Mathers Hydraulics Technologies

Sliding Vane Technology

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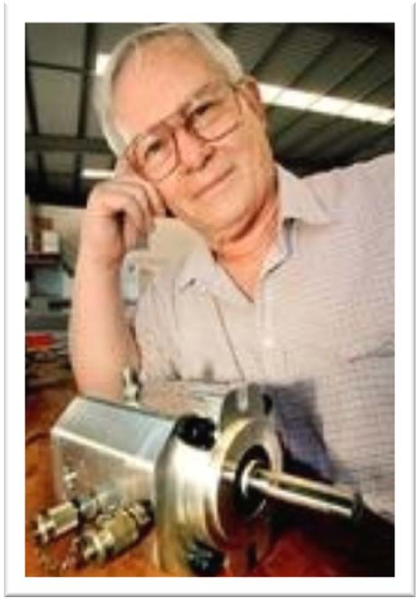
- Fuel Saving Vane Pump
- Fluid Coupling
- HMT and the Torque Amplifier
- Hydro-Mechanical Transmission
- Hydraulic Power Regeneration
- Testimonials

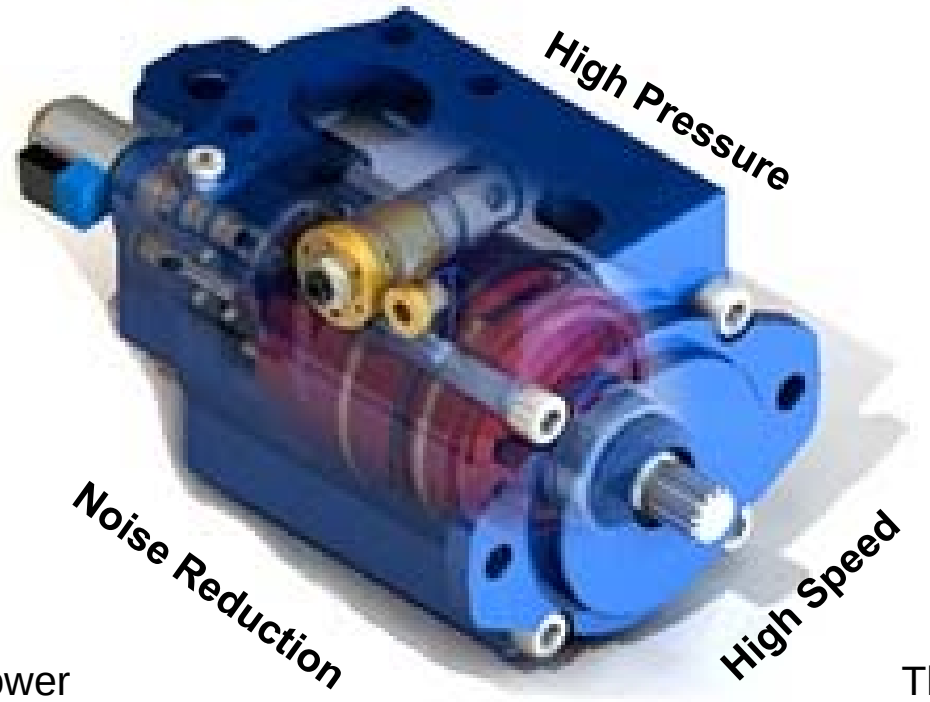
Overview

- The Fuel Saving Vane Pump (FSV), was developed by the Australian engineer Norm Mathers, and in 2007 was awarded the Queensland Engineering Award for Sustainability.
- The FSV incorporates the Mathers Sliding Vane Technology.
- Mathers Hydraulics have also developed this technology for other applications:
  - Fluid Coupling
  - HMT/Torque Amplifier
  - Hydro-Mechanical Transmission
  - Hydraulic Power Regeneration

Fuel Saving Vane Pump

The Heavy Duty Fuel Saving Vane Pump (FSV) is a hydraulic pump that can be switched on and off with an electrical signal or hydraulics pilot.





In applications like power steering it will save thousands of dollars in annual fuel bills and reduce greenhouse emissions.

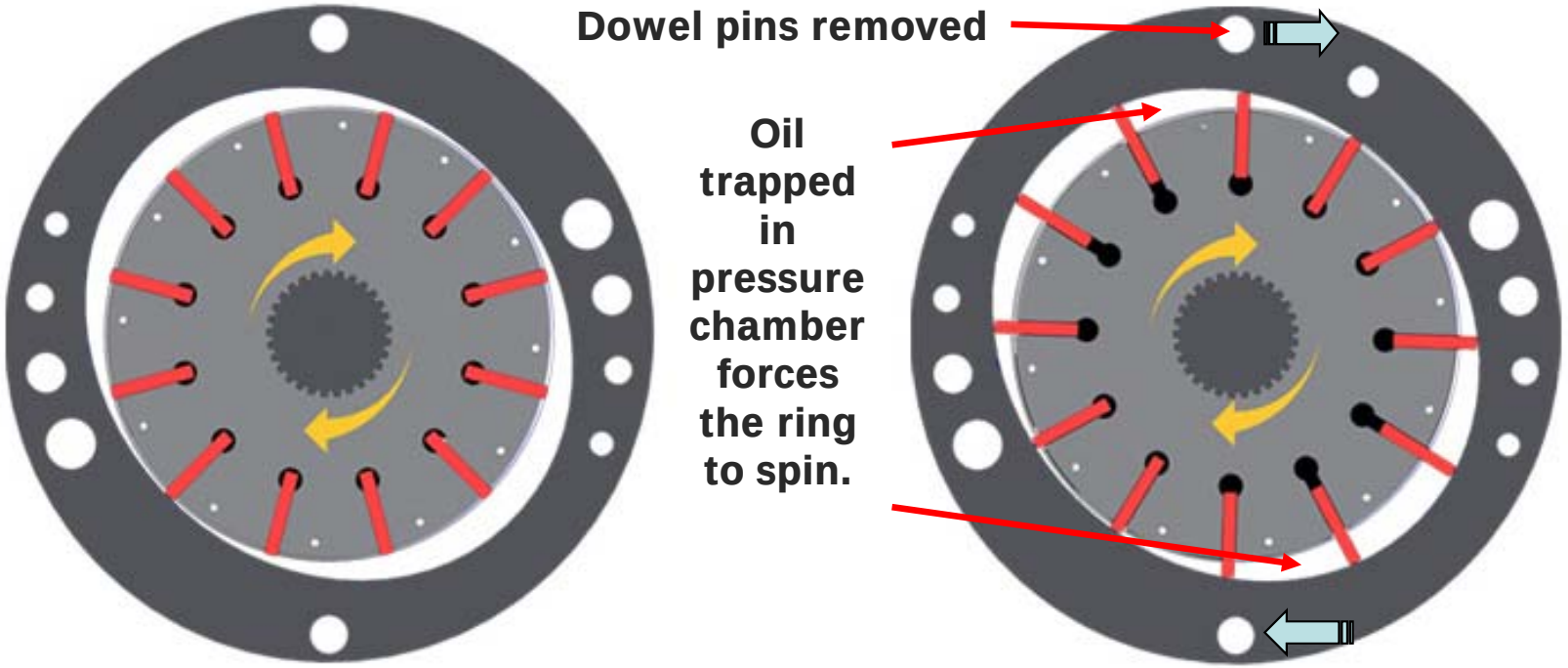
The high speed capacity enables the FSV to be direct “Line Drive” mounted, replacing existing wear prone power take off drives.

