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our opinion

Golden years

From the rise of autonomous vehicles and artificial intelligence to the advent of Industry 4.0 and the all-electric unmanned racing car, there's no doubt that we're living through a time of profound technical change, an age where yesterday's sci-fi musings become today's disruptive technologies with almost monotonous regularity.

It's a point that is seized upon in this issue's interview with GKN Automotive boss Phil Swash, a British engineer at the heart of this technological maelstrom, who enthusiastically declares that automotive engineers will look back on current times as golden years. The changes in the automotive sector at present are particularly rapid and have many implications, not least in terms of the skills requirements that the industry has – something that we examine in this issue's careers feature (p66).

But while there is no getting away from the excitement of profound change, we shouldn't lose sight of the fact that technological progress isn't always about new ideas. Indeed, more often than not it's about finding improved ways of doing things that we've already been doing for years; and it's hard to think of a better example than the subject of this issue's cover story: pumped hydro.

“But while there is no getting away from the excitement of change, we shouldn't forget that progress isn't always about new ideas”

As we report (Untapped potential, p72), pumped hydro – whereby water is pumped uphill, stored, and released downhill to power turbines – has been with us since at least the 1890s, but now, as engineers continue to struggle with the intermittency challenges posed by renewable energy sources, it's being viewed by many as the missing piece in our clean-energy jigsaw. We take a look at some of the pumped hydro projects currently under development, and examine the potential for the technology in the UK and beyond.

On a completely unrelated note, I would like to take this opportunity to encourage readers to register for our annual Collaborate To Innovate conference (C2I), which takes place at the MTC, Coventry next month (7 December). Alongside presentations from the winners of *The Engineer's* annual C2I awards programme, the event will also feature keynote presentations from Sir Vince Cable, Prof Rajkumar Roy and BAE's Dr Steve Harris on a variety of collaboration-related topics, including the power of cross-sectoral collaboration; collaborating in the digital age; and the challenges of protecting intellectual property.

To find out more and to register visit: <http://conferences.theengineer.co.uk/>

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AUTOMOTIVE

Autonomous drive is all in the data

Trials could speed up the development of automated driving JON EXCELL REPORTS



Trials underway in Greenwich, South London, are providing valuable data that could accelerate the development of autonomous vehicles and make them safe enough for the UK's roads.

The purpose of the Move_UK project, which has received £3.4m funding from the government's Intelligent Mobility fund, is to develop new validation methods that will reduce the time taken to test automated driving systems, thereby speeding the technology's time to market. Results from the trial are also expected to help shape new safety requirements and insurance products designed for autonomous driving.

Led by Bosch, the three-year project also involves Jaguar Land Rover (which is supplying

the test vehicles); Telematics specialist The Flook; the Transport Research Laboratory (TRL); and Direct Line insurance.

A further consortium partner, the Royal Borough of Greenwich, is operating a fleet of five conventionally driven, but heavily instrumented, Land Rover vehicles that have already completed more than 30,000 miles of driving on public roads around Greenwich.

These cars are being used to collect data on how human drivers react to range of different driving events. They are also equipped with driver-assistance systems that have been decoupled from the operation of the car so that engineers are able to compare in real time the behaviour and decision making of the vehicle's autonomous systems with that of the human driver.

Conventional approaches to validation typically involve

acquiring data through road or track trials that is then downloaded from the vehicle and pored over by engineers and technicians. However, according to the initiative's lead project manager, Bosch engineer Simon Morley, the huge amounts of information generated by driverless systems make these traditional approaches impractical.

"Industry faces a real challenge when it comes to validating automated driving systems," he said. "They generate huge amounts of data, around 8GB per second and as we get to ever-more-complex autonomous drive systems we need a smarter method of validating."

The Move_UK project is taking a different approach by only concentrating on particular types of data and using connectivity technology to transfer data in real time via either Wi-Fi or 3G to a cloud-based system operated by TRL. According to the team, this helps to reduce the total volume of data collected and speeds up the validation process.

"We're not just going out and recording every bit of data we can," said Morley, "we're trying to be very intelligent about the data we record. A car generates well over 1,000 different signals and for this project we're concentrating on 250 signals we've identified as being key." Perhaps most significantly, the system is also programmed to be triggered by events such as harsh braking by the human driver, or where the on-board system thinks there should be braking but the driver has not braked.

The project, which launched in 2016, is now coming to the end of its first phase, which has primarily involved the use of front-facing cameras to acquire road data. The next two phases will combine cameras with radar technology – so that by the end of the project the data gathered will be from full 360-degree surround sensing.

Jaguar Land Rover's Richard Holland said that he expects the findings of the project to feed directly into the carmaker's plans for driverless technology. The project is also proving helpful for the motor insurance industry, a sector that will be profoundly affected by the rise of the driverless car. ■

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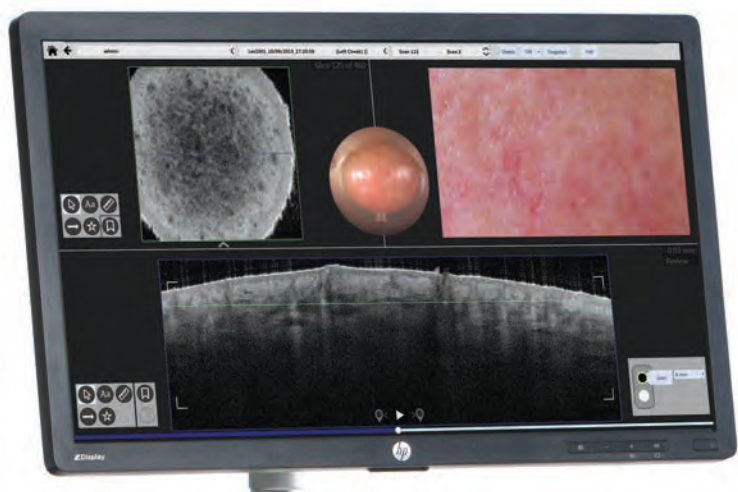
GRUNDFOS 

MEDICAL

Cancer detections in just 30 seconds

Scanner could diagnose a malignant melanoma in real time

HELEN KNIGHT REPORTS



UK firm Michelson Diagnostics led the project.

Blood vessels grown by dangerous skin cancers known as malignant melanomas can be detected in just 30 seconds using a handheld laser scanner.

Skin-cancer diagnosis can take weeks, involving referral to a dermatologist for a skin biopsy, and then possibly an invasive

sentinel lymph node biopsy under general anaesthetic.

The new technology, developed in a European project led by UK-based Michelson Diagnostics, could dramatically speed up this process by allowing dermatologists to diagnose a malignant melanoma in real time. The scanner allows dermatologists to view a 3D image of the blood vessels under the skin, up to a depth of 1mm.

The technology is based on Optical Coherence Tomography (OCT), conventionally used in retina scans, in which a laser beam is projected onto tissue and the reflected light is detected by a microscope and used to create a 3D image.

Unlike conventional OCT, however, the new technology, known as dynamic OCT (D-OCT), is able to detect motion within the tissue, according to Jon Holmes, co-founder and chief technology officer of Michelson Diagnostics. This reveals the flicker of light patterns created by moving blood cells against the background of solid tissue.

