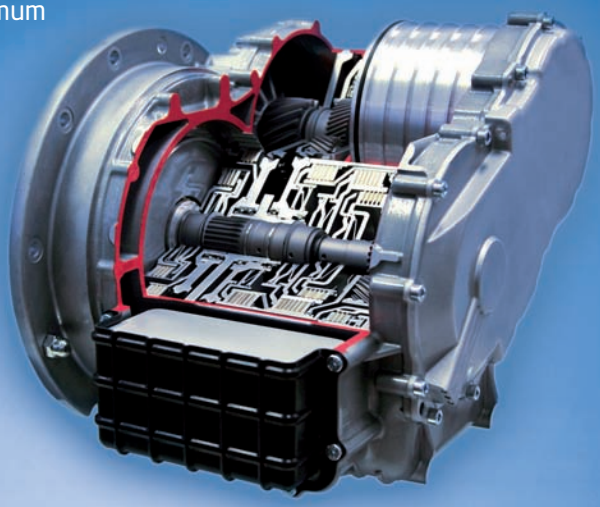
automotion

Excellence in Automotive Research & Development · IAV Customer Newsletter · 1-2010

Not Evolution, but Revolution

IAV Engineers Generate Optimum Transmission Structures

By Erik Schneider and Tom Tibbles



In order for vehicles to meet future fuel economy, emission and drivability targets, new transmissions are shifting toward increased ratio ranges with well-stepped gear ratios. Generally, transmissions with a large number of ratios become less efficient, physically larger and heavier, and necessitate a higher degree of packaging and controls complexity. IAV has developed a powerful transmission-synthesis program which systematically searches through all powerflow permutations for a specific application, and then selects the architecture with the highest mechanical efficiency and the lowest number of loaded components.

The IAV computer-aided transmission search team is housed in the Transmission and Hybrid Systems Department located in Chemnitz, Germany. Erik Schneider, the department manager, maintains that "modern transmission systems, paired with highly efficient combustion engines and greater electrification, bring down CO_2 emissions significantly. This is why," he elaborates, "there are so many new developments on the transmission front; the pace is so fast that it is no exaggeration to speak of it as a revolution." Such innovation demands first-class engineering expertise and an integrated approach to powertrain development.

Wider Spread, More Gears, Less CO_2 Emissions

Functioning as the combustion engine's map converter, the transmission has many ways of influencing vehicle performance and fuel economy. As Schneider explains, "Widening the overall spread is gaining significance because, among other effects, a greater operating range can be covered with lower specific consumption levels. A high number of well-stepped gears is necessary to achieve the desired engine map ranges and to provide a comfortable graduation of available traction power. This is why vehicle developers are working on new transmissions with a higher number of gears."

Design departments are examining prototypes with more than eight speeds. The advantages are obvious, as made clear by the example of a compact-size car with a direct-injection spark-ignition engine in the New European Driving Cycle (NEDC). Increasing the number of gears from six to eight prevents the emission of almost 4.5 grams of CO_2/km. A further increase to ten gears cuts emissions by another three grams per kilometer. In the more realistic HYZEM driving cycle (Hybrid Technology Approaching Efficient Zero Emission Mobility), these advantages are even more pronounced: changing from six to eight gears results in a CO_2 savings of around nine grams per kilometer.

Unfortunately, engineers have to overcome some major challenges in order to achieve practical transmissions with ten or more gears. "Eco-friendly transmissions of the future must fit into the limited package space available in vehicles, add as few components as possible and support increasing hybridization," Schneider elaborates. "The aim of achieving greater efficiency while enhancing driving comfort and increasing driving dynamics will ultimately be possible only by consistently improving the vehicle and its powertrain."

Wanted: The Optimum Transmission

Initial investigations into systematically generating and evaluating new vehicle transmissions began four years ago at the Chemnitz University of Technology, where the basis for the software was created. The program was developed jointly with IAV's Transmission and Hybrid Systems Department. For the last 18 months, developers have been testing, improving and using the program for customer projects.

The transmission synthesis program considers numerous boundary conditions within which to search for an optimum powerflow. The software automatically generates transmission structures for boundary conditions, such as number of gears, transmission ratios and hybrid functionalities.

The search is literally like looking for a needle in a haystack. For a transmission with three planetary gear sets, the computer must investigate no fewer than approximately 1.6 billion possible combinations. Four planetary gear sets push this figure up to almost 1.1 trillion!