A measurable carbon reduction foot print for many industry applications.

MATHERS HYDRAULICS

Fluid Coupling

Principal of Operation



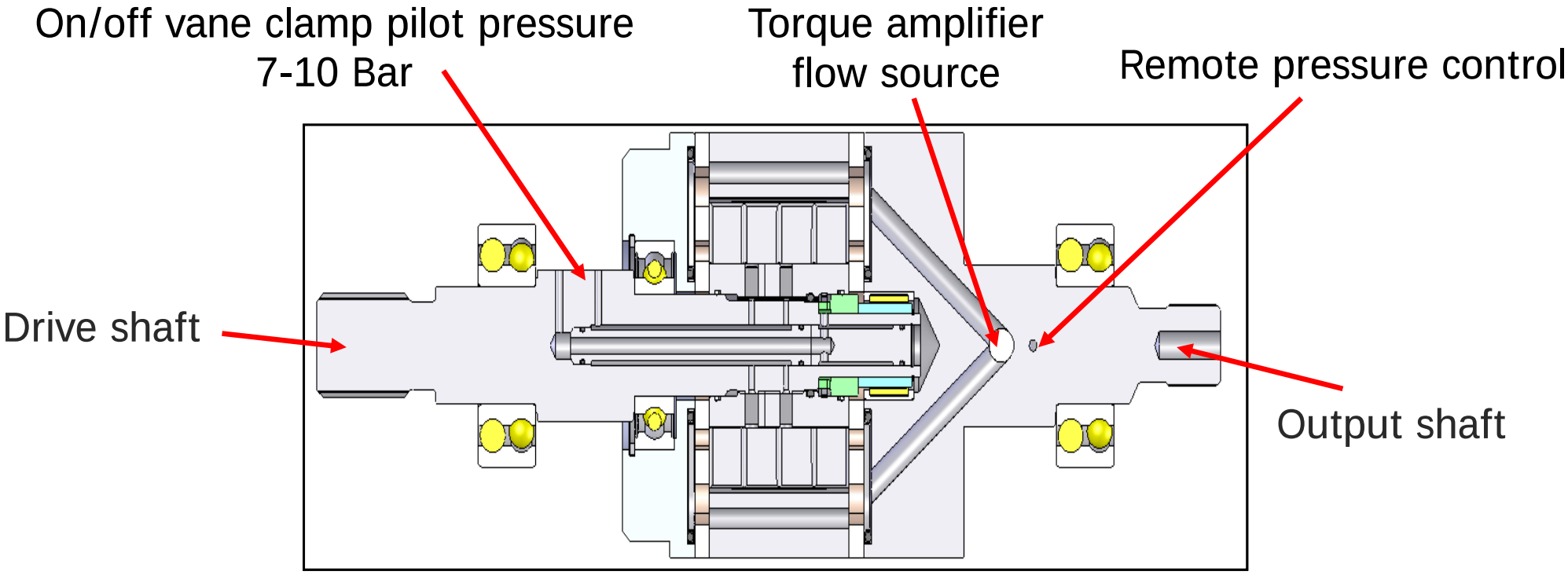
Vanes clamped. Freewheeling.

Vanes released and pressure outlet blocked causes the ring to rotate.

The principal of operation of the Mathers fluid coupling is quite simple, however our minds keep thinking of a vane pump where the ring is held stationary while the rotor and vane rotate creating pumping chambers. If the outlet was to be blocked, the energy can not go anywhere and a catastrophic failure occurs. If the ring is connected to an output shaft and allowed to spin, the ring and rotor compress the oil against the ring contour and imparts rotary force on the ring.

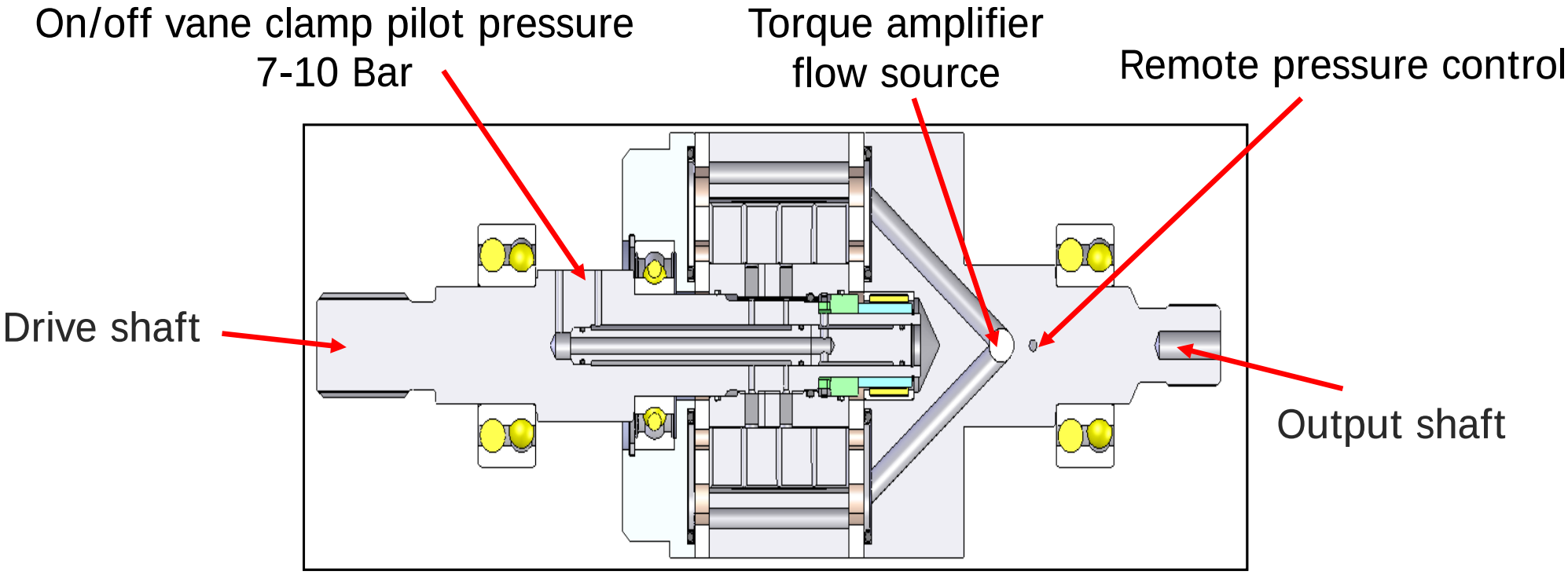
Torque = **Pressure** X **Displacement** , so by controlling pressure we can control output torque.