"Traditional OCT gives you the structure of the tissue, and if there is a tumour you can see it as a shape within that," said Holmes. "Dynamic OCT, in contrast, detects motion, so it is able to compare two OCT images, taken within a short space of time, looking for differences."

The system uses algorithms to extract the motion information and reveal the structure of the blood vessels. Cancers are known to grow their own blood vessels. But unlike the blood vessels in healthy tissue, these vessels tend to grow in an abnormal fashion, said Holmes.

"The vessels in normal tissue are like a network, whereas the vessels that feed tumours are more like twisted tree roots," he said.

This allows the system to detect blood vessels grown by the tumour from within healthy tissue, and there are also hints that the irregularity of the vessels may indicate how far the tumour has progressed, he said. ■

MATERIALS

Making 2D shapes with liquid metal

Researchers are working with an alloy of indium and gallium

STUART NATHAN REPORTS

Researchers from Sussex and Swansea universities have invented a method for morphing a liquid metal into two-dimensional shapes that

can be changed seamlessly. The technique could be useful in reconfigurable electronics, in displays and in soft robotics, the team said.

The researchers, led by Yutaka Kotuda at Swansea's Future Interaction Technologies laboratory and Prof Sriram Subramanian of Sussex's Interact laboratory, are working with an alloy of indium and gallium called EGaln that is liquid at room temperature and whose surface tension is very sensitive to external electric voltages.

Placing a blob of liquid metal onto a 7x7 array of graphite electrodes,

they manipulated the pattern of electric charge across the array to affect the tension across the surface of the blob, pulling it around so that it formed letters and a heart shape.

The array was under the control of a prototype graphical user interface, allowing the shape of the metal to be changed dynamically.

"One of the long-term visions of us and many other researchers is to change the physical shape, appearance and functionality of any object through digital control to create intelligent, dexterous and useful objects," said Subramanian. ■

Newsinbrief

Stakes are high

Airbus is to acquire a majority stake in Bombardier's C-Series aircraft business, potentially shoring up thousands of UK jobs put at risk by a recent US decision to impose sharp import tariffs on the aircraft. Airbus will acquire a 50.01 per cent stake in the C-Series Aircraft Limited Partnership, while Bombardier will own approximately 31 per cent of the business.

Frack attack

Scotland won't exploit its unconventional oil and gas reserves after the Scottish government banned fracking. A moratorium on fracking has been in place since January 2015 and the announcement of an outright ban follows a four-month public consultation with 60,000 responses. Approximately 99 per cent of the responses were opposed to fracking.

Farming afloat

The world's first floating wind farm is delivering electricity to the Scottish grid. Comprising six 5MW floating turbines, the 30MW Hywind Scotland project is located 25km offshore from Peterhead in Aberdeenshire, Scotland and will provide power for approximately 20,000 households. The £190m Hywind project is expected to pave the way for export opportunities.

Sense of autonomy

Boeing's venture capital arm has made an investment in Near Earth Autonomy, a company that developed the world's first full-size autonomous helicopter flights. Near Earth Autonomy, a spin-off from Carnegie Mellon University's Robotics Institute, develops software and sensor technology that enables aircraft to inspect, map and survey terrain and infrastructure.

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MEDICAL

Robot hands have the surgical touch

Dutch team gets to grips with microscopic surgery procedures STUART NATHAN REPORTS

ADutch team claims to have achieved the world's first super-microscopic surgery with surgical robot hands, in an operation on the lymphatic system.

One advantage of a surgical robot is that by scaling down the movements of a surgeon's hands on their controls they allow greater precision than can often be achieved by manual surgery.

The Dutch team, at Maastricht UMC+ (University Medical Centre), was using robots developed by Microsure – a spin-off from the medical centre and Eindhoven University of Technology – to perform the procedure to surgically treat lymphoedema.

Lymphoedema is a common side effect of breast cancer treatment. It occurs when the lymphatic system – part of the body's processes for dealing with waste products in the bloodstream – becomes compromised and allows fluids to build up where they should not. This is potentially serious, as it can be painful and lead to infection.

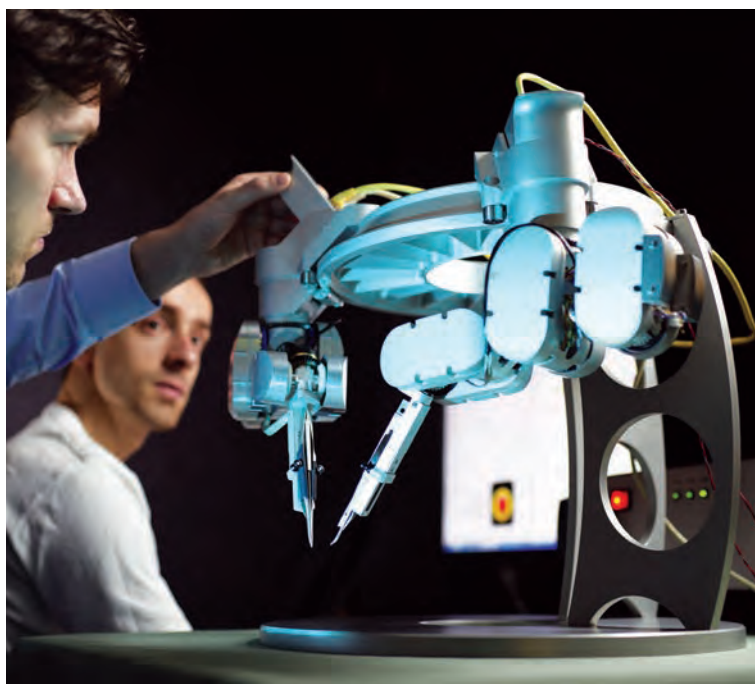
The super microsurgery is a new and promising treatment for this condition, involving the connection of lymphatic vessels to blood vessels to give the fluid another route through

which it can drain. But because the vessels involved are so small, the operation is difficult and stressful and only a few surgeons in the world are capable of carrying it out.

The Microsure surgical robot was used by Shan Shan Qiu Shoa, a plastic surgeon at Maastricht UMC+, to suture vessels of 0.3 to 0.8mm in diameter in a patient's arm. According to Microsure, as well as scaling down Shan's movements, it also filtered out tremors.

"Microsure enables us to be very precise in our movements during procedures that need a surgical microscope," Shan said. "Their robot allows us to operate on minuscule lymph vessels and blood vessels with more ease, while getting better results for these complex and fatiguing interventions. Besides, it is very convenient that, within microsurgery, we can operate on vessels of every size with this robot. Most importantly, of course, this is good news for the patients concerned."

Microsure technical director Raimondo Cau claimed that the operation represented a "key breakthrough" in improving surgery. "As a next step, we aim to assist surgeons during other types of complex microsurgical procedures such as tissue reconstructions after removal of a tumour." ■



The Dutch team was using robots developed by Microsure

AUTOMOTIVE

All along an Australian highway

Netherlands team takes pole position in solar-racing challenge

JON EXCELL REPORTS



A team from the Netherlands has won the 2017 World Solar Challenge, a gruelling 3,000km solar-powered car race from Darwin to Adelaide along the infamous Stuart Highway.

The Nuon Solar team, which is based at the Delft University of Technology crossed the finish line five days after leaving Darwin. It was almost two hours ahead of its nearest rival, a team from the University of Michigan and two-and-a-half hours ahead of the third-placed Belgian Punch Powertrain team. The win is Nuon Solar's seventh title.

