adhesion coefficient of

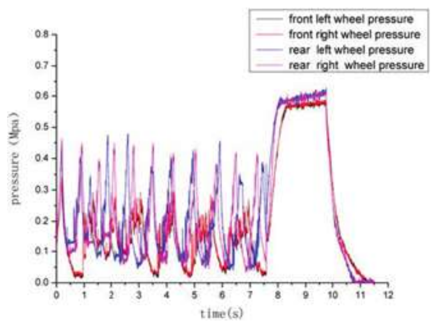


Fig 20. The pressure curve of loaded conventional brake

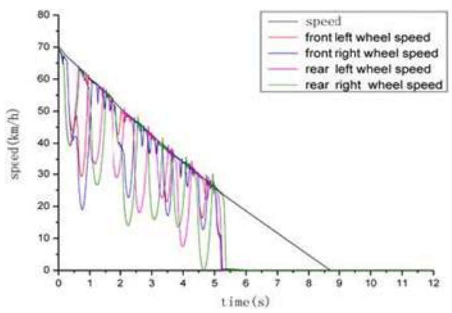


Fig 21. The wheel speed curve of unload emergency brake

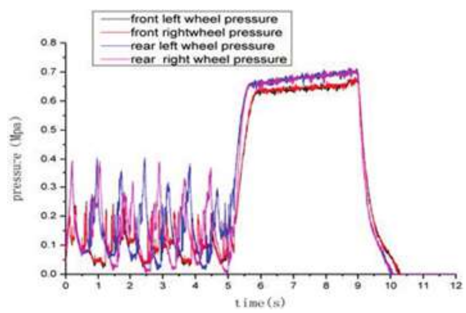


Fig 22. The pressure curve of unload emergency brake

the ground is 0.77. The result of the simulation is shown as the figure. At the beginning of the braking, the load of the front and rear axle changed largely. Proportional relay valve and axle modulator needs to follow the pressure currently, so it changed rapidly. After the load is stable, the actual pressure of the front and rear axle is close to the target pressure. Its value is pro rate to the axle load. The pedal's open degree of maximum load conventional braking and unload conventional braking is approaching; the control algorithm can ensure the vehicle gets the same braking deceleration in the two conditions.

Loaded Emergency Brake

When it is full load conventional braking, the open degree of pedal gets to 100% rapidly, at the beginning of the braking the speed is 70km/h, the adhesion coefficient of the ground is 0.23. The result of the simulation is shown as the figure.

Because of the adhesion coefficient of the ground is the law, the wheel will be located when fully touch the pedal. The assist braking and antilock braking system will control the ABS value. When the speed is less than 25km/h, the braking time is 9.612s and the braking length is 90m if it does not take the braking control.

Unload Emergency Braking

When unload emergency braking, the open degree of pedal gets to 100%, at the beginning of the braking the speed is 70km/h, the adhesion coefficient of the ground is 0.23. The result of the simulation is shown as the figure. Because the adhesion coefficient of the ground is low and the vehicle is unloading, the wheel will be located when fully touch the pedal. The assist braking and antilock braking system will control the ABS value. When the speed is less than 25km/h, the braking time is 8.689s and the braking length is 79.45m if it does not take the braking control.

Brief Summary

During conventional working condition, if the open degree of the pedal is the same, the control algorithm will ensure the vehicle get the same deceleration, which will make the deceleration the same to the driver's expectation and make the drivers easy. We can see that the control strategy can make the vehicle to get the better braking result on emergency or conventional braking condition.

CONCLUSIONS

This paper aims at the software design of electronic control unit, and makes it compiled into the controller in the form of C language by the in-depth study about control strategy of EBS in different braking conditions. The test results show that the control strategy in different conditions can achieve the expected result, and the program meet the requirements of real-time, accuracy, reliability, easy modify and portability. Experimental work confirms that the designed software can be used as the basis of the product development. But there are still some problems to be solved in the future studies. This paper includes the estimation of the mass of vehicle, but we have not finished the estimation of axle load, and the control algorithm of ABS has carried on the design of control algorithm on homogenous pavement, but does not include the docking pavement. For this, there is still long way to go. ■

REFERENCES

1. Yang Shengnan and; Zong Changfu, "Development and HIL Validation of Electronic Braking System ECU for Commercial Vehicle", Master Graduate Dissertation, JinLin University.

2. Guo Yuping, "Design of Braking System for Truck"[D], ChangChun, JinLin University, 2011.

3. Ju Wang, "Analysis and Simulation for Automobile Brake System"[D], NanJing, Nanjing University of Science and Technology, 2002.

4. Yu Zhisheng, "Theory of Automobile" [M], BeiJing, China Machine Press, 2009.

5. Guo Jingang, Wang Junping, Cao Binggang. "Study on braking force distribution of electric vehicles" [C]. IEEE: 27-31, March 2009.

6. Meng Shuxing, "Study of automobile braking force distribution optimization and braking performance computer simulation" [D], HeFei, Hefei University of Technology, 2003.

7. Yuan Huang, Peng Xiaoyan and Zhen Tan, "Study and Simulation of Brake Force Distribution Method for Brake-by- wire System" [J], computer simulation, 2011, 28(10): 324-327.

8. Hu Xiaobing and Huang Xiyue, "Ant algorithms for Optimization and Application" [J], computer simulation, 2004, 21(5):81-85.

9. Du Tianqiang, Li Haibin and Kun Wang,"Application Status of Break Assist System" [J], Automotive Engineer: 2011(4):52-55

10. Breuer Joerg J, Faulhaber Andreas, Frank Peter, et al. Real world safety benefits of brake assistance systems [R]. Mercedes Car Group

11. Gu Jiayun, "Study on CAN Communication of Electronic Brake System for Commercial Vehicle" [D], ChangChun, JinLin University, 2007

Engineering **the Motivo Way**

Motivo's young engineering team at the company's SoCal headquarters. (image: Mike Ditz Photo/Motivo)

Broad capabilities, unparalleled project diversity and an innovative culture have put this thriving California "idea factory" in high demand.

by Lindsay Brooke

"When we hire new engineers, I'm usually the last guy to talk with the candidate during the interview process," said Praveen Penmetsa, CEO and founder of Motivo Engineering. "And that's when I to try to convince them NOT to join the company.

"I tell them it's going to be a crazy job," he asserted. "You have to put your ego aside because our client's vision may not line up with your vision. I tell them the designs they've developed and are proud of will likely change during the course of a project—are they OK with throwing that away? And after all this, why do they want to work at Motivo?

"The right kind of people love that kind of challenge," Penmetsa noted with a smile. "The people who show up here and those who we recruit are looking for fulfillment. The ones who succeed here are highly motivated, intellectually curious people who enjoy our project diversity—and who like to get things done."

Engineers who make the grade find themselves in one of the most project-diverse product development environments of any industry sector. Motivo clearly would not be a good fit, professionally, for those with a singular focus. The company currently serves three market "pillars"—Mobility and Energy, Agtech (agricultural technology), and Aerospace. A glance through the mind-blowing portfolio of nearly 400 projects completed by Motivo since its 2010 founding is like peering into the future. Autonomous vehicle systems. A virtual-reality parachute simulator. Robotic automation for harvesting vegetables as delicately as a human hand can pick them. Battery systems. Drone aircraft propulsion and controls. Biz-jet cabins and aircraft seating solutions. Power grids. Advanced gearboxes. An electric multi-purpose tractor. Audio headphones and wearables!

The growing client base served by Motivo's two California facilities (Los Angeles and San Francisco Bay area) ranges from tech start-ups to global automotive, aerospace and consumer products giants including Airbus, Hyundai, Designworks, Panasonic, Foster Farms, and Nissan, to name a few who have made public their engagements with Motivo.

"Very often the 'large incumbents' come to us wanting some outside thinking," he noted. "Their advanced R&D says, 'Our engineering group says X is not possible—what do you guys think?' We then take a different perspective to it and feed that information back to them. Start-ups, on the other hand, will seek help because they lack bandwidth, resources. A lot of them have raised a 'seed round' or a Series A round [early stage capitalizations] and are still in 'stealth mode'. They look to us as a resource to help them better define their product before the next round of financing."

SWAY Motorsports partnered with Motivo for the development of an innovative, purely mechanical articulated suspension that enables the electric trike to lean into corners like a motorcycle. (image: SWAY Motorsports

Developed in house, Motivo's fully electric HARVEST tractor serves as a mobile power source and has successfully completed a year of in-field testing in India and California. (image: Motivo)

And sometimes the 'start ups' are semi-independent entities set up inside the big incumbents to promote innovation while trying to avoid traditional big-company pitfalls.

Innovation is optimal "if you can marry it, in a balanced way, with experience," he explained. "Too much of either will squash the other! Too much innovation won't make it to market; you see this a lot with the start-ups."

Deep involvement in both the 'wheels' and 'wings' worlds has helped cross-pollinate future programs across Motivo's business. "Our Aerospace clients love it that we bring experience from both the automotive and consumer-electronics worlds. And the Automotive guys like that we bring Aerospace experience," Penmetsa reported.

Scott Parazynski's young company, Fluidity Technologies, develops controls for drone aircraft in Houston, Texas. He and his three-person executive team "had looked far and wide for the right expertise in robotic flight controls. We needed a special combination of electrical and mechanical engineering, with a good deal of robotics and human-factors experience," he told *Automotive Engineering*.

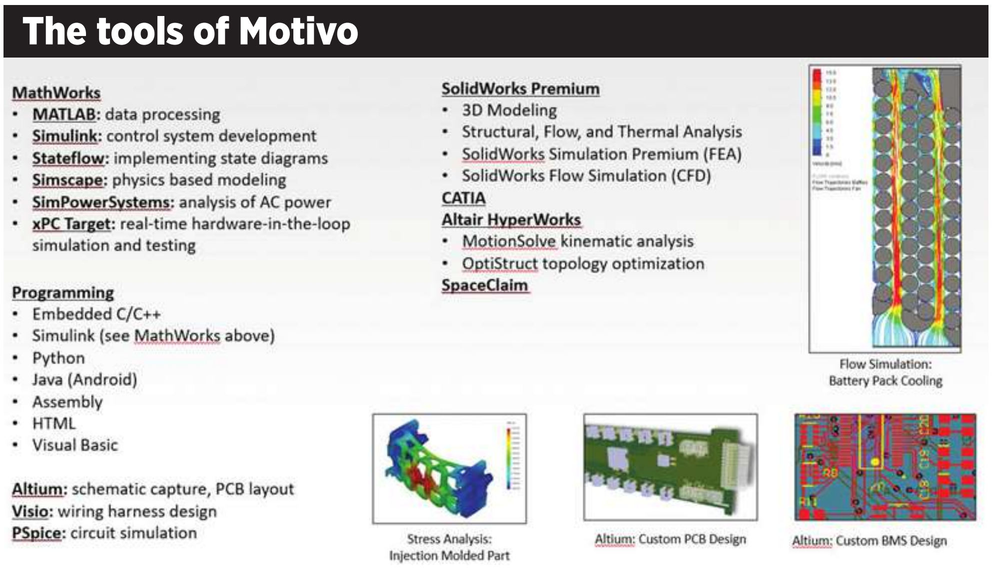
Motivo has several engineers with aerospace backgrounds who delivered "lots of ideation and active engagement" in helping the Fluidity team develop three flying prototypes and their single-handed control systems. "They were a good fit for us," he said.

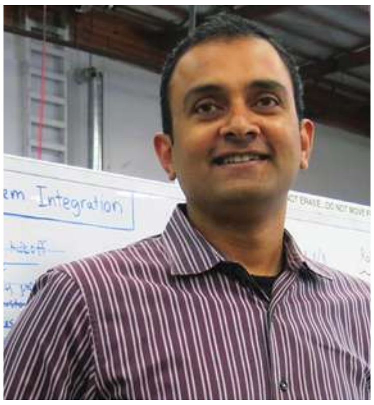
Aerospace seating and first-class-level cabins have been a Motivo specialty for some of the big players in the commercial-aircraft market segment. Learnings from these projects are being applied to autonomous-vehicle projects. Notes Penmetsa: "The space inside the fully-autonomous automotive cabin has much more in common with seating inside a commercial aircraft or biz jet than it does with a traditional car. From a pure business perspective you're selling a space along with the mobility from Point A to Point B—exactly what the airlines do," he said.

Rapid innovation and agility

Penmetsa, a co-founder degreed in aerodynamics and aerospace engineering, was previously director of commercial and automotive products at SoCal technology innovator MillenWorks prior to its acquisition by Textron. A student of innovation history and how it impacted icons such as Bell Labs, he notes that Motivo engineers are part of an exclusive group.

"We will never have more than 49 core people because a small team is important," he said. "There is a strong need across markets for an organization that understands the huge convergence of technologies, of propulsion,





CEO Praveen Penmetsa will only take on engineering projects that are complex and challenging for his 49-person core team. (image: Lindsay Brooke)

sensors, and the abstract layers in between. We also understand the increasingly fragmented use cases—customers want solutions customized. Unless you have all that expertise—from software to controls to the nitty-gritty mechanical devices like electric motors and gearboxes—in a small team, you really cannot innovate."

