

# A Proposed Hybrid Electric Power Train for Trucks

Demand for lower fuel consumption and reduced exhaust emissions in the transportation industry mandates storage and re-use of vehicle retarding energy. Since electrical energy storage currently offers maximum storage density, we envisage that future vehicles will be driven electrically. In line with the current trend in passenger cars, with increasing sales numbers of Hybrid Electric Vehicles (HEV), the heavy vehicle industry is likely to follow suit.

Energy regenerating concepts are available for heavy vehicles such as the Hybrid Electric Bus drives used in some metropolitan applications and the hydro-pneumatic regenerating technique developed by Permo-Drive and Eaton. However, they are add ons to existing power trains, increasing bulk and cost, with limited regeneration capabilities.

Pempek Systems Pty. Ltd. is actively pursuing the development of HEV power trains for cars and is developing a novel free piston engine-generator module, dubbed FP3. The patented FP3 concept has been recognised by some research and development companies as a promising technology for use in HEVs [2, 3]. We are confident that the FP3 will out-perform alternative concepts such as other free piston engines and fuel cells in fuel efficiency, power density and cost.

Encouraged by favourable critique of our work on HEV power trains for cars, we explored the application of our technology to heavy trucks and buses. We have developed a regenerative power train concept with enhanced performance in terms of efficiency, power density and environmental acceptability, when compared to other technologies. The main components of our proposed system are the FP3, an IGBT inverter, an Electric Differential Drive Axle and Li-Ion Battery Modules.

## **The Generator:**

Fig. 1 depicts the proposed FP3 generator for on-road truck applications. At 450 kW (600 hp) maximum output it will equal output power of conventional truck diesel engines. In order to achieve maximum power density, the FP3 mover mass must be minimal, permitting the highest possible operating frequency. Our innovative short flux path generator technology allows a mover mass as low as 10 kg, permitting an operating frequency of 33 Hz or 2000 cycles per minute, similar to conventional truck diesel engines. The FP3 utilises a supercharged two stroke cycle, with an efficient gas exchange process and high mechanical efficiency and can readily develop a power output of 450 kW with only 12 litres displacement.

Electric output of the 12 generator coils is controlled by our compact, water cooled IGBT inverter technology, measuring 200 x 200 x 900 mm (8 x 8 x 36 inches), about one quarter of the volume of the FP3. Overall dimensions of the 450 kW FP3 will be 400 x 400 x 1000 mm (16 x 16 x 40 inches), which is half the size of a conventional diesel engine without an electric generator.

## **The Electric Differential Drive Axle:**

Current hybrid power trains use conventional drive shafts with a mechanical differential to transfer power to the wheels. Although some electric wheel hub drives have been built, they are not suitable to drive a rigid axle with four tires. What is needed is an electrically powered drive axle that still incorporates all the attributes of a conventional prime mover axle; the rigid axle beam, conventional wheels and brakes, the same space provision for suspension components and no wheel hub planetary reduction.

The Pempek Electric Differential Drive Axle (Fig. 2) (patent pending) incorporates all the above mentioned features and provides the same torque and power as a conventional differential drive axle. Critical in fitting the required electric power within a given envelope is the use of an induction motor with a single stator and two independent rotors. If two independent motors were to be used, significantly more axial space would be required to accommodate the additional end windings. This would severely restrict the available space for suspension components.

The two rotors within the same stator can operate at different speeds and provide the differential characteristic needed to prevent tire slip. An additional advantage of this concept is that it behaves as a non slip differential. If a tire loses traction, the torque in that wheel will be reduced due to the increasing rotor speed, relative to the stator field speed, while the other tire will still be able to drive at maximum torque.

A sliding spline parking lock is incorporated at the high speed end of the planetary gear. The sliding spline is spring-on and released by emergency air brake pressure. The spring force of the parking lock is well below the emergency air brake spring force, which ensures that the sliding spline cannot be engaged as long as the driving wheel rotates, and will be disengaged before the parking brake is released.

The Pempek Electric Differential Drive Axle requires only a plug-in power cable and brake hoses to connect with the chassis; it can be mounted in any desirable location on a road train and be readily retro-fitted to an existing truck chassis.

## **Batteries and Regenerative Braking:**

The number of storage batteries used on a truck will in the main be determined by economics, considerations are the grades encountered and stopping frequency on a given truck route. A typical configuration would consist of eight battery banks (Li-Ion 56 cells, 200 Volts) measuring 180 x 180 x 600mm, (7 x 7 x 24 inches) and weighing 25 kg each. Total regenerating power of this battery configuration would be 300 kW and its storage capacity 11 kWh. With this arrangement the impending No Idle Law requirements can readily be met without an APU.

Regenerative braking will be provided by the electric drive motor acting as a generator to charge the batteries. It is not necessarily economical to install sufficient battery storage capacity to provide regenerative braking for a long descent. Therefore, additional means of dynamic braking must be provided for when the batteries become fully charged. A water cooled resistor bank is proposed for that purpose, similar in size to an engine cooling radiator, and using the existing engine cooling system to dissipate the heat energy. As the FP3 is not on when driving downhill, noiseless dynamic braking power dissipation is available with this water cooled resistor bank.

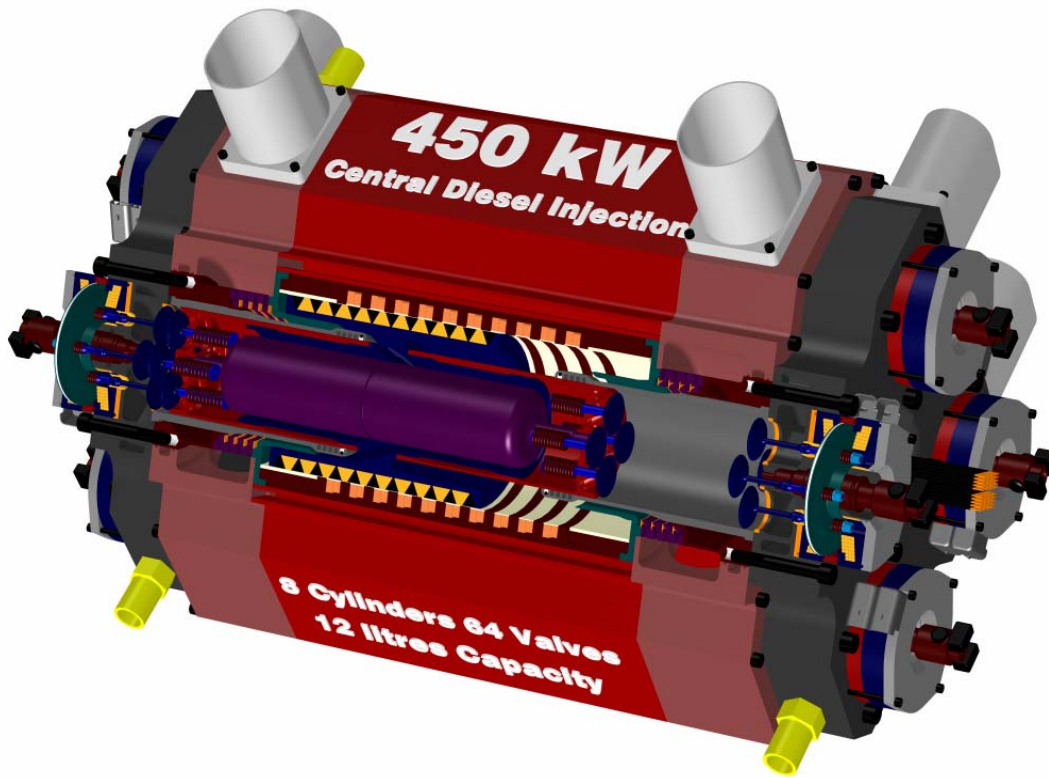


Fig. 1 The FP3 (16 x 16 x 36 inches)

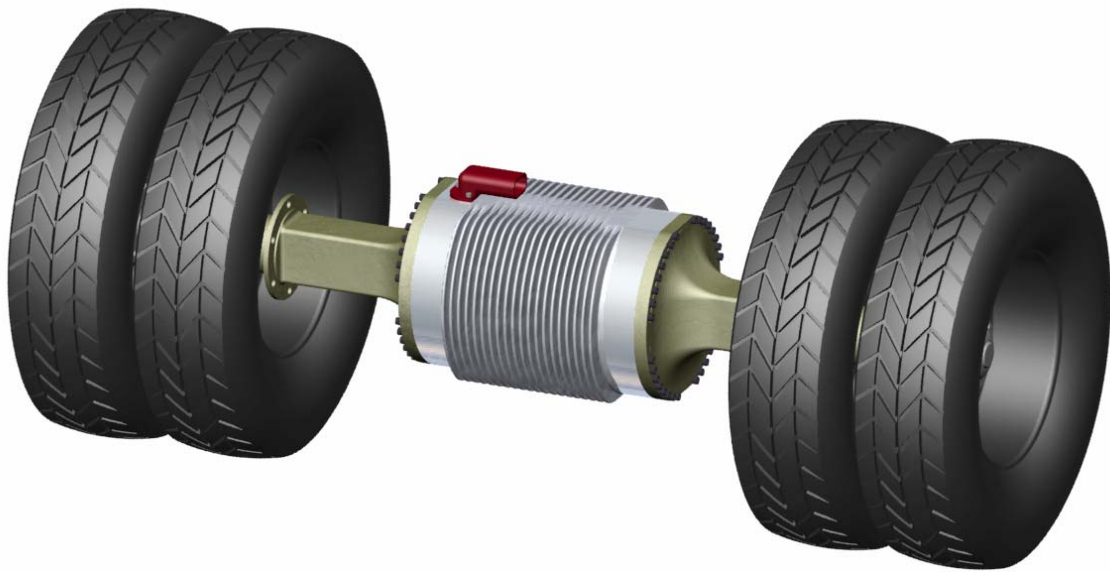


Fig. 2 The Electric Differential Drive Axle

## References:

1. Douglas Carter and Edward Wechner, "The Free Piston Power Pack: Sustainable Power for Hybrid Electric Vehicles", SAE Paper 2003-01-3277, October 2003.
2. Martin Goertz and Lixin Peng, "Free Piston Engine Its Application and Optimization", SAE Paper 2000-01-0996, March 2000.
3. Steven R. W. Cooper, "AVL Assessment of Merits of FP3" June 2003.