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WHO NEEDS RAILS?

Rhomberg Sersa's exercise in lateral – and longitudinal – thinking

SIGNALLING BARES ITS SOUL

At the IRSE's ASPECT 2019 conference in Delft, resilience and the capacity challenge were the major topics.

PERMANENT WAY

NEW TRAIN INTRODUCTION

With 8,000 new coaches ordered in eight years, commissioning new train fleets is a challenge for operators, owners and manufacturers.

INVOLVING END USERS IN DESIGN

Early involvement in the design process can improve both functionality and buildability, though changes are always likely.

Steering a Course TO THE FUTURE

MALCOM DOBELL

Manual steering wheel.

Over 200 years ago, George Stephenson developed the principle of coned wheels firmly attached to solid axles - the familiar wheelset. George Stephenson noted the self-centring performance and also the oscillations on plain track. Despite the latter limitation, the development could be said to have been "quite successful", and its less-desirable features have been controlled quite well by means of both bogies and various forms of damping.

There have been suggestions, over the years, that the wheelset could be replaced by individual wheels which could be individually controlled to provide better performance than a wheelset, especially if they could be steered around curves.

In what appears to be a non-sequitur, your author participated on a panel of judges in 2013 which were considering entries in the RSSB Radical Train competition. One of the successful entries was for a permanent-magnet synchronous traction motor integral with a rail wheel, with a control system that could steer the wheels. This was a joint proposal from SET Ltd and the University of Huddersfield. With the motor in the wheel, there was no need for an axle, and steering was provided by a sophisticated control system. This development was tested under a Blackpool tram - with one low floor bogie and one more conventional bogie - but both with steering capability.

There was a further RSSB competition in 2016, seeking vehicle dynamics solutions to reduce rolling contact fatigue as well as wheel and rail wear. A winning bid, from SET Ltd in partnership with the Institute of Rail Research at Huddersfield University (IRR), the Control Systems Engineering department at Loughborough University and VivaRail, proposed a further development of the wheel motor, now called ActiWheel.

ActiWheel live!

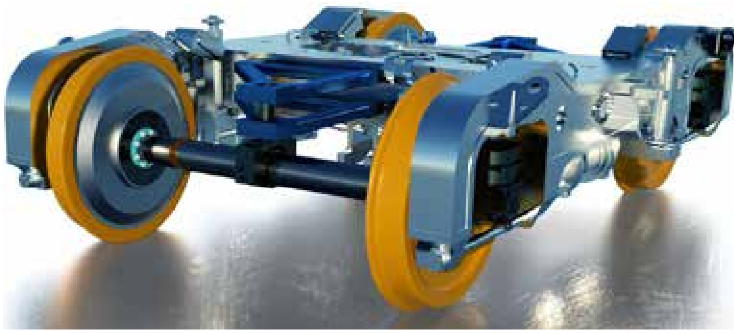
On a cold late-October morning, a spectacularly impressive demonstration took place at the Ecclesbourne Valley Railway in Derbyshire. As a small group of rail professionals were greeted by SET's director Martin Whitley, a single-car ex-London Underground D stock vehicle glided, almost silently, into Duffield station. Martin explained that this battery-powered vehicle, provided by VivaRail, had been fitted with ActiWheels for all eight wheels, and the motors on one bogie had been enabled to demonstrate the steering concept.

SET's Justin Hawley kicked off one of two presentations given on board the vehicle as we travelled along the line. He explained the benefits of steering wheelsets in reducing flange contact. Just steering conventional wheelsets can deliver significant benefits but, with individual wheels controlled so that they rotate at the exact speed to follow the different curved rail lengths, the results could be even better. That is the theory which SET proceeded to demonstrate. Indeed, probably for the first time ever, they had provided a steering wheel to change the angle of attack of the wheels manually!

Significant changes to the vehicle were necessary to enable this. Firstly, all four wheelsets were modified. The axles no longer rotate and a pair of ActiWheels rotate around each axle. ActiWheels are permanent magnet, outside rotor, synchronous, water-cooled motors, each delivering approximately 45kW.

Secondly, the primary suspension was replaced by a design that replicates the vertical stiffness of the D stock design, but with very low longitudinal stiffness, and the axles are anchored longitudinally on a frame fixed to the bogie transom to withstand traction and braking forces, but are able to respond to vertical suspension movement and yaw.

Modified primary suspension.



Axle with ActiWheels and frame.

Thirdly, each motor has its own inverter, supplied by and regenerating to the underslung 740V DC battery pack. As well as the motors, the inverters are cooled using water circulated from a 100-litre tank.