Motivo is organized flexibly to tackle the only type of projects Penmetsa will accept—those that are complex, challenging and professionally rewarding for his staff. There are generalists, specialists and special project teams dubbed 'Seal Teams' that operate on the premise that innovation typically is ambiguous. To innovate successfully you must be nimble and move quickly. Sometimes the teams must pivot, with the urgency of Navy Seals, depending on the situation.

Customers herald Motivo's ability to solve problems rapidly, a key element of what Penmetsa calls the Motivo Way.

"We won't take on projects that lack complexity or aren't challenging. We don't do product cost-optimization projects. If the vision is not audacious, you don't need Motivo," he pledged. "Most clients who approach us with projects come to Motivo because they were told that whatever they want to achieve is impossible. We're an 'idea factory.' Our approach is always 'how do we solve this problem' rather than, 'let's research this thing to death.'"

He noted that a racecar-engineering mentality burning inside the company constantly keeps the team focused on high-value use cases for each project first, rather than starting with the technology problem. Big-company clients come to Motivo for innovation—for the fact that a small team of

Motivo engineered the electronics hardware and manufactures the STISIM Drive simulators for Systems Technology Inc. STISIM Drive's scenario modelling and driver performance measurement capabilities are utilized by universities for research and for driving training. (image: Motivo)

fewer than 50 can do complete projects from the ground up, quickly.

Penmetsa sees Motivo as a 'bolt-on start-up' for both larger customers as well as entrepreneurs.

"They made the difference for us in finalizing our suspension linkage design," noted Joe Wilcox, founder and CEO of San Francisco-based SWAY Motorsports, developers of an electric motorcycle with unique articulated, three-wheeled chassis that allows the rider to lean into turns like a motorcycle.

"When we began our product design there was not a lot of background engineering information, said Wilcox, who was formerly with IDEO. "Motivo brought deep expertise in Systems Engineering and mechanical engineering. Their team had crazy linkages know-how, with the ability to rapidly iterate on the shop floor. Their agility also allows them to tailor their resources to individual projects.

"They're a really great partner for smaller companies like mine. We were just starting out, so we had to be resourceful. Motivo worked with us to tailor the project to fit our budget." Wilcox explained.

A new HARVEST

The diversity of Motivo's client base and development work is clearly evident during a walk through the company's Gardena engineering spaces with Penmetsa as tour guide. In one area a Class-8 semi-tractor is being retrofitted for automated/autonomous operation. In another engineers are prototyping a device for harvesting onions—its robotic jaws caress a plump Vidalia as a technician adjusts the vision system controls. Various white boards provide visual updates on the status of programs for major automotive OEMs. At a long work bench, an engineer assembles a prototype wiring harness while colleagues tweak control software on laptops nearby.

Penmetsa has keen interest in all of this company's work, but he's especially proud of HARVEST—the Hybrid Agriculture/Road Vehicles with Electricity Storage and Transformation. This small red electric tractor shown on the magazine's cover is conceived as a "Swiss Army knife" platform for a range of agricultural mechanization and power-related challenges facing farmers in Africa and Asia, and rural populations in other regions. Penmetsa himself hails from an Indian farming family so knows the challenges intimately.

HARVEST was developed as part of a competition hosted by the United States Agency for International Development (USAID), in collaboration with private partners, to develop innovative technical solutions for mobile power and agricultural duty, to assist global humanitarian and economic development efforts. Called "Powering Agriculture: An Energy Grand Challenge for Development," the competition attracted 450 companies and entrepreneurs. Motivo's entry was among a dozen finalists who were granted funding to bring their ideas to reality.

Motivo's HARVEST tractor brings 21st century capabilities. It can use multiple energy sources including solar panels and micro-wind-turbines, or the grid, to power not only implements but also serve as a mobile communications platform for farmers and those who live in remote communities.

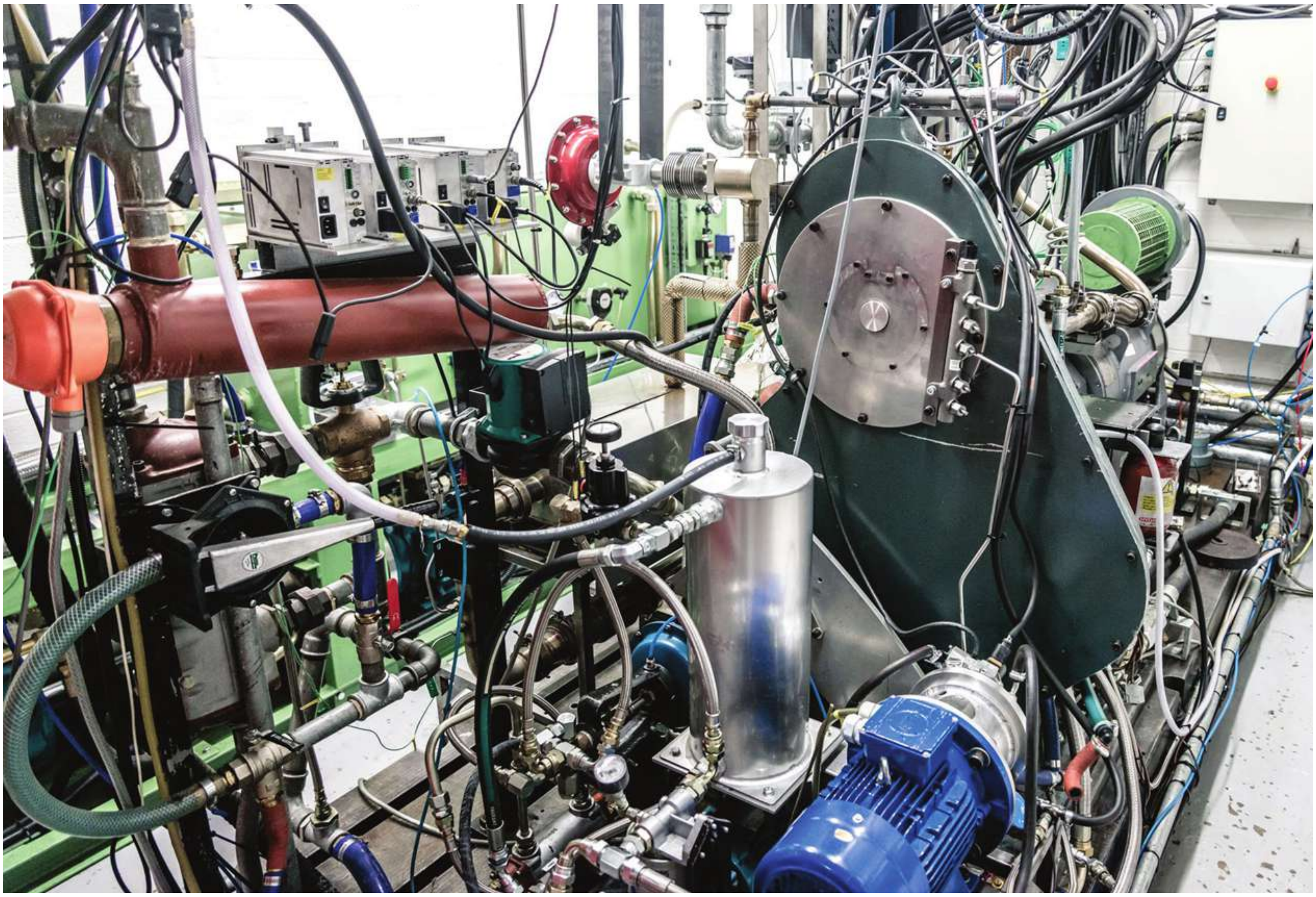
The agtech (agriculture technology) sector is a growing slice of Motivo's work in robotics, automation and systems engineering. Shown is a prototype onion harvesting tool under trials. (image: Lindsay Brooke)

Among Motivo's many auto-industry programs is this Class 8 tractor being retrofitted for SAE Level 4 autonomy testing. The company's clients are evaluating various autonomous strategies and utilize Motivo's diverse engineering capabilities that span software, controls, electrical and mechanical engineering for rapid evaluation and development. (image: Motivo)

According to Penmetsa, two prototypes have been field tested and he is optimistic that a large pilot fleet will provide further, more detailed evaluation of this clever, do-it-all unit.

Currently around 60% of Motivo's business is on the mobility side including aerospace. Within the other 20-30%, robotics/automation and Agtech projects are growing fast. Penmetsa expects Mobility to become a smaller slice of the pie.

"We apply our insights to line up with where the technologies will be five years from now," he said. "If you're too early, you end up too expensive and too niche. But if you're too late, the competition will engulf you. And your competition these days may not even exist yet." ■



Ricardo partnered with local universities to help develop the new technologies. CryoPower development rig is shown at the University of Brighton. (image: Ricardo, University of Brighton)

Developing an alternative engine concept

Ricardo's CryoPower engine leverages two unique combustion techniques for reduced emissions and fuel consumption—liquid nitrogen and split combustion. Long-haul trucking and stationary power generation will be the first beneficiaries of the technologies.

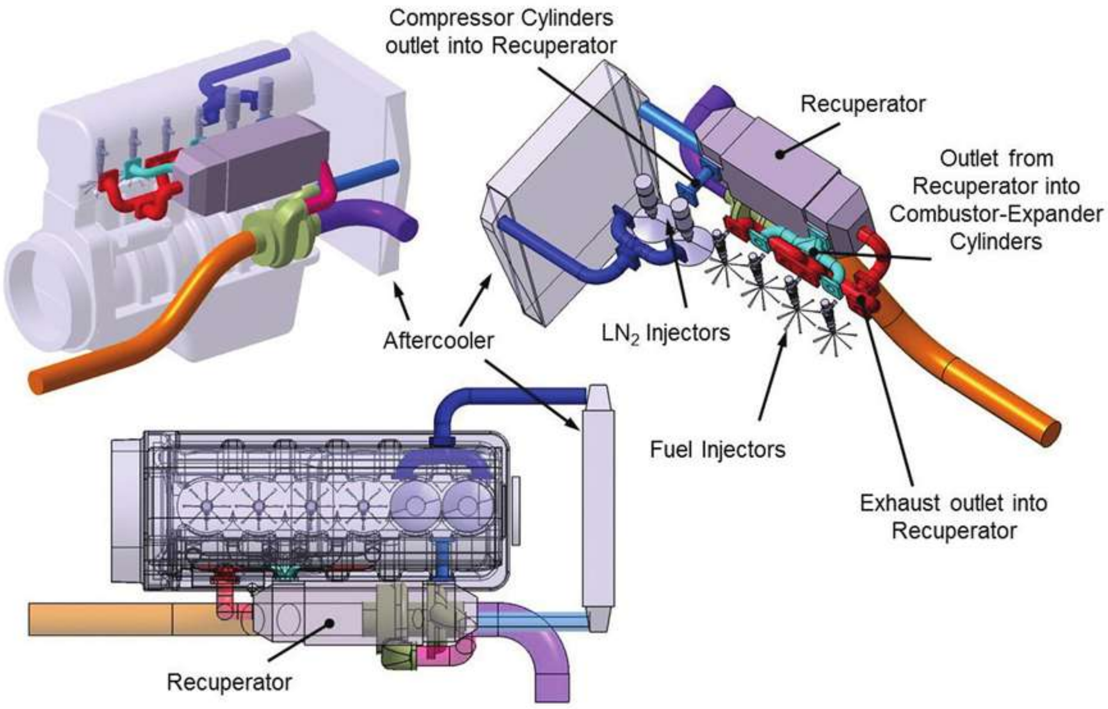
by Matthew Borst

As the transportation industry begins to enter the next stage of power sources, a wave of new options is becoming available to consumers. What was once an industry dominated by gasoline spark-ignited and diesel compression-ignition engines is now diversifying into electrified, natural gas, hydrogen fuel cell and bio-sourced powertrains. However, not all of these alternatives present viable options for the long-haul heavy-duty trucking market due to its extensive distance and payload requirements.

Ricardo, a global engineering and environmental consultancy, has developed a new engine concept called CryoPower that the company believes can offer significant emissions and operating fuel cost reductions over current diesel powertrains. The engine, which has been in development for 10 years, is now ready for a full-system demonstration and subsequent pilot applications. To achieve this next stage, Ricardo has spun the CryoPower technologies and assets off into their own company, Dolphin N2 Ltd.

The CryoPower engine leverages two unique combustion techniques for reduced emissions and fuel consumption—liquid nitrogen and split combustion. Combining these two methods has allowed Ricardo to claim a 30% reduction in CO_2 output as well as a 20% improvement in operating fuel costs. The company believes that long-haul trucking and stationary power generation applications would be the first beneficiaries of these new technologies.

"We're aiming at the heavy-engines market," Neville Jackson, Chief Innovation and Technology Officer for Ricardo told *Truck & Off-Highway Engineering*. "The key element in



The CryoPower engine design utilizes liquid nitrogen injection in the compression cylinder to cool the intake charge as it enters the recuperator, and then it enters the expansion cylinder. (image: Ricardo)

choosing a large engine is total through-life cost. Because we can deliver the reduction in fuel cost where that cost is a significant portion of the through-life cost, then what we are offering becomes extremely appealing."

