EIP

How could internal combustion engines help drive decarbonisation?

Last week, the UK Government announced that sales of new petrol and diesel heavy goods vehicles (HGVs) will be banned by 2040. The UK's Road Haulage Association supports the aim, but in a press release they say the proposal is unrealistic because alternatives don't yet exist.

What's the problem?

Many car companies are, of course, investing heavily in alternatives to petrol and diesel engines, and several electric vehicles (EVs) are already on sale. Some are battery electric vehicles (BEVs), which derive all their electric power from onboard battery packs. Others are fuel cell electric vehicles (FCEVs), which use fuel cells for onboard generation of electricity but often still have a sizeable battery to store it.

The trouble is that these technologies are unsuitable for heavy-duty machines like HGVs. Recharging a BEV can take hours. However, HGVs tend to travel for long periods, meaning there is less time available to recharge. Add the need for HGVs to have higher battery capacities due to their greater weight and journey lengths, and the problem is compounded. FCEVs can be refuelled in a comparable time to diesel-fuelled vehicles, but fuel cell technology remains very expensive. With both BEVs and FCEVs, there are also challenges around sourcing materials for batteries, and how to handle them at the end of their lives.

These are issues shared by manufacturers of heavy construction and agricultural equipment, such as JCB.

In a fascinating episode of Harry's Garage on YouTube last week, JCB's Chairman, Lord Bamford, highlighted that owners of heavy machinery want it to work long shifts to get maximum return on investment. For a mini excavator, that could be 4-5 hours per day, for a backhoe loader it could be 8 hours, and for larger machines it could be 16 hours over a double-shift. HGVs work for similarly long shifts.

JCB have a range of small BEVs for which the technology is appropriate because the batteries can power the machines for their relatively short shifts before needing a recharge. However, the technology isn't as suitable for harder-working equipment, since the necessary recharging would interrupt operations too much.

Weight and cost are also issues. JCB's experience is that battery costs aren't looking to reduce any time soon. Moreover, were a 20-tonne excavator to be converted to a BEV, its weight would increase by over 40%, so many components would also have to be upgraded to deal with the additional load. The result is a machine that would cost double the diesel-powered equivalent yet be unable to work equivalent shifts. Obviously, this would be unattractive to customers.

They are also exploring FCEVs, but indications are that they would be an expensive solution. Apparently, whereas the price of a 20-tonne diesel-powered JCB excavator is about £130k, a FCEV equivalent would be nearly £300k.

What's the solution?

JCB's solution is an internal combustion engine (ICE), albeit one that runs on hydrogen.

"It's not the combustion engine that's the problem, it's the fossil fuels" – Lord Bamford

Lord Bamford is of the view that there is a great future for ICEs. Indeed, they are highly reliable, relatively simple, cheap to manufacture, there are well-established supply chains for components, and they are well understood by manufacturers, service centres and many customers.

The concept of a hydrogen ICE has been around a long time. Indeed, the world's first ICE-powered automobile, at the beginning of the 19th century, ran on hydrogen.

JCB's hydrogen engine was unveiled in May, as reported in this Autocar article. The design, which first ran on a dyno in December, is based closely on their existing diesel engine architecture. In the Harry's Garage video, Paul McCarthy (Chief Engineer, JCB Power Systems) explains that the engine shares the same block as JCB's standard 4.8L diesel unit, but has a new cylinder head to accommodate the move to spark ignition.

Challenges overcome

A concern with hydrogen ICEs is that, while they do not emit CO2 (other than potentially a negligible amount from burning any engine oil in the cylinder), they can emit NOx generated from nitrogen and oxygen in incoming air. Hydrogen engines can run very lean, reducing the cylinder temperature and therefore the amount of NOx generated, but running lean reduces flame velocity and therefore power, so a balance needs to be struck.

Engine timing also needs consideration. Hydrogen's high diffusivity means a more uniform fuel-air mixture can be achieved in the cylinder, providing more complete combustion and efficiency, but there's potential for it to pass through intake valves before they are fully closed, resulting in backfiring.

Nevertheless, JCB seem to have overcome these issues and produced a viable ultra-low emission ICE that still delivers the required performance, with the low-end torque demanded by customers, while running a suitably lean mixture. In the Autocar article, it is also commented that:

"...the 'raw' exhaust from the prototype engine contains less NOx than a diesel, even with the latest after-treatment that cuts diesel pollutants by 98%."