Hydro-Mechanical Transmission(HMT) and Torque Amplifier



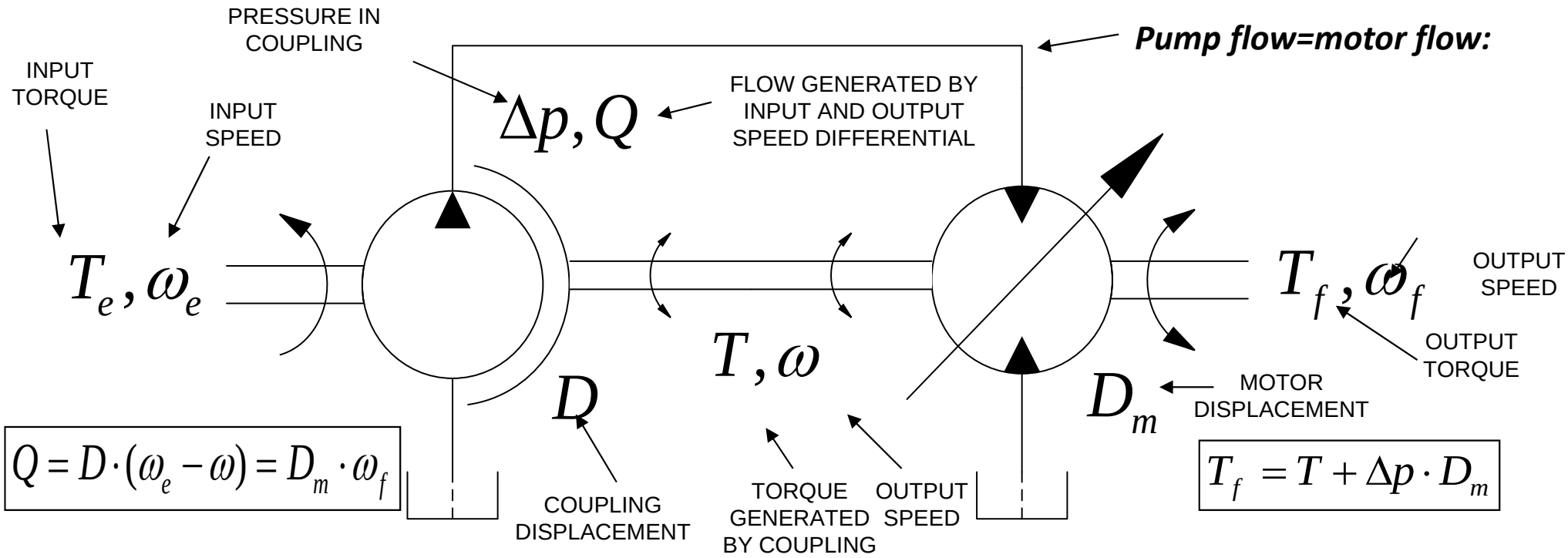
- This cut away shows the coupling half of a Torque Amplifier. The operation is the same as the Fluid Coupling, except there is a flow path from the pressure chambers in the ring, rotor and vane set.
- When vanes are clamped no torque is applied to the ring offering a neutral position.

Hydro-Mechanical Transmission(HMT) and Torque Amplifier



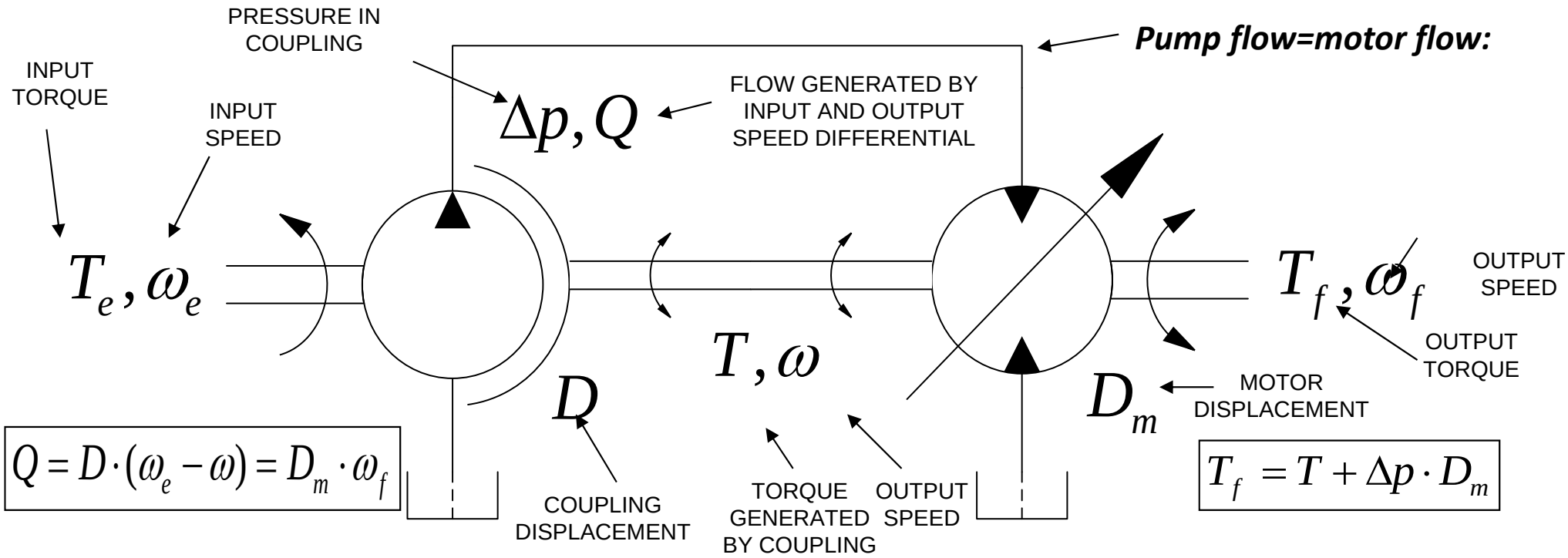
- When the vanes are released pumping chambers are form and create pressure on the ring contour, this pressure can be remotely ramped up for smooth torque application.
- The ring will try to spin the output shaft and dependent on output torque requirement, the shaft will start to spin or pressure will climb and activate the variable motor to amplify the torque to what is required.