The investigations vary in duration. Calculating the structural combinations for an automatic transmission with three planetary gear sets, for example, takes the computers several days. To generate the structures with four planetary sets, several

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Editorial

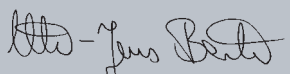
Dear Readers,

"**Eco**llaboration" is the visionary theme of this year's SAE World Congress. Driven by the task to better protect the environment and the world's finite resources, automakers across the globe have significantly ramped up efforts to build vehicles which demonstrate real ecological responsibility. Fundamental to such an endeavor is the sensible collaboration of OEMs, tier ones and engineering service providers in developing sustainable powertrain solutions and drawing on more recyclable and lightweight materials, all of which will be vital to the future success of the automotive industry.

Taking direction from the show's many supporters, SAE announced its intentions to revise and revamp the World Congress in reflection of the significant changes which have taken place across the automotive industry. As every year, IAV is excited to play a part in such a noteworthy show.

Another important event that I would like to draw your attention to is the 2010 CTI Symposium & Exhibition, which will also relate, in some measure, to environmental consciousness. Hybridization and other advancements in transmission technology have received an increasing amount of attention since CO_2 emissions have moved into the spotlight. These events, among others, will no doubt provide an excellent platform on which to build the alliances necessary to manage costs and complexity. We look forward to welcoming you there to discuss new ideas and opportunities. With global locations around the world, IAV feels well positioned to support customers in producing an environmentally sound vehicle for global markets.

As in every issue of automotion, IAV provides examples of how our company has been hard at work. This issue focuses on topics such as the new tools necessary to optimize transmission systems and IAV's new turbocharger test bench, fully equipped to benefit your research and further optimize engine components – in this case, the increasingly important turbocharger. In closing, please note the article featuring Square One, a very impressive educational organization and one which will enable future generations of engineers to continue to optimize the powertrains we are developing today.



Utz-Jens Beister | President of IAV Inc.

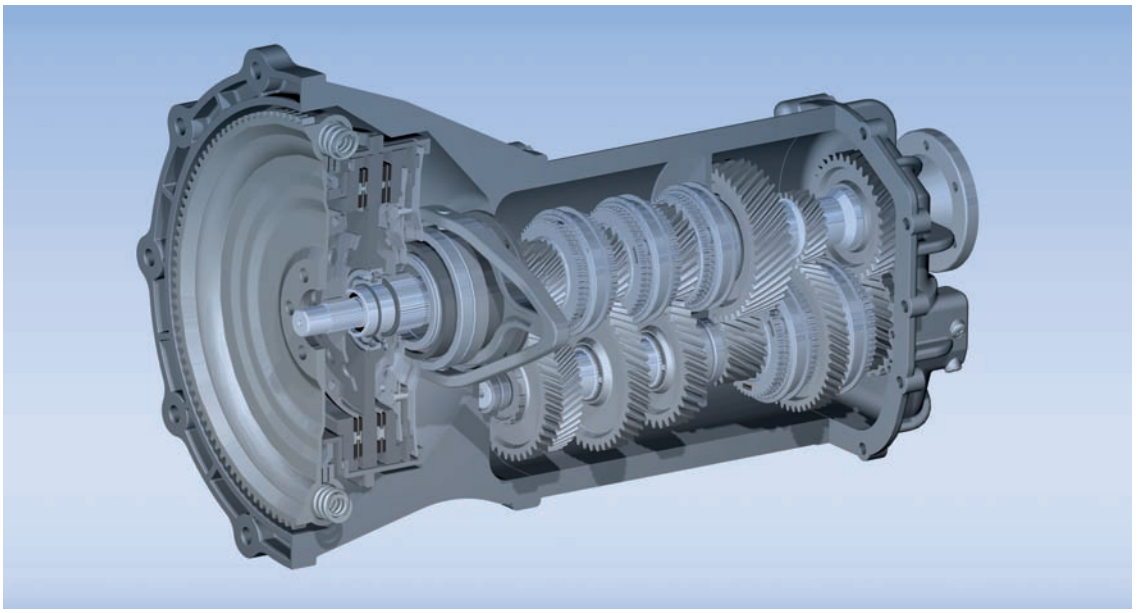
IAV at the 2010 CTI Conference

Advanced Transmission on Display at the Upcoming Show

By Tom Reedy

The 4th annual CTI Symposium and Exhibition will take place June 8 – 9, 2010 in Ann Arbor, Michigan. An interesting lineup of technical presentations is scheduled for the two-day event, all of which center on the conference focus: automotive transmission and driveline technology. In parallel to the technical symposium is the exhibition, which hosts a variety of companies showing the latest transmission technology and services.