Future applications like permanent power and train engines are also viable options for CryoPower technologies. However, the company also realizes this is not the alternative option for every market's needs. "We recognize that for mobile applications of lighter duty and short-haul that electrification offers some strong benefits," Jackson said. "But when you get to the heavier end, the energy density of batteries becomes less practical over 500 or 1000 miles."

Liquid nitrogen and split combustion process

The CryoPower combustion process begins like most engines, but then quickly deviates from the standard course. Air enters the cylinder during the intake stroke. During the combustion stroke and after the intake valve has closed, liquid nitrogen is injected into the cylinder. The spray evaporates and cools the intake air as the pressure increases. Near TDC (top dead center), the exhaust valve opens and the high-pressure intake charge is released from the compression cylinder into a heat exchanger.

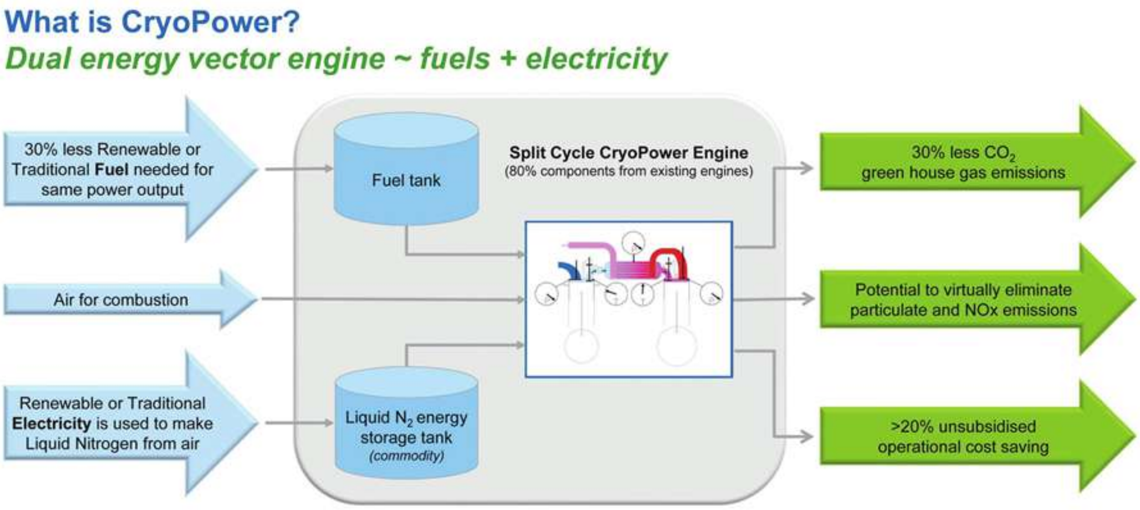
Once in the heat exchanger, the intake charge is heated by the exhaust gases. The intake mixture is then released into a second cylinder over a short crank angle near TDC. Fuel is then injected into this high-pressure and high-temperature condition, which allows for ignition and expansion without the typical mixing tumble and swirl requirements. After the power stroke, the combustion gas is released from the expansion cylinder through an exhaust valve and back through the heat exchanger. This process is designed to work with or without EGR (exhaust gas recirculation) assistance.

"There are three specific areas that deliver high efficiency, not because the engine is split cycle but what the split cycle enables," Jackson explained. "The first is that as we compress the gas in the compression cylinder and as we cool the gas down, we are doing less work than a conventional engine with the same compression pressure—between 15 and 20% less compression work. The second thing we are doing is recovering exhaust gas heat to the hot part of the cycle like a recuperating gas turbine. The third thing is having the two cylinders have different swept volumes. We have a lower volume in the compression cylinder than we do in the expansion cylinder, so we have a true Miller cycle."

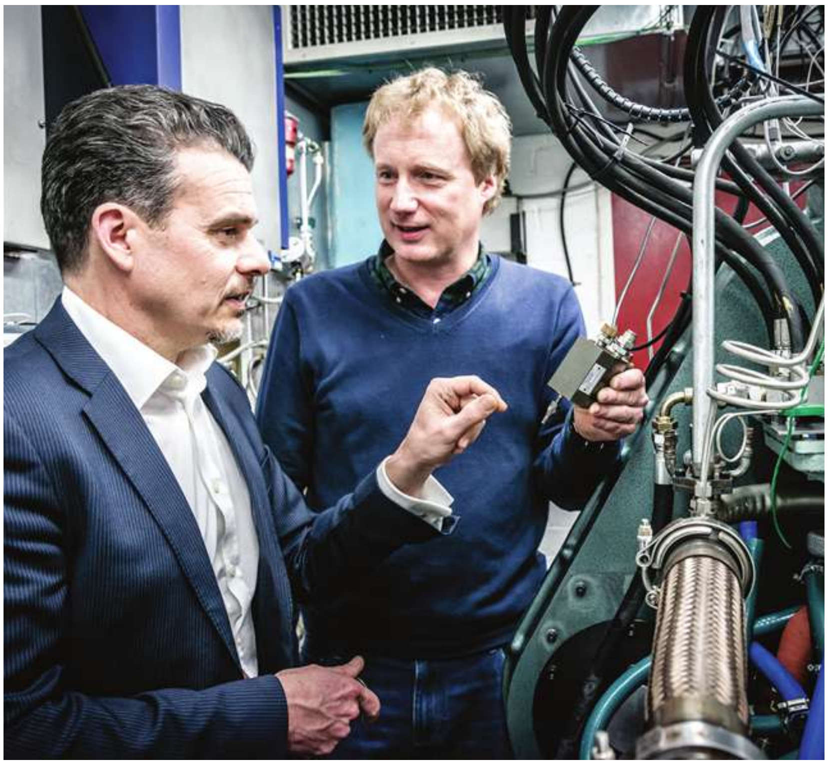
The only additional components required for the system include the liquid nitrogen storage tanks and injectors as well as the heat exchanger between the compression and expansion cylinders, which Ricardo calls a recuperator. An image of a possible CryoPower engine application shows a six-cylinder configuration. In this instance, two cylinders are used for compression and four cylinders are used for expansion. This allows for four power strokes per crankshaft revolution since the expansion cylinders function on a two-stroke cycle.

A decade in the making

Ricardo has been developing the CryoPower technologies for the past 10 years. The research has been focused on proving individual improvements to the powertrain before bringing it together in a single system. The liquid nitrogen was tested to determine the process of injection and evaporation. Other gases were tested, but nitrogen was determined to be the best option due to it



80% of the components for the split-cycle CryoPower come from existing engines. (image: Dolphin N2, Ricardo)



Simon Brewster (left) is leading Dolphin N2 to invite investor support. (image: Dolphin N2, University of Brighton)

being a stable, inert gas and its evaporative properties. The valvetrain was also designed to handle the split combustion process.

However, one aspect proved to be more difficult than the others. "The one critical area we struggled with was the combustion system," Jackson told *TOHE*. "More recently, we have had a major breakthrough in getting the combustion system to work and to work exceptionally well. That's been the breakthrough in getting a split-cycle, recuperating engine to work."

The team at Ricardo has partnered with local U.K. universities to aid with the development research. The University of Brighton and the University of Southampton have helped with providing additional simulations to prove out these new combustion techniques. While Ricardo has been the leader in the development process, the universities have allowed for more experimental research that has led to some of the combustion advancements.

Next steps: demonstration, further refinement

As those developments have come to realization, the time has come to apply them in demonstration and pilot units. All CryoPower property and assets are being spun into their own company called Dolphin N2. While Ricardo will remain an active member of Dolphin N2, the company believes now is the time to include other partners in this research.

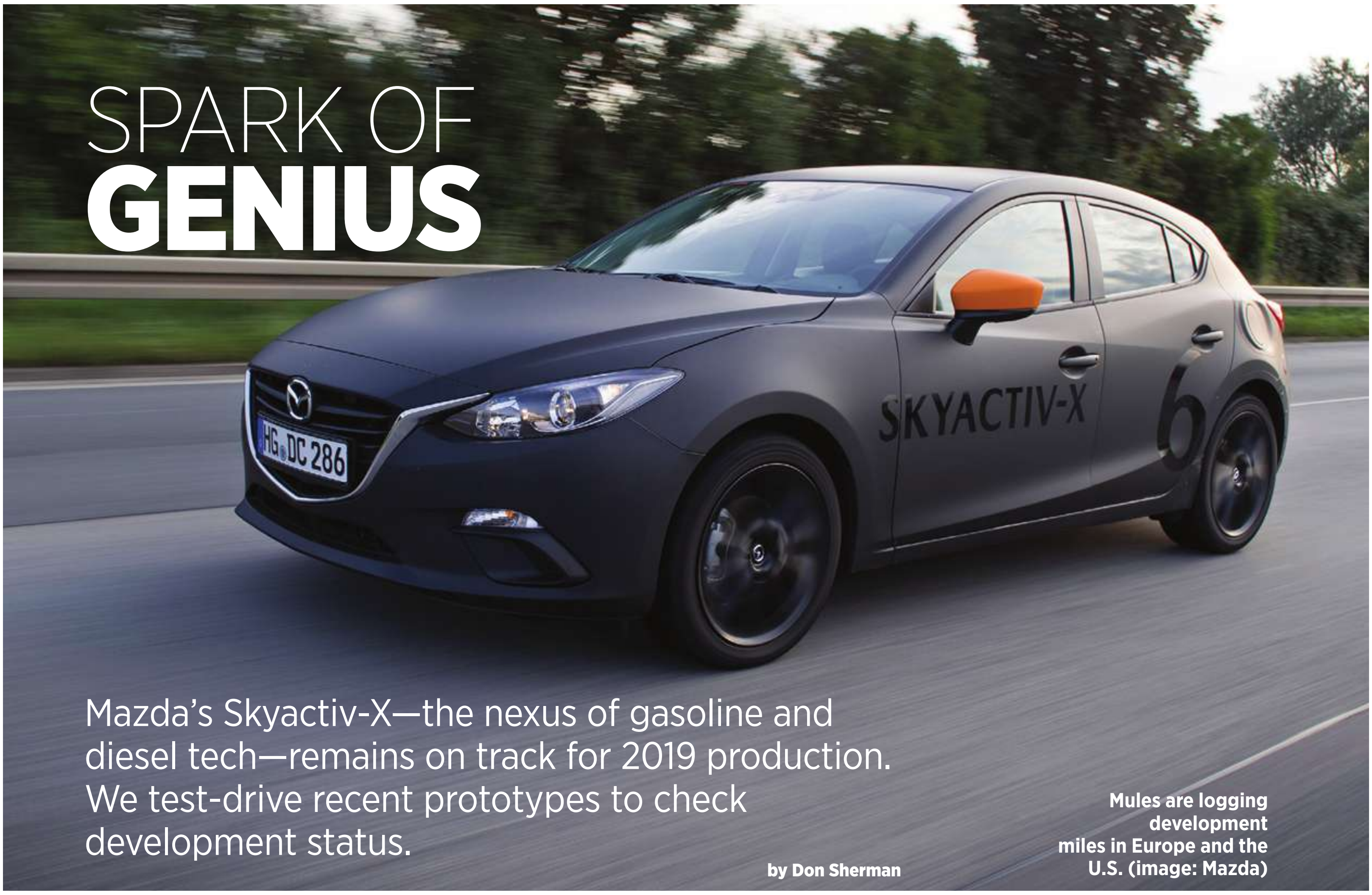
"We have reached the stage of maturity in all of the subsystems now," Simon Brewster, CEO of Dolphin N2 told *TOHE*. "Now is the time to piece all of those together and take them into a multi-cylinder demonstrator that will look like a normal engine so you can simply install it into a vehicle or a gen-set."

The cost of this next phase to bring the CryoPower technologies into a production atmosphere is beyond the standard investment level of a single company. Dolphin N2 now fits into a venture capital investment space that will include multiple backers. While Ricardo did evaluate the opportunity to bring the engine to market through a single customer, the team felt the technology still requires some continued development that goes beyond the abilities of a single company over a shorter timeframe.

Dolphin N2 realizes that the long-haul trucking and power generation industries are in need of fuel-efficiency improvements along with emissions reductions to meet both future regulations and consumer demands. While the CryoPower system has been in development for a decade, the market now is more receptive to these alternative power source technologies. The liquid nitrogen and split combustion processes allow for these improvements while minimizing the changes required to current infrastructure.

Another powertrain option appears poised to come to market in the not-too-distant future.

SPARK OF GENIUS



Mazda's Skyactiv-X—the nexus of gasoline and diesel tech—remains on track for 2019 production. We test-drive recent prototypes to check development status.

by Don Sherman

Mules are logging development miles in Europe and the U.S. (image: Mazda)

In 2016, after six frustrating years of R&D invested in an ultra-lean-burn, high-compression gasoline engine, Mazda's managing executive officer, Mitsuo Hitomi, 63, had this brainstorm: Adding spark ignition might help stabilize the new Skyactiv-X engine's fickle compression-ignition combustion process. Like at least four other OEMs, Mazda considers the marriage of gasoline and diesel attributes to be the next and possibly last opportunity to reap significant efficiency gains from internal combustion.