Hydro-Mechanical Transmission(HMT) and Torque Amplifier



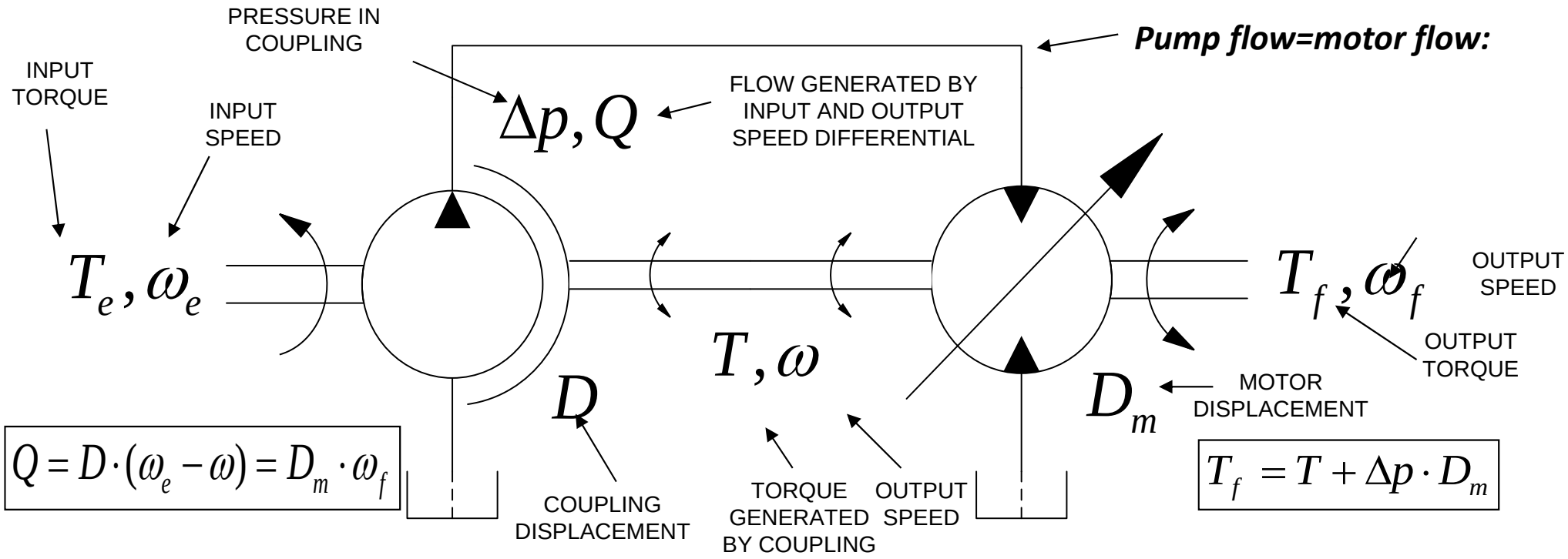
- Theory of operation of the HMT drive carries on from the Fluid Coupling concept.
- The concept uses the same principal of compressed oil rotation the ring via the ring contour, however if the output torque requirement is greater than the pressure set torque available in the coupling the ring will not rotate.
- The rotor and vanes then operate as a standard vane pump.
- This pressurized flow can be channeled to a variable motor on the same output shaft.
- The output torque is then the sum of the pressure acting on the ring contour and the pressure drop over the displacement of the variable motor.

Hydro-Mechanical Transmission(HMT) and Torque Amplifier



- This increases torque and reduces output speed.
- As output torque requirement is met and the output shaft starts to spin and the differential speed between the input and output shafts becomes less offering lower flow to the variable motor.
- The displacement of the motor is decreased maintaining a preset pressure in the coupling, Torque is decreasing and speed increasing as the load is accelerated. When the torque requirement is met by the coupling alone the variable motor is at zero.

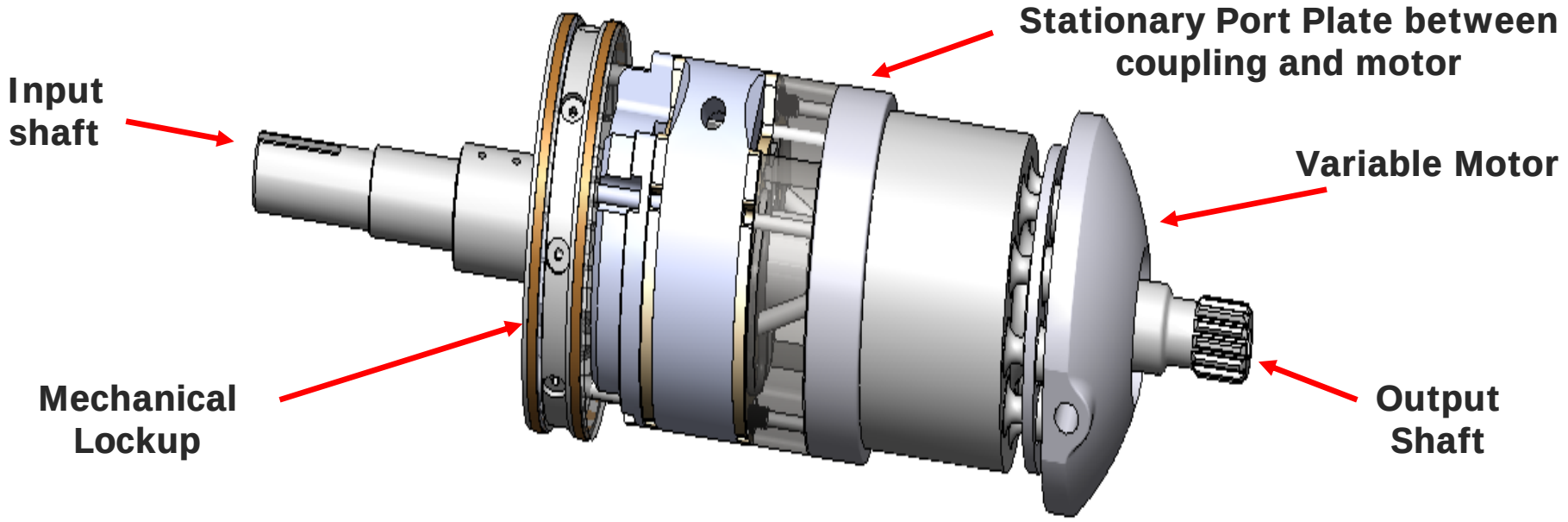
Hydro-Mechanical Transmission(HMT) and Torque Amplifier



- When the shafts are at similar speeds, they can be mechanically locked up for a pure mechanical drive.
- This variable motor can also be used for speed control by metering of oil from the coupling pressure chambers.
- Remember that the vanes can be clamped in the coupling giving a non-burn out clutch.