The main UK contender, Cambridge University Eco Racing, was forced to pull out of the competition following an accident during testing, resulting from a sudden loss of dynamic stability.

Nuon took an early lead in this year's competition, which its strategists say they maintained by carefully watching the weather, energy consumption and predicting the best way through the clouds. The team also had to adjust its strategy and driving style to "nerve-wracking" weather conditions that saw wind gusts of up to 60kmph.

Jasper Hemmes, aerodynamics expert for the team, said drivers were instructed to position the solar car in such a way to profit from the winds as if it were a sailing ship.

The World Solar Challenge, which occurs every two years, has been running for three decades. ■

ENVIRONMENT

Under Icelandic skies

CO₂ will submit to direct air capture

A new trial scheme in Iceland is claiming to be the world's first to combine direct air capture (DAC) of CO₂ with permanent geological storage.

The CarbFix2 project is a collaboration between Swiss start-up Climeworks and Reykjavik Energy.

The first stage in the process sees CO₂ captured

from ambient air using Climeworks' DAC technology, which involves a patented filter made of porous granulates modified with amines. In use it binds CO₂ with the moisture in the air. Next, low-grade heat from the geothermal plant is used to release pure CO₂, which is then sent more than 700m underground. Here, it reacts with the basaltic bedrock and forms solid minerals, creating a permanent storage solution.

The trial will test the technology under the specific weather conditions in the south west of Iceland. **AW**



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COMMUNICATIONS

Optical route for broadband speed

New receiver is designed for use in optical access networks HELEN KNIGHT REPORTS



Super speeds will be needed to meet future bandwidth demands

Super-fast broadband speeds of over 10,000 megabits-per-second to every home could be possible with technology developed in the UK.

Broadband speeds in the UK lag behind other countries, averaging 36Mbps. By 2025, speeds up to 100 times faster will be needed to meet the bandwidth demands of ultra-high definition video and online gaming.

The receiver is designed to be used in optical access networks,

which link internet users with their service providers. It has been developed by researchers at the UCL Optical Networks Group and Cambridge University in a project funded by EPSRC and Huawei Technologies.

The technology has been designed as a simplified alternative to existing coherent technology, which maximises the capacity of optical fibre links by transmitting data to individual users in dedicated wavelengths of light, according to lead researcher Dr Sezer Erkilinc at UCL.

The coherent receivers are too complex and expensive for use in transmitting to individual homes, and their use is limited to core networks that link different areas.

In coherent technology, the light transmitted along optical fibres is modified and sent across each of two polarisations.

“We have removed some optical complexity using digital techniques”

Dr Sezer Erkilinc
Alstom UK

However, by the time the modified signal is received at the user end, this polarisation has typically rotated, meaning it needs to be adjusted using complex optical receiver technology.

Instead, the researchers used a coding technique to transmit the polarised signals, so that the received signal can be recovered independently of any polarisation rotation that occurs along the fibre link. This allows the complexity of the optical receiver to be simplified.

“We have removed some of the optical complexity using digital techniques, while some complexity has shifted from the optical to the digital domain,” said Erkilinc.

The receiver provides each internet user with a dedicated wavelength, meaning broadband speeds remain constant no matter how many other people are logged on at the same time, said Erkilinc.

The device was recently tested on a dark-fibre network between Telehouse in East London, UCL, and Powergate in West London. ■

RAIL

Hyperloop rebrands with Branson

Project aims to move people and cargo at speeds of 670mph

JASON FORD REPORTS



Richard Branson's Virgin Group is backing Hyperloop One with an undisclosed investment into technology that could one day transport people from London to Edinburgh in 50 minutes.

The rebranded Virgin Hyperloop One aims to move people and cargo in vehicles that travel in tubes at speeds of up to 670mph.

Hyperloop vehicles are being designed to accelerate gradually via electric propulsion through a low-pressure tube. The vehicle then floats above the track using magnetic levitation and travels at high speed over long distances due to ultra-low aerodynamic drag.

Branson said: “From our airlines to our trains to our spaceline, we have long been passionate about innovation in transport, especially the development of technology that could transform people's lives. This is just the latest example. Importantly, Virgin Hyperloop One will be all-electric and the team is working on ensuring it is a responsible and sustainable form of transport too.”

In July 2017 the company said it had completed tests at a DevLoop site outside Las Vegas. The vehicle reportedly coasted above the first portion of the track for 5.3 seconds and reached nearly 2G acceleration while achieving a target speed of 70mph. Hyperloop One XP-1, the company's first-generation pod, then completed phase two with a top speed of 192mph over a maximum distance of 436m. ■

STRUCTURAL

After the shaking stops

Protecting buildings from earthquakes

UK-developed structural engineering technology could protect buildings from earthquakes, preventing collapse and reducing the damage.

Developed by a group at Heriot-Watt University in Edinburgh, the system makes use of stainless steel ‘sacrificial devices’ that are placed strategically in the

structure so that they are the only damaged components during earthquake loading.

Current European ‘earthquake-proof’ buildings do not prevent extensive damage, or the permanent deformation of a building after it has stopped shaking.

Dr George Vasdravellis, assistant professor in structural engineering at Heriot-Watt, has used computer simulations to prove that his new system minimises the damage caused to buildings up to 10 storeys high in an area of high seismicity, with one in 475-year seismic events. **JE**

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MEDICAL

Quicker scans for heart disease

UK technology undergoes clinical trials in the US

HELEN KNIGHT REPORTS

A UK technology that scans patients for signs of heart disease quickly and non-invasively is to undergo clinical trials in the US, following clearance by the Food and Drug Administration.

Vitalscan, which is already two-thirds of the way through a clinical trial in four UK hospitals, will now be tested in emergency departments in the US.

In Britain, over five per cent of visits to A&E departments, and up to 40 per cent of emergency admissions, are the result of chest pain.

While around three-quarters of these patients will ultimately be

you turn up to a hospital with chest pain, it is very easy to detect a heart attack or other serious cardiac event, but the reality is that it can take up to 20 hours of investigations for clinicians to be able to tell that you do not have a serious heart problem."

The Vitalscan device is based on magnetocardiography, which maps the magnetic field of the heart, said Parker.

"The heart has an electrical function, and obviously with every electrical function there is a magnetic signal," said Parker.

Although these magnetic signals

are extremely small, even a slight disruption, caused by ischaemic heart disease, for example, will distort the entire magnetic field, and can be clearly seen on the scan.

The device uses a noise-reduction algorithm that allows it to detect these small magnetic signals.

"The signals given off by the heart are about one-millionth the size of the magnetic field of the Earth," said Parker. "So a big part of the advance has been in the software, and the noise-reduction algorithm that we use to be able to see the signal and differentiate it from the background," he said.

The portable, battery-powered device can be used to perform a quick, non-invasive scan lasting up to five minutes at a patient's bedside. This can then allow doctors to quickly and accurately rule out ischaemic heart disease, meaning patients can move on to the most appropriate care. ■



In Britain, over five per cent of A&E visits are the result of chest pains

"With electrical functions there is a magnetic signal"

Steve Parker

Creavo Medical Technologies

found not to have a serious heart condition, they must all undergo a series of rigorous and expensive tests, according to Steve Parker, CEO of Vitalscan developer Creavo Medical Technologies.