What's most commonly known as Homogeneous Charge Compression Ignition (HCCI) is the IC engine's holy grail. Unlike conventional IC engines, where a flame front initiated by a spark spreads throughout the gasoline-air mixture, ignition in an HCCI engine is instantaneous—like all of a city's street lights illuminating at once.

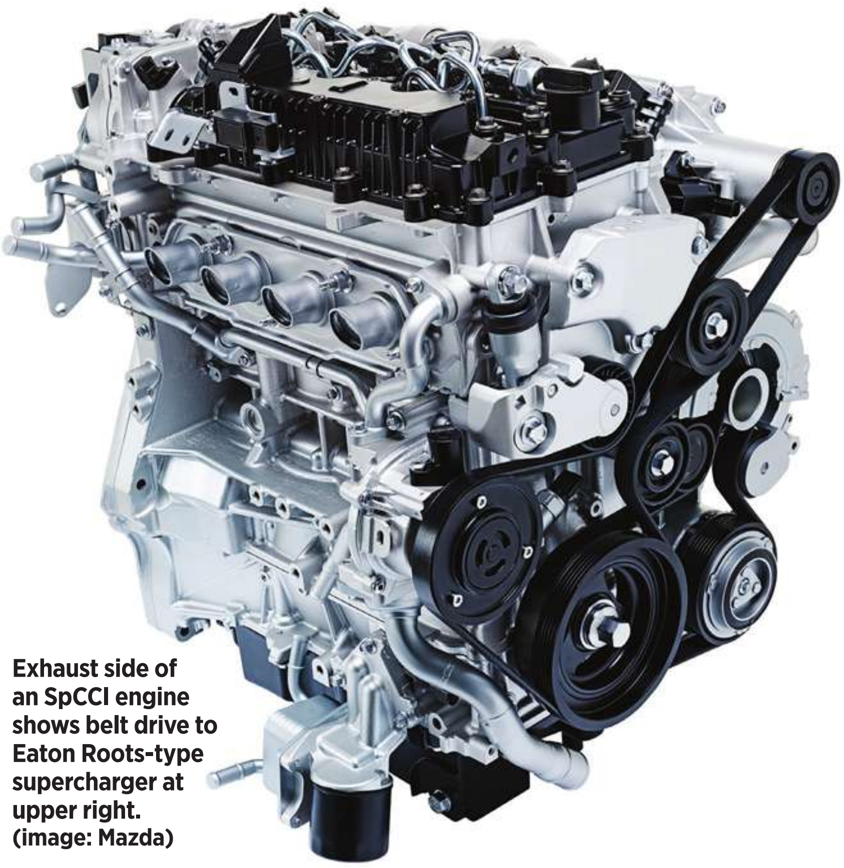
While other makers have slowed further development of the ICE to devote greater resources to electrification, Mazda is hesitant to cease development of propulsion technology that has served it well. From the Skyactiv efficiency initiative launched in 2007, Mazda engineers set two ambitious goals: a 50% reduction in CO_2 (from the 2010 baseline) by 2030 with combustion engines shouldering most of the load. And, by combining more efficient engines with electrification, a 90% CO_2 reduction by 2050.

For the small but feisty Hiroshima-based automaker, revolutionizing 19th-century inventions by Nikolaus Otto and Rudolf Diesel would be a monumental feat. Accentuating that goal, the X in the Skyactiv-X name coined last year stands for the intersection of gasoline and diesel attributes. The program remains on track for 2019 production and Mazda has kept *Automotive Engineering* apprised of development progress at two dedicated events since summer 2017, including mule-vehicle test drives (see sidebar). Hitomi-san's development team has also published SAE Tech Papers on their work (https://www.sae.org/publications/technical-papers).

Like every other 21st-century attempt to ignite a homogeneous mixture of gasoline and air without a spark, Mazda's approach creates a lean, cool blend during the intake stroke. A higher-than-normal (currently 16.0:1) compression ratio raises the charge's temperature and pressure to the point of auto ignition as the piston nears the top of its stroke.

Then the trouble begins.

If the air-fuel mixture lights prematurely, energy in the form of pressure against a rising piston and heat transferred to surrounding



Exhaust side of an SpCCI engine shows belt drive to Eaton Roots-type supercharger at upper right. (image: Mazda)

engine components is wasted. When ignition is tardy, with the piston well past top-dead center, a significant portion of the expansion (power) stroke is squandered, also greatly diminishing efficiency.

Hitomi-san realized that a well-timed spark could be perfect for triggering compression ignition. What he and his engineering team have developed (they call it SpCCI—Spark-Controlled Compression Ignition) during the past two years in hopes of a production start sometime in 2019 is three engines in one. In high-load and -rpm circumstances, Skyactiv-X operates like a conventional high-output spark-ignition gasoline engine with a stoichiometric (14.7:1) air-fuel ratio. The second mode also is stoichiometric, but with compression-ignition triggered at the right instant by a pressure rise in the combustion chamber resulting from the spark ignition of a locally rich air-fuel mix. Mode three also uses a spark to trigger compression ignition, but now with ultra-lean (λ up to 2.5) mixtures.

Although the Skyactiv-X's basic architecture continues Mazda's 2.0-L engine fundamentals,

Skyactiv-X on the road

Even though there's barely a glimmer at the end of the development tunnel, Mazda offered Skyactiv-X test drives on a 30-mi (48-km) public road route near its Irvine, CA, North American Operations campus. The matte-black mules, which resembled standard Mazda3s, embodied several notable seventh-generation upgrades: revised front seats, recalibrated suspension systems and key body structure revisions.

The experimental dash was fitted with three large green lights supplementing standard speedometer and tachometer gauges and seat-of-the-pants observations. Light number one indicated the conventional spark-ignition engine-operation mode. When the second light illuminated, the Skyactiv-X 4-cylinder engine was running with spark-assisted compression ignition of a stoichiometric mixture. Light three indicated very lean running with spark-assisted compression ignition. How lean? Mazda won't say.

While no cold starts were offered, the two mules I drove—one with a manual transmission, the other with an automatic, both six-speeds—felt primed and ready for customers. They were as smooth, quiet and refined as any production car from idle to redline. The spunk and spirit under the throttle pedal were consistent with Mazda's Zoom-Zoom marketing posture.

Unlike other manufacturers that use low-engine-speed cruising to improve mileage, Mazda lets the Skyactiv-X engine sing on the freeway, claiming it's efficiency doesn't wilt with rpm. This improves throttle response and diminishes the need for downshifts to pass; a tach reading of 3000 rpm equated to 80 mph with the manual and 88 mph with the automatic. That gearing is comparable to Honda Civics equipped with a manual transmission but a good 20% shorter than Civic automatics. That said, the Mazda3 automatic eagerly downshifted in response to modest increases in accelerator-pedal pressure.

During aggressive acceleration, the No. 1 green light glowed steadily with both transmissions. Likewise, both drivelines lit their No. 2 green light at idle. Light No. 3 was more elusive. In the cut-and-thrust of traffic and while cruising on the freeway, I saw only short-duration flashes of that goal-line light with the manual transmission. But, in the more placid automatic, light No. 3 glowed encouragingly for 20 seconds or longer at a time while cruising at steady speeds ranging from 30 to 70 mph.

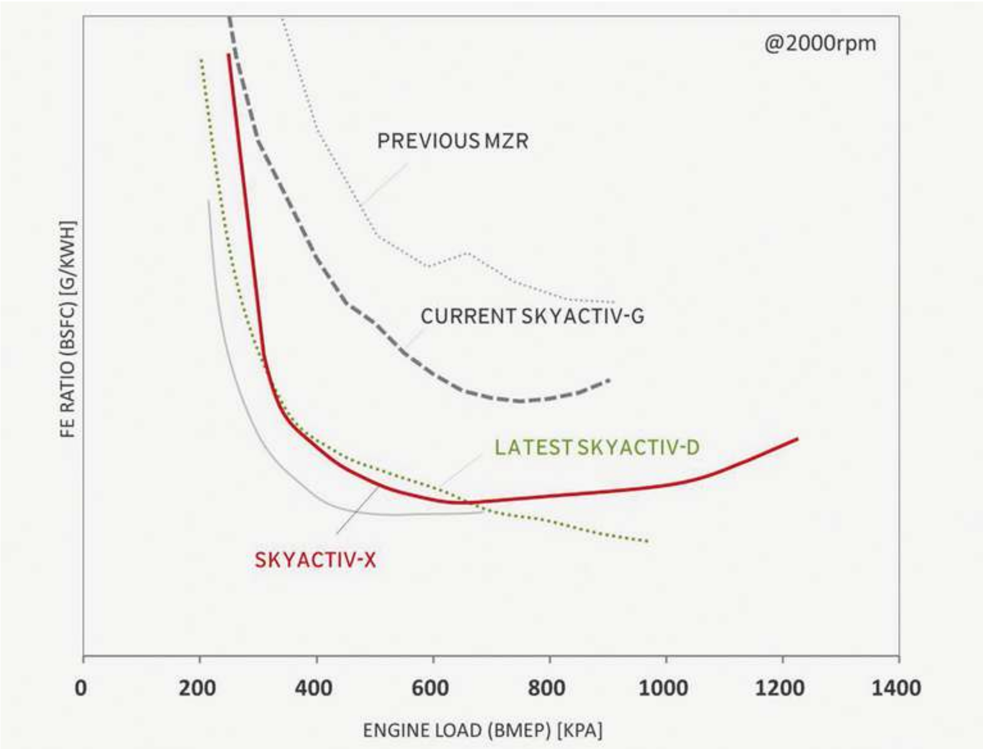
Except for the flashing lights, there was no noise or vibration hint of Skyactiv-X's mode changes. All three lights were off during coasting, indicating a total interruption of fuel delivery. The planned stop-start function was disabled in these test vehicles.

Detonation—evident here as a subtle metallic tapping—cropped up now and then. There was a steady rattle while climbing a slight grade at 50 mph in the automatic. Driving host and powertrain engineer Kentaro Takaki noted, "Eliminating that fault is our current top priority."

Mazda's to-do list likely contains several additional items. Such as more frequent and longer-lasting use of the ultra-lean mode to achieve hoped-for mpg and CO_2 goals. Validating durability. Finding suppliers able to contain costs associated with the added engine hardware. And creating a marketing gambit that will convince customers the "SpCCI" Skyactiv-X engine is well worth spending their hard-earned money to own.

–DS

Skyactiv-X mules are fitted with the mother of all engine covers. Mild detonaton was noticeable in *AE*'s early 2018 test drive. (image: Mazda)



Fuel-consumption-rate plot showing Skyactiv-X vs. similar displacement Mazda gas and diesel engines. (image: Mazda)

key features have been added. The direct fuel-injection system currently operates "between gasoline and diesel levels" according to Mazda engineers; *AE* has previously reported a 500 bar (7250 psi) operating pressure (see October 2017 issue). One squirt is delivered during the intake stroke and a second injection occurs just before the sparkplug fires. The engine is significantly undersquare (bore and stroke dimensions remain proprietary) to diminish combustion-chamber volume.

Mitsuo Hitomi leads the Skyactiv-X engineering team. (image: Mazda)

Electric actuators provide variable intake and exhaust valve timing. The intake system is enhanced with the addition of an Eaton-supplied Roots-type supercharger with a clutched belt drive to allow switching between normal and pressurized aspiration. An engine coolant heat exchanger diminishes the temperature of recirculated exhaust gas (EGR). A belt-driven motor-generator wired to a 24-V battery powers this engine's stop-start feature and its ECM. A three-way catalytic converter and a particulate filter treat the emissions leaving the combustion chamber.

Swirl motion within the Skyactiv-X cylinder assists fuel vaporization and creates a consistent air-fuel mixture. The piston crown has a volcano-shaped bowl to tumble the rich mixture created near the spark plug.

While these features have been seen before, Mazda's Skyactiv-X breaks ground with the addition of a pressure sensor in each cylinder and the use of a powerful, high-speed processor to control each and every combustion event. Details of that equipment's speed and cost have yet to be revealed. Exact mpg and CO_2 details also are pending.

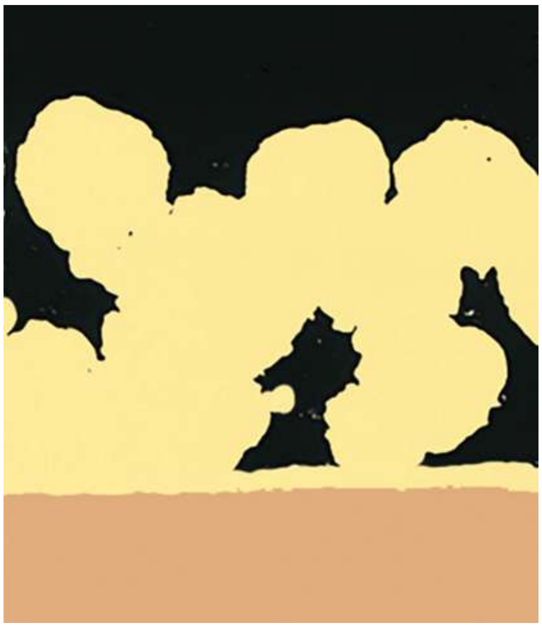
What is known is that current prototype engines deliver 178 hp (133 kW) and 170 lb·ft (230 N·m) with 6000 rpm within easy reach on 87-octane regular gasoline. To support the three combustion modes, Mazda uses valve overlap at the end of the exhaust stroke to scavenge the cylinder of hot gasses. When necessary, closing the intake valves well after BDC on the compression stroke inhibits full-load detonation (Miller cycle). Heavy doses of EGR reduce throttling losses and the supercharger aids full-throttle performance.

