Introduction
At present, motors for FEV (Fully Electric Vehicle) and HEV (Hybrid Electric Vehicle) applications develop their highest efficiency of around 93-95% within a speed range of typically 1/4 to 1/3 of the maximum rotating speed, and at an ideal torque, whereas in real usage – in the majority of driving cycles – the motor operates at a wider range of speeds and at partial load (low torque) resulting in lower overall efficiency.

Hi-Wi addresses the mismatch between the region of HIGH efficiency and the WIDE region of frequent operation with advances in the design and manufacture of drivetrains optimized for efficiency and the WIDE region of frequent operation with advances in magnetic materials which utilize wider range of speeds and at partial load (low torque) resulting in reduced Dy consumption by over 75%.

In addition to efficiency gains, Hi-Wi couples its novel design approach to developments in magnetic materials which utilize nano composite micro-structural control to deliver reductions in the consumption of rare earth elements. This is of interest due to the restricted nature of their supply chain and the rapid fluctuations in price which have been associated with the increase in use of these materials.

Developments in magnetic materials
Exchange coupled nanocomposite materials offer the opportunity of either passing the theoretical limit to NdFeB energy product of 465 kJ/m³ or reducing the amount of rare earth elements required while maintaining performance. Developing a process route to allow the production of bulk nano composite magnets is of interest.

The addition of Dy to NdFeB magnets is required to improve their coercivity and allow them to operate at elevated temperatures. Dy is most effective at coercivity enhancement by 25% by addition of the amount of rare earth elements.

The exchange of Dy deposited onto NdFeB sintered magnets causes Dy to diffuse through grain boundaries. Heat treating coated magnets could allow them to operate at elevated temperatures.

Current magnets use Nd2Fe14B which is a material of high energy product of 485 kJ/m³. The cost of Nd2Fe14B is a decreasing factor in the price of electric drives.

Nd2Fe14B magnets, however, have several limitations due to the presence of Dy.

- Dy consumption: Nd2Fe14B magnets are Dy-rich magnets with a high content of Dy.

- Diffusion of Dy: Dy can diffuse through grain boundaries, affecting the magnetic properties of the magnets.

- Heat treatment: Heat treatment at 900 °C for 6 hours followed by 500 °C for 30 minutes.

- Reduction of Dy: Reduction of Dy in Nd2Fe14B magnets is difficult and requires specific heat treatments.

Problem: Current drivetrains are not optimised for real drive cycles

Drive cycle analysis

- NEDC drive cycle
- Energy consumption over NEDC drive cycle
- Optimisation simplified by reducing NEDC cycle to 12 representative points

Optimisation of a three motor drive train over NEDC and Artemis drive cycles

- Drive train configuration: two motors optimised for different speed ranges
- Efficiency map for optimised drivetrain

Outcomes

- Prototype front motor
- Prototype rear motor

Conclusions

The reduction of driving cycles to key representative points in the torque, speed envelope and the development of new optimisation tools has allowed drivetrain design to be optimised over a realistic, usage case and has allowed the effect of a dynamic torque split across motors of differing characteristics to be assessed.

The most suitable topologies have been found to be a stator mounted permanent magnet machine which provides most torque at low speeds and a permanent magnet assisted asynchronous reluctance machine which is more efficient at higher speeds while not requiring NdFeB magnets the use of a dynamic torque split for the front and rear motors have been predicted to offer an improvement in efficiency of 0.95 % over the NEDC cycle.

Two new process routes have been investigated for the production of magnetic material with reduced rare earth content. The most promising route is two new process routes have been investigated for the production of magnetic material with reduced rare earth content. The most promising route is an increase in the use of Nd2Fe14B magnets.

On-going Future Work

- Assessment of HiWi motor designs over driving cycles
- Validation of Optimisation Process
- Production of reduced Dy magnets for HiWi motor

