# Hydraulic technology to benefit the transport sector

## Australian inventions improve transport sustainability

Glenn Johnson

*The Australian transport sector currently contributes 15% of Australia's greenhouse gas emissions, with road freight accounting for one-third of this figure. Rigid and articulated trucks alone account for some 20% of the total fuel consumption of all vehicles on our roads, with average fuel consumption rates exceeding 25 L/100 km for rigid trucks and 50 L/100 km for articulated trucks. Two new hydraulic technologies invented in Australia, if employed, are set to help lower these statistics.*

Two major sources of energy wastage in trucks are the energy wasted in braking and slowing a heavy vehicle, and in hydraulic steering systems that are utilised inefficiently. Two Australian companies have developed new hydraulic technologies to reduce wasted energy in trucks.

Permo-Drive Technologies, a research and development company based in Ballina, NSW, since 2000, has developed an intelligent hybrid hydraulic regenerative drive system (RDS) that captures and stores braking energy for re-use in helping to accelerate the vehicle.

Last year, Norm Mathers, of Mathers Hydraulics in Brisbane, received the Queensland Engineering Excellence Award for Sustainability for a Fuel Saving Vane (FSV) pump that has particular application in truck power steering systems.

### The regenerative drive system

The RDS works by storing braking energy from the drive train in an accumulator by compressing a gas. When the driver depresses the accelerator, the pressure is released back to the vehicle's drive train, providing power to help accelerate the vehicle.

The RDS is composed of a hydraulic pump connected to the driveline, accumulators, reservoir, sensors, hydraulic control manifold and a programmed software controller.

#### *How it works*

The braking energy is stored by using the hydraulic pump to move hydraulic oil under pressure to compress nitrogen gas in the accumulator (see Figure 1). Since the energy to compress the gas comes from the vehicle, this will help slow the vehicle, reducing the use of the brakes. The process is initiated simply by the driver releasing the accelerator pedal.

When acceleration is initiated, by the driver pressing the accelerator pedal, the energy stored in the accumulator is released, allowing the pressurised nitrogen to move the accumulated oil back through the pump, which acts as a motor to provide power to the drive train (see Figure 2).

An intelligent control system manages the storage and delivery of the energy, adapting to the operator demand and the driving conditions.

#### *Benefits*

The parallel hydraulic regenerative system provides a number of key benefits, including:

- A fuel economy improvement of between 20% and 30% for urban usage;
- Reduced carbon emissions in proportion to the fuel saved;
- Continued vehicle operation should an