"Most people would think that if

MATERIALS

Small screen breakthrough

Material could mean cheaper phone screens

Silver nanowires have been combined with graphene to develop a material that could make smartphone screens cheaper and less prone to shattering.

Screens are currently made with indium tin oxide, which is brittle and expensive. Indium is also a rare metal and is ecologically damaging to extract.

"What's exciting about what we're doing is the way we put the graphene layer down," said Prof Alan Dalton, from the School of Mathematical and Physical Sciences at Sussex University. "We float the graphene particles on the surface of water, then pick them up with a rubber stamp... and lay it on top of the silver nanowire film in whatever pattern we like."

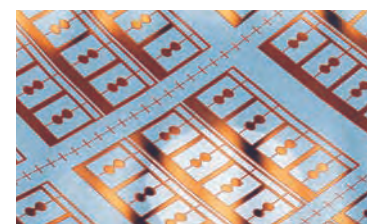
"And this breakthrough technique is inherently scalable. It would be relatively simple to combine silver nanowires and graphene in this way on a large scale using spraying machines and patterned rollers." **JF**

ELECTRONICS

Graphene is growing for flexible form

Detector could feature in wireless networks

HELEN KNIGHT REPORTS



Researchers at Chalmers University of Technology in Sweden have developed a first-of-its-kind flexible detector for terahertz frequencies using graphene transistors on plastic substrates.

The detector, which is presented in a paper in the journal *Applied Physics Letters*, could extend the use of terahertz technology to applications such as wearable electronics and low-cost wireless sensor networks.

Terahertz radiation refers to electromagnetic waves whose frequencies range from 100GHz to 10THz.

To develop the terahertz detector, the team used chemical vapour deposition to grow a single-layer graphene sheet, which they then transferred to a 10cm wide, 175µm thick plastic substrate.

They then used electron beam lithography to fabricate the electronic circuits needed to create the detector.

Graphene is a promising material for terahertz detectors, as it is flexible and mechanically stable, and is a good conductor of electricity, according to Prof Jan Stake, head of the Terahertz and Millimetre Wave Laboratory at Chalmers.

"Graphene has the advantage of both good electrical properties and good mechanical properties," said Stake. "It could be used in sensors that are placed close to the body, or even for imaging applications."

At room temperature, the flexible device can detect signals in the range of 330 to 500GHz. ■

MATERIALS

Let there be polarised light

Breakthrough has potential to boost data transfer and drug discovery **ANDREW WADE REPORTS**

Researchers at King's College London have developed a new technique for instantly switching the polarisation of light.

The breakthrough, which has the potential to provide a major boost for data transfer and drug discovery, uses nanostructured metamaterials to manipulate light. Changing light's polarisation is how digital information is transmitted along fibre-optic cables. However, current commercial techniques for doing so are approaching their physical limits, according to the King's team.

"We report a switching rate of over 300GHz"

Luke Nicholls
King's College London

"Currently, Pockels Cells or Faraday Rotators are used to electronically control the polarisation of light with an electric or magnetic field," said Luke Nicholls, the PhD student who carried out the experiments.

"The commercially available fastest product operates at a rate

of 40GHz. We report a switching rate of over 300GHz. The metamaterial approach also has the advantage that it is easily integrated with nanoscale technologies. Pockels Cells and Faraday Rotators are big and bulky in comparison, and could never be integrated 'on chip' for example."

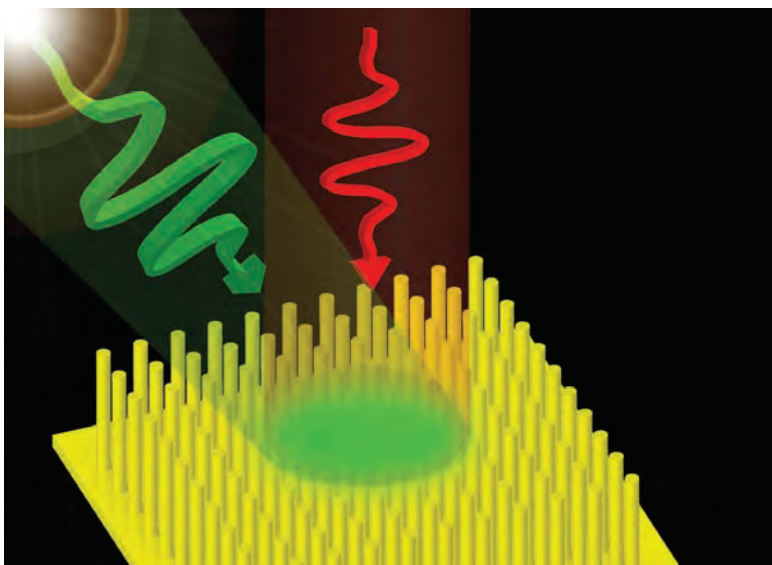
Made from gold nanoparticles, the metamaterial manipulates the light using a technique known as 'all-optical polarisation control'. A high-intensity light pulse is fired into the metamaterial, injecting energy into electrons in the gold particles, which changes the

refractive index of the material.

A second pulse is fired at the metamaterial simultaneously. As this pulse passes through the material, the change in refractive index changes its polarisation. This happens instantaneously, allowing polarisation to be changed trillions of times per second.

As well as improving data-transfer rates, the technology could also be used to aid pharmaceutical R&D. According to Nicholls, many drugs have only one specific configuration that is effective, while others can range from useless to toxic. By studying how chemicals interact with light polarisation, it is possible to determine which configurations are present.

"However, chemical processes tend to happen very fast," said Nicholls, "so if you can quickly switch to different polarisation states of light and observe how they interact with the chemical as it is being made, drug developers can understand the processes that lead to unwanted configurations and remedy them." ■



Changing light's polarisation is how digital information is transmitted

TRANSPORT

Share a future ride on the Big Smoke streets

Project looks at autonomous vehicles

JASON FORD REPORTS

A year-long project is underway to study how autonomous vehicle ride-sharing can work and connect with London's transport network.

Backed by Innovate UK, the Merge Greenwich consortium – led by global fleet operator Addison Lee Group and including partners Ford, TRL, Transport Systems Catapult, DG Cities and Immense Simulations – will develop a world first, custom-designed blueprint that demonstrates Britain's mobility capability.

"The Merge Greenwich partnership will pave the way for autonomous vehicles on the streets of London at scale, to provide significantly improved transport," said Paul McCabe, Addison Lee Group's director of mobility. "This will put London at the forefront of mobility development, globally."

The consortium believes that autonomous ride-sharing services could account for a third of all trips by private drivers in London by 2025, and a study predicts that 34 per cent of private drivers' journeys could be replaced. Up to 30 per cent of taxi and private hire journeys could also be served by Autonomous Vehicle (AV) ride-sharing.

Overall, an AV ride-sharing service could serve up to one in seven of all trips in London within eight years, equivalent to 2.5m trips per day, and take up to 25 per cent of the total transport market by value, which is currently worth around £3.5bn.

"The idea that one in three London car journeys could be replaced by autonomous vehicles by 2025 shows the huge potential in the sector," said Andy Boland, Addison Lee's CEO.

The next stage in the project could see real-world testing to see how AV ride-sharing services could contribute to London's new mobility vision. ■

SCANNERS

Bringing up the 15th century

Scanners reveal navigation tool on old Portuguese explorer ship

Scanning technology at WMG has been used to reveal details of an astrolabe, a navigation tool found in the wreck of a Portuguese explorer ship that sank in 1503.