For this year's conference, IAV will be presenting papers on two different ultra-compact and fuel-saving transmissions designed using IAV's powerful transmission architecture synthesis toolset. The first paper addresses IAV's eight-speed hybrid front wheel drive automatic transmission for passenger cars. The latter concerns IAV's eleven-speed DCT for commercial-truck applications. In the exhibit area, IAV will display a cut-away model of the eight-speed transmission; expert staff will also be available for questions.



IAV's dual-clutch transmission

Utz-Jens Beister, President of IAV Inc., is a member of the advisory board for the CTI North America event. Working alongside industry experts in the organization of such an event is an exciting opportunity, and IAV looks forward to another successful CTI symposium in 2010.

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IAV Partners with the University of Michigan to Host Inaugural DoE Conference

Exploring DoE in the US Automotive Market

By Tony Gullitti

In 2001, IAV GmbH introduced what was to be a biennial conference on the Design of Experiments (DoE) approach to engine development. To date, the conference is well attended by many OEMs and suppliers in the European automotive market. So as to establish a forum for discussion in the US market, IAV, in cooperation with the University of Michigan, is bringing the DoE conference to the United States in 2010. In the nine years since the inaugural conference in Europe, the presentations have focused on advanced methods for DoE. For the initial conference in the US, IAV is soliciting manufacturers and suppliers to present their current state-of-the-art processes in applying DoE methods to a production environment. In this way, a foundation will be established on which to grow the conference in future years. Starting in 2010, IAV plans to hold the DoE conference on an annual basis, alternating between the US and Europe. Mark your calendars for June 24, 2010, and plan to participate in IAV's 1st US DoE conference in Northville, MI.

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Continued from page 1: "Not Evolution, but Revolution"

weeks are necessary. Such an investment in computer time, however, proves worthwhile in deriving a better product.

Demonstrating the efficiency of the development methodology, IAV specialists have used the process to generate two particularly sophisticated transmissions: an eight-speed hybrid planetary automatic transmission and a dual-clutch transmission, also with eight gears.

There is good reason for IAV to continue focusing its attention on both transmission technologies. As Schneider explains it, "Nobody knows in which direction transmissions will go in the future. Dual-clutch and planetary transmissions are currently thrashing it out in a neck-and-neck race."

Both systems are expected to be used in different markets and vehicle segments in the foreseeable future.

The transmission synthesis group's focus is to further improve the performance and speed of the search software. Given the large number of influences, applying a systematic approach of this type is the only practical method to select future optimum transmission structures.

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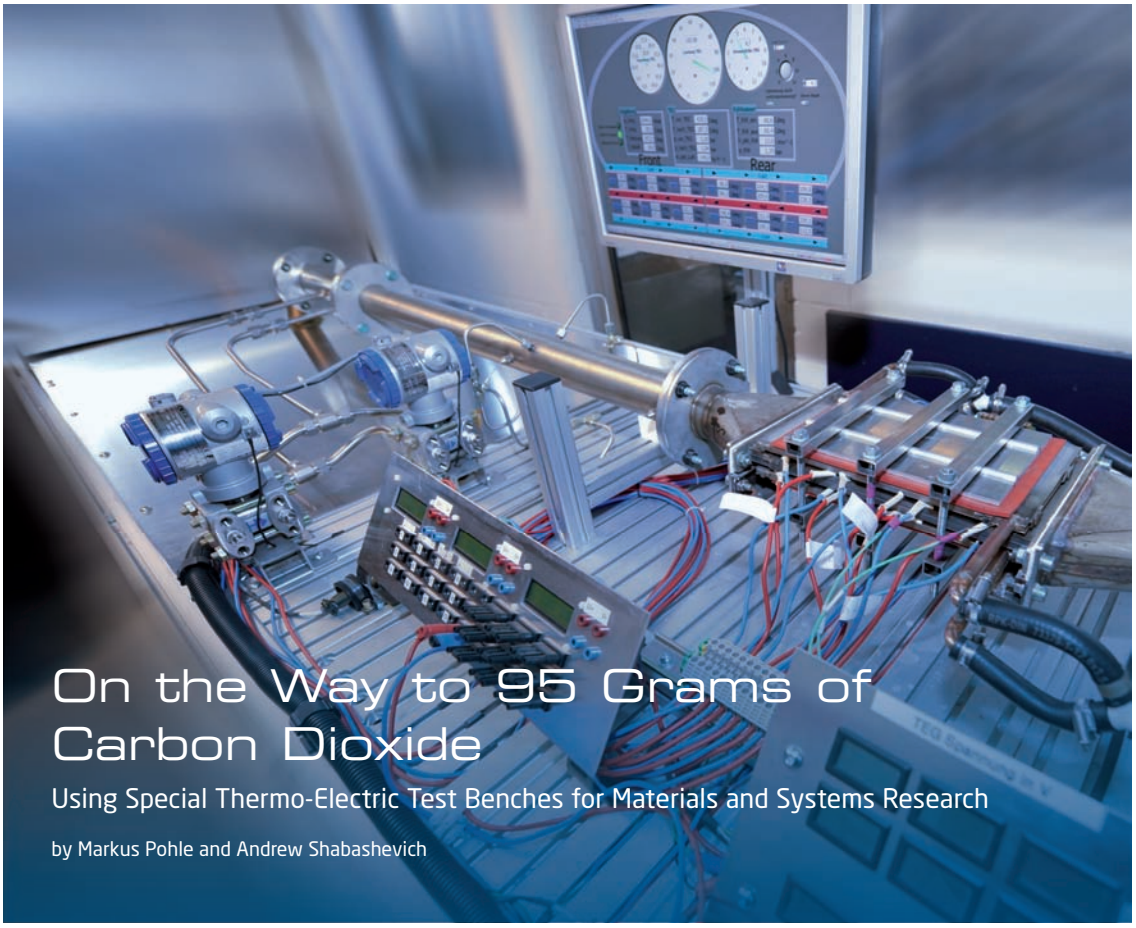