The magic ingredient is the control system. The demonstrator uses laser sensors to locate the position of the rails for the control system that adjusts torque to the individual wheel motors. The principle is that the torque to the wheels on the low rail will be reduced compared with that on the high-rail wheels. Justin explained that the laser has its limitations and can be confused by grass growing in the track; something that is not unknown! Justin said that a new control system based on estimated track irregularity will replace the lasers but confidentiality precluded him from giving any details, apart from it not being necessary to rely on vehicle position (GPS).

The principle of the system was demonstrated during a stop where the group examined the hardware at track level. The control system was set into a demonstration mode which made a single pair of wheels yaw back and forth under the control of the motors. The longitudinal movement of the wheel was approximately +/- 5mm. In response to the question "how does this work if the tread brakes are applied", the answer was, "it doesn't, and it doesn't matter!" More anon...

What if?

Neil Cooney delivered the second presentation. He said that the design principles had been based on a 90mph train where the gross mass of each car is circa 40 tonnes (five tonnes/wheel) with an acceleration rate of $1.3m/s^2$ and brake rate up to $2.3m/s^2$.

Aside from the steering ability, the system is designed with no friction brakes in mind. With eight individual motors per car, each of which can provide an emergency retardation force in the absence of control electronics, the way is open to eliminate normal friction brakes even for emergency brakes. This is also the case for eliminating friction parking brakes as SET have ideas for locking the rotors when the train is proved stopped. Having eight individual motors on a car provides twice the number of inputs for control of wheel slip or slide, and the individual inverters can be controlled faster than a conventional electro-pneumatic wheel-slide protection system.

No development would be complete without a proper examination of what might happen if the system fails to work correctly. What if it decides to steer in the wrong direction? The cases outlined in Group Standard GMRT2141 Permissible Track »

Forces and Resistance to Derailment and Roll-Over of Railway Vehicles were assessed by IRR for credible wrong side failures of the system and they concluded that there was no appreciable increase in derailment risk compared with a conventional system.

There was discussion about unsprung mass. The overall mass of the wheels/motors/axle was said to be lower than would be expected from a conventional wheelset with wheel-cheek disc brakes and semi-suspended gearbox and this is based on the technology demonstrator, not an optimised system.

Outlining the benefits in terms of wheel and track wear, Neil noted that the impact is route-specific. He said that there could be a 15 per cent reduction in track maintenance cost and a 15 to 65 per cent reduction in variable track access charges, depending on the scale of reduction of T_Y, and the estimate for improved wheel life is between four and 10 times, noting that the flange root is barely being run on.

Neil described the benefit of eliminating all the components of the pneumatic brake. He added that they had reduced the net weight of the D stock motor bogie (which formerly had nose-suspended, axle-hung motors) by approximately 2,000kg. That said, the friction brake had been retained for the demonstrator, although only used as a parking brake. Further safety assessment would, of course, be required to ensure that the probability of brake failure is at least as good as it is for a pneumatic system.

To turn this technology demonstrator into a production reality, it will be necessary to show that the safety and derailment risk have been adequately controlled including failure modes and effects analysis and, as already mentioned, the requirements of GMRT2141, including failure modes of the wheel motors. Durability and reliability proving is essential, as will be demonstration of compliance with the majority of standards and work to modify certain standards written before wheel motors were even considered.

To exploit fully the technology, bogie design should be optimised for wheel motors, and the safety assessment should consider how to assess the risk of flange climb derailment if flange contact is unlikely. Probably more challenging is the safety assessment of a train with no friction brakes!

Neil concluded by looking into the even more distant future, where the output of the closed-loop control system could be used to monitor track condition, when single axle bogies might be looked at and there could even be active steering at junctions. Interestingly a presentation at University of Birmingham the following day on the Shift2Rail project S-Code put forward the concept of a switch with no moving parts with the vehicle being steered in the right direction. Pie in the sky? Perhaps not, as many small children with wooden train sets might tell you!

Whilst this system was developed in response to a call for reduced RCF and wear by the development of an active-steering bogie, the motors also bring benefits to a conventional bogie, not least of which is the possibility of eliminating friction brakes. One factor that became very apparent during the test was the quietness of the system. The train was moving under its own power, but the only noticeable sound was that of the jointed track. The noise levels were comparable to those of a more conventional trailer car!

SET believes that industry-wide adoption of such technologies could result in a reduction in network maintenance costs by hundreds of millions of pounds per year, energy savings of over 10 per cent and other environmental and passenger benefits. Cumulatively, these would equate to a significant move towards meeting government sustainability targets and expectations.

As the next step, SET aims to explore collaborative relationships within the industry to enable this technology to reach the rail industry by the most efficient and direct route. Rail Engineer wishes them well in their quest for the next stages of bringing this innovation to market.

Thanks to Robert Staunton of RSSB for making the visit possible and to Martin Whitley and his team for assistance with this article.

A switch with no moving parts, familiar to many budding engineers!