Hydro-Mechanical Transmission(HMT) and Torque Amplifier

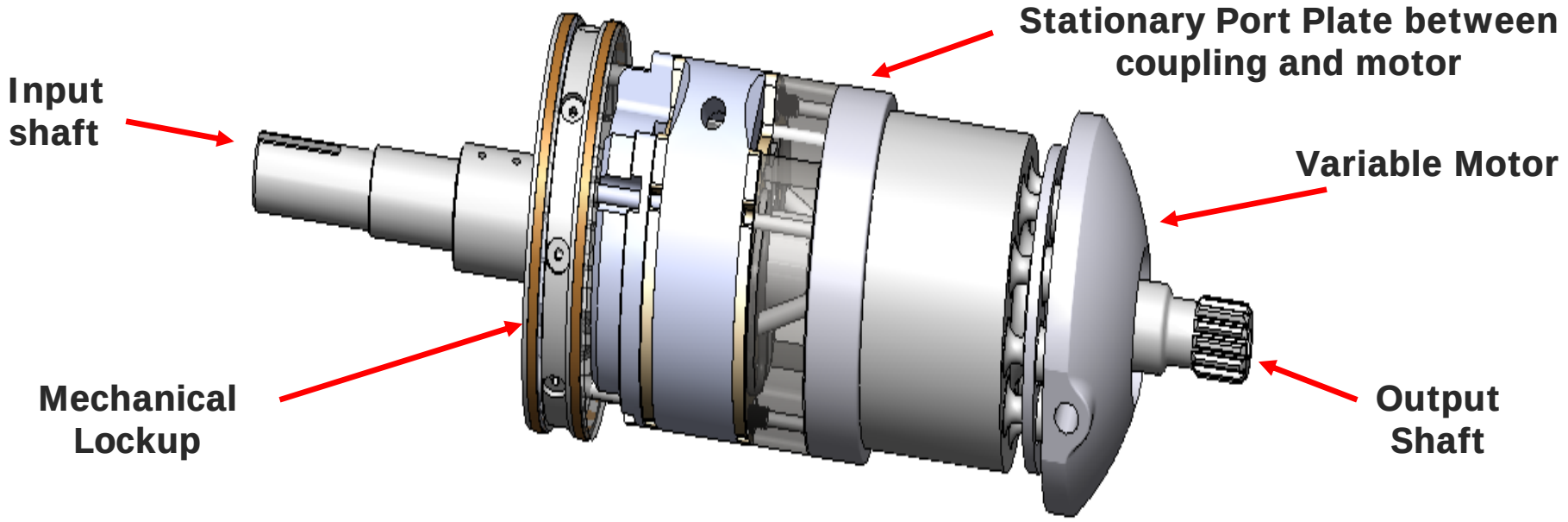
Zero Stroke – No Oil Flow



- The amplifier assembly shown has a Fluid Coupling, Variable Motor and a Lock Up mechanism in a single package.
- The motor is shown at zero stroke which will not allow any oil flow through the motor.
- The Lock Up mechanism is activated when the input and output shafts are virtually the same speed to offer a pure mechanical drive.

Hydro-Mechanical Transmission(HMT) and Torque Amplifier

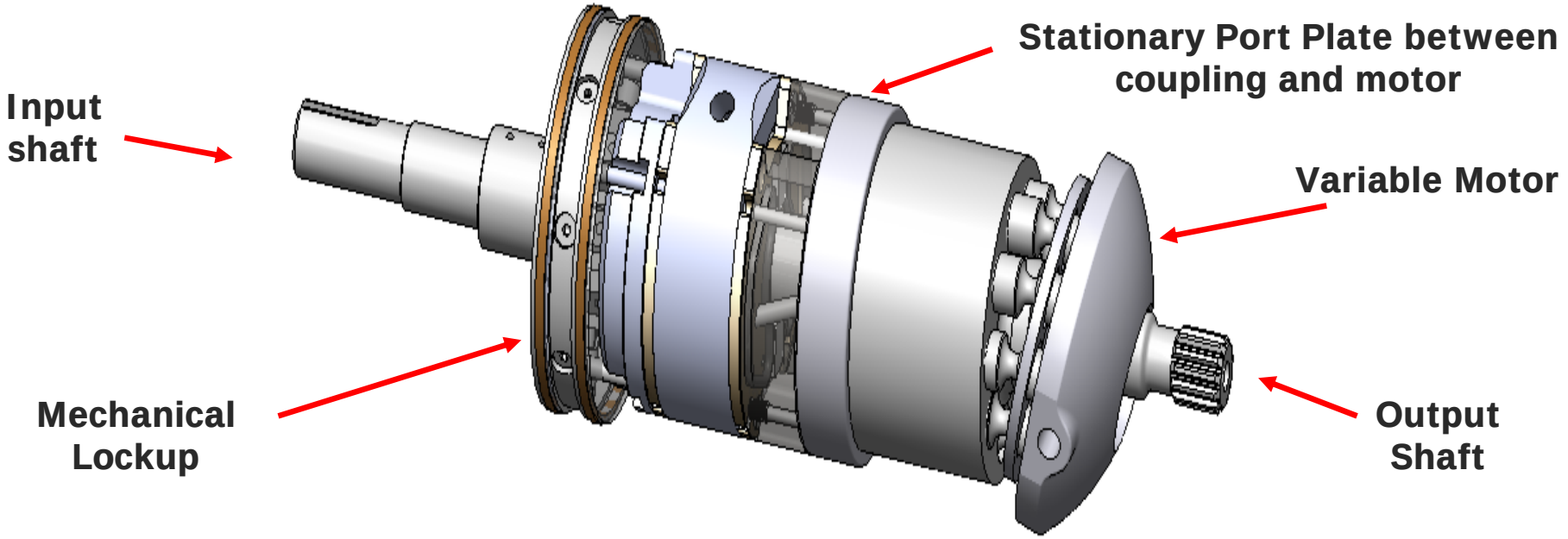
Zero Stroke – No Oil Flow



- To get the shafts to identical speeds the motor displacement angle can go to negative angle which pumps enough oil into the coupling pressure chambers to replace any internal leakage and a 1 : 1 speed ratio is achieved.
- Many applications will not require lock up and improvements in volumetric efficiency of the coupling may mean it is not required at all.

Hydro-Mechanical Transmission(HMT) and Torque Amplifier

Motor at full displacement offering maximum torque and minimum speed

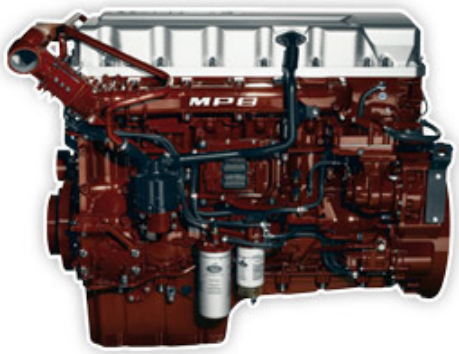


- With the swash angle at full stroke the full displacement of the motor and coupling impart torque on the output shaft, the variable motor can be designed to work as a pump as well.
- This allows it to become a hydraulic regeneration pump/motor (mump) when integrated in a transmission.
- This offers a very high versatility and power density, offering power regeneration at any road speed.

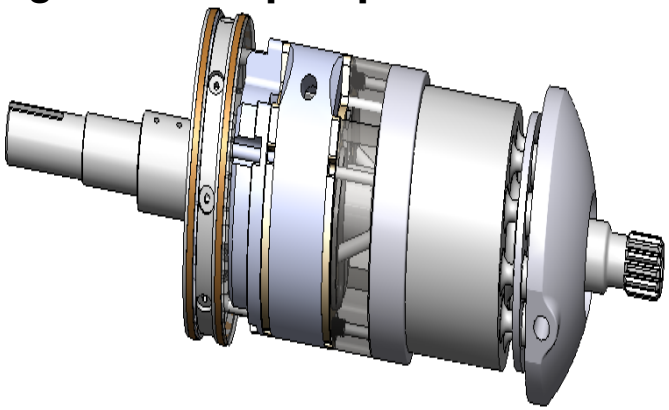
Hydro-Mechanical Transmission(HMT) and Torque Amplifier

Truck and Car Transmission Drives

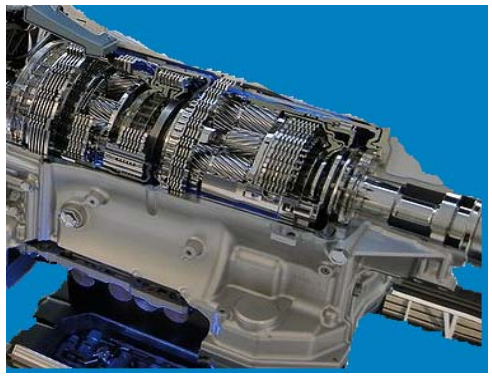
Engine Rpm and power draw is relatively constant improving fuel efficiency



HMT drive system, Clutch, torque amplifier, speed control and regeneration pump / motor in one unit.



