Digital Displacement project shows potential to reduce emissions in non-passenger rail

With challenging targets to radically reduce railway CO_2 emissions, one project has shown the potential of Digital Displacement® hydraulics as an achievable route to lower emissions for diesel freight locomotives, shunters and on-track plant

The UK rail industry is committed to contributing to the UK Government's goal of reaching net carbon zero by 2050 – however, the route to getting there is not easy. While low carbon electricity offers an obvious solution, the electrification of GB's entire rail network is challenging and other fuel solutions such as green hydrogen are not yet market ready. Today around 60 per cent of the network is not electrified, and with a UK Government mandate to halt diesel-only powered locomotion after 2040, the industry needs to look closely at all approaches.

One recently completed RSSB-funded project has shown how the adoption of Digital Displacement hydraulic pumps can make a significant impact.

The project – Digital Displacement for Non-Passenger Rail – examined the possibilities provided by Digital Displacement technology as a more efficient alternative to conventional hydraulic pumps for providing traction and auxiliary power for freight locomotives, shunters and on-track plant.

The twelve-month programme, funded by the RSSB as part of the Intelligent Power Solutions research competition, brought together the University of Huddersfield, Direct Rail Services and technology leader Artemis Intelligent Power to identify adoptable opportunities for the ground-breaking Digital Displacement technology.

The project was completed in two phases: an initial research period looking at each application area in non-passenger rail, followed by a more in-depth study of three chosen applications. Each of the three applications included a fuel and carbon saving analysis and business case study.

The three areas were:

- Specification of a Digital Displacement hydrostatic cooling system for a large locomotive.
- Investigation of the pump swap opportunities for road-rail and track maintenance vehicles.
- Development of a modular drive system concept for small locomotives and track maintenance vehicles.

Project engineer with Digital Displacement pump

The completed project has delivered positive results:

- Specification of a Digital Displacement pump hydrostatic cooling system for a large locomotive could lead to annual fuel savings corresponding to 2500-5000 litres per vehicle and six to thirteen tonnes of CO_2 emissions depending on duty cycle.
- The pump swap opportunities for road-rail and track maintenance vehicles indicated that fuel savings of 20 percent could lead to 7,200 litres fuel saved per vehicle per year, corresponding to CO_2 savings of around 19 tonnes per year.
- A modular drive system concept already demonstrated as a prototype in a previous project for passenger diesel-powered railcars (DMUs) (see below) could be adapted for use in small locomotive and track maintenance vehicles. This could lead to a fuel and carbon reduction of around 30 per cent dependant on specific vehicle and duty cycle. Further refinement of this estimate could be made with further input from OEMs and operators.

Commenting on the results, Artemis's project lead, Dr Gordon Voller, said: 'At the outset, the project examined four possible application areas for Digital Displacement hydraulics. The first part of the programme helped us understand which areas would most benefit from applications of the technology. We focused on those with greater commercial potential that would most likely motivate the development of specific products.

What is Digital Displacement®?

Digital Displacement is a fundamental innovation which utilises a radial piston machine which enables and disables cylinders in real time, using ultra-fast mechatronic valves controlled by an embedded computer. These intelligent, digital controls mean a Digital Displacement pump is highly controllable and extremely efficient – individual cylinders are only called into action as and when required.

The net result is:

- Dramatically lower energy losses (typically less than a third of swashplate machines).
- Dramatically faster response (typically ten times faster).
- Complete elimination of high-frequency noise.

A new series of commercially available Digital Displacement pumps is now being produced by Artemis majority shareholder Danfoss.

Project engineers at Bo'ness

'Our results showed some applications, such as driving compressors and cooling fans, could benefit immediately from access to the commercially available Danfoss DDP096 pump.

'Our study confirms that the hydrostatic cooling system in large locomotives can be made significantly more efficient, providing CO_2 reduction and fuel savings with a simple pump swap. For on track plant, almost all of these already use hydraulic systems, making this an ideal application area for Digital Displacement' Gordon says.

Adoption of DDP096 pumps will immediately reduce fuel use in both new and refurbished vehicles. Also, development of a modular drive system for small locomotives and self-powered uses could enable very positive changes to lighter rail vehicles (for light freight and a variety of other purposes) in the UK and elsewhere.

This project is not the first time Artemis has been involved in rail. In 2018 the Edinburgh specialists completed a project with ScotRail to demonstrate using a Digital Displacement pump to replace the conventional pump powering the hotel loads in a Class 170 DMU. The successful trial of 3,500 hours on an operating train indicated a fuel saving of 10,000 litres per vehicle per year (6.7 per cent).

In 2019 Artemis concluded a £1.7 million, 18-month programme – which was part-funded by the RSSB through its 'Advanced Powertrain' competition – to demonstrate a fully hydraulic transmission for a DMU on a trailer car, from an Intercity 225 (Mark 3 DVT), loaned by Chiltern Railways. The prototype [pictured], was developed using two standard JCB 129kW ecoMAX engines for the primary power units. It underwent a full test programme on a private rail line at the Bo'ness and Kinneil Railway in central Scotland.

Results included:

- Over 30 per cent reduction in fuel use.
- Faster acceleration and shorter journey times.
- Lower pollution in stations.

Gordon believes that all three studies demonstrate the wide-ranging potential for the adoption of Digital Displacement technology in rail.

'If fully integrated, Digital Displacement pumps and motors can be combined to create a hydrostatic transmission suitable for on-track machines. It would be particularly appropriate where vehicles have both transport and working modes – each at extreme ends of the speed range. It can also be used in small shunting locomotives. Hydraulic accumulators can be added to provide energy storage for power smoothing or braking energy capture, with significant performance and efficiency benefits.

'The drive to decarbonisation could also see the growth in light intermodal rail freight as a lower carbon alternative to road haulage. This would take place on largely non-electrified local lines, and further underscores the opportunity for Digital Displacement to reduce emissions and accelerate the decarbonisation of rail freight in the UK and overseas.

'The main challenge remains accelerating the early adoption of this technology into the rail market in the short term' Gordon concludes.

'Commenting on the project, Giulia Lorenzini, Senior Grants and Partnerships Manager, RSSB, said:

'The railway remains a very low carbon form of transport for both passengers and freight. Freight, in particular, has journey characteristics which demand very high energy and power requirements, high acceleration and long periods between refuelling. Our research has shown that there are no suitable direct replacement alternatives to electric and diesel traction currently available for these journey types. Therefore, the Digital Displacement technology is a valuable transitional arrangement for rail freight, where it could be applicable on a transitional basis at least, and perhaps in long-term use, to small locomotives, track maintenance vehicles and large locomotives to help reduce CO_2 emissions.'

The Institute of Railway Research (IRR) at the University of Huddersfield was very pleased to be able to support the project.

Professor Paul Allen, Assistant Director of the Institute sees the project as an exemplar of how industry and academia can work together in bringing new innovations to the rail market: 'Working with our Business School, we have helped demonstrate there is a place for Digital Displacement technology in decarbonising the railways, particularly in the very challenge case of the freight sector, with its reliance on diesel technology, necessitated by high traction power demand coupled with 'go-anywhere' service patterns.'

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