On the Way to 95 Grams of Carbon Dioxide

Using Special Thermo-Electric Test Benches for Materials and Systems Research

by Markus Pohle and Andrew Shabashevich

In the near future, thermo-electrics may be used to cut fuel consumption and CO_2 emissions by as much as ten percent. Experts at IAV are working hard to realize the potential of this new technology.

The magic number is 95 grams: the average amount of carbon dioxide per kilometer the European Union will allow from every vehicle manufactured beginning in 2020. Every gram above this limit will be fined 95 euros. This presents the automotive industry with a tremendous challenge, as vehicle CO_2 emissions are still significantly above this level (modern compact gasoline and diesel vehicles emit 150 grams or more of CO_2 per kilometer).

Manufacturers must continue to design for reduced fuel consumption by improving vehicle efficiency. In addition to enhancing the combustion process, it is also important to extract more useful energy from available waste heat. Today, most waste heat energy is dissipated unharnessed, which results in only one in every three liters of fuel actually being used for propulsion.

IAV has been hard at work on this technology over the last three years. By using thermo-electric generators (TEG), experts at IAV intend to generate electric power from waste heat and feed it into the vehicle electrical system. The results are expected to manifest as reduced fuel consumption and CO_2 emissions by about five percent during normal operation, and by as much as ten percent in specific instances.

TEG Test Benches for Materials and Systems

The science of thermo-electrics, though widely studied, is still in its infancy. IAV's TEG specialists have been investigating materials and systems for over a year using two special test benches in Berlin; their goal has been to understand the full potential this technology harbors. "The component test bench allows us to measure the thermal and electrical properties of thermo-electric modules (TEM), interfaces and TEG components," explains Markus Pohle of the Powertrain Integration Development department. "The hot-air test bench enables us to investigate entire systems, including the heat exchanger." The test bench recreates exhaust conditions similar to those that occur in a vehicle on the road, and also a broad range of other flow conditions, such as exhaust gas temperatures up to 650 degrees Celsius. The test bench has a 35-kilowatt electric heater, which simulates exhaust gas heat; the hot air is channeled through the test specimens. "These investigations are important because one can measure how much energy is gained from waste heat in practice," Pohle says. Using the components currently available, TEG experts have managed to achieve 80 to 90 watts of electrical power at 100 kilometers an hour in sixth gear. During operation, a modern compact car with numerous comfort and assistance systems consumes some 300 watts of power (larger vehicles use much more) from the alternator, which adds to fuel consumption. In general, every 100 watts of electricity produced increases fuel consumption by around 0.1 liters per 100 km (~0.3 mpg penalty).