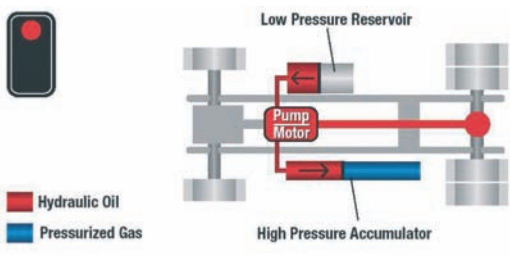



**Figure 1**: *Storing braking energy.*

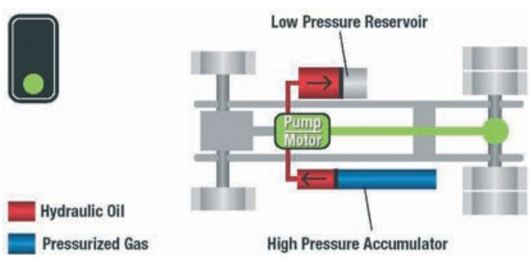
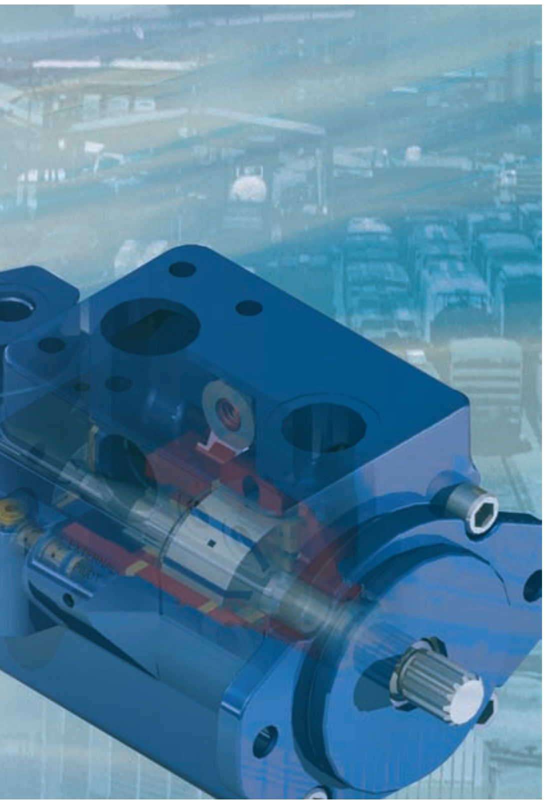



**Figure 2**: *Releasing energy during acceleration.*



RDS failure occur;
- Easy to fit and easy to maintain; and
- No change in the way the vehicle is driven

The energy, emissions and cost savings can be significant. Based on 100,000 km travelled, ignoring carbon tax offsets and with a fuel price of $1.50 per litre, Table 1 shows the estimated yearly savings for three different sizes of truck.

### *Comparison with electric hybrid technology*

Electric hybrid systems are already well known in the passenger vehicle market, with the availability of cars such as the Toyota Prius. While these systems have improved the fuel consumption and emissions of these vehicles, the technology itself has

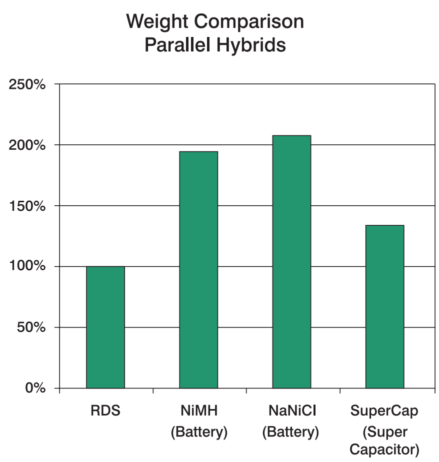



*Figure 3.*

| Truck | Fuel saving | $CO_2$ saving | Cost saving |
|---|---|---|---|
| Class 3, 5,450 kg | 3305 litres | 9 tonnes | $4958 |
| Class 6, 10,200 kg | 5205 litres | 14 tonnes | $7808 |
| Class 8, 17,000 kg | 7925 litres | 21 tonnes | $11,888 |

***Table 1:*** *RDS fuel and emission savings.*

certain drawbacks when compared with a hydraulic hybrid system for commercial vehicles greater than 6.5 t.
- Energy storage density — the weight of battery storage for a given energy capacity is considerably larger than for hydraulic systems. For the same type of vehicle, an electric hybrid using NaNiCl batteries would weigh double that of the hydraulic system (see Figure 3). This is why electric hybrid technology is not available for heavy trucks.
- Braking energy transients — hydraulic accumulators can cope with the type of energy created quickly by braking, while battery systems must be larger and heavier to absorb the energy flow, creating redundant storage capacity.
- High-voltage systems — 650 V components don't exist in hydraulic systems and so don't present a safety hazard.
- Purpose-built versus retrofit — hybrid electric vehicles are purpose built as a complete vehicle, while hydraulic RDS systems can be retrofitted cost effectively to an existing vehicle.
- Maintenance — hydraulic RDS can be maintained with normal automotive mechanical skills.

The superior power-to-weight ratio of the parallel regenerative hydraulic drive system means that the heavier the vehicle the greater the advantage becomes. Heavy vehicles need higher power to move their loads and to stop, which requires high-power hybrid system motors, controllers and storage systems that battery-based systems cannot provide.

