The hybrids are coming!

AFTER YEARS OF HYPE, INDUSTRIAL VEHICLES WITH POWERTRAINS THAT OFFER THE BEST OF BOTH WORLDS ARE FINALLY STARTING TO HATCH. WILL THEY DEVOUR THE MARKET OR TIMIDLY INFILTRATE IT?
**HYBRID POWERTRAINS**

Engineers of innovative mobile drives must find solutions rather appealing – prototypes of many hybrid drives shown at trade fairs go on to be installed in refuse trucks. For good reason, of course: if the vehicle moves in a stop-start manner and wheel slip can be excluded, hybrid drives work particularly well.

It is now becoming hard to find a vehicle OEM that is not considering hybrid or other alternative drives. There are many prototypes and real-world trials, and suppliers are preparing for – or have already begun – series production. It is important news, too, that the fuel cell may work better with a special kind of hybrid drive.

### Hybrid electric or hydraulic?

For refuse trucks (Figure 1), trolley buses and light delivery vehicles, Eaton has developed hybrid electric and hybrid hydraulic drives, and claims that it is the world’s only manufacturer of both types of hybrid systems considered viable for today’s commercial vehicles.

“The HEV concept is well suited for refuse trucks typically, such as refuse trucks, shuttle buses and other larger vehicles. For these applications, the company has developed two distinct technologies, both designed to capture the vehicle’s braking energy, which is stored and then used for acceleration. The first, Hybrid Launch Assist (HLA) technology, is designed as a parallel hybrid system, supplementing the conventional powertrain (Figure 2). Braking energy is saved in a hydraulic accumulator and for several seconds, the system delivers 300hp from a motor that measures approximately 12×18in – high-power density indeed!

According to the company, this system not only reduces energy consumption, but also doubles the life of the brakes.

Eaton is also developing a hybrid hydraulic technology system that completely replaces the conventional transmission and driveline. Energy is recovered, stored, and transferred from the engine to the drive wheels using hydraulic pumps, motors and other integrated components.

The initial project specification called for a bent-axi pump, because that geometry has better efficiency at partial loads than an axial piston pump,” says Brad Bohlman, business development manager, Eaton’s Hydraulic Operations’ advanced technology division.

What we found, though, is that the system is typically operating at, or near, full capacity so we were rarely able to take advantage of that extra efficiency. As a result, our production systems will use axial piston pumps, which are a lot easier to incorporate into a parallel architecture because of the through-shaft capability.”

On-road prototypes of vehicles such as panel-delivery trucks with this drive system have shown that fuel economy can be improved by 50-70%. Eaton has already produced more than 220 hybrid-powered vehicles for testing and evaluation.

According to Eaton, the next generation of hybrid power systems promises even greater efficiency. One embodiment is a series hydraulic system in which a diesel engine drives a variable-displacement hydraulic pump linked to a variable-displacement hydraulic motor connected to the vehicle’s final drive, or directly to the wheels. This arrangement creates an infinitely variable transmission (IVT)

“IVT will be a stop up in efficiency from today’s advanced CVT systems because it does not need a clutch to achieve zero driving force,” explains Davis. “You can drive the engine from the final drive simply by adjusting the pump and/or motor displacement to zero.”

**Hybrid drives in off-highway**

Hybrid concepts have been engineered as prototypes by several construction equipment OEMs. At Bauma 2007, for instance, Weyhausen, the German wheelie-loader manufacturer, presented an Atlas A86S with a hybrid mild hybrid drive, jointly developed with Deutz and Heinemann, which supplied the engine-control system. In this machine, the flywheel between the 36-kW diesel engine and hydraulic pump is replaced by a compact unit containing a motor-generator with a rated power of 10kW and a peak power of 36kW.

At the current development stage of the Atlas loader, all functions on the equipment side remain hydraulically driven. The next step involves the loader being powered by a full hybrid-drive system. It will then be possible to temporarily realise a strictly electric, and therefore emission-free, operation. Caterpillar is adopting a similar strategy, introducing an electric-drive track-type tractor that will be ready for sale in selected markets during the next year. The D7E is in the 27-tonne weight range and is powered by a Cat C9 engine producing 175kW. According to Caterpillar, it will deliver 25% more material moved per gallon of fuel, 10% greater productivity and 10% lower lifetime operating costs.