Mazda engineers also are exploiting a 'gram strategy approach' to curb the new engine's mechanical losses. Claims thus far are 31% lower water-circulating loss; a 74% reduction in oil-pumping loss; 25% less reciprocating loss; a 54% more-efficient valvetrain (using roller-finger followers and hydraulic lash control), and 27% lower accessory drive belt losses.

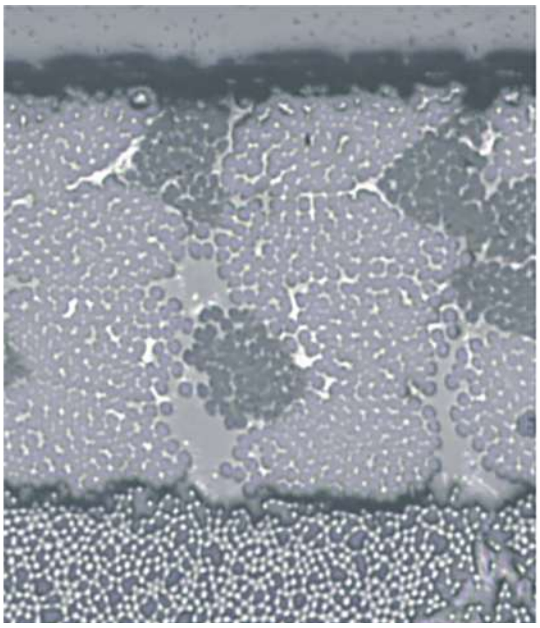
Achieving the program's near-term goals of more power with a 30% gain in efficiency indicates that genius is indeed present under the hood. ■

Plain bearings for aerospace applications

GGB's HPMB® fiber reinforced composite bearing.



Metal-polymer bearing material structure.



Fiber reinforced composite bearing materials structure.

Plain bearings are used across a wide range of aerospace applications to help achieve better fuel efficiency, extend maintenance intervals, and lower carbon emissions. These applications include installation in aircraft wing systems (flaps, spoilers, and slats), flight controls, cockpit controls, auxiliary power units, landing gear, door systems, and aircraft interiors (seats, bins, latches, and hinge points). "Our plain bearings even have a footprint on Mars," said Brett Ricci, GGB Aerospace Strategic Account Manager for North America. "Operating in temperatures between -200°C to +280°C, our plain bearings have served as the primary suspension components in the robotic drilling arm of NASA's Curiosity Mars Rover since 2012."

Just as impressively, all of these applications are served by just two types of plain bearings: metal-polymer and fiber reinforced composite (FRC).

Metal-Polymer Plain Bearings

Metal-polymer bearings consist of an outer metal backing with a porous bronze inner structure that is coated with a polymer-resin lining. Each part of this structure contributes to the overall characteristics of these bearings: the polymer liner provides lubricating properties with low friction and wear; the bronze inner structure provides the mechanism to contain the polymer liner while also transferring load and heat; and the metal backing provides mechanical strength. Metal-polymer bearings are made in two varieties: self-lubricating and pre-lubricated.

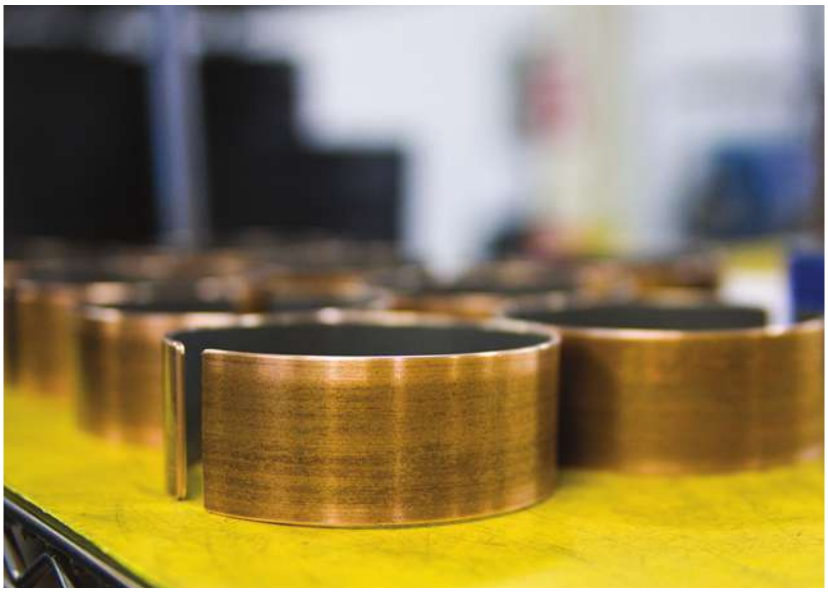
Self-lubricating bearings have a smooth, PTFE-based liner that is transferred to the mating surface during operation, forming a lubricant film. This results in very good wear and low friction performance over a wide range of loads, speeds, and temperatures in dry running conditions. Pre-lubricated bearings utilize different materials for this liner and include circular indents that are filled with grease before operation.

"Self-lubricating metal polymer bearings are GGB's most popular products with the aerospace industry—particularly the DU-B," says Kim Evans, one of GGBs aerospace application engineers. "I'd say it's the industry standard for aircraft landing gear struts."

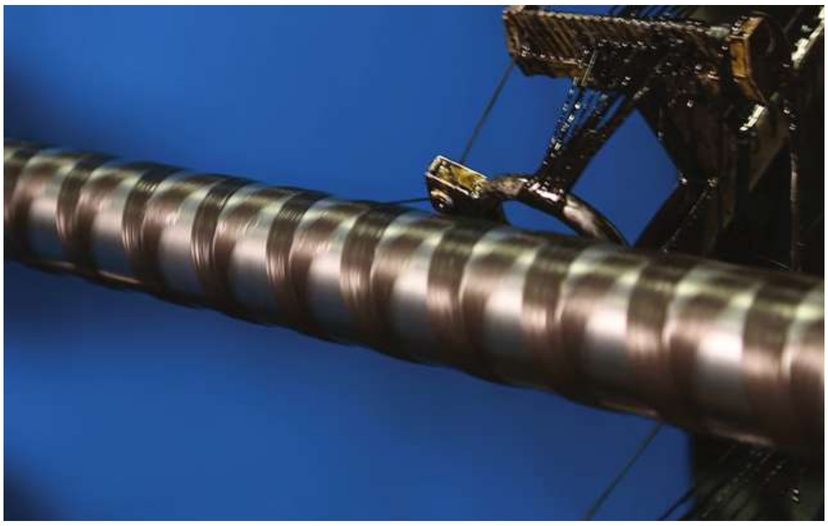
Fiber-Reinforced Composite (FRC) Bearings

FRC bearings consist of a self-lubricating liner backed by continuously wound high-strength fiberglass. To ensure they fit a variety of ap-

GGB's DU-B bearing.



GGB metal-polymer bearings on the production line.



The filament winding process for fiber reinforced bearing manufacture.

plications, FRC bearings use two different forms of liners: fiber and tape. A fiber liner offers high abrasion resistance and improved ability to handle shocks and misalignment. Due to a greater PTFE content, a tape liner additionally offers higher speed capability and improved machinability. Regardless of the liner, all FRC bearings are self-lubricating through the use of dry lubricants. This method of lubrication results in a low coefficient of friction, low wear rates, and extended maintenance intervals, as re-lubrication is unnecessary. In addition, FRC bearings are able to operate in a wide range of temperatures and are also resistant to acids, bases, salt solutions, oils, fuels, alcohols, solvents, and gases.

FRC bearings can have the self-lubricating liner on the inner or outer diameter and can contain flanges or grooves with or without a liner as well. FRC washers, plates, and other custom forms are also available to serve different applications. "The versatility and specifications of these FRC products make them an excellent choice for most heavy load, low speed, oscillating applications," says Yuri Klepach, GGB's FRC Product Manager.

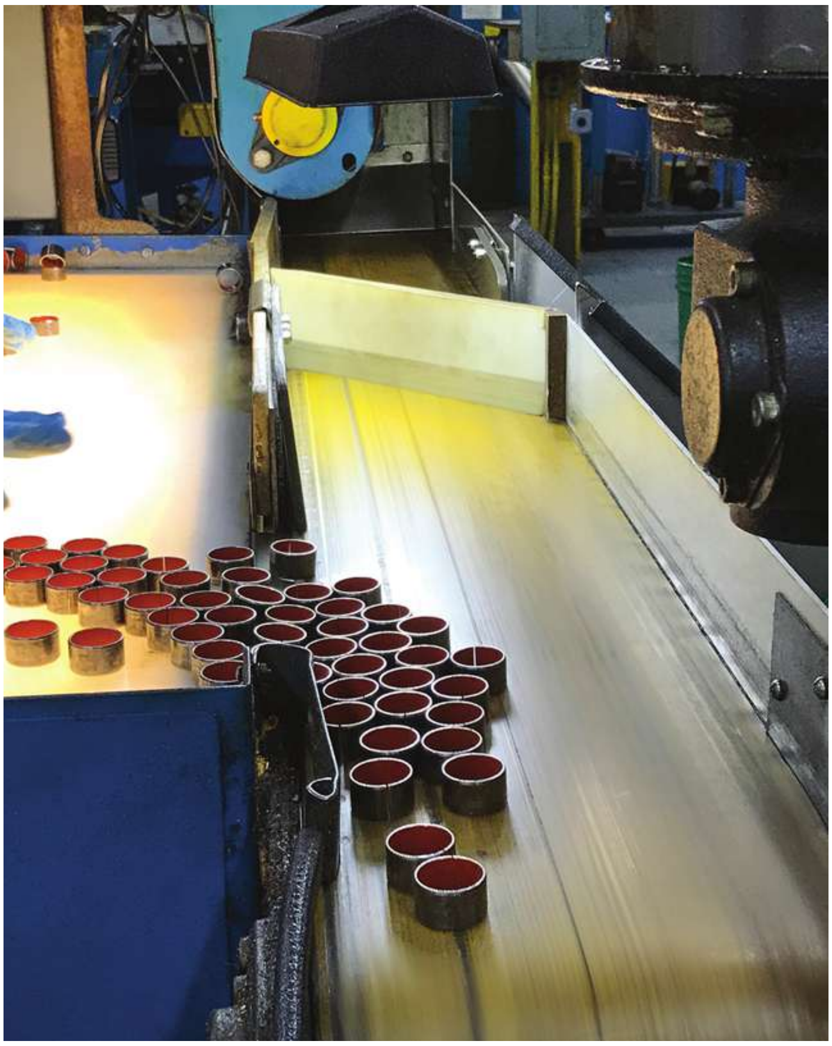
Plain Bearing Manufacturing

Metal-polymer bearings are produced using a series of technologies that combine the steel or bronze metal backing, bronze powder, and polymer liner. To start, a coil of backing metal is fed through a machine that applies bronze powder to one side through the use of heat—a process known as "sintering." The sintered strip is then cooled and ready for impregnation. Impregnation is the application of a polymer liner onto the sintered strip and can be done with the polymer in either mush or tape form. According to Evans, "For GGB's self-lubricated bearings, a mechanical arm drops the polymer onto the sintered strip, which is then rolled out through downstream machines to create a smooth self-lubricating liner. GGB pre-lubricated bearing liners are made with a polymer tape that is applied directly onto the sintered strip."

The impregnation process for both forms of polymer includes a series of mill-rolling, heating, and cooling operations in order to create a smooth-surfaced metal-polymer strip. After impregnation, the strip is finished and coiled for later shaping into bearing products. As Evans explains, "This shaping process utilizes roll-forming or pressing, depending on the bearing size, to create a smooth, cylindrical-shaped product."

FRC bearings are manufactured through a winding process that utilizes automated winding machines. For bearings with the liner on the inside diameter, the liner material must first be applied to the length of a mandrel. For wound liner products, this is done by a winding machine that is continuously fed strings of high-strength fibers encapsulated in an

Plain bearings for aerospace applications



Metal polymer bearings on the manufacturing line, after visual inspection.

internally lubricated epoxy resin. For tape liner products, a PTFE tape is applied on a mandrel. After this base liner is applied, the fiberglass backing is wound around the mandrel through the use of automated winding machines. Once this backing reaches the required thickness, the mandrel is removed and later cured in an oven. This process hardens the winding around the mandrel into a solid tube. At this point, the inside diameter is smooth and finished while the outside diameter is rough and oversized. In order to finish the outside diameter, it is ground down to its desired final size. The tube is then cut to produce multiple finished bearings whose edges are deburred as needed. "The length and diameter of the mandrels used in this process can vary," Klepach says, "to achieve different dimensions based on customer need."