Transmission with reduced gears

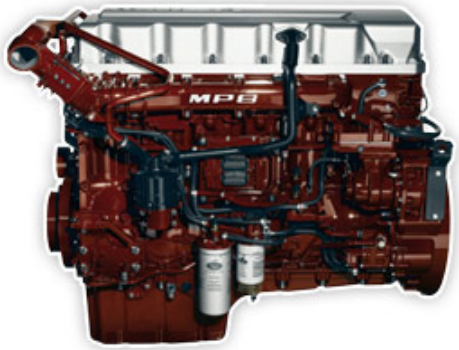


- The opportunity for this technology in vehicle transmissions is enormous.
- If the HMT and variable motor are sized to be the same displacement, we have variable torque ratios of 1:2 through 1:1 and variable speed for 2:1 through 1:1 and mechanical lock up for cruising speeds.
- This means the number of gears can be reduced by half. Using a class 8 truck as an example, common manual transmissions had 15 to 18 gears, the new Automated manual/mechanical transmission (AMT) have 10 to 12 gears as gear changes are accomplished in around 300 milliseconds, far faster than a driver can, which reduces the loss of momentum during gear shifts.

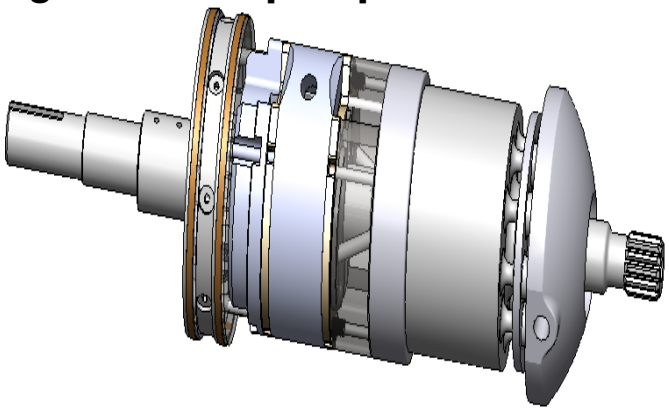
Hydro-Mechanical Transmission(HMT) and Torque Amplifier

Truck and Car Transmission Drives

Engine Rpm and power draw is relatively constant improving fuel efficiency



HMT drive system, Clutch, torque amplifier, speed control and regeneration pump / motor in one unit.



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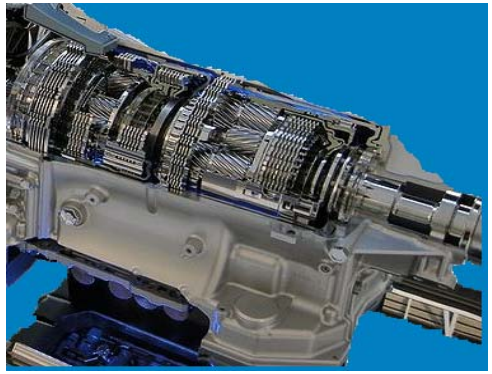
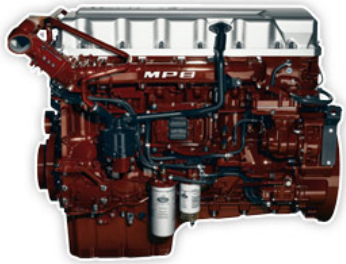
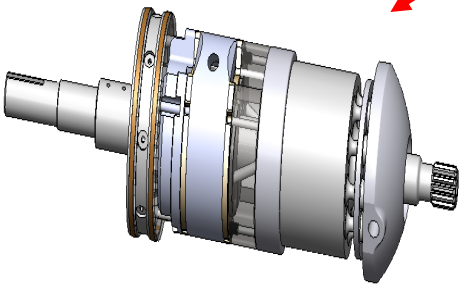


- Using our HMT we can cut the amount of gears down to 5 or 6 and have variable torque and speed between all gears. Engine manufacturers are desperately try to find a way of drawing relatively constant torque/power from the engines where possible because their engine management systems take around 16 to 20 seconds to find the correct settings.
- But by this time the conditions can have changed and it is recalculating. Using electronic control systems similar to the one used in AMT boxes we can select gearing and torque requirements to suit the most efficient engine speed and torque requirement. This would create a very significant fuel saving and greatly reduced emissions.
- The concept remains the same for all vehicle types from small cars to heavy mining equipment.
- The HMT can be incorporated in either the engine or gearbox.

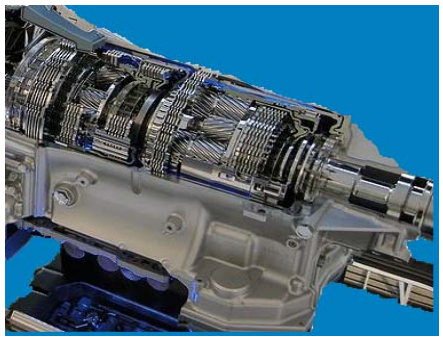
Hydraulic Power Regeneration

Pump/Motor used for braking and acceleration when not being used for torque amplification



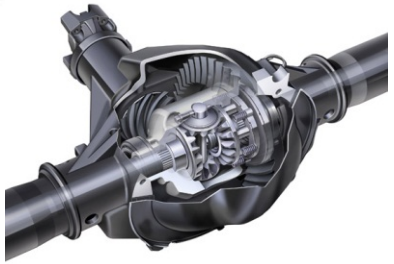


High power braking and acceleration.
Instantaneous response.
Very high power density.



Automated manual gear box keeps Pump/Motor at optimum speed

Accumulator

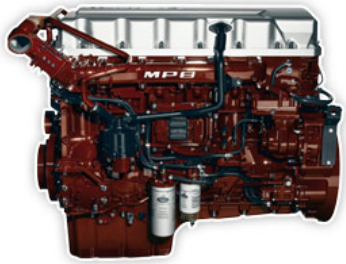


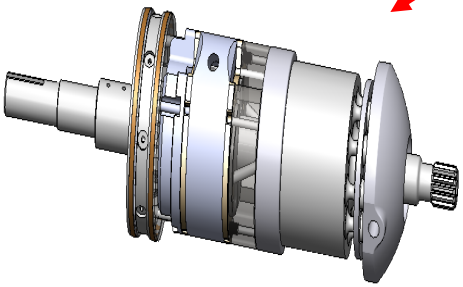
Energy transferred to and from the wheels via differentials

- Making a gearbox incorporation HMT technology opens up significant advantages as the box can be designed to offer a non – burnout clutch, variable gear rations, hydraulic regeneration at any road speed, auxiliary drives for compressors, alternators etc.
- This gearbox will rival any manual, automated manual and fully automatic gearbox.
- The system will allow engine speeds to remain relatively constant, which allows the engine management system the best chance of offering fuel efficiency.
- Hydraulic power regeneration through the transmission will offer higher efficiency than most systems because we can operate the pump/motor at speeds better suited to high performance operation.