## The fuel saving vane pump

The FSV is an innovative hydraulic pump design in which the vanes can be captured to suspend the pumping of the oil. This technology was developed to reduce energy wastage when the vehicle is being driven at highway speeds or travelling between jobs.

### *The problem*

In a power steering system, maximum pump displacement is only required when the maximum steering load occurs. This occurs at low engine speed, in city driving and when short turning circles are being negotiated. In highway driving, which in many cases can be as high as 80% of the use of the vehicle, the load is much lower — there are no tight turns to negotiate — but the vehicle speed is higher. So the pump, driven by the engine, is pumping at a higher flow rate.

This excess pump flow is diverted over the system flow control valve and results in considerable wasted energy through excessive pumping of fluid that is not required. At 1500 to 1700 rpm, this wasted energy can exceed 4 kW and is wasting fuel, causing more engine wear and creating excess greenhouse gas emissions.

The FSV has been designed to capture the vanes under certain conditions, so that the pump ceases to displace any oil.

### *How it works*

The FSV is effectively a vane pump with the added feature of being able to be switched on and off. The off state is achieved by restraining the vanes to prevent the formation of a pumping chamber, as shown in Figure 4.

The FSV utilises a hydraulic pilot that locks the vanes inside the rotor using a small ball detent system (see Figure 5). The pilot is

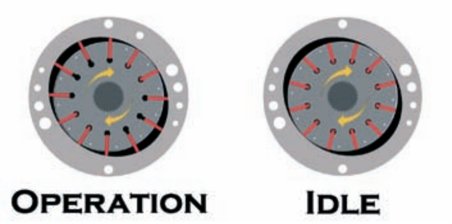



***Figure 4:** FSV method of operation.*

electrically actuated. In this way, the vanes can be locked in the retracted position by a signal from an engine speed sensor.

The pump design can accommodate stacked, double and triple pumps, internally piloted or externally piloted. When the vanes are retracted, the FSV pump has the ability to run at higher than maximum engine speed using minimal energy and enabling the FSV to be 'live drive' mounted. This saves component and labour costs, as the conventional PTO box drive is no longer required. Further greenhouse gas savings are realised as savings on the manufacture of the PTO box drive.

In a truck power steering application, a double vane pump would be used, with one standard rotor and one retractable rotor. Both rotors are used when maximum displacement is required at low speed, and by switching off one rotor, only the standard rotor would be used to maintain power steering pressure at highway speeds.

Mathers Hydraulics has estimated that its FSV pump in normal use on a 6- to 7-class truck over a five-year life would provide a reduction in greenhouse gas emissions of approximately 38 t and a saving in fuel costs of around $18,750, based on a fuel cost of $1.50 per litre. Further savings can be achieved by switching off the pump manually when the extra load is not present. In addition, the FSV rotor design can also be used as an energy saver in other pump applications, such as tip truck mechanisms and forklifts.

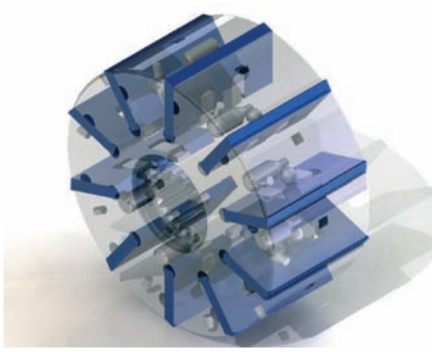


***Figure 5:** Transparent rotor showing vane restraint.*

## Conclusion

The hydraulic regenerative hybrid drive solution and the FSV pump are examples of innovative design that if widely used in trucks will help make a considerable impact on our greenhouse gas emissions. There is also no reason why manufacturers of new commercial vehicles, as well as owners of existing vehicles, could not use both technologies simultaneously to reduce fuel consumption and emissions even further.