The late 15th century astrolabe, which is believed to be the earliest-known marine navigation tool, was

used by mariners to measure the altitude of the sun during voyages.

It was excavated by Blue Water Recoveries, which could not see any navigational markings on it so the firm took it WMG's Prof Mark Williams to reveal the artefact's invisible details. Scans proved it was an astrolabe because markings were found etched around the edge of the object, each separated by five degrees.

These would have allowed mariners to measure the height of the sun above the horizon at noon to determine their latitude model. **JF**



Addressing the EU particulate problem

Is too much being expected of electric vehicles in our efforts to cut air pollution, given that non-exhaust emissions play a significant part in air quality too?

Road traffic has had a bad press in recent times over its influence on air pollution. Current estimates are that air pollution in the UK is associated with around 40,000 premature deaths per year, which exceeds the number of deaths in road traffic accidents by more than a factor of 20.

Hence this is an important public health problem, but is it solely due to road traffic, and will electric vehicles provide the necessary solution?

As with many environmental questions, the issues are not black and white. There are two air pollutants that are largely responsible for the excess mortality and hospital admissions associated with air pollution exposures, which are nitrogen dioxide (NO₂) and particulate matter. Measures recently announced by the government are intended to address NO₂ levels, which widely exceed health-based air-quality guidelines and the EU Limit Value.

Most outdoor exposure to NO₂ arises from tailpipe emissions from road traffic of both NO₂ and its fellow oxide of nitrogen, nitric oxide. Other sources such as fossil-fuel power stations also emit oxides of nitrogen but these are relatively dilute when they reach ground level. Oxides of nitrogen are a product of high-temperature combustion processes; consequently, a switch to electric vehicles would wholly eliminate emissions from the vehicles themselves, although there would be enhanced emissions from power stations if burning fossil fuels.

The case of particulate matter is more complex. Tailpipe emissions of particles, mainly from diesel engines, impact significantly on urban air quality but are not the sole consequence of road vehicles. The oxides of nitrogen emitted mainly from diesels are converted slowly in the atmosphere to nitrate particles, which contribute to the atmospheric concentration of fine particulate matter referred to as PM2.5.

The other source from road traffic comes from non-tailpipe emissions that arise from the wear of brakes, tyres and road surface, and from the suspension of road-dust particles in the wake of passing vehicles. These sources of particles are not currently the subject of regulatory controls and

they now exceed the exhaust emissions from the vehicle fleet.

This situation has evolved over recent years; the Euro 5 and Euro 6 diesels that have been on sale since 2011 are fitted with diesel particle filters and have greatly reduced exhaust emissions of particulate matter. There have been numerous studies of the effects of airborne particles on human health, many of which in recent years have tried to differentiate the toxicity of particles of different composition and size arising from various sources. These do not paint a consistent picture and the current advice from the government's advisory committee, COMEAP, is that all should be treated as being of equal toxicity per unit mass.

So will there be a benefit from electric vehicles? As noted above, diesel vehicles currently on sale are fitted with particle traps and emit low levels of particulate matter, as do petrol vehicles. Hence the introduction of electric vehicles will have relatively little influence on exhaust emissions compared to a fleet of current-technology diesels.

The situation with regard to non-exhaust emissions is more complex. It is likely that emissions of brake-wear particles from electric vehicles will be greatly reduced because much of the deceleration will be achieved through regenerative braking as opposed to the application of mechanical brakes. However, it has been argued that, due to their heavy load of batteries, electric

vehicles will be heavier than internal combustion engine vehicles and, if this is the case, they would be expected to generate higher emissions of particles from tyre and road-surface wear and from suspension of road-surface dusts.

Yet current evidence suggests that not all electric vehicles are heavier than their fossil-fuel counterparts, so the change in fleet-averaged emissions is uncertain.

There are clear solutions to the brake-wear particle issue through regenerative braking on electric vehicles, use of low-emission materials (discs and pads) and the development of particle collection devices for disc brakes. However, the solution for tyre/road-surface wear has received far less attention and will require extensive research on the influence of the tyre compound and the road-surface material and texture upon particle generation and emissions.

Studies of road-surface washing have shown a substantial reduction in suspended dust particles, but lasting for only a few hours. Dust-suppressant coatings such as calcium magnesium acetate have also been tested as a way of sticking particles to the road surface, but these too are of limited efficiency. Hence solutions to the dust resuspension source are currently elusive. ■

Prof Roy Harrison OBE, FRS works at the School of Geography, Earth & Environmental Sciences, University of Birmingham



Particles from tyre and road-surface wear have received far less attention than exhaust emissions



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The **hot** topic



Train time?

Our recent online poll on the future of rail sparked a heated debate

As a form of public transport the train is dying; very few people will abandon their car to go by train. Inner-city transport still works but for long journeys the train is not a viable option, unless it is a very popular route. However, it's not all doom and gloom: freight transport does work because time and cancellations are not an issue. I like the train and I don't want to see its demise but too much time and money will be required to bring it up to date. The money is there but the powers that be want to spend it on a white elephant called HS2.

Chris

The solution to the rail problems is driverless trains. All the other issues can be dealt with by self-funding improvement. An efficient rail service is cheaper to run than an inefficient one, so problem-fixing and improvements will fund themselves.

Ian Downie

The mistake was not to mothball the Great Central in the 1960s. HS2 will be using parts of that line now but at considerable cost. Downgrade HS2 to 125mph and serve more stops on the way. Then more people will be able to access it, not just a few highly paid folks in the cities.

David Child

The reality is that no government will take the hard decisions about railways. China can build a bullet-train service running at 300mph by laying dead-straight tracks of suitable gauge and very few stops. Anything in the way gets not just demolished but rebuilt as close to its original location as possible. That is what HS2 should be. The reality of HS2 is too many bends, too many stops, poor planning and a real speed of 125mph – if we are lucky. And, yes, driverless trains if possible and safe. The RMT can keep the local services and run them into bankruptcy.

Steve

The train will disappear; quite simply because it will become an anachronism. Why do we need tracks now we can have automated steering? Why do we need heavy rolling stock designed to pull a line of similar units in a 'train'? Why do all passengers have to endure stops at other stations en route to their destinations? And perhaps worst of all, why does all the traffic have to be speed limited by the unit in front, with no passing facilities? This is not a rant for roads. What we need is lines – where non-rail transport units can follow fixed routes and with scope for 'overtaking'; and much, much smaller units that can take passengers direct to their destination, so that every trip is on an 'express' and many more of these smaller units, allowing greater frequency of services. It's high time we started planning the end of the 'age of the train'.