Yet, to make any noticeable contribution to climate protection, TEGs need to become even more effective. "The system currently has an efficiency of two to three percent," Pohle reports. "We feel that average efficiency in the operating range needs to increase to at least ten percent." This will involve developing new thermo-electric materials, manufacturing methods and integration concepts that convert heat into electricity more effectively.

Wanted: The Swiss Army Knife of Thermo-Electric Materials

The thermo-electric materials available today (in most cases - bismuth telluride, lead telluride or silicon-germanium) yield poor results and fail to meet several automotive industry requirements. They are currently too expensive (~$0.80 per watt); some are unable to tolerate high temperatures in the exhaust system, and, in many cases, contain rare earth materials or toxic lead. Material scientists worldwide are working on entirely new material classes for TEGs in order to address the problem. The targets they set are clear: thermo-electric modules must withstand temperatures of up to 800 degrees Celsius, work at efficiencies significantly above ten percent, not pollute the environment and cost less than $0.10 per watt. Future TEGs must also be robust enough to operate in the harsh automotive environment for at least ten years.

The job will not be complete when new materials alone are discovered. TEGs must also be integrated into the vehicle. "This is where demands are made on every department," says Pohle. Vehicle electronics engineers need to develop more efficient voltage transformers; integration specialists must find a suitable place for the TEG system and link it with the other vehicle components; and engine experts face the task of integrating the additional system into the engine control unit.

The first batch of TEGs have been targeted for release starting in 2015 by American and German manufacturers, with energy-saving technology expected to go into mass production by 2020. All of this is, of course, just in time for the magic figure of 95 grams of CO_2 per kilometer to be achieved.

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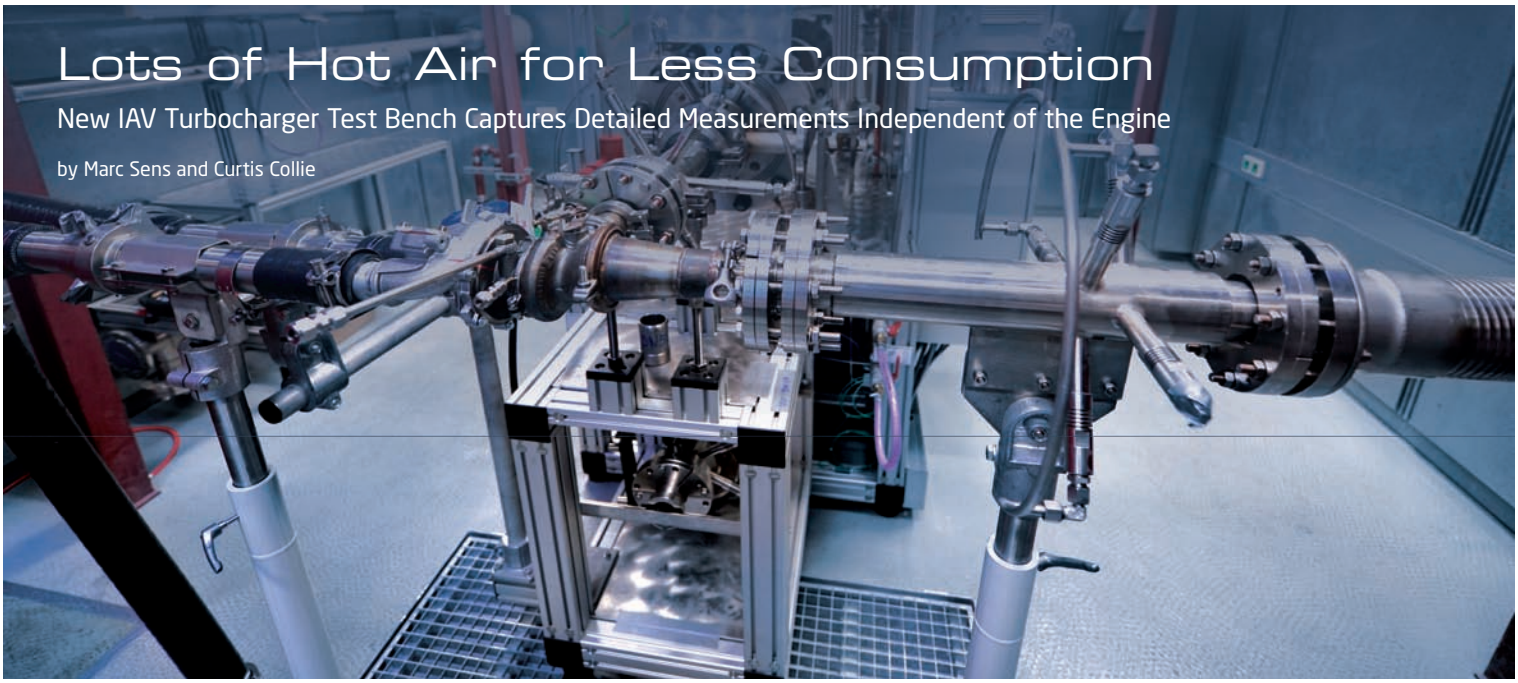
Lots of Hot Air for Less Consumption