The Trend Toward Self-Lubricating Bearings

As mentioned previously, many plain bearing models are used in aerospace applications—most of them self-lubricating. Self-lubricating bearings utilize a pre-applied dry lubricant, usually PTFE, in place of traditional liquid lubricants. Dry lubricants do not require reapplication and thus entail less maintenance than traditional bearings. This makes them extremely effective in applications where re-lubrication maintenance would prove difficult. Dry lubricants are also able to operate in conditions where fluid lubricants are ineffective, such as environments susceptible to corrosive gases, dirt, and dust; high temperatures; cryogenic temperatures; radiation; extreme pressures; or vacuums—all of which are hazards found in the aerospace industry. Due to these benefits, it is no surprise self-lubricating bearings are being used over traditional metal bearings both here on Earth and beyond in the following applications:

In aircraft landing gear struts, or shock absorbers, where they eliminate ladder cracking and heat damage on the strut rod surface. GGB's DU-B bronze-backed metal-polymer bearings were chosen by one of the world's leading commercial aircraft manufacturers to be used in all current production of their landing struts due to their high load capabilities, resistance to corrosion, and increased component life.

In aircraft ground support, which requires reliable equipment to ensure flights leave safely and on time. According to Klepach, "GGB's HSG [High-Strength GAR-MAX®] FRC bearings are found in scissor-lift-type applications, which handle significant loads during intermittent operations, often while being exposed to harsh environmental conditions." This type of bearing offers ultimate compressive strength up to 620 MPa (90,000 PSI) and more consistent friction than greased bronze bearings—with the added benefit of being both abrasion and corrosion resistant. This helps extend maintenance intervals and improve the efficiency of aircraft ground support services.

In NASA's Curiosity Rover, the largest and most successful Mars Rover to date. As Ricci says, "Curiosity's arm-drill required bearings that could withstand the harsh Martian temperatures—ranging between -153°C and 20°C—and atmosphere. DU® bearings were chosen due to their high wear resistance, ability to operate comfortably in the temperatures of Mars, and resilience towards dust and debris." The operation of this arm-drill was critical to the discovery that Mars once had conditions suitable for microbial life.

GGB has also worked with Airbus, Airbus Helicopters, Boeing, Lockheed Martin, private spaceflight companies, the military, and other private aircraft manufacturers to create custom solutions for their plain bearing needs.

Plain bearing solutions provide the aerospace industry with weight and space reduction, enhanced energy efficiency, improved strength and safety, and increased operating temperatures for its ground, air, and outer-space applications. ■

This article was written by GGB Bearing Technology (Thorofare, NJ). For more information, visit http://info.hotims.com/69503-503.

Plug-in hybrid brings Honda into sharper Clarity

Honda's recently introduced Clarity plug-in hybrid sedan is the third variant of this revitalized and electrified nameplate. It joins the Clarity Fuel Cell, which debuted in December 2016 and the Clarity Battery Electric that arrived in the U.S. market in August 2017. The Plug-in Hybrid is the only one that's available in all 50 states and the sole version customers can purchase.

The base Plug-in is $33,400 with a more upscale Touring model offering features like leather seats and satellite navigation ringing in at $36,600. Available by lease only, the Fuel Cell is just for California consumption and the Battery Electric version is currently offered only in a couple U.S. West Coast states at present. Honda will also offer the Plug-in in Canada.

Honda engineers sweated the CFD and wind-tunnel details to create a Nash-beating .2x Cd for the new Clarity. (image: Ron Sessions)

The latest Clarity is currently the only passenger car that's available with a choice of these three propulsion systems. Its overtly aerodynamic form may conjure up a sort of modern Tatra or Citroen, but the skirted wheelhouses (think 2000 Insight), scoops, air curtains, tall tail and full-figured shape are the result of careful CFD analysis and wind-tunnel work.

Packaging and lightweighting

Work on the second-generation Clarity began in March, 2013. The car appears a tad 'bloated' because it has to accommodate a wide range of componentry. The "engine" compartment had to be large enough to fit a power control unit, the 181-hp (135-kW) four-stage synchronous electric motor and related hardware, the plug-in version's 103-hp (77-kW) 1.5-L, LEV3 SULV20-certified Atkinson cycle 4-cylinder engine or the fuel-cell model's stack. Compared to the previous generation FCV Clarity, Honda succeeded in developing a more power-dense fuel-cell stack for the new car that is 33% more compact.

The cabin had to be tall enough to package a large-capacity lithium-ion battery (25.5 kW·h for the electric, 17.0 kW·h for the plug-in hybrid) under the passenger floor. In the case of the fuel cell version, a small 1.7-kW·h lithium-ion "buffer" battery under the front passenger seat and a 6-gal (22-L) composite-reinforced/aluminum-lined, cylindrical hydrogen tank beneath the rear chairs.

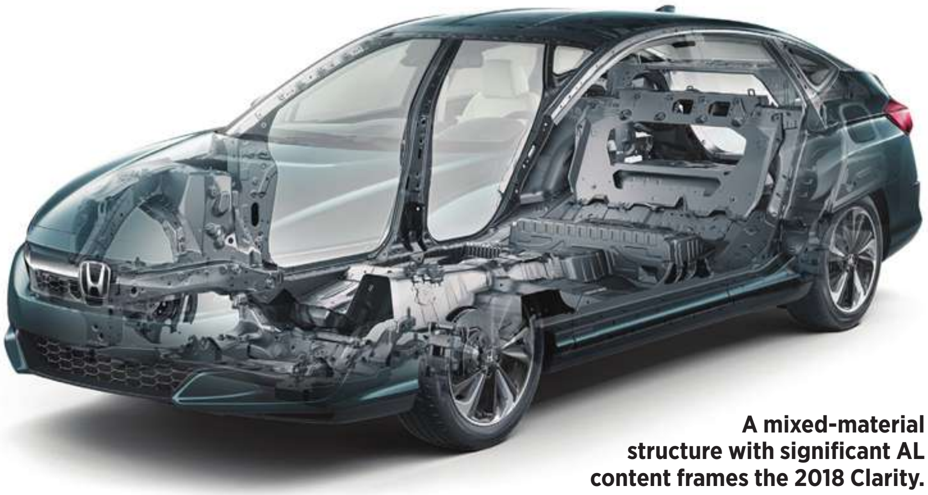
Underhood view of the Atkinson-cycle ICE and power electronics of the PHEV Clarity. (image: Ron Sessions)

Finally, the cargo bay needed to be roomy enough to house the fuel-cell's bigger 31-gal (117-L) H2 tank or the second part of the full-electric's 25.5 kW·h battery and the electric charger, while not unduly impinging on luggage space (an impressive 15.5 ft^3 in the Plug-in) and enabling trunk pass-through and fold-down rear seats on the Plug-in version to handle longer objects.

With new Clarity's larger footprint came added mass. To combat the weight gain, the company employed premium materials in key areas. Honda says that more than 40% of the Clarity's structure utilizes super high-tensile steel. To be specific, there's 1500 MPa material in the front door apertures and some roof sections and 980 MPa alloy in sections of the cabin floor, front load-path rails, rear bulkhead and roof crossmembers.

The hood, door outers, decklid, front fenders and front bumper beam are constructed of aluminum, and the front bulkhead is a resin-hybrid structure. Clarity's rear bumper beam is a GFRP hybrid molding, the world's first application says Honda. There's more use of aluminum in the Clarity's lightweight chassis, including a front strut and rear multilink suspension with forged aluminum control arms, cast-AL tie-rods, an AL subframe and a hollow die-cast front subframe.

To meet or exceed U.S. crash standards going forward, the Clarity employs a new 'straight' body frame structure to handle small-overlap front



A mixed-material structure with significant AL content frames the 2018 Clarity. (image: Honda)

impacts, side impacts and rear impacts. The door B-pillars connect to a roof crossmember, so the Clarity does not offer a sunroof.

Shimizu's greatest challenge

At the media preview in Northern California, *Automotive Engineering* sat down with Clarity Development Leader Kiyoshi Shimizu, who expounded on the plug-in's basic mission of providing EV range sufficient to meet daily driving needs with the ability to handle longer routes without the range anxiety of a full-electric. For the record, that range is 47 mi (76 km) of EV range with a full charge and 340-mi (547-km) total range using the 7 gal of liquid hydrocarbons in Clarity's fuel tank.

EPA estimates are 44 mpg city/40 mpg highway/42 mpg combined using the engine, or 110 MPGe of gasoline-equivalent electric-only operation. The Clarity operates in electric model most of the time, deploying the engine just to keep the battery charged or for bursts of power; 0-to-60-mph (97 km/h) acceleration occurs in about 7.5 s.

The biggest engineering challenge, Shimizu-san said, was fitting the fuel-cell stack under the hood. Beyond that, his team had to tune the chassis to manage different weight distribution. The Battery EV model offers almost a 50/50 mass balance, while the Fuel Cell and PHEV versions are closer to the front-heavy bias of other Honda FWD sedans.

When asked why Honda had to create an all-new midsize platform for the Clarity triplets, with a footprint within inches of the all-new Accord, Shimizu explained that aside from some components not being able to fit in the Accord, company planners felt it was necessary to make an eco-aspirational design that would set the table for its electrified future.

58.2 mpg observed

Operated with console-mounted buttons, the driver can choose between Econ, Normal and Sport modes which provide increasingly sharper throttle mapping and acceleration response along with an associated reduction in fuel efficiency. At engine start, the Clarity always defaults to the Normal mode. A fourth mode is activated by pushing the HV button on the console, wherein the driver can choose to maintain the battery's charge level, say during a long interstate trip, by running the engine more to save electric power for later use.

The steering wheel paddles aren't used for shifting gears (the Clarity has no transmission) but adjust the amount of regenerative deceleration. Pushing the right paddle maximizes deceleration, pushing the left one minimizes it. And just like paddle shifters, after some seconds the regen braking function returns to the baseline setting unless Sport mode has been selected.

Because the Clarity is so quiet while cruising, occupants didn't notice the engine running and had to rely on the dash readouts. Later in the day after several restarts, *AE* saw an indicated 58.2 average mpg in Normal mode mixed driving after the initial EV range was depleted.

Ron Sessions

JCB reveals new range of crawler excavators, first fully-electric mini excavator

Global construction, agricultural and industrial equipment manufacturer JCB is meeting the current upturn in demand for machinery with the launch of a host of new and updated equipment. This includes the first models in a completely new range of crawler excavators, a range of lithium-ion-powered scissor lifts, along with the British firm's first full-electric-drive mini excavator, unveiled in pre-production form at a March press event.

Chief executive officer Graeme Macdonald said that the global market for construction equipment rose by 21% in 2017, to more than 897,000 units. Crawler excavators, in particular, were up by 47%, with mini excavator sales rising by 23%, to more than 240,000 machines worldwide.

"We are on a path of growth and markets around the world are in good shape," he said.

X Series excavators

JCB has invested £110m (approximately $155m) and four years in the development of a completely new line of crawler excavators. The X Series machines boast new levels of durability and build quality, promising lower fuel consumption, increased production, a more comfortable operator cab and reduced total cost of ownership.

The first two models to arrive are the 22-tonne 220X and the 21-tonne 210X, which has a slightly lighter counterweight and reduced performance. Both machines point the way forward to a complete range of excavators, as JCB will transition from its existing JS line of machines.

The X Series excavators have a new upper structure that is 200 mm (7.9 in) wider than previous models, at 2.7 m (106.3 in) overall. This has allowed JCB to mount the main boom centrally, rather than at an offset, reducing stress on the slew ring and increasing digging accuracy for the operator. A 38% larger slew motor delivers 16% higher slew torque.

The machines are powered by JCB's existing 4.8-L Tier 4 Final/EU Stage IV EcoMAX diesel engine, providing 129 kW (173 hp) and 690 N·m (509 lb·ft). This drives twin variable-displacement axial piston pumps from Kawasaki that provide 2 x 228 L/min (60.2 gal/min) of hydraulic flow. JCB has stayed with Kayaba hydraulic valve blocks but has increased spool sizes by 14% for improved flow.

In addition, the company has moved to larger, 25-mm Gates hydraulic hoses with four-bolt flanged connections, delivering reduced backpressure and increased efficiency. The company claims that the 220X delivers a 15% fuel consumption benefit compared to the previous generation, while providing a 10% increase in digging productivity. The machines are offered GPS-ready from the factory, to work with a range of 2D and 3D machine guidance systems.

The X Series excavators have a new upper structure that allows JCB to mount the main boom centrally, rather than at an offset, reducing stress on the slew ring and increasing digging accuracy. (image: JCB)

The X Series uses the proven undercarriage from the previous-generation machines and the same sturdy main boom and dipper arm designs. However, the operator's cab is all-new and is now produced in-house by JCB Cabs. Taking advantage of the wider upper structure, the cab is now a full 1 m (39.4 in) wide and 100 mm (3.94 in) longer than the older JS model. That means an internal volume that is 15% larger than the last generation of machines.