In the D7E’s powertrain (Figure 3), the engine drives a generator to produce electricity that ultimately powers two AC drive motors connected to a differential steering system. A traditional mechanical transmission is not needed, because the variable-speed electric motors serve the function of a continuously variable transmission. The drive is similar to the diesel-electric concepts of diesel locomotives and Stäubli’s forklifts. The electric drivetrain has 60% fewer moving parts than the D7R, while the electric system powers auxiliary components so that no engine belts are needed. Volvo presented a hybrid solution for heavy-duty vehicles in 2006, and is currently delivering six double-decker buses, run entirely on hybrid engines and transmission, for a test year in London. Now its construction division has produced an L220F hybrid wheeled loader that has the potential for fuel savings of 50%. It features Volvo’s integrated starter-generator technology, which allows the engine to be turned off when idling (Figure 4). This hybrid mode alone will reduce fuel consumption by up to 18%.

**Partnering with OEMs**

Suppliers are eager to respond to these needs and to partner OEMs. Eaton, in targeting the off-highway market, develops hybrid drives on its own or with OEMs. JF makes use Google it!
of the experience that was gained in the passenger car and commercial vehicle markets (see page 70).

Sensor Technik Wiedemann, in co-operation with other project members, has also developed a hybrid drive system, called powerMELA (Figure 5). This is a diesel-electric drive designed for use in construction machinery, and agricultural, service and community vehicles. Its open electric network can be extended to drive auxiliary devices and external machinery. A battery for energy recovery can also be included.

The components are developed especially for rugged conditions and extreme operating temperatures from -40 to +85°C. The motor/generator is offered in various power ranges, from 20-200kW. The 125kW machine has a nominal speed of 3,000rpm, a shaft height of 132mm, weighs 120kg and has a rated torque of 450Nm, representing an exceptionally high power density. The electric motor can be controlled over a CANbus interface and depending on the application, the torque, speed, voltage or position can be regulated. A protection and safety concept provides for secure handling up to 750V.

Regenerative braking with hydraulic bladder accumulators

In the field of hybrid drives, Rexroth can benefit from its huge experience in hydraulics and from the know-how of Bosch’s automotive business in designing alternative drives. The company has already developed several hybrid concepts for off-highway vehicles, such as the hydrostatic regenerative braking system (HRB, Figure 6). The engineers have opted for a hydraulic hybrid, using bladder accumulators to store the energy – a concept that can also be successfully applied to large hydraulic presses.

The energy generated during braking is stored in the accumulator, and during the next acceleration event, the accumulator supplies enough energy to reduce the load on the combustion engine. Rexroth is currently developing a parallel HRB for vehicles with a mechanical drivetrain as well as a series HRB for those with a hydrostatic transmission. The former can even be retrofitted. Simulations indicate that fuel savings of up to 25% are possible – this is going to be validated during field tests in Berlin and New York with prototype garbage trucks later this year. Similar savings are expected by the series HRB, for instance in forklift trucks.

A 10-tonne lift truck needs only a 20-litre accumulator to store the energy. Furthermore, Rexroth has patented a solution to integrate the working hydraulics of forklift trucks into its series HRB system to increase energy savings.

Hybrid triples

Hybrid is the Greek word for mixed, so any drive with more than one power source can be described as a hybrid – for instance, a forklift drive with fuel cell, supercapacitors and battery. Sounds over-engineered? In fact, it is not – and it is readily available. German fuel cell developer

Development of battery systems

Crucial to the operation of hybrid drives is the battery technology used for recovery energy – OEMs and suppliers are waiting for increased power and/or energy density. Ricardo has therefore announced the establishment of its Battery Systems Development centre to offer turnkey engineering and development of complete high-voltage battery-pack systems for hybrid, plug-in hybrid and electric vehicles.

The facility will feature three Li-ion-capable development chambers, large HEV/EV-capable battery cyclers and equipment to facilitate the development of battery systems in simulated vehicle environments. The centre will be used to validate Ricardo’s design, analysis and simulation of advanced high-power battery packs. Projected to grow to a staff of 32, it will focus on engineering complete Li-ion and nickel-metal-hydride (NiMH) battery-pack systems (as opposed to the development of battery cells).