New IAV Turbocharger Test Bench Captures Detailed Measurements Independent of the Engine

by Marc Sens and Curtis Collie



IAV's new turbocharger test bench can also be used for examining systems with two turbochargers

In an effort to reduce fuel consumption, more and more vehicles are now being powered by turbocharged engines. Both manufacturers and OEMs are stepping up efforts to optimize turbocharger systems and, anticipating this trend, IAV began to work on turbocharger test stands more than ten years ago. IAV was confident that full-range, whole-system testing would be critical in optimizing the more complex boosting configurations that would eventually come into use. To this day, IAV believes that independently produced testing data is of great value to OEMs working toward optimized boost systems.

In October 2009, IAV commissioned a new, enhanced turbocharger test bench at the IAV Technical Center in Berlin. After 12 months of construction, IAV experts are now able to execute detailed performance measurements on such key engine components. "Test benches allow us to measure turbochargers independent of the engine," explains Marc Sens, head of the Thermodynamics and Turbocharging department. "We are thus able to minimize any disturbing influences, including those caused by the engine, such as oscillations, vibrations or irregular gas flows."

The test bench consists of both a compressor and a combustion chamber running on compressed natural gas. It can generate an air-mass flow rate of up to 2,640 lbs/hr, with pressures up to five bar and temperatures up to 2010° F. The facility is capable of replicating any condition encountered with a turbocharged engine application up to 400 bhp, which covers most passenger cars and light/medium trucks. Although most testing is conducted with a single turbocharger, systems with two turbochargers can be investigated as well, either as a complete assembly or with the subassemblies measured individually.

Sensing temperatures and pressures at points where the flow of hot gas enters and leaves the turbine, and where air enters and leaves the compressor, the test bench records mass flow rates along with the temperatures of cooling medium and lubricant. The testing includes monitoring the air or combustion gas in the crankcase; "blow-by" may penetrate the running gear by leaking through the seals between the compressor and turbine.

Technical Specifications

Max. combustion chamber output: 330 kW

Max. flow rate:
0.013–0.32 kg/s

Turbine inlet temperature:
Adjustable between 150–1100 °C

Max. pressure ratio: 5

Operating mode:
- Steady-state
- Transient
- Thermo-shock
- Exhaust-gas back pressure adjustable
- Pressure adjustable upstream of compressor

Fields of application:
- Measuring turbocharger maps to VFI instructions
- Measuring shaft displacement
- Measuring oil consumption
- Compressor instabilities
- Sound pressure level maps
- Endurance tests
- Admitting hot gas to components ranging from individual parts to entire exhaust systems

Turbochargers Still in Need of Much Research

IAV was motivated to develop the new facility due to the need to achieve a better understanding of turbochargers. Heat-flow behavior and mechanical components are still in need of much research: for example, plain bearings might be replaced with roller or air-cushion bearings to reduce friction and improve efficiency. A good turbocharger currently achieves efficiencies of 78 % (compressor) and 65 % (turbine plus mechanical components). The overall efficiency is the product of these two values. Since more and more manufacturers are planning to use turbocharged engines, it is vital that any advancement be fully investigated for its benefit and application.

Turbochargers allow for higher power densities, enabling manufacturers to use smaller engines for improved fuel economy ("downsizing and boosting"). If a high level of torque is made available at low engine speeds, the powertrain's transmission ratios can be altered to benefit running the engine at lower engine speeds ("downspeeding"), thereby reducing overall fuel consumption and CO_2 emissions.

Most of today's diesel engines are turbocharged; still, system complexity and sophistication continue to increase as the diesel-engine segment seeks out performance-related improvements. IAV experts foresee that gasoline turbocharging systems will follow suit. Those working in the automotive industry need to fully understand all of the influencing parameters necessary to capitalize on the many potential improvements to turbochargers. New fuels and combustion processes offer further possibilities for turbocharging: natural gas and ethanol both have antiknock properties superior to gasoline, and open the door to increased boost pressure and engine performance.