Mounted on double isolating viscous mounts, the cab is a full 5 dB quieter than its predecessor, with an interval noise level of just 68 dB. It boasts a new HVAC system with a 43% increase in capacity and 11 air vents. JCB has worked with seat provider Grammer to offer a choice of three operator seats that include heating and cooling functions. The CommandPlus cab has joysticks and controls mounted on the seat unit, to allow them to move with the operator. Improved ergonomics include a 7-in monitor with an automotive-style rotary controller and simplified switchgear, all mounted to the right of the operator's seat.

The new upper body work features a pronounced skirt that is designed to provide impact zones on the rear corners. New cassette-style service doors offer increased strength and durability, while providing easy access to service points. Indeed, the X Series machines boast a 30% improvement in SAE service rating. The machines also offer 5000-hour hydraulic oil changes and 2000-hour hydraulic filter intervals, while an auto-lube system is available from the factory. The latest-generation Donaldson Powercore air filter also offers a 2000-hour service life, reducing operating costs.

Taking advantage of the wider upper structure, the cab is now a full 1 m (39.4 in) wide and 100 mm (3.94 in) longer than the older JS model. (image: JCB)

All X Series machines will be delivered with JCB's LiveLink telematics system, providing location and operating data remotely to service departments and management.

JCB has gone to extreme lengths to ensure durability and reliability with the new excavators. Up to 42% of the machine is now built in subassemblies off the main line, to ensure quality targets are met. There are now 13 quality inspections, covering more than 1100 checks during assembly. The company even put an excavator on an automotive shaker rig for 150 hours, simulating 15,000 operating hours, while climate testing was carried out from -30 to +55°C (-22 to +131°F).

"Every detail of these excavators has been examined and perfected to provide maximum durability and reliability in operation," said Tim Burnhope, JCB's Chief Innovation and Growth Officer.

Global VEHICLES

Electric mini excavator

JCB has unveiled its first electric mini excavator, offering a zero-emission solution for contractors working within buildings, or in a noise-sensitive environment. Based on the Premium version of the company's 19C-1 mini, with electrohydraulic servo controls, the machine swaps the diesel engine for a permanent magnet motor. This is connected to the standard excavator's Bosch Rexroth load-sensing hydraulic pumps, while the rest of the machine's driveline is unchanged.

Power is supplied by three latest-generation NMC (nickel-manganese-cobalt oxide) automotive 104 A·h (5 kW·h) lithium-ion batteries, offering a total 312 A·h (15 kW·h) output through a 48-V electrical system. The instant torque afforded by the electric motor ensures that performance is at least on par with the diesel-driven model, while productivity is unchanged. However, the electric machine produces no emissions and boasts an external noise level that is 7 dB lower than the standard 19C-1.

JCB said that the machine has enough power to work through a full shift on normal duties, though constant hard digging would reduce the operating time to around four hours. The E-TEC has a built-in charging system that will allow a six-hour recharge from a 230-V supply. An optional rapid charger will allow a fast charge in just 2.5 hours using suitable charging infrastructure, while the standard charger can also be used with a 110-V supply.

The machine carries a compact hydraulic oil cooler with a thermostatic electric fan, but otherwise there is no requirement for a cooling pack. With no engine oil or fuel filters, service and maintenance are minimized and the machine has graphite-impregnated bushes on all pins to allow 500-hour greasing intervals.

Initially the mini excavator will be offered with a ROPS/TOPS and FOGS canopy; there is no cab option. However, as the E-TEC is based on the Premium 19C-1, the machine boasts proportional rocker switches for auxiliary functions and for boom offset. It also has a membrane switch pad for additional controls and the fuel meter has been changed for a charge level readout. A smartphone app can be installed that will provide battery charge information remotely through the excavator's sophisticated battery management system.

JCB said that the 19C-1 E-TEC can power all of the attachments available with the standard model, making the machine ideal for demolition and tunnel work, as well as construction within buildings.

There is no on-sale date available yet but expect the machine to be available

Based on the Premium version of the company's 19C-1 mini, with electrohydraulic servo controls, the E-TEC machine swaps the diesel engine for a permanent magnet motor. (image: JCB)

JCB Access has launched a range of five scissor lifts powered by lithium-ion battery packs that will compete alongside its standard lead-acid battery-powered models. (image: JCB)

to customers later in the year, with additional electric models to follow.

"The 19C-1 E-TEC will provide contractors with a zero-emission, low-noise solution allowing them to work independently, in late-night urban conditions, within buildings and even in rail tunnels, with no requirement for costly exhaust extraction equipment," said Burnhope. "The 19C-1 E-TEC points the way to a new zero-emission future for JCB mini excavators."

Lithium-ion scissor lifts

Just one year after its entry into the powered access market, JCB Access has launched a range of five scissor lifts powered by lithium-ion battery packs. The five machines offer working heights of 6.6 m through to 10.1 m and will compete alongside the firm's standard lead-acid battery-powered models.

However, unlike the lead-acid equipment, lithium-ion batteries offer up to 40% longer operation, with a 50% reduction in recharging times. In addition, there is less risk of battery abuse or incorrect recharging, which can see a conventional lead-acid machine consuming three to four sets of batteries in its lifetime. The lithium-ion solution has been designed to provide up to 2000 recharging cycles, four times as many as a lead-acid battery and in line with the lifetime of the machine. Lithium-ion batteries also require no maintenance, no topping up with fluid, and there are no hydrogen emissions during recharging.

JCB Access has developed a Battery Management System that allows customers to monitor the health and charge of each cell within the battery pack. The BMS works with the motor controller to ensure that batteries deliver maximum power and performance throughout their lifespan.

"The main customer benefit is ease of charging, with no worries about short charging periods," said Phil Graysmark, Sales Director at JCB Access. "The battery life equals the life of the machine, so there is a greatly reduced requirement for replacement batteries. This is a more environmentally friendly solution."

Dan Gilkes

Leaf turns to the 2020s

The 2018 Leaf carries over much of the outgoing car's underbody but adds a new battery pack and cells that are more energy-dense. (image: Nissan)

Seven years is nearly twice the duration of a typical automotive product cycle, but it's been that long since Nissan turned a new Leaf. The original 2011 Leaf boldly pioneered 5-passenger practicality with nearly silent, zero-tailpipe-emission driving. Its operating range on a single charge, about 75 mi (120 km), suited some commuters (and the EV faithful) in thermally-ideal regions such as California. Drivers in colder climes, however, often faced the dilemma: "Do I run the heater or make it home on the rapidly-dwindling charge?"

Then came Tesla's Model S and the humble Leaf, despite a modest upgrade in range, got raked backstage amid Ludicrous-mode hoopla. Last year Nissan sold just 10,000 Leafs in the U.S. and it took until January 2018 for the car's six-year global sales total to reach 300,000 units. That makes Leaf the world's EV sales king, but battery electrics outside the Musk halo find it tough to earn mainstream converts. Globally they account for about 0.5% of passenger vehicle sales. In the U.S., the low retail price of hydrocarbon fuels isn't helping the ZEV cause, either.

But with CO_2 and greenhouse-gas regulations set to tighten further during the 2020s—and more nations ruling to outlaw new non-electrified vehicles—experts expect battery-EVs to steadily gain share, albeit more slowly than hybrid-ICE models.

The 2018 Leaf, now packing 150-mi (241-km) operating range, and with +200-mi (321-km) battery capability coming for 2019, will lead Nissan's electric march into the new decade. It brings Nissan's ProPilot Assist feature (see sidebar) that combines adaptive cruise control with lane centering for single-lane freeway driving—it won't change lanes, however, and requires hands on the wheel.

Assembled in Japan, the U.K. and Smyrna, Tennessee, with mainly suspension calibrations separating the regional variants, the 2018 version is not 'all-new.' Much of the new Leaf's underbody, 106.3-in wheelbase, and suspension (front struts, rear torsion beam) carry over from the outgoing model. But it's a significant leap forward in nearly every static and dynamic metric except its 3,468-lb (1,573-kg) base curb weight that's about 33 lb (15 kg) heavier than the old car.

Nissan engineers consider that an achievement, as will many SAE readers, who know the challenges in combating 'mass creep' in new vehicle programs. But Nissan's thorough FEA work during Leaf body engineering helped extract about 110 lb (50 kg) from the structure. That's impressive considering it is still steel-intensive (as are the closures), is reinforced at key points, and is 1.4-in (35 mm) longer and fractionally wider and taller, noted Chris Reed, Vice President of the Nissan Technical Center North America in Farmington, MI. The 2018 body is about 15% stiffer in torsion than the 2017 body, Reed said.

Nissan engineers almost achieved mass parity with the 2017 Leaf via thorough FEA work on the steel-intensive structure. (image: Nissan)

Lower Cd, more kW

Reducing structural mass, aided by use of high-strength steel alloys in the sills and pillars, helped offset weight gains in other areas. Reed noted that upgrading rather than replacing the body structure, as well as cost reductions through various propulsion and battery improvements, enabled Nissan to aggressively price the new Leaf. The US$29,990 base price (before federal EV rebates) is about $700 less than the outgoing mode. The low pricing is a key to Nissan's market strategy for its revamped EV.

Broadening the car's visual appeal was important for hooking potential EV customers who don't yet understand amps and kilowatt-hours. Nissan Design gave the new Leaf a contemporary exterior form that no longer "shouts EV." The 0.28 coefficient of drag represents a 4% improvement over the first-gen car's Cd, according to Reed.

The aero gains, along with greater attention to cabin sealing, help create one of the quietest cabins of any production car, Reed claimed. He said interior noise levels are reduced by more than 1 dB at 62 mph (100 km/h) versus

ProPILOT offers SAE Level 2 automation

The ProPILOT Assist feature on the 2018 Leaf provides SAE Level 2 partial-autonomous functionality by leveraging Nissan's Intelligent Cruise Control (ICC) and Steering Assist systems.

"ICC was enhanced to add 'stop and hold' capability, so now the system does not disengage when the vehicle comes to a stop. And the steering assist provides lane centering capability as opposed to 'lane keeping' which can bounce the vehicle between lane markers," explained Andy Christensen, Senior Manager of Intelligent Transportation Systems Research at the NTCNA.

The system is activated via two steering wheel buttons. Operation is similar to today's ICC; that was intentional in order to be intuitive for customers, said Christensen. Once the system is activated, a torque sensor in the steering wheel detects if the driver's hands are on the wheel. A' no-hands' detection sends an audible and visual alert to the driver.

ProPILOT button on Leaf wheel, which contains a torque sensor. (image: Nissan)

Along with the new Leaf EV, the 2018 Rogue also offers ProPILOT. The popular CUV brings scale to the sourcing, "allowing more customers to have access to a driver assistance technology," noted Ryan Rumberger, Senior Manager of Autonomous Drive Marketability at NTCNA.

A single radar, located behind Leaf's front emblem, senses the speed and distance of the vehicle ahead (ICC functionality), and a single camera at the top of the windshield detects lane markers and determines the vehicle position in the lane (steering assist function), according to Christensen.

Confirming that the system's performance would meet U.S. drivers' expectations required plenty of seat time. NTCNA engineers drove the ProPILOT Assist test fleet of 13 vehicles more than 150,000 mi (241,401 km) across the continental U.S. as well as in Hawaii in all weather conditions.

"When different road markings created concerns, we would work with our U.S. and Japan teams to break-down the data to understand the issues and engineer solutions to resolve them," Rumberger explained.

The technology will soon be available on other Nissan models in the U.S. as well as models in other markets.