Prototype pack systems will undergo exhaustive development. Each will feature high-capacity EV/HEV-capable battery cyclers, high-voltage instrumentation, hardware-in-the-loop systems and other equipment to enhance development in simulated vehicle environments. Once a battery-pack design is verified, the battery system can be integrated into, and further developed on, a vehicle in Ricardo’s adjoining garage facility.
The classical elements and hybrid engine technology

If we look outside the traditionally ‘fire-driven’ engines, it’s possible that other ‘elements’ could also play an increased role. Viohl is currently researching air hybrid technology, which will use braking energy to work as a compressor, compressing air into a onboard tank. The air motoring mode can then power the engine from the stored air with or without burning fuel by using air injection to get up to speed.

The internet is awash with books revealing how you can run internal combustion engines on water. Some claim to be using it to enhance combustion in combination with another hydrocarbon fuel, while others claim it can be used as a fuel in its own right. It is an interesting subject for discussion. For a start, how would fuel be taxed if it falls from the sky for free? One thing is for sure, whoever finds a way to really run an internal combustion engine on water could retire very wealthy.

However, back in the real world, there is one thing all the suggestions about using water as fuel have in common: the maths never seems to add up. Perhaps this is why the mainstream engineering community apparently refuses to take the concept seriously.

Using a little sprout of water to take the heat out of combustion has been used for many years, and racing applications have been known to spray water onto an intercooler to reduce charge density. Research and fine-tuning of these systems will doubtless continue, although industrial vehicles may not be the ideal platform to demonstrate the technology.

Most internet claims centre on Brown’s Gas (HHO). The process appears to use a modified electrolyser to split water into constituent hydrogen and oxygen parts, but when it comes to the energy requirements to do this, exact figures are hard to come by. With installation claimed to cost around US$100, some of the products for sale look downright dangerous. One company is promoting what appears to be a 2-litre jug with an electrolyser inside. This is clamped somewhere in the engine bay, filled with water and supplied with a current. The gas produced goes into the intake manifold of a petrol engine with scant regard to the technical niceties like what would this do to combustion charge ratios, or how lambda sensors would react to the changes in exhaust gases. Despite this, there are many ‘endorsements’ from satisfied customers, claiming increased economy (20-50%) and that emission tests are being passed without the aid of catalytic converters. They seem impressed – and if it works, who’s to blame?

However, with the greatest respect to all those working in this fascinating field, without a giant leap forward it seems industrial vehicle compression ignition engine designers need not lose sleep just yet – surely the diesel as we know it will remain with us for some time yet.

And as far as our research suggests, there are no signs of an earth- powered engine on the horizon either…

(Jon Lawson)

The 10kW fuel cell delivers enough power to drive the forklift for one minute. Long battery charging times, expensive charging stations and the associated logistics are therefore no longer needed.

The step from prototype to production is near or has already arrived, and the operators will be able to choose from a much broader selection of drive concepts in the near future. The fuel-cell forklift can be ordered today, hydraulic hybrid drives can even be retrofitted, and 2009 will see the series production of hybrid wheeled loaders and track-type tractors. Considering that fuel savings of 10-20% or more are possible with comparatively simple measures such as a compact motor-generator or a hydraulic blader accumulator, one question remains: why have we taken so long to get to this stage?

The Prius pays off...

Visitors to CeMAT 2008 saw the European premiere of the Toyota Hybrid Concept Forklift – a truck using technology inspired by the Toyota Prius. As businesses look to reduce fuel costs and CO2 emissions, Toyota Hybrid technology offers a practical, proven solution by capitalising on the advantages of existing fuel sources and infrastructure. The Toyota Hybrid Concept Forklift is designed to cut CO2 emissions and fuel consumption considerably while delivering the same overall performance as internal combustion models.

Developed in Japan by Toyota Industries Corporation (TICO), the Toyota Hybrid Concept Forklift draws on the pioneering Toyota Hybrid Technology. As part of the Toyota Group, TICO works closely with Toyota Motor Corporation in the development of new technologies.

Previously displayed only in Japan, the Toyota Hybrid Concept Forklift combines the best of electric and internal combustion technology, taking advantage of the strengths of each power source. The concept forklift combines an IC engine, electric generator and battery in a design that allows the engine to operate with optimum fuel consumption efficiency. The forklift shifts automatically between battery and engine modes, simultaneously recharging the battery during operation.

Figure 7. The drive concept ‘fuel cell plus supercapacitor plus battery’ is readily available for forklifts – and the drive systems fit into the battery case.