BRAKING REVOLUTION

Technology developed to radically improve heavy-duty commercial vehicle stopping distances is just a whisker away. Brian Tinham assesses the technology, the systems and whether the transport market will bite

Braking technology set to shave a massive 25% off truck stopping distances looks set to come to fruition this year. However, its developers believe their systems may not be widely available for at least five years, possibly double that. That's despite the considerable and obvious benefits, in terms of preventing accidents, mitigating others, saving lives, reducing accident damage, and cutting downtime and insurance premiums.

So why not? Partly, developers at CVDC (the Cambridge Vehicle Dynamics Consortium) make the point, because there is still a formal engineering process to be followed and these things take time. Fine, but not a decade – particularly given the eight years of development to date and the fact that the technology is now ready for track testing at MIRA's proving ground. No, it seems the reason for the timeframe stems from a belief that truck OEMs won't stump up any additional cost, if they're not required to do so by legislation. All the more so, given that their customers, the operators, are already being asked to pay the price hike for Euro 6 emissions, which comes into force in 11 short months.

Electric dreams

So what's the latest with Haldex's all-electric brakes project, which, we were told a couple of years ago, was ready to revolutionise brake actuation by getting right away from pneumatics? Parked, is the company's ironic answer. "The project got as far as it could, from a technology perspective, but hasn't attracted enough market interest," states Bob Prescott, Haldex's chief engineer for trucks.

"Given the economic downturn, it was just a bad time to bring our technology to market. Manufacturers switched their attention to cost out: we just have to wait until their focus returns to further improvements in safety." And to that we might add: given that UN ECE Regulation 13 (Braking) has no guidelines for electromechanically-operated brakes, there's a bit of a Catch 22 here, too.

Are there safety benefits? Prescott insists there are, pointing to a clear improvement in reaction time with electromechanical equipment over air systems. No pneumatic delays, due to air pipes and solenoid valves releasing air into brake chambers, means faster actuation, so shorter stopping distances, he argues.

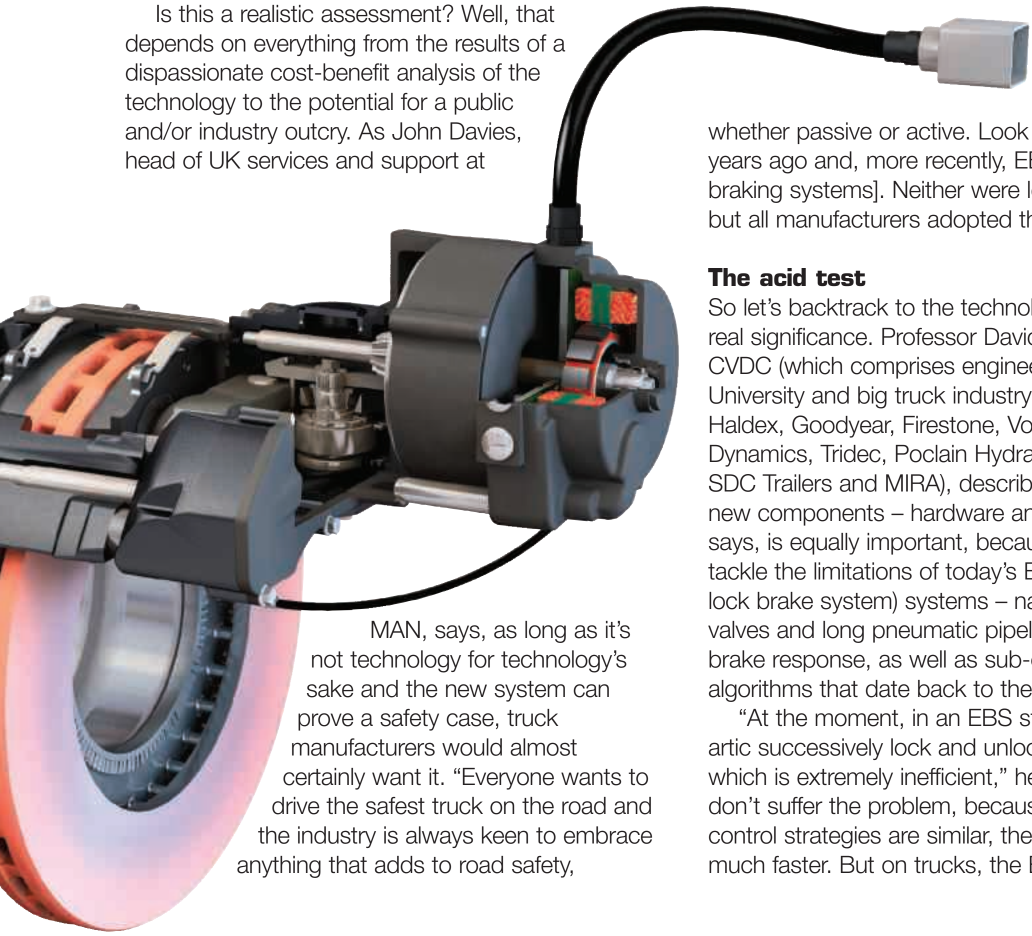
What's more, the system is founded on independent brake control for each hub, unlike the vast majority of commercial vehicle brake systems today. "Electric brakes are much faster and, with individual control, it's much easier to optimise break performance," states Prescott. That, in turn means more potential for the kind of work being done by CVDC (Cambridge Vehicle Dynamics Consortium – see main feature), as braking forces can be modulated very quickly.