Jeff Holden

The railways have been ill served by politicians and the industry itself for decades. It has become fat dumb and happy, and treated passengers and freight customers as an inconvenience. The rail sector has lost touch with markets it could service, including freight at shorter sector distances than the 300km mantra always suggests. It became enamoured of big, slow and heavy trains only to find the government shot them in the back by closing coal-fired power plants. The rail sector believes it can just walk into markets on the basis of being a good thing. Its prevailing commercial, operating and technical model is not relevant for high-value, time-sensitive logistics traffic, which brings with it imperatives rail does not even recognise. The sector is excessively regulated by comparison with road transport. The rail sector can be meddled with by, for example, the Department for Transport (DfT) and Network Rail, but these agencies bear none of the responsibility for selling services into a very competitive market. Perhaps they should be seconded to do so. The superstructure is excessive and will capsize the sector. It needs to be simplified and driven by commercial imperatives. Recent failures by the DfT/Network Rail in relation to electrification need to be clearly pointed out. This has compromised other sound electrification schemes but the DfT seems to believe in hydrogen, fuel cells and other exotics. The secretary of state for transport believes diesel trains are "better" than electrification. His grasp of physics, traction technology and economics is patently flawed. Perhaps stopping HS2 and using the money for more practical options to wire up much more of the network for freight and passenger operations would be a scheme yielding greater value for money.

Phil Mortimer



The **secret** engineer

There are few things more irritating than a senior management team that wilfully ignores sensible advice, writes our anonymous blogger

A few years back I had a constant battle with keeping my temper at work. I was suffering from a building rage that came from fighting a steady battle over a number of years but finding my efforts constantly dismissed or thwarted.

Ours was a small company with less than 10 members of senior staff and by this stage it was a company and team that I'd been a part of for a few years. The process had started on my arrival there. Immediately I had identified a number of serious failings and risks, and brought them to the attention of anyone who would listen. However, there was a complete lack of interest from the top all the way down. You will have to take my word for it that I am talking about extremely basic matters, and that if I was only 20 per cent correct in my assessment then that was still an awful lot of the company that was worryingly sub-optimal.

Then a combination of steady erosion of performance and a few temporary loadings towards those areas of risk resulted in quite a sustained problem. Yet not only were my views still rejected but the same old tactics of inefficient fire fighting and knee-jerk reaction were deployed once more.

This resulted in us generally muddling through day to day but did very little to claw back the situation – and what it did achieve was attained in the least-efficient way possible. Approximately 50 per cent of the senior team agreed with me (or I with them, if you prefer) regarding where the problems lay and the



obvious ways to tackle them. Unfortunately the problems were also led from the top along with the other 50 per cent of the senior team through their inadequacy or inefficiency.

I tried everything to change things for the better. Private informal chats; encouragement; explaining how good working practices could mitigate against risk; blazing rows even. Sadly nothing could sway the CEO from his suicidal course or those who were failing us all from maintaining their woeful performance. To be able to see such problems, and to have what you know to be sound advice coupled with appropriate skills to help resolutely ignored is an infuriating experience.

The obvious solutions are 'leave' or 'put up with it and take the money'. These bring their own problems though and it's because of the dreaded 'p word' – professionalism.

With the company in such a parlous state I

knew that the loss of a senior member of staff might be enough to tip it over the edge. Of course, no one is indispensable but this could have been the final problem that would sink the whole enterprise. Probably not too horrendous for the members of the senior team who could either retire or move into positions in other companies, but possibly critical for the workforce on the shop floor. A mixture of skilled and semi-skilled, mainly on the minimum wage, few transferable skills and probably without savings to keep them going while they found somewhere else.

Equally it was difficult to carry on as a complicit drone while those who should have been central to rescuing the company from its predicament continued to swing the lead and cause further problems while bleating on about how terrible it all was.

I'm not sure if how it all ended was the best that could be hoped for given the circumstance (nothing radical or shocking but something that must remain shrouded in mystery to prevent my accidental unmasking) but for my part I did the best I could at the time. Not for the shareholders perhaps, nor the rest of the senior team or even possibly the customers (although by default I should imagine it was); but rather for those whose direct livelihood was most vulnerable.

Altruistic or selfish, shareholder or customer – just how does one determine where professional loyalties should lie and how such problems are dealt with? ■

In **your** opinion

The Scottish government's ban on fracking triggered a lively discussion

With North Sea oil diminishing, it is economic madness for us in Scotland to ban fracking. I would put this scaremongering on the same level as the GM protests of a few years ago.

Graham Sturgess

Having worked directly in drilling operations for 10 years I would be extremely uncomfortable with any drilling operations going on in the central belt of Scotland. Oil companies, drilling contractors, and service companies are experts in box ticking. The mantra of safety is a 'cover-your-backside' operation where, if the correct procedures have

been followed, your work is done. It would be nice if procedures could be written that cover every eventuality but that is simply not possible.

John William

What areas might benefit from a Bloodhound-style STEM strategy?

We are currently working on introducing a robotics competition in China where there is a great deal of enthusiasm for this technology as a mechanism for exciting youngsters, both boys and girls. If it works well, we will explore the UK as well.

Martin Stevens

I think the work of Reaction Engines is ideal for this in terms of a unique UK technology. The next

stage of moving to an actual spacecraft – Skylon or others – would be good for young people to explore and get involved with.

Paul Reeves

There are a lot of interesting projects out there but they are rarely promoted in the mainstream media. Maybe the problem is the lack of real, committed STEM promotion to the nation rather than just promoting it to those in the trade?

Steve

Space rockets worked for me back in the 1960s.

Clive Bagley

Join the debate
theengineer.co.uk



Budget could have big consequences

The forthcoming budget is an opportunity to promote the growth of high-value innovative engineering

On 22 November, the Chancellor of the Exchequer will deliver a Budget that has the potential to be of great significance for engineering. With economic growth sluggish at best and the headwinds expected to increase as the country drifts closer towards exiting the EU, the package of measures to be unveiled in the House of Commons may have a significant bearing on the outlook for the UK's engineering companies. This is important because engineering-based sectors make a vital contribution to UK growth and jobs.

For starters, engineering companies play a central role in fuelling UK exports. Historic data suggests that engineering-related sectors account for nearly half of all UK exports, more than double the share of gross value added accounted for by those sectors. Engineering also accounts for a significant proportion of business R&D investment. Government has recognised that the UK under-invests in research and development, and has committed to meet the current OECD average for investment in R&D – 2.4 per cent of GDP – within 10 years, with a longer-term goal of 3 per cent. Towards this end, in the 2016 Autumn Statement, government announced an uplift of R&D investment amounting to £4.7 billion over the next four years – the biggest increase in total government R&D investment since records began in 1979.

A substantial body of evidence has shown that public investment 'crowds in' private investment but it is clear that additional action will be needed to stimulate the business investment in R&D required to reach the 2.4 per cent target. The top six sectors for R&D investment, which together account for 65 per cent of the total UK business R&D expenditure, are either engineering-based (such as motor vehicle manufacturing) or highly dependent on engineering (such as the scientific R&D industry). Business investment in R&D includes both activity undertaken entirely within the private sector and in collaboration with universities. The latter can deliver substantial business benefits, as well as giving academics access to a rich seam of intellectually stimulating real-world problems, as evidenced in the 2015 Review of Business-University Research Collaborations by Prof Dame Ann Dowling.

The Dowling Review also highlighted that business engagement in these collaborations was extremely patchy. A recent analysis published by Elsevier noted that, although the UK accounts for a small proportion of global patenting activity, a high proportion of UK research is cited in patents internationally. Increasing the number, range and depth of UK business-university collaborations could help to ensure that the government reaps the benefits of its investment in the research base, as well as improving the competitiveness of UK businesses.

Another key contributor to growth is innovation – the process by which ideas are converted into value, in the form of new and improved products, services and approaches. While it may draw on R&D, innovation is not synonymous with it and can arise out of developments in design, business models and mechanisms of service delivery, as well as in technology. Once again, engineers have a vital role to play: sectors with high concentrations of



graduate engineers report higher-than-average levels of innovation activity and innovation-related income, as well as higher levels of labour productivity.