Hydraulic Power Regeneration

Pump/Motor used for braking and acceleration when not being used for torque amplification





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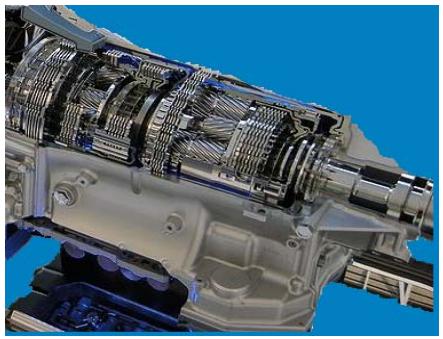

Automated manual gear box keeps Pump/Motor at optimum speed

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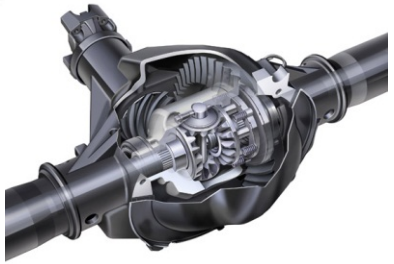
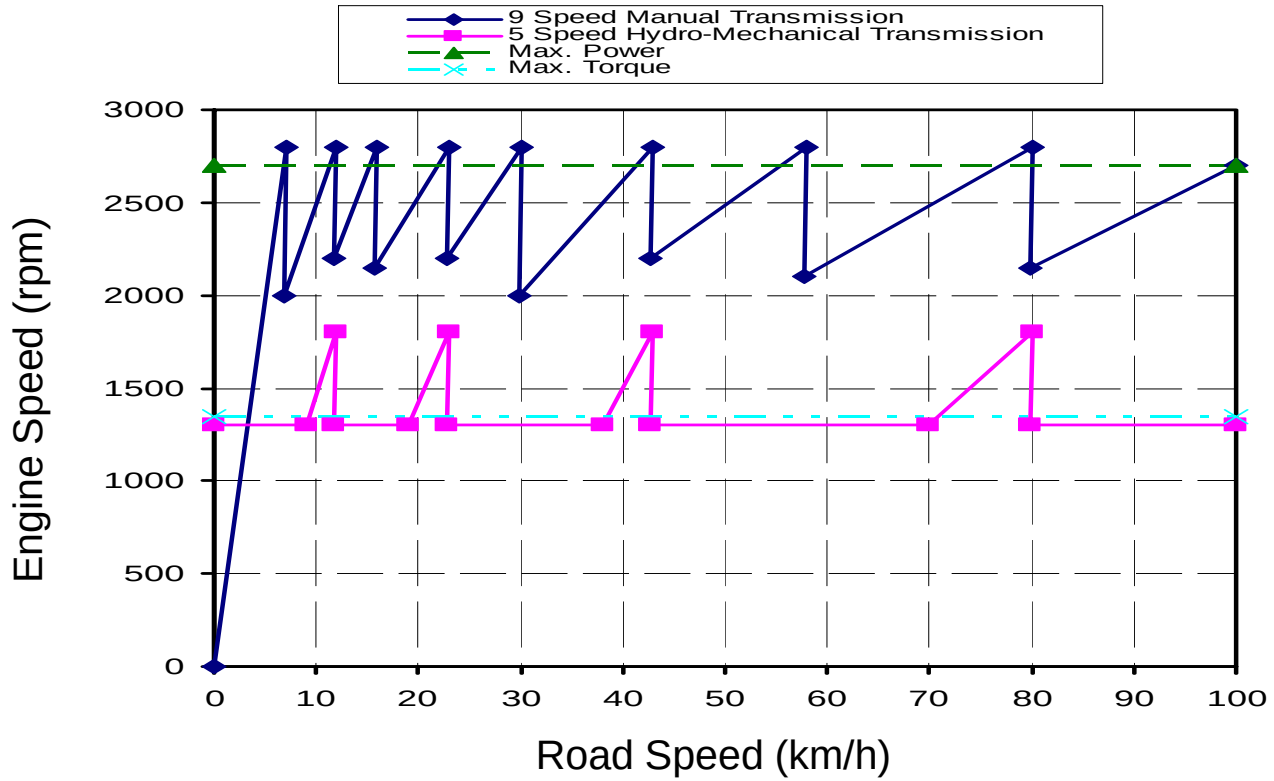


Energy transferred to and from the wheels via differentials

- Some tail shaft regeneration systems have no gear ratios and can not be hot shifted, limiting them to relatively low speeds.
- Potentially an automated HMT with hydraulic regeneration would be a fraction of the cost of existing systems. Bus and coach fleets are substantial and hydraulic regeneration is being developed by many companies, but none can offer the functionality, value for money and power density this system offers. The energy should be re-used at the highest fuel demand points which is the moments of inertia and high acceleration.

Hydraulic Power Regeneration

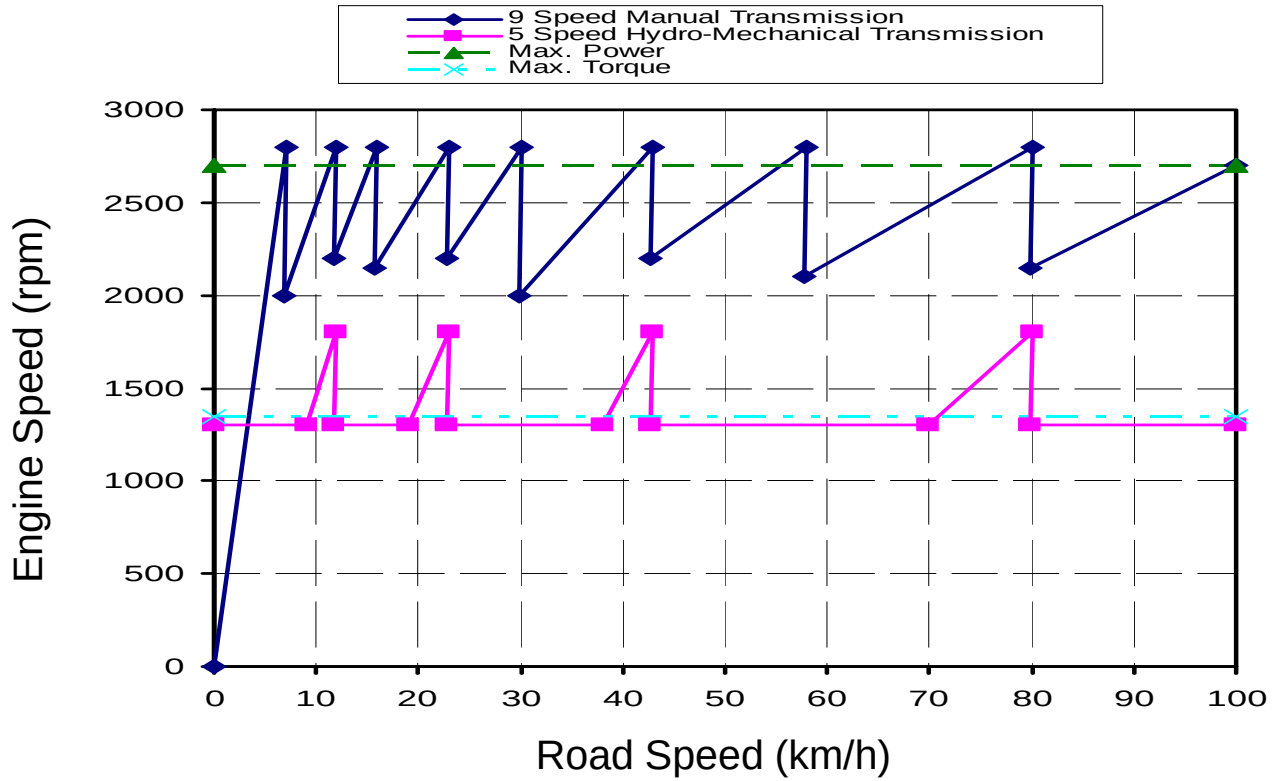
Theoretical Gear Change Comparison



- The above is a theoretical gear change chart comparing a standard 9 speed manual transmission and a 5 speed Automated Mechanical Transmission using the Mathers' Torque Amplifier.
- Maximum torque is where the maximum fuel efficiency is and by maintaining high torque with minimum engine speed, over all efficiency is increased.

Hydraulic Power Regeneration

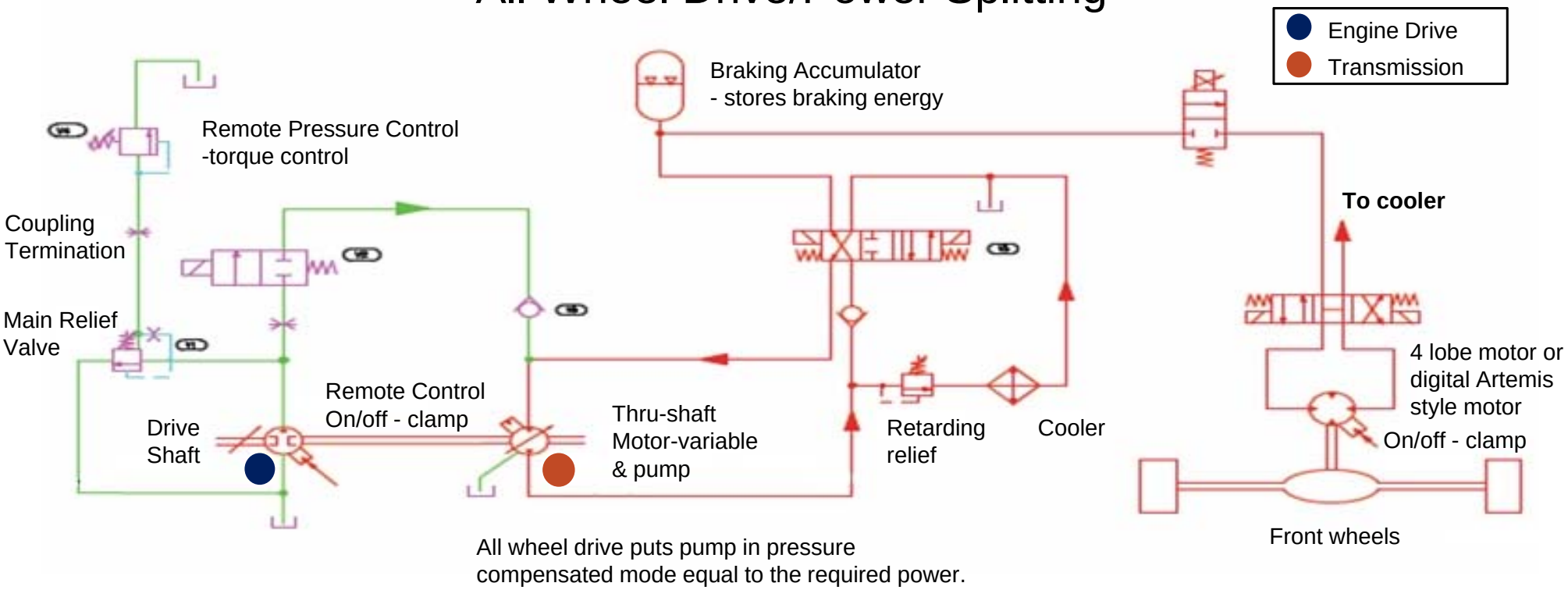
Theoretical Gear Change Comparison



- Maximum power is not the most efficient use of fuel as torque is reducing and excess fuel is used to increase engine speed and hence total power.
- The greater the diesel engine speed the shorter time the fuel has to “burn” in compression. Diesel is a relatively slow burning fuel and if it does not have sufficient time to burn, high emissions and poor efficiency occur.

Hydraulic Power Regeneration

All Wheel Drive/Power Splitting



- The HMT can power split and send power to other sources such as front wheels for improved traction.
- The HMT coupling section can also be designed to supply fluid power to other sources such as the front wheels of buses and heavy vehicles. By supplying some tractive effort to the steer wheels, when required in snow, ice mud ETC, increases mobility and safety. This option will be attractive to municipal transport and defense equipment.

Testimonials

"…*The Mathers pump, a vane pump with retractable vanes, is an important new development that has many practical applications. Many functions on mobile hydraulic equipment are only used intermittently. When not in use, the pumps on such circuits waste a considerable amount of energy. Examples of such functions include the dump circuit for trucks and hydraulic fan drives. There are many others. The retractable feature of the Mathers vane pump can greatly lower the energy use in such circuits.*

The Mathers pump can also be used to make a power-split transmission, also known as a hydro-mechanical transmission. Such transmissions have the potential of being more efficient than hydrostatic transmissions, but retain the continuously variable effective gear ratio feature. The reason for the increased efficiency is that some of the power is transmitted mechanically rather than solely hydraulically…"

Kim A. Stelson
Professor and Director
NSF Engineering Research Center for Compact
and Efficient Fluid Power

Testimonials

"…I am writing to endorse support for continuing research of an exciting new technology offered by Mathers Hydraulics, an Australian R&D firm. The technology leverages the field proven concept of hydrostatic fluid power with a parallel mechanical drive path to create a continuously variable hydro-mechanical transmission(HMT) that promises to be not only compact in size, but efficient and cost effective. The net result is an extremely adaptable transmission which is easily integrated with an electronically controlled engine to create an intelligent powertrain solution that has potential to provide substantial fuel savings. In addition, it is relatively straight forward to include a fluid power energy storage device, called an accumulator, to create a hybrid powertrain resulting in further fuel savings.…"

Michael J.Gust
Director of Industry relations Centre for
Compact and Efficient Fluid Power
University of Minnesota

Mathers Hydraulics Technologies

Further information is available on our website:

www.mathershydraulics.com.au