Beyond that, the Haldex prototype does not need pneumatic back-up, instead relying on dual-redundant brushless dc motors on each hub that effectively push the brake pad up a ramp, under ECU control, onto the disc. Prescott does not claim a massive weight advantage. "Weight is always dominated by the foundation brakes," he concedes, "but there would be some weight reduction on the parking brakes."

And stripping out all that pneumatics not only eliminates the piping, but also reduces demand on the compressor, saving weight there and in terms of smaller air tanks – although you do need a secondary battery. "On top of that, they're also nearly silent in operation – important for urban vehicles, such as buses. And there can be installation benefits, with the brake package being slightly smaller," adds Prescott.

Above: David Cebon beside CVDC's newly adapted trial trailer, with brakes ready for testing at MIRA. Inset: the classic tyre slip braking curve
Photo: Charlie Milligan

Is this a realistic assessment? Well, that depends on everything from the results of a dispassionate cost-benefit analysis of the technology to the potential for a public and/or industry outcry. As John Davies, head of UK services and support at MAN, says, as long as it's not technology for technology's sake and the new system can prove a safety case, truck manufacturers would almost certainly want it. "Everyone wants to drive the safest truck on the road and the industry is always keen to embrace anything that adds to road safety, whether passive or active. Look at disc brakes 25 years ago and, more recently, EBS [electronic braking systems]. Neither were legal requirements, but all manufacturers adopted them."



Left: Haldex's all-electric brakes

The acid test

So let's backtrack to the technology and establish its real significance. Professor David Cebon, director of CVDC (which comprises engineers at Cambridge University and big truck industry names, including Haldex, Goodyear, Firestone, Volvo Trucks, AB Dynamics, Tridec, Poclain Hydraulics, Wincanton, SDC Trailers and MIRA), describes it as involving two new components – hardware and software. Each, he says, is equally important, because together they tackle the limitations of today's EBS and ABS (anti-lock brake system) systems – namely slow brake valves and long pneumatic pipelines, which delay brake response, as well as sub-optimal brake control algorithms that date back to the 1970s.

"At the moment, in an EBS stop, the wheels of an artic successively lock and unlock every second, which is extremely inefficient," he explains. "Cars don't suffer the problem, because, although the control strategies are similar, their hydraulics are much faster. But on trucks, the EBS effectively slams the tyres from one end of the friction slip curve to the other. And every half second, when the tyres accelerate back to free rolling, the brakes generate no stopping force at all."

Cebon argues that, to minimise stopping distances, braking tyres must be maintained at peak stopping force, without slipping. So let's look at the detail. First, you need to know where the top of the friction curve is. That means software and sensors that can estimate tyre friction as it changes, on the move. "Our system can do that in about half a second, by measuring brake pressure and wheel speed, using conventional sensors," he says.

Software and hardware

Secondly, the system has to know the vehicle road-speed (not the slipping wheel speed). "We get that from accelerometers and gyros that can live in the brake ECU. Our system is like an inertial navigation system, but much lower cost, because we're only interested in estimating motion in the 20 seconds or so of an ABS stop."

Thirdly, radically different software is required, capable of continuously controlling brake pressure at each wheel and maintaining tyre slip at the top of that torque curve. "For that, we have developed new, non-linear control algorithms, capable of tracking the target tyre slip level, even in the unstable region past the peak of the friction curve."

And finally, you need much fast brake hardware. CVDC has achieved that with two innovations. First, the team moved the pneumatic control valve away from the central vehicle ECU, instead locating one unit on each brake chamber. That eliminates pneumatic delays and enables fast individual wheel braking. But secondly, working with Camcon and Haldex, the team developed a new air control valve that is 10 times faster than conventional solenoid valves.