While most investment in innovation takes place in the private sector, government can greatly influence the climate for innovation, as well as playing a catalytic role in financing it. Investing in innovation is inherently risky because the outcome is uncertain and benefits may be delivered over long time horizons. Patient capital – which refers to investments made with an expectation of yields over longer time periods than is typical – is therefore of critical importance for innovation financing and, as such, is currently the focus of a government review. In general, the investment structure in the UK is perceived to be quite short term in nature, with many funds structured so that returns on investments are expected in seven to 10 years. The findings to date show that fewer UK firms receive follow-on investment compared to the US, and those that do receive less.

However, the picture for innovation financing in the UK isn't all bad. The UK actually has one of

the most favourable environments for angel investing, largely due to the highly successful Enterprise Investment (EIS) and Seed Enterprise Investment (SEIS) schemes, which provide tax reliefs to investors who buy new shares in qualifying companies. In addition, the British Business Bank has made a positive contribution, including through significant investments in growth finance funds and lenders in the UK scale-up sector.

It remains to be seen if the UK can continue to maintain a relationship with the European Investment Fund (EIF). From 2011 to 2015, this fund supported 144 venture capital and private equity funds in the UK and had €2.3 billion in commitments in the UK, leveraging a further €13.8 billion of additional funds.

The Budget provides a valuable opportunity for the Chancellor to bolster business confidence and promote the growth of high-value, innovative engineering businesses that generate jobs and opportunities. Let's hope he delivers. ■

Dr Hayaatun Sillem is deputy chief executive of the Royal Academy of Engineering

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Untapped potential

Pumped hydro is an old solution to a new problem. Andrew Wade reports

It's often assumed that to mitigate the worst effects of climate change we need an energy revolution incorporating a raft of new ideas. However, the core technologies needed to decarbonise the power sector already exist in the form of renewables, with wind and solar now the fastest-growing sources of new generation.

One major problem, as critics are quick to point out, is intermittency. If that problem could be solved, the energy sector could be transformed within a few short decades. And, as it happens, several countries are betting that we already have the answer.

In pumped hydro storage there is a tried-and-tested technology that not only fits the bill but has been doing the job for well over a century. First employed in the 1890s, pumped hydro makes up 97 per cent of energy storage worldwide, with around 168GW currently installed. Excess off-peak grid power – theoretically from renewables – is used to pump water uphill, where it's stored as gravitational potential energy. When electricity demand is high, water is released downhill to power turbines, the elevated reservoirs essentially acting as giant batteries to help balance the grid.

Currently, the UK has four operational plants. When the youngest – Dinorwig in Snowdonia – was built over 30 years ago, it was the largest civil engineering contract ever awarded by the government. Today, just up the road in Glyn Rhonwy, a new pumped storage venture is being developed by private company Snowdonia Pumped Hydro (SPH). With 99.9MW of output and 700MWh of storage capacity, it won't solve the climate change problem singlehandedly. However, the process behind its selection also threw up hundreds of other viable UK sites. By exploiting just a handful of these, pumped hydro could be the last missing piece of the clean energy puzzle.

"We basically started with a few databases of lakes, mines, quarries and so on, and we wrote a little algorithm that would compare them, to see how close they were and try and make matches," explained Dave Holmes, managing director of Quarry Battery Company (QBC), the parent firm behind SPH.

"We got down to maybe 1,000 sites, or potential pairs, and then we cruised around the country on Google Earth having a look at them all and trying to figure out which ones were the best."

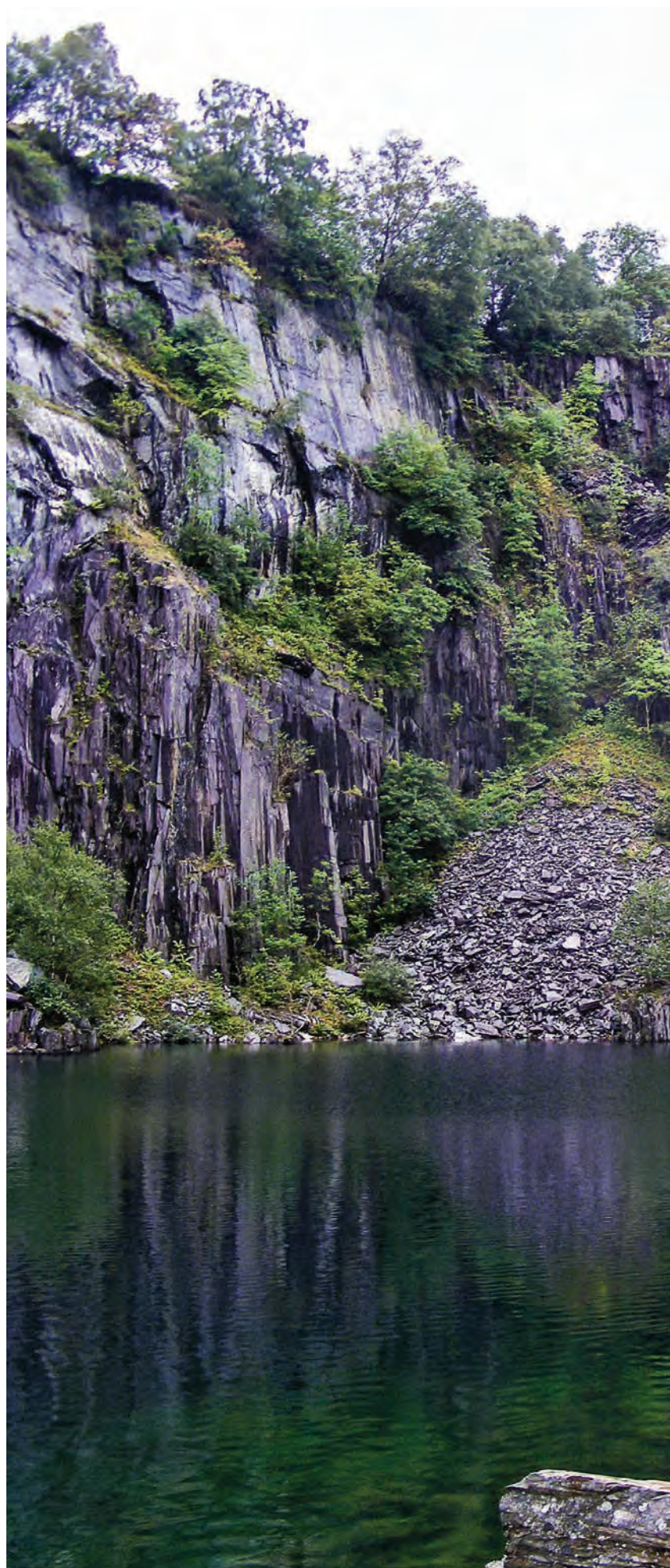
The dual bodies of water ideally need to be similar in size, with a suitable disparity of altitude, or head. As well as identifying sites that were technically desirable, the team had to consider other factors such as planning risk, proximity to the grid and nearby areas of conservation. Glyn Rhonwy's two disused slate mines ticked a lot of boxes.