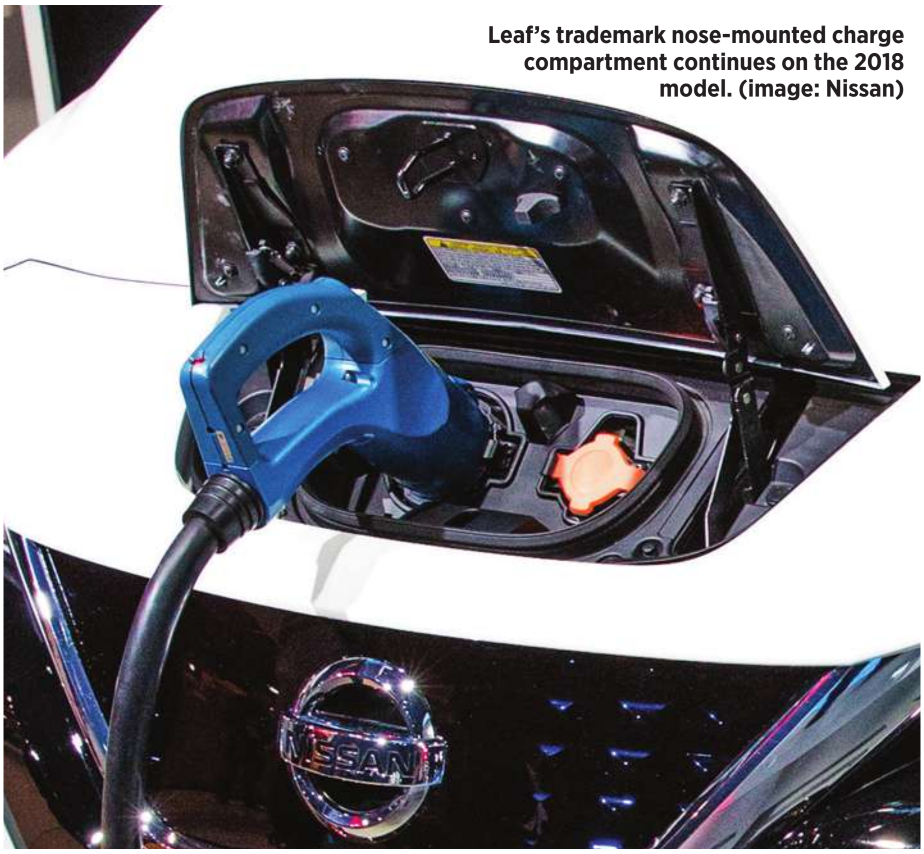
-Kami Buchholz

Improved Charging Efficiency of the 2018 Leaf

Connection Type	AC Voltage (V)	AC Current (A)	Input Power (W)	Charge Rate per Hour	Battery Charging Time: MY16 24 kW·h	MY17 30 kW·h	MY18 40 kW·h
DC (CHAdeMO)	–	125	50	–	>52 mi 80% 30 min	>72 mi 80% 30 min	>88 mi 69% 30 min
					–	–	>105 mi 80% 40 min
AC (SAE J1772 'Combo')	Level 2 -240V	30	6.6 kW	>20 mi	4 h	5.5 h	7.5 h
		16	3.3 kW	>11 mi	7 h	9.5 h	12.0 h
	Level 1 - 120V	12	1.4 kW	>4 mi	21 h	26 h	35 h

*Claimed charge times based on timing of "Low Battery Warning" activation (-4 kW·h remaining)
Charge time will vary based on the condition of the charger and battery

Nissan remains wedded to the CHAdeMO charging protocol and hardware. The new Leaf supports Levels 1-3 charging. (image: Nissan Data)



Leaf's trademark nose-mounted charge compartment continues on the 2018 model. (image: Nissan)

Engineering VP Chris Reed noted significant reduction in cabin noise. (image: LIndsay Brooke)

the previous Leaf. Indeed, *Automotive Engineering*'s early test drive in late 2017 revealed outstanding interior noise attenuation with less gear whine evident, to our ears, under deceleration than on Chevrolet's Bolt EV, VW's e-Golf or the earlier Leaf.

Nissan's program investment included a new permanent-magnet traction motor rated at 110-kW (147-hp) and 236 lb·ft (176 N·m) driving the front wheels. Still an EM57-type AC induction machine, it includes a new inverter and delivers 37% more power (30 kW) and a 26% gain in torque (49 lb·ft/66 N·m) versus its predecessor. With a final drive ratio of 8.193:1, the new e-motor helps make the 2018 Leaf about 15% quicker from zero to 60 mph, Nissan engineers said. *AE*'s 122-mi (196-km) test route of mixed driving (accomplished on a single charge) showed Leaf to be superb for squirting through traffic—and to be more confidence-inspiring in moderate-speed cornering than the '17 version.

Driver engagement is enhanced with the standard "e-Pedal" mode. Like the paddle-controlled system on Bolt, Nissan's provides a "one pedal" driving experience. "The combination of regen and friction braking offer up to 0.2-g decel capability," said Owen Thunes, Manager, Engineering/EV Development. He claims the system will stop and hold the car on a 30% grade.

Packin' more battery

Storing and supplying the 'Leaf juice' is a 40-kW·h battery pack that's 33% more energy-dense than the 30-kW·h pack used in 2017. It retains the old pack's passive air cooling and 192 prismatic-form-factor lithium cells. And its 'footprint' also remains the same due to improved cell chemistry. The new cells (still supplied by AESC) feature a new nickel-manganese-cobalt chemistry with a graphite anode. They are .9-mm thicker and use a thinner separator, to reduce internal resistance. They're now bundled eight per module, 24 modules total, versus 48 modules of four cells each.

New Leaf interior features 7-in touchscreen and higher-grade tactile surface quality on more visible trim parts. (image: Nissan)

EV Development Manager Owen Thunes said e-Pedal performance benefits drivers on steep hills. (image: LIndsay Brooke)

The new cell design and pack layout makes the 2018 Leaf fully competitive in range and power to other new EVs including Hyundai's Ioniq Electric and the Honda Clarity EV, according to Thunes. And the 60-kW·h pack slated for MY2019—which is expected to use prismatic NMC cells supplied by LG Chem, according to a battery-supplier source—should give Leaf range to challenge Chevy Bolt (~238 mi/383 km).

Thunes said the new 40-kW·h pack, made at Smyrna, can retain 90% of its capacity after 500 charge/discharge cycles or over 60,000 mi. The 8-year, 100,000-mi (160,934-km) pack warranty carries over.

The new Leaf retains its trademark centrally-located charge port under a door on the car's nose. Nissan adheres to the CHAdeMO DC charge coupler developed with its Tokyo Electric Power Co. partner rather than using the SAE 'combo' connector favored by most other OEMs except Tesla. Leaf's onboard 6.6-kW unit offers 120-V and 240-V charging along with a Level 3 fast charge that can load 90 mi (144 km) of electrons in 30 minutes.

According to Nissan V2X manager Scott Brierley, the new Leaf has bi-directional charging capability. But its car-to-grid feature, which he said can deliver up to 6 kW from the car's battery to a home for emergency lighting, for example, is not yet approved for U.S. use.

Inside Leaf's cabin the driver is struck by good all-around visibility due to the high seat mounting. There's a 7.0-in touchscreen centered in the IP and Android Auto and Apple CarPlay are now standard.

Also visible are more soft-touch surfaces but there's still excessive hard plastic—a questionable cost saver in cabins, the author believes, as is the steering wheel that adjusts for tilt but does not telescope.

Small issues, perhaps, in a high-value EV that's squarely back in the global electric-car race and appears to be engineered and fully equipped to deliver on its design goals.

Lindsay Brooke

I-Pace: Jaguar reveals its twin-motor, battery-electric crossover

Ahead of the 2018 Geneva motor show, Jaguar unveiled the production version of its first-ever electric vehicle: the twin-motor I-Pace crossover. In perhaps any EV's most crucial measure, Jaguar claimed an official driving range (based on the European WLTP test cycle) of up to 480 km (298 mi).

There's plenty of performance, too, for the first mainstream-automaker riposte to Tesla's Model X: the I-Pace has a 0-100 km/h (0-62 mph) acceleration time of 4.8s and all-wheel-drive capability from the arrangement that places a drive motor on each axle. The I-Pace also has a 0.29 drag coefficient, an aluminum architecture, intelligent GPS for better use of energy and advanced-connectivity features.

At its reveal prior to the Geneva show, I-Pace Vehicle Line Director Ian Hoban described it as "the complete package," with innovative engineering that includes rapid charging to 80% battery capacity in 85 minutes from a public charger and a 30-minute charge delivering around 130 km (80 miles) of driving range.

The midsize, 5-seat I-Pace—built in Austria in partnership with Magna-Steyr—joins the compact, conventional-drivetrain Jaguar E-Pace and performance-oriented F-Pace to create a family of Jaguar crossover models.

The I-Pace's electrical architecture is based on a 50-kW charger but is compatible with 100-kW charging, the company said. Drive comes from two Jaguar-designed synchronous permanent-magnet electric motors, one each at the front and rear axles. Power per motor is 147 kW (197 hp) and torque per motor is 348 N·m (257 lb·ft).

"Each (motor) fits concentrically around a compact, single-speed epicyclic transmission and differential," said Hoban; the configuration was designed to provide precise longitudinal torque distribution.

The 90-kWh liquid-cooled lithium-ion battery pack uses pouched cells (432 in 36 modules). To control cell temperatures and maximize available power, the battery pack has a cooler for operating in moderate temperatures and a refrigeration unit linked to the vehicle's air-conditioning system to cope with higher thermal-dissipation requirements. A heat pump operates in cold conditions to look after the cells as well as to condition the I-Pace interior, drawing energy from outside and using heat scavenged from the electrical system's inverters and power electronics, all of which can bring a range bonus of up to 50 km (31 mi). The battery has a pre-conditioning system (when the vehicle is plugged in) to manage its temperature to maximize range from journey start—and Jaguar states that the I-Pace has been tested to operate in temperatures down to -40°C.

The I-Pace was conceived from the outset as a high-performance EV using riveted and bonded aluminum construction. Its torsional rigidity is 36 kNm/degree. The battery, positioned centrally, is placed low in the chassis to achieve required CofG. The crossover has 50:50 front:rear weight distribution.

Double-wishbone front and integral-link independent rear suspension should provide Jaguar's brand signature of excellent ride and handling. Self-levelling air suspension with adaptive dynamics is an option.

The I-Pace of course has energy-regeneration capability; instead of a conventional brake vacuum servo, an electric brake booster is used to give the braking system required flexibility when blending regenerative and regular mechanical braking, which allows precise and consistent feel in all situations, states Jaguar.

Added to this is a driver-controlled selection of high or low levels of regeneration to augment driving range. High mode effectively provides single-pedal control, as the I-Pace decelerates immediately once the driver's foot lifts from the accelerator. Maximum regenerative braking force is 0.4g, Jaguar said.

Stuart Birch

I-Pace is a midsize, 4-door crossover that can seat five. (image: Jaguar)

I-Pace, Jaguar's first electric vehicle, has a 90 kWh lithium-ion battery pack and a driving range up to 298 miles. (image: Jaguar)

The I-Pace situates its 90-kWh battery pack to provide ideal 50/50 weight distribution. (image: Jaguar)

Mike LaLande: VR and simulation growth are 'tremendous.' (image: Nancy Lesinski)

Dassault grows its VR toolset portfolio to meet autonomous-tech demands

If the game-show $1000 question is "CATIA," the easy winning answer is "Dassault Systemes." The iconic design software is fundamental and ubiquitous across the mobility industry and the France-based company continues to innovate and iterate at a rapid pace. Customers are calling for expanded simulation capability for ADAS development, and for pretty much all hardware and software supporting the automated/connected and electrified vehicle revolutions.

In Sept. 2017 Dassault acquired Exa Corp. to further enhance its 3D mock-up and PLM solutions toolset; this followed a 2016 partnership with HTC that adds virtual reality capability to its powerful 3DEXPERIENCE platform. *Automotive Engineering* Editor Lindsay Brooke caught up with the busy Mike LaLande, Dassault Systemes' Director of North American Transportation & Mobility Systems, to find out more about this flurry of activity.

Simulation tools continue to get more sophisticated and capable, and Dassault Systemes seems to be building related capabilities, both internally and through partnerships.

We've had a number of acquisitions to help us round out our platform. VR [virtual reality] use is growing fast in the industry. We now have a full suite of VR-based simulation tools – for airflow, NVH, durability, thermal management, batteries, anything needed to simulate and do analysis to eliminate physical testing. In 2014 we acquired a stake in a company [Realtime Technology] that does very high-fidelity renderings in VR; to see a great video Google 'Honda crash test in VR.' A luxury vehicle today has a million lines of code in it—we can simulate how that code will operate within the context of the vehicle's hardware and software.

Engineers continue to tell us that Systems Integration is becoming more critical in developing automated and connected vehicle technologies. What is Dassault Systemes doing in this trend?

ADAS has become a major focus of our tool called CATIA Systems Engineering. One customer we're working with completely modeled, simulated, tested, and put into production a Ped-Pro system with our tools.

Our test case was a cyclist darting out between a parked truck and car in traffic. What will the car's radar, lidar and cameras see? How quickly will the system react in daylight? At night or in fog? Testing for autonomy requires realism—to create a virtual but truly 'real' environment. We change environmental test conditions in real time—change the road surface and the traction conditions. We don't have to wait for it to snow or rain. This reduces testing time and money.

OEMs are looking for ways to integrate software and hardware.

Yes, historically they've been separate development systems, including simulation. With our platform concept, it's like your cell phone—running apps that are integrated on it. We're doing that through an integrated platform. We're not yet at the level of including vehicle calibration in an ADAS design.

But we can get the inputs from the sensor developers and distribute that information through the vehicle electronics. We're getting a lot of interest from the Tier 1s, as they're designing these systems. The OEMs are serving as system integrators.

Is vehicle electrification driving new DS solutions?

We have customers in Europe using our tools to design their entire electrical architecture. One of them, in designing their battery-electric hybrid using our platform, can virtually 'plug in' the number of battery cells, experiment with and analyze different battery configurations, and investigate different vehicle wheelbases for packaging. They then run a systems test and put the vehicle on a virtual road to examine the effect on vehicle dynamics and ride quality.

It's all done under different driver scenarios; some drivers have a 'heavy' right foot, some are more moderate. The simuation tools being used for EV systems and vehicle development are also capable of analyzing battery-life optimization, all within one model.

There is no need for physical prototypes. To build one of them may cost a quarter of a million dollars—and typically you need more than one. ■

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