Lord Bamford says the design is still in its infancy, and it will be a zero-emission engine.

Importantly, the cost to JCB's customers will be only slightly higher than that of their diesel-powered equivalent machines. Weight and packaging will also be very similar – the hydrogen tanks will locate where the diesel tanks are at present – so there is no need to modify numerous other components. Also, and key to attracting customers, work cycles needn't change; the tanks can be filled in minutes and supply enough fuel to complete a full day's shift.

Challenges remaining

The remaining hurdles relate primarily to generating and storing hydrogen, but even these appear relatively surmountable.

Hydrogen can be produced by electrolysis of water. Siemens have technology relating to green hydrogen production using wind turbines to power electrolyzers, and Ryze Hydrogen, of which Lord Bamford's son Jo Bamford is Executive Chairman, is building the UK's first network of green hydrogen production plants. They also offer storage and

distribution.

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For the UK at least, there should be ample renewable energy available to power electrolyzers. At a recent conference I asked Dale Vince, founder of green energy company Ecotricity, whether it is possible for the UK to generate all its required electricity from the sun, wind and sea, and it was pleasing to hear that the answer is "yes, many times over". Apparently, solar alone could generate 8x the requirement, before considering land-based windfarms and offshore technologies.

Can JCB leverage IP?

There will be much interest in this technology, so it will be interesting to see whether JCB can leverage intellectual property (IP) in their work.

Although the broad concept of a hydrogen ICE has been known for 200+ years, the team at JCB will have devised solutions to numerous technical problems in designing a product that suits today's world. Some of these could be patentable, meaning they could get monopoly rights on them for up to 20 years. These rights could be used to prevent other companies from using the technology, or they could be licensed-out to permit use of the technology in return for payment of royalties.

The market for licensing could be substantial. In principle, the technology could be used by companies making other heavy-duty machines and vehicles, such as JCB's competitors in the construction and agricultural industries, as well as manufacturers of HGVs, buses and coaches. Moreover, it could be retrofitted to some existing machines, avoiding the need for scrappage and replacement with newly designed and manufactured ones – itself an environmental benefit. As such, so long as the claims of any patent rights cover retrofitting, further potential licensing revenue streams could exist.

Aside from licensing, JCB might be able to use the UK's Patent Box scheme to benefit from a reduced 10% corporate tax rate on profits from patented products, as explained on our Patentise website.

At this stage, it is not possible to see whether JCB have filed any patent applications from this project. Patent applications are, by default, published 18 months after being submitted to the patent office. As the project is about a year old, we will likely need to wait at least six months before any publications are made.

Freedom to operate

It is worth bearing in mind that JCB would be free to commercialize their new technology only if doing so wouldn't infringe third parties' patent rights.

Others are investigating hydrogen ICEs and might have filed patent applications of their own. For example, just last week, Cummins announced they have begun testing a hydrogen engine, and the week before AVL announced they are working with Westport Fuel Systems and TUPY to develop a hydrogen ICE for heavy goods transportation with first results expected by early next year. Ricardo also recently announced they are researching hydrogen ICEs.

If a third party owns IP rights that cover JCB's planned commercialization, aside from agreeing to pay royalties to take out a licence, JCB might be able to use to the third party's technology through cross-licensing of both sides' rights.

What about cars?

A challenge with smaller vehicles is accommodating the fuel tanks without impacting on passenger and luggage space. Hydrogen ICEs are less efficient than hydrogen fuel cells, so more space is needed for fuel storage for a given range.

BMW unveiled their Hydrogen 7 bivalent car fifteen years ago, but it returned very low mpg. Toyota clearly think this is still an area worth exploring, as shown by their recent demonstration of a hydrogen-powered Corolla with a modified GR Yaris ICE. Moreover, in an interview last Friday, Ross Brawn suggested that hydrogen could be the route to help F1 become carbon neutral while keeping the familiar noise.

With so much brain power now being directed at this technology, one suspects that a feasible small vehicle with a hydrogen ICE could materialise. If JCB or their competitors obtain IP rights that are also relevant to this large market, they could prove very lucrative indeed.

Written by Rick Gordon-Brown.