New Guidelines on Turbocharger Measurement Methodology

The new test bench enables IAV to provide OEMs and turbocharger manufacturers with the development assistance crucial to building a better understanding of the system and its details: the improvement of individual components and precision-map measurements. IAV's turbocharger mapping research project has developed measurement methodology guidelines recognized by OEMs and component suppliers throughout the industry. "We now have the ability to compare turbochargers on the basis of standardized measurements," comments Marc Sens.

In the future, it will be possible to do this automatically with the new test bench's unmanned operation feature. Depending on the number of measurement points involved, conventional measurement methods may take four to six hours to fully map a turbocharger, but, using new approaches, IAV sees the potential to reduce test-operation time significantly.

The IAV facility is also capable of measuring other powertrain components requiring development in which hot gas may play a part. There is space available to set up and test even entire exhaust systems under realistic vehicle conditions.

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Moving Forward to Give Back

IAV Teams Up with Square One to Provide Hybrid Vehicle Development Support

By Kathleen Rafalko

IAV's relationship with the Square One Education Network began by chance at the 2009 Management Briefing Seminars in Traverse City, Michigan. A curious onlooker strolling down the aisles of exhibitors, IAV President Utz-Jens Beister caught sight of an electric vehicle developed as part of the Square One Innovative Vehicle Design (IVD) competition. The contest, whereby teams of high-school students are encouraged to hone their budding engineering skills, promotes friendly competition and teamwork in accomplishing a given (vehicle-design) task. Beister was immediately interested: "It's heartening to see today's students being provided the opportunity to begin the study of engineering at such an age," he remarked. "Given the degree of hands-on experience within this program, I believe that Square One is generating a lasting interest among these students. By supporting this endeavor, we're helping bring forward the engineers of tomorrow."

The Square One Education Network (SQ1) is a nonprofit, educational organization that works alongside corporate and university partners to provide learning opportunities for students in kindergarten through twelfth grade. The group's educational focus is on the areas of Science, Technology, Engineering and Math (STEM).

The Innovative Vehicle Design family of projects is a leading program within Square One: high school student teams build full-size, hybrid-electric and mini battery-powered vehicles, including underwater, lunar and aero vehicles. Co-sponsored–both financially and with engineering expertise–by an industry partner, the IVD programs spur healthy competition while demanding innovative design and building skills from today's youth. Currently, schools in Southfield, Bad Axe, Ferndale, Big Rapids, Melvindale and Dearborn are participating in the full-scale competition. The smaller competitions are linking, on a larger scale, schools in Portage, Roscommon, Traverse City, Manistique, Port Hope, Utica, Waterford, Dollar Bay, Alpena, Flint, Spring Lake and more!

IAV is excited about exploring opportunities to assist SQ1 in its efforts to educate children in such subjects. A natural first step has been to support the Innovative Vehicle Design competition. Students working to develop hybrid vehicles for the competition clearly benefit from the ability to review development problems with experts.

On March 1, 2010, students from eight Michigan high schools gathered at the IAV Technical Center North America in Northville, MI, to interact with IAV hybrid engineering experts. Working together, they further developed their vehicle design plans while troubleshooting existing problems. Jason McConnell, Manager of the Powertrain Control Systems group at IAV Inc., began the day by briefly introducing IAV. The high school teams then had the chance to present their hybrid-design concepts and describe the particular challenges for which they were seeking assistance.

Although IVD is designed to be a competition, the teams openly discussed the design challenges encountered during initial development. Each team collectively reviewed opportunities, potential solutions and methods that might lead to further solutions. "The thought process of the student teams is very impressive; many of the issues and opportunities discussed are those very topics on which IAV's engineering teams are actively working. This program and competition is providing a unique experience for these young individuals," commented Jason McConnell.

Karl Klimek, one of the leading proponents of the Square One Network, has offered some humbling words in return: "IAV represents the exact kind of new partnerships that bring true excitement to the teachers and students in our schools. Recognizing that partnerships can take many forms, IAV offers available experts, first-class facilities and programming contributions and provides premier class experiences to our students."

As the afternoon at IAV drew to a close, students, teachers and engineers alike were energized by the productive day. The event proved to be beneficial to all who participated, and IAV looks forward to a continuing relationship with SQ1 and additional opportunities to make a difference through education.

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Drive for Innovation

IAV Exhibiting at the 2010 SAE World Congress

By Jeremy Goddard

In keeping with the changes in the marketplace for the automotive industry, the SAE has adjusted its format and focus for the 2010 World Congress, to be held from April 13 - 15 at the Cobo Center in Detroit. The Ford Motor Company is the 2010 Host Company and is leading the investigation into "Ecollaboration." The exhibit area is considerably reduced over previous years, with a deliberate limitation to 400 ft² (35 m²) per exhibitor booth. Companies joining Ford are invited to de-emphasize extravagant product displays and to focus as an alternative on Innovation and Collaboration.

For IAV, the reduced area will not allow for the themed display structure now in storage. Instead, the booth will provide an inviting area for clients to sit down with IAV experts and discuss the company's innovations and collaborative engineering programs. Two key IAV technologies will be examined in depth: the Design of Experiments method, Dynamic DOE; and the Vehicle Longitudinal Dynamics simulation software, VeLoDyn.

Dynamic DoE offers the ability to model transient engine behavior and provides an efficient and systematic approach to engine calibration. The VeLoDyn simulation environment presents a consistent framework to foster IAV engineers' design, development and validation efforts from the earliest stages of vehicle development through to volume production. The IAV team will review with clients the benefits in modeling accuracy and development time-saved in using such innovative approaches.

In addition to the two main topics of interest, IAV experts will be well prepared to address the many other innovations developed, or in development, at IAV to maximize powertrain and vehicle efficiency, integrate hybrid solutions and reduce tailpipe emissions.

IAV will be meeting with clients at Booth #412.

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Public Appearances & Publications

April

April 13 – 15, 2010
SAE World Congress
Detroit, MI
Booth: 412

April 23 – 24, 2010
2010 International Symposium on Transmission Innovation and China Industrialization
Beijing, China

April 29 – 30, 2010
31st International Vienna Engine Symposium
Vienna, Austria

Paper: "Continuous Injection-Rate Shaping for Passenger-Car Diesel Engines – Potential, Limits and Feasibility"
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May

May 20, 2010
9th International Conference on Turbochargers and Turbocharging
London, United Kingdom

Paper: "Performance Measurement Method for Low Turbocharger Speeds"
panagiotis.grigoriadis@iav.de, marc.sens@iav.de, rene.berndt@iav.de

May 26 – 27, 2010
SIA – Diesel Engines
Rouen, France

May 28 – 29, 2010
Exposition Journées Jeunes SIA 2010
Versailles, France

May 31 – June 01, 2010
4th IAV Conference on "Simulation and Testing for Automotive Electronics – From the Concept to Mass Production"
Berlin

Papers: "Process for Systematically Selecting Testing Methodology for Validating Control Units / Example: Transmission HiL Test"
jens.riese@iav.de

"Statistical Calibration of Physical Models"
mirko.knaak@iav.jp

MTZ 5/2010
"CO_2 Neutral Particulate Reduction in the Diesel Particulate Filter"
michael.frambourg@iav.de, juergen.rohr@iav.de, benjamin.felchner@iav.de, matthias.eder@iav.de, alexander.boeswetter@iav.de

ATZ/MTZ Automotive Engineering Partners
"Doppler Global Velocimetry (DGV) as an Indispensable Tool in Developing Combustion Processes"
michael.guenther@iav.de, dr.thomas.seidel@iav.de, henry.steuker@iav.de

June

June 08 – 09, 2010
4th CTI Symposium & Exhibition, Automotive Transmission North America
Detroit, MI

Papers:
"Advanced Power Shiftable Transmissions for Commercial Vehicles"
rico.resch@iav.de, joerg.mueller@iav.de, mirko.leesch@iav.de

"A New 8-Speed Hybrid Automatic Transmission for Transverse Applications"
joerg.mueller@iav.de, rico.resch@iav.de, mirko.leesch@iav.de

June 14 – 15, 2010
3rd IAV Conference on "Engine Process Simulation and Supercharging"
Berlin, Germany

June 14 - 16, 2010
Emissions 2010 Conference
Ann Arbor, MI

Paper: "The Future is Driven by Structurally Optimized Transmissions"
tom.tibbles@iav-usa.com, joerg.mueller@iav.de. mirko.leesch@iav.de, rico.resch@iav,de

June 17 – 18, 2010
Electro-Mobile Congress
Bonn, Germany

June 22 – 23, 2010
VDI Conference "Transmissions in Vehicles 2010"
Friedrichshafen, Germany

June 24, 2010
IAV DoE Conference
Northville, MI