"There were a few things in its favour," said Holmes. "It's pretty close to the National Grid transmission system. The length of the tunnel that you need in comparison to the head; it's a very steep site, which means the tunnel we're building isn't too long. The gradient is actually quite a challenge. It's 19 per cent... and we're looking to go in a single slope all the way to the top."

The site also happened to be owned by the local council, which had plans to develop the lower reservoir into an industrial estate. Accommodating SPH's powerhouse would not be a huge departure.

01 Glyn Rhonwy's lower reservoir is a disused slate mine

02 The upper reservoir, with views across Snowdonia





01



02

“It’s a proven technology that can be deployed at the tens of GWh scale”

Andy Gregory, SSE

“We see it as recycling the land rather than using some new land for the site,” said Holmes.

Glyn Rhonwy gained approval for a 49.9MW plant several years ago, but changes in the energy market prompted SPH to rethink the design. The revised plan for the 99.9MW facility was greenlit in March 2017. According to Holmes, the only significant change was the inclusion of two 49.9MW turbines instead of the original pair of 24.95MW devices.

“We found there was more capacity there than we first understood, and it would have been a waste of that capacity to not have a more powerful turbine on it,” he explained.

The National Grid’s capacity mechanism also helped incentivise the change. Despite having 600MWh of storage in the original plans, SPH would have been rewarded only for its 49.9MW output. By doubling that to 99.9MW, the project will double the income it earns via the mechanism. The revised 700MWh capacity will be enough to supply 200,000 homes with electricity for seven hours a day. Although construction costs will increase from £140m to £160m, Holmes believes the payback period on the investment should be halved to under 10 years – a fraction of the plant’s projected 125-year operational lifetime.

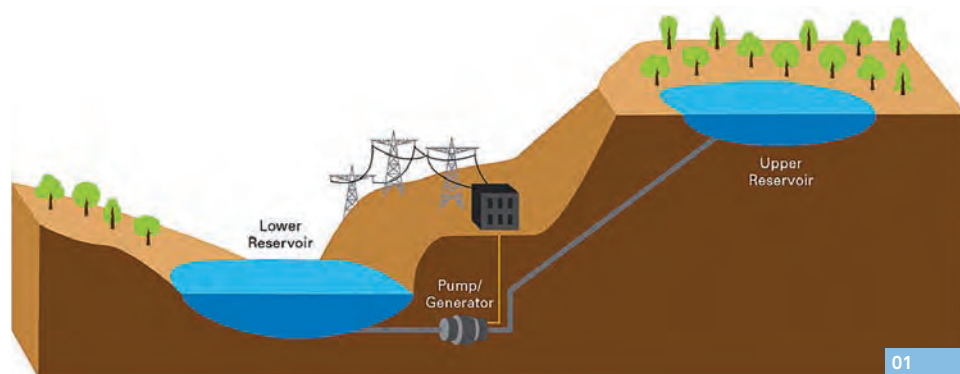
“It’s a very exciting time because we can see a light at the end of the tunnel,” he said. “We’re hoping to break ground sometime next year, but it could be early the year after.”

As construction gets under way in Glyn Rhonwy, a pumped hydro plant of an altogether different breed will be nearing completion some 8,000km away. Located just to the north of Beijing, the Fengning Pumped Storage Power Station will have an installed capacity of 3,600MW, making it the largest pumped hydro facility in the world. Its generators will be fed by an upper reservoir holding nearly 49 million cubic metres of water – enough to fill about 19,500 Olympic pools. By comparison, each of Glyn Rhonwy’s reservoirs will hold just over 1 million cubic metres.

The \$1.87bn (£1.42bn) Fengning plant will be equipped with 12 x 300MW pump turbines in a single cavern. Ten of these will be fixed-speed units contracted from local suppliers. The final two will be variable-speed pump turbines provided by Andritz, the Austrian engineering giant with a long history in hydro power.

“The major difference is in a completely different generator design,” Alexander Schwab, Andritz SVP of market management, explained to *The Engineer*. “With conventional synchronous generators, the number of poles and the frequency of the grid are defining the rotational speed of the unit. That defines the design speed of the turbine/pump. Consequently, for pump turbines it is necessary to find a compromise between optimal turbine and optimal pump.”

According to Schwab, the variable turbines will allow operation ranges for pumping and generating to be designed individually. This should enable Fengning to better manage its output and provide more grid flexibility.



Andritz has previously installed the technology at Germany's Goldisthal pumped storage facility, but this is the first time variable speed units will be used in China's ever-expanding hydro sector. "Taking all the facts into consideration, it will be a project needing the utmost attention from the Andritz side," said Schwab.

When Fengning comes online, China will have three of the four biggest pumped storage facilities in the world. The technology is seen as increasingly vital if the country is to wean itself off the coal that has powered the industrial progress of recent decades. Air pollution across China, particularly around Beijing, has reached such worrying levels that it is no longer simply a public health issue. Speaking recently, the country's environment protection minister, Li Ganjie, admitted that air quality had become a matter of social stability. Although it remains the world's biggest polluter, China has committed to reducing CO₂ emissions by 60-65 per cent before 2030. If this is to be achieved, massive expansion of renewables, coupled with pumped storage, will need to play a key role.

Back in the UK, plans are afoot for another major project. While not on the same scale as Fengning, the Coire Glas pumped hydro plant will boast an output of 1,500MW. It will lie to the east of Fort William, in the Great Glen of the Scottish Highlands. Using Loch Lochy as the lower body of water, developer SSE plans to build an upper reservoir 500m above, with a relatively steep incline delivering good energy efficiency.

The project received planning permission several years ago for a smaller 600MW plant but, similarly to Glyn Rhonwy, those plans have had to be scaled up in a bid to make the project more commercially attractive. In May 2017 SSE submitted a scoping report for the revised scheme, and a decision from the Scottish government is expected in the near future. Importantly, Coire Glas will have the capacity to store a massive amount of energy – around 30GWh – more than all existing UK storage capacity combined, according to SSE. The firm says this will help provide the flexibility required for integrating more renewables, as well as the changing usage patterns expected from the growth in electric vehicles.

"SSE considers there to be clear benefits in the delivery of new pumped storage projects in the UK," Coire Glas project manager Andy Gregory told *The Engineer*. "It's a proven technology that can be deployed at the tens of GWh scale, with a short response time and the ability to provide a number of important services to the system."

Across the UK there are hundreds of potential pumped hydro sites, with the low-hanging fruit adding up to around 50GWh. According to QBC's Holmes, these are mainly in Scotland and Wales due to topography.



01 Excess electricity is used to create gravitational potential energy

02 Andritz is supplying variable-speed pump turbines for China's Fengning project

"Our best guess at how much is economic already or will be economic soon is around 50GWh," he said.

Some of these sites are similar in nature to Glyn Rhonwy and Coire Glas, where dual bodies of fresh water would work in tandem. Other sites, however, are less conventional. QBC has been awarded funding to explore the viability of non-standard sites around the UK, looking at seawater, drinking water and lower-head opportunities.

Seawater, in particular, presents both a unique opportunity as well as unique challenges. Using the sea as the lower 'reservoir' unlocks a host of locations that would previously have been overlooked as, in theory, all that's required is elevated land close to the coast. But seawater brings complications such as fouling and corrosion, and using the open sea can impact on marine life, and have unwanted effects on the coastal profile.

To date, just a single seawater project has been commissioned – Japