Edited by **Darlene Fritz**

DiesOtto: a diesel-gasoline technology blend

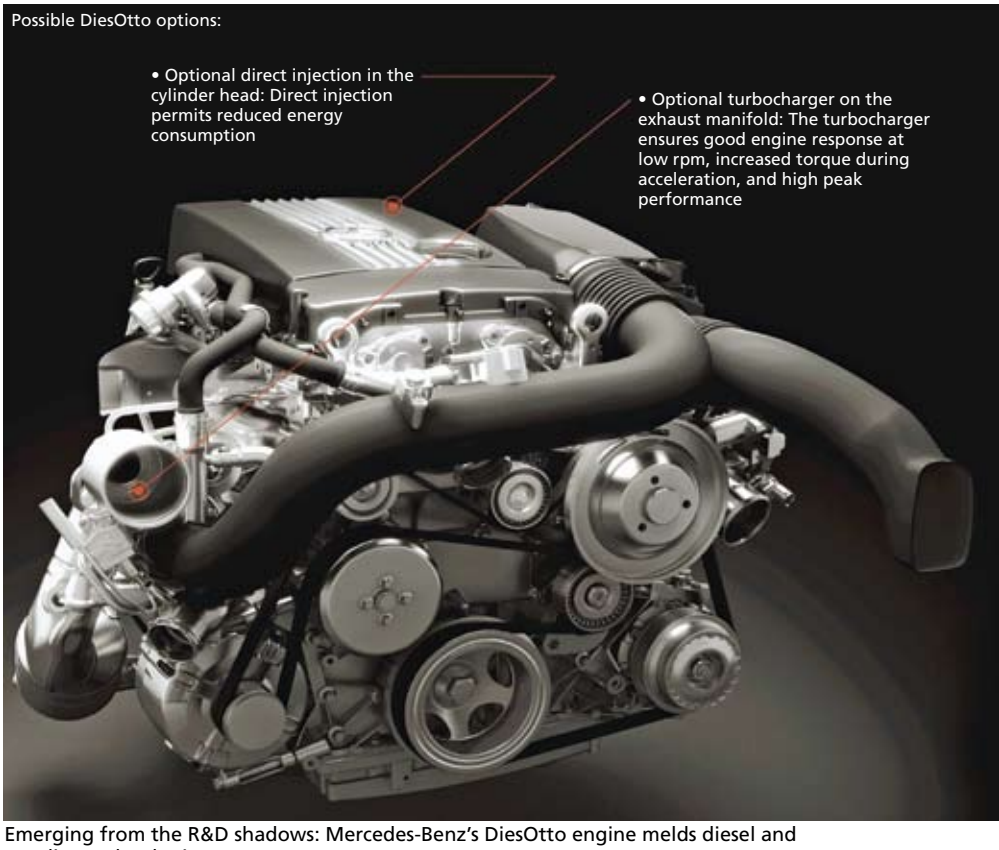
A new twist has been given to the dialogue about whether the future of the hybrid leans toward the gasoline or diesel solution, with the announcement by **Mercedes** of its highly complex DiesOtto (Diesel Otto-cycle) unit—a mix of the two based on a gasoline engine block. Claimed to combine all the advantages of both engine types, it was revealed to *AEI* shortly before the Frankfurt Motor Show where it was installed in a concept vehicle.

Volkswagen unveiled its work on a similar combined combustion system (CCS) engine late last year based on a diesel block that burns biofuel; however, the Mercedes engine uses a gasoline block and is fueled by gasoline. Professor Herbert Kohler, Vice President, Group Research and Advanced Engineering, Vehicle and Powertrain, and Chief Environmental Officer, **Daimler**, said that in a sense, diesel and gasoline engine technology—which had gone their separate ways for decades—"will be celebrating a marriage beneath the hood." He also said that if the specific strengths of each were combined, the result would be an almost-optimal concept, which he described as "an engine that achieves top ratings for output, torque, emissions, and fuel consumption, and is also very appealing in terms of cost."

Kohler admits, however, that turning this "marriage beneath the hood" into reality is not quite so easy, although "we are well ahead with our development work. And the DiesOtto engine becomes even more economical if combined with a hybrid module—for which it was designed." Kohler would not be drawn on the likely timescale for a production DiesOtto other than to say that it was feasible "in the mid-term."

The DiesOtto has direct gasoline injection, turbocharging, and a variable compression ratio. It also has "controlled auto ignition, a combustion process similar to that of a diesel," as well as variable valve control.

Mercedes-Benz's Herbert Kohler (left) discusses the company's newest research power unit, noting that "the DiesOtto engine becomes even more economical if combined with a hybrid module—for which it was designed."



Emerging from the R&D shadows: Mercedes-Benz's DiesOtto engine melds diesel and gasoline technologies.

The engine uses spark ignition when starting and also under full load, with the controlled auto ignition sequence taking over under partial loads and low to medium engine speeds. The technology is said by Mercedes to provide "very low" NOx emissions typical of homogeneous combustion at reduced reaction temperatures. The engine has a regular three-way catalytic converter.

"While the direct injection of our 350CGI engine is intended to stratify an ignitable mixture around the spark plug in lean-burn operation, its main purpose in the DiesOtto is to get an excellent homogeneous mixture and to control the self-ignition by the injection process." He added: "The art lies in controlling the combustion point using the fuel quantities and injection timing. As the mixture ignites simultaneously at numerous points, the resulting combustion is very uniform—*i.e.*, homogeneous."

A "variable crank train" is fitted, but as *AEI* closed for press, Mercedes had not released full details of how its variable combustion system operated.

The research four-cylinder DiesOtto unit produces 175 kW (235 hp) and for the hybrid application is allied to a 15-kW (20-hp) electric motor. Maximum torque for the total system is 400 N·m (295 lb·ft).

"A comparison with our current gasoline 2.5-L V6 naturally aspirated engine and the 3.0-L V6 turbodiesel confirms that the DiesOtto engine shows performance and torque values for 1.8-L displacement which are presentable," said Kohler. "The specific values that correspond to particular displacement demonstrate peaks that compare with conventional powertrains. This proves that we really have combined the best of two worlds," added Kohler. "The rated fuel consumption achievable together with hybridization is below 6.0 L/100 km—and we are not talking about a compact car but a research car with the approximate dimensions of the present S-Class."

Mercedes is to place ever-greater emphasis on hybrids, not only in conjunction with a gasoline IC engine or, further ahead, the DiesOtto. The company is also developing diesel hybrid solutions and expects to overcome the challenge of high costs; typically a complete diesel engine may be up to 50% more expensive to build than a gasoline unit.

"In future, Mercedes-Benz will only develop vehicles and engines which can be enhanced with hybrid technology," said Kohler.

Stuart Birch

Viki III's 3M technologies

A **3M** demonstration vehicle's 2007 technology tour provided a showcase of various in-development and production-ready technologies, including an energy-saving film that improves the brightness of the back-of-vehicle image.

Close-up views of navigation screens made brighter with reduced reflectivity by 3M optical films.

The technology preview vehicle's rearview mirror—produced by **Gentex** and debuting in the 2008 model year on a **Ford** truck and a **Mazda** crossover vehicle—uses a 3M brightness enhancement film to sharpen the rear-of-vehicle scene that is displayed on a portion of the mirror when the vehicle is in reverse gear.

"We're not creating any new light. The film is just managing the light to come out toward you," said Brian Pospy, a Business Development Manager for 3M Automotive. In contrast to improving a display image's brightness and uniformity, 3M's light control film prevents unwanted in-dash display reflection and glare from being cast onto the windshield.

"It's like having horizontal blinds in the display," said Pospy. This production-ready film would mean instrument-panel displays would not need "a hood for the gauges—which essentially means more available real estate in the vehicle as well as design freedom for the interior designer," said Pospy.

3M's Viki III—short for Vikuiti Display Enhancement Products—demonstration vehicle also showcases trim films, which are still in development. "Thus far, our automotive film applications have been for the exterior of vehicles—to prevent stone chips and abrasions—but this is our first major effort with trim films for the interior," said Doug Smith, a Business Development Manager for 3M's Automotive Division.

The trim films simulate the look and feel of real wood and metal via color, pattern, and texture for applications including door panels and instrument panels. "3M has been supplying these films to the architectural industry for several years, but now the company is creating film grades for automotive interior applications," said Smith, noting that the final steps before commercialization—not expected before the 2009 model year—are heat- and scratch-resistance confirmation testing.

Metallic reflective film is another in-development technology spotlighted on the Viki III. "LEDs fire into the edge of the film, and the light bends 90° because of the optical properties in the film," said Robert Miller, Lighting Designer and Marketing Manager for 3M Automotive. Further refinement of the film is ongoing for a variety of applications, including dome lights and other ambient lighting areas inside the vehicle.

The demonstration vehicle also sports several light distribution systems—*e.g.*, precision lighting elements, light string, and light-by-wire—aimed at giving vehicle interior designers new ways to illuminate consoles, cup holders, and sill plates, as well as under seats. Viki III was seen by numerous automotive and supplier company representatives in the U.S. and Europe.

Kami Buchholz

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GM's surprising new V8 diesel has no manifolds

General Motors recently took some of the wraps off of its 2010 Duramax diesel V8, revealing clever design features and technologies that clearly push the state-of-the-art in Vee-type compression-ignition engines.

Unveiled during a media briefing at its Milford, MI, Proving Grounds, the new 4.5-L powerplant will be one of the most powerful, lowest-emitting, and package-efficient light-duty V8 diesels in the marketplace, company engineers claimed.

The new Duramax is scheduled to enter production in late 2009 at GM's Tonawanda, NY, engine plant. It will power GM's full-size pickup trucks and utilities, among other potential applications. Rated output is targeted at more than 310 hp (231 kW), for 68 hp/L (51 kW/L), and 520 lb·ft (705 N·m).

The Duramax was designed to fit within the ultra-compact envelope of GM's small-block gasoline V8. Its NVH profile also targets the gas engine. These aggressive requirements drove many of the engine's innovations announced to date.

The new engine's aluminum cylinder heads' exhaust ports face inboard, toward the valley of the cylinder block. This allows the single variable-geometry turbocharger, exhaust-gas recirculation (EGR) cooler, and close-coupled oxidation catalyst to reside within the valley. The layout negates the need for separate exhaust manifolds while reducing overall width.

The reversed-head orientation also means the new diesel does not use a conventional intake manifold. Its intake ports are internal, rather than arrayed along an exterior face of the head as in common practice. The ports are fed pressurized charge directly through the tops of the intake camshaft covers.

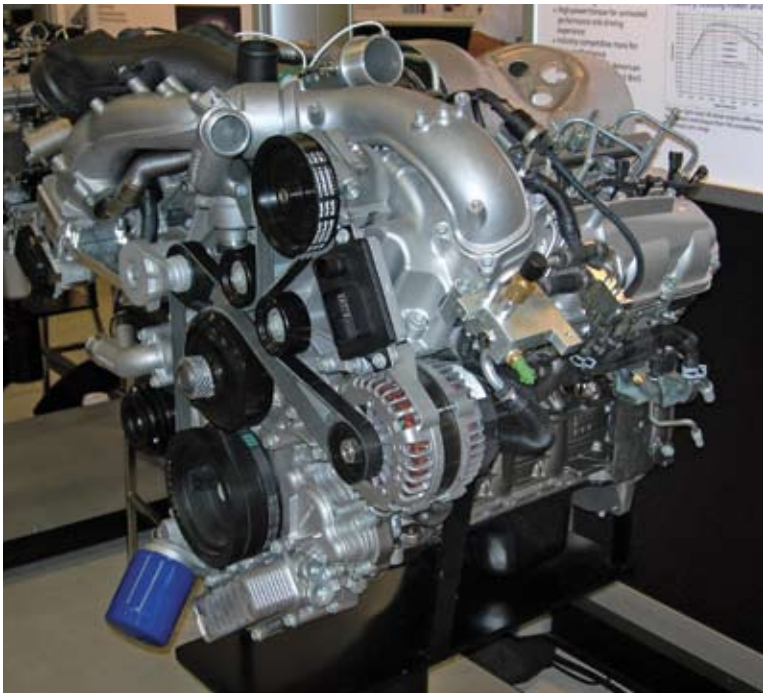
The heads' unique two-tiered internal construction segregates the intake route, the chain-driven DOHC valvegear, and water jacket. (The fully dressed engine on display was not sectioned, so no internal details were revealed.)

Compacted graphite-iron (CGI) optimizes the cylinder block's strength and mass. The block's cylinder banks are splayed at 72° to achieve a narrow overall package with even firing, but the narrow vee requires a balance shaft for smooth running. GM studied aluminum block castings but determined that the light alloy would not deliver sufficient long-term durability and could not cope with the cylinder pressures planned for the new engine.

Right side of the new V8 shows lack of exhaust manifold. Intake route is straight into the top of the intake cam boxes.

All images by Lindsay Brooke

Chief Engineer Gary Arvan (left) and GM Diesel Engineering Director Charlie Freese with their latest baby at Milford.



Cast-aluminum intake plumbing on the current prototype engine may be superceded by reinforced plastic before the program reaches production. The ultra-compact diesel V8 has its turbocharger hidden between the cylinder banks.

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The main bearing caps are precision-fractured ("cracked"). This novel application of a feature that is commonly used for connecting rod big-ends enables closer crank-to-bearing tolerances with greatly improved assembly accuracy.

Piezo-type common-rail fuel injectors operating at 2000 bar (29,000 psi) are one of the keys to the new diesel meeting ultra-stringent U.S. Tier 2 bin 5 and California LEV2 emissions regulations. Another enabler is the engine's urea-based selective catalytic reduction system for reducing engine-out NOx (oxides of nitrogen) emissions.

The Duramax is package-protected for closed-loop cylinder pressure monitoring, a technology GM will introduce on its new 2.9-L turbodiesel V6 next year in Europe.

The initial concept for the new Duramax sprang from impromptu brainstorming sessions between GM's Director of Diesel Engineering, Charlie Freese, and the V8's Chief Engineer, Gary Arvan.

"It was totally clean-sheet," Freese recalled. "Starting with very rough sketches, our path to every technical solution began with a 'what if.' We ended up avoiding traditional approaches."

Features of GM's compact V8 diesel

- Aluminum cylinder heads with inboard-facing exhaust ports
- Conventional intake manifold replaced by internal intake ports fed through camshaft cover tops
- Complete segregation of intake route, DOHC valvegear, and water jacket
- CGI cylinder block with a narrow, 72° vee and a balance shaft
- Precision-fractured ("cracked") main bearing caps for closer tolerances
- Piezo-type common-rail fuel injectors operating at 2000 bar
- Urea-based selective catalytic reduction system
- Package-protected for closed-loop cylinder pressure monitoring

And Mountain Dew, rather than coffee, was the engineers' preferred beverage during the meetings, which stretched into many late evenings.

According to Arvan, one strategic goal was to eliminate the component duplications that make Vee-type diesels inherently more complex and costly. Hence the single turbocharger and absence of exhaust manifolds.

Another goal was "to shorten the typical long induction and exhaust paths and minimize surface area along the way, to quickly get the hot exhaust out of the heads and into the turbo," he noted.

Eliminating the intake manifold and employing internal exhaust-gas recirculation also reduces the number of noise-radiating surfaces, Arvan said. And the stout CGI block "is stiffer than any competitive cylinder block we've analyzed—and we've analyzed them all," Freese added.

The Duramax's bills of design and materials (BoD and BoM) were developed to achieve some commonality with the current-generation 6.6-L V8. Shared features include the quick-start system with intake air heater, electronic EGR, and some elements of the larger diesel's electronic control system. The 4.5-L engine will employ a new E86 engine controller.

GM will uncloak more of the V8's secrets next year, after the automaker establishes patents in a number of areas, said Freese.

Lindsay Brooke

Green powertrain technology developments

Development of all aspects of powertrain technology, including fuels and transmissions, is becoming central to OEM and specialist consultancies' programs. Some of the work is an extrapolation of established systems; some involve the application of novel fueling technologies, while other projects concern more advanced technology and widening partnerships.

A British company seeking solutions for lower CO_2 emissions has made what it claims as a major breakthrough in converting a conventional gasoline car to run on pure hydrogen. A regular **Ford** Focus has been converted to bi-fuel capability and has successfully completed initial trials in a program conducted on behalf of **ITM Power** by the **University of Hertfordshire**. During the testing program, the vehicle was able to travel over 40 km (25 mi) on a single charge of hydrogen—more than the average commuting journey—with zero hydrogen emissions, before being switched back to run on gasoline.

"We believe combining electrolyzers with an internal combustion-engined vehicle brings affordable hydrogen transportation forward by many years," said Jim Heathcote, CEO of ITM Power.

Of equal significance is how the hydrogen was generated and the car fueled, according to ITM Power, which describes itself as Europe's largest electrolyzer and fuel-cell company. A low-cost electrolyzer has been developed that can convert off-peak electricity or renewable energy such as wind, wave, or solar power into hydrogen. The company used its own prototype "home refueling system" to fuel the car. The refueling system, which will be able to generate and store hydrogen at home or at work, will be publicly demonstrated later this year along with the bi-fuel car.

ITM Power is now finalizing the design of a manufacturing facility, which, it claims, will deliver one of the largest electrolyzer production capabilities in the world, with manufacturing slated to begin in the first half of next year.

"Both these developments represent a seismic advance in our efforts to cut ourselves free from the dependence on oil and other fossil fuels," said Jim

Heathcote, CEO of ITM Power. "The bi-fuel car and refueling system clearly demonstrate a simple, convenient, and low-cost transportation solution that can significantly reduce greenhouse gases and help mitigate climate change.

"We believe combining electrolyzers with an internal combustion-engined vehicle brings affordable hydrogen transportation forward by many years," continued Heathcote. "Although some hydrogen-powered cars are currently undergoing trials, they have no access to a hydrogen refueling infrastructure and rely on liquefied hydrogen which must be stored at ultra-low temperatures." The bi-fuel Focus test car runs on pure hydrogen gas that can be produced anywhere that has access to water and electricity, added Heathcote.

ITM has just installed an electrolyzer and onboard emissions monitoring equipment into a Range Rover 3.6-L diesel. According to the company, the equipment has demonstrated that an ITM electrolyzer can operate successfully in the demanding environment of a moving vehicle, and direct, reproducible observations verified that the principle emissions were reduced while the electrolyzer was active. However, the full commercial or military implications of the results could not be judged in advance of a specific research program.

Another UK institution, the **University of Coventry**, is also involved in the pursuit of cutting CO_2 emissions. The MUSIC (Merritt Unthrottled Spark Ignition Combustion) engine project was presented in May at the Engine Expo Technology Congress in Stuttgart, and project partner Knibb, Gormezano & Partners (**KGP**) revealed that prototype engine build would begin in July.

The University of Coventry's Dan

"In the long term, the automotive industry needs to pull together to find ways to decrease CO_2 emissions," said Mike Kimberley, CEO of Group Lotus.

Merritt and a specialist team developed MUSIC. "Its key benefit is that it offers diesel-engine efficiencies from a gasoline engine with all the implications for CO_2 improvement that this brings," said Merritt. Central to the technology is the incorporation of an indirect combustion chamber with built-in helical swirl that can not only run successfully at air/fuel ratios of over 100:1 but also reduces HC and NOx emissions significantly. MUSIC has been the subject of a development program partly funded by the **Energy Savings Trust** (EST) in the UK. **Powertrain Technologies Limited** (PTech) is undertaking the development work. Support has also come from Ford and **BP Castrol**. KGP is responsible for managing commercialization of the technology.

Another R&D program, this one to demonstrate a vehicle with low CO_2 emissions in combination with a high-performance gasoline and hybrid engine, sees **Lotus** Engineering, the engineering consultancy division of Group Lotus, joining forces with **Siemens VDO**.

The vehicle will demonstrate an integrated systems approach to reducing CO_2 emissions through key technologies from both companies. A particular target is to make it "pleasurable to drive."

Lotus is contributing its downsizing and systems-integration expertise based upon a recently developed three-cylinder engine, and Siemens VDO is supplying its systems capability and experience in engine and powertrain management, particularly in the areas of direct fuel injection systems, hybrid drives, integrated powertrain management, emissions after-treatment systems, and system components.

"The project will highlight the CO_2-reduction benefits of an integrated approach for these systems in a demonstration vehicle," said Mike Kimberley, CEO of Group Lotus. "We are currently researching how to increase powertrain efficiency, as well as power and performance with both alternative and conventional fuels, whilst simultaneously reducing net emissions. In the long term, the automotive industry needs to pull together to find ways to decrease CO_2 emissions and reduce our dependence on fossil fuels. I believe that this research cooperation will go some way in finding a solution to these issues."

Adds Siemens VDO Group Vice President, Klaus Egger, "We see clear benefits in the combination of both companies' experience in regard to low CO_2 know-how. With its expertise in the field of combustion engines development and vehicle integration, Lotus is our ideal partner."

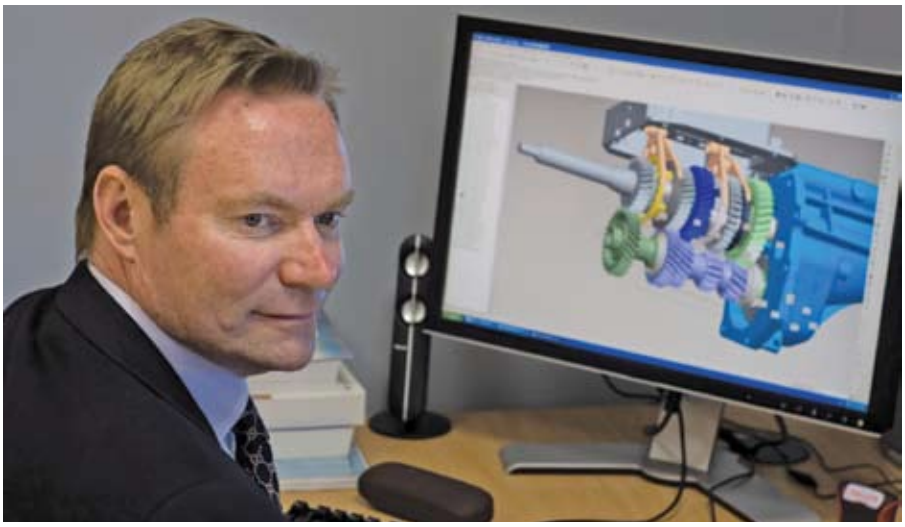
Stuart Birch

Zeroshift torques down AMT technology

Automated manual transmission (AMT) systems are fine in theory but often less satisfactory in day-to-day use; the down side is the torque-interruption effect that accompanies ratio shifts. Driving a car fitted with an AMT invariably calls for a degree of accelerator control together with an appreciation of engine speed almost akin to the precision of playing a musical instrument. Timing is everything; without it, progress is an uncomfortable experience, with the heads of driver and passengers nodding in a syncopated rhythm to torque interruption as gears shift, whether in auto or manual mode.

Improvements to software have lessened the effect on later AMTs, but the system is invariably something of a compromise at best. However, the potential benefits of an AMT are real and the UK company **Zeroshift** has developed a system to overcome the torque-interruption effect. That system is now being integrated into an engineering and technology demonstration vehicle. At the **SAE** World Congress earlier this year, *AEI* editors singled out the Zeroshift system as being one of the most innovative technologies to be presented.

Zeroshift was established in 2002 specifically to research and develop a solution to the drawbacks of regular AMT applications. Said Managing Director, Bill



Zeroshift Managing Director, Bill Martin: "Zero torque interruption improves performance, potentially allowing engine downsizing and a further reduction in CO_2."

Zeroshift's solution uses control rings to smooth the operation of an automated manual transmission.

Martin: "We realized that in many respects conventional AMTs were close to providing an ideal transmission solution in terms of cost, packaging, and operating convenience, but were limited by poor shift quality and emissions issues introduced by sudden on/off torque required to change gear. We are now confident that Zeroshift technology can transform almost any manual gearbox into a compact, low-cost automatic that changes ratio with zero torque interruption."

The company's five-year development program has now resulted in a second-generation solution. Martin regards the concept as "proven" and said the company is starting engineering programs with OEMs and transmission suppliers. Shift quality is equivalent to a traditional planetary automatic with torque converter, he claimed, but via a smaller, lighter, and substantially lower-cost system: "In a typical mixed-drive cycle, the Zeroshift system should generate a fuel-economy saving of at least 2% compared to a manual transmission and 7% when compared to a planetary automatic with an equivalent number of ratios. CO_2 emissions are similarly reduced. Zero torque interruption improves performance, potentially allowing engine downsizing and a further reduction in CO_2. We expect engine downsizing to become one of the most important solutions to emissions reduction, particularly in Europe."

From manufacturing and vehicle systems integration aspects, Martin stated that his company's system is cheaper to produce than a dual-clutch transmission (DCT) or an equivalent planetary auto, and that the shift mechanism could be built into an existing manual gearbox. "It can be assembled on currently used manual-transmission production lines. The Zeroshift's capability centers on its design innovation and control systems, making it mechanically so simple that only a few workstations would have to be modified to accommodate a choice of different components—Zeroshift or conventional synchromesh. We believe that for an established manufacturer of manual gearboxes, it is an economically affordable option."

Martin explained that the second-generation Zeroshift gearbox is essentially an AMT in which the synchromesh has been replaced by interlocking drive rings that engage and disengage the drive gears in a similar manner to dog clutches. Each drive ring incorporates three drive elements in a single forged component that is moved on a splined hub shaft by lightweight shift forks. A compact, low-cost electrical actuator system is being developed to replace the pneumatic system initially used to prove the concept.

The instant before a shift takes place, the clutch is opened to a point where it is capable of transmitting only the exact torque being delivered by the engine. As the shift takes place, inertial forces cause the clutch to slip, allowing the engine speed to synchronize with the gearbox input shaft speed. One side of the drive element has a retention angle to take up the drive, the opposite side using a ramp face to smoothly disengage the drive. The Zeroshift-designed control system coordinates gearshift actuation, engine management, and clutch operation.

"Shift forces are about 40 N, compared to some 1000 N for a typical current AMT," said Martin. "When shifting from neutral, ring one is engaged to take up drive while ring two is engaged within a few degrees of revolution to take up backlash. The next shift is made with ring two taking up the drive and ring one taking up the backlash. As ring two is unloaded during the change, it requires less than one-twentieth the axial force required by a conventional synchromesh. The ratio change is completed with clutch pressure reapplied. There is zero torque interruption throughout the shift sequence."

Stuart Birch

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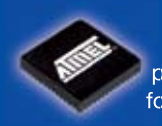

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