"It's essentially an electromagnetic valve, which uses a flexure and binary actuation technology to flip back and forth to open and close the air port," explains Cebon. "It took three years to perfect, but we've brought it to a level where it now reliably switches full brake pressure within 3msec, compared to solenoid valves at 40msec."

Why does it need to be so fast? Cebon gives the example of truck wheels traversing rough ground

Above: Professor David Cebon, director of the Cambridge Vehicle Dynamics Consortium

Brake and stability regulation

Curiously, it's not brake regulations that have been driving uptake of EBS (electronic braking systems) or earlier ABS (anti-lock brake systems). It has been market forces. But, within the next few months, legislation demanding installation of ESP (electronic stability program) on commercial vehicles will change all that.

Gary Brown, who looks after OE (original equipment) sales for Knorr-Bremse in the UK, points out that commercial vehicle manufacturers and operators have increasingly been turning to EBS over ABS, not only because of its improved control and responsiveness, but also for its functionality. He cites: brake force distribution; continuous, independent brake pad monitoring; and wear balancing.

"But upcoming legislation on ESP is further increasing migration to EBS, because, while it's possible to use ABS to get the required stability functions, it results in a more complicated system. So most of the major OEMs are now turning to EBS platforms."

So what's the timeframe? In fact, ESP has been mandatory for new vehicle type approvals since 1 November 2011 – the main exemptions being city buses and vehicles with more than three axles. However, on 1 October this year, given the advent of Euro 6 and the requisite type approval processes, ESP will have to be on most vehicles. "Although the second phase of the ESP regulations don't come in until 1 November 2014, from a commercial vehicle point of view, Euro 6 forces the OEMs to the earlier date," explains Brown.

How does ESP work? On braking, electrical demand signals are transmitted via CANbus to the hub valves, which are part of a closed loop, intelligent system. "The system knows the air pressures being applied at each wheel end, so, because it also monitors wheel speed, feeds back differences and changes the pressures to optimise braking in real time. It does that all the time, without driver involvement, as it works out what's needed for stability."

So where does that leave AEBS (advanced emergency braking systems) and LDWS (lane departure warning systems)? From a regulatory viewpoint, the first phase covers vehicles over 8 tonnes with rear air suspension, and systems becoming mandatory on 1 November 2015. All remaining suspension types and weights then fall under the legislation from 1 November 2016, although there remains some doubt about that.

Brown suggests that, because of the impending ESP regulations, the industry focus has been on implementing these systems. "But we have AEBS/LDWS development systems running on customers' vehicles and we'll be picking this up again from the middle of this year."

For Knorr-Bremse, TRW and the others, the issue has been perfecting the systems – all of which involve forward-looking radar and video cameras – so they recognise when braking is required and when it is not. As Brown puts it, the main challenge is identifying when an object is an object and when it isn't. "If the system sees a manhole cover, you don't want to put the brakes on," he quips.

And there's the adaptive cruise control element, which needs to monitor moving vehicles ahead and maintain the gap, right down to autonomously applying the emergency brakes. This is all about collision mitigation and Brown is confident that Knorr-Bremse, at least, will be ready well before the legislation.

and causing the load on the tyres to change, potentially at up to 10–12Hz. "So the brake force has to be continuously modulated at that frequency, too, to keep the tyre torque correct. That's where today's brakes fall down, because they oscillate at 1Hz. Our system is much faster, so we can control wheel slip accurately under all conditions."

Hence CVDC's claim of a 25% improvement in stopping distances, compared with today's EBS. And hence also its suggestion of secondary weight, cost and energy savings. "Our system reduces air consumption by about 50%, because, instead of filling and dumping the brake chambers every second, it quickly slides up to the desired brake pressure and stays there, rapidly modulating around that point. So manufacturers will be able to use smaller air tanks and compressors," insists Cebon.

So there you have it. Six of the new brake valves have been built and are currently being installed on a three-axle semi-trailer, which is now being prepared for testing with the new control system at MIRA next month. Phase two will see the technology installed on a tractor unit either later this year or early in 2014.

"We will prove the technology outside the lab and in real road conditions this year. Widespread uptake will then depend on the industry," comments Cebon. And he makes the point that adoption need not be restricted to new vehicles alone. "The system could be retrofittable and compatible with all other braking developments, including the new AEBS [advanced emergency braking systems]."

Time to make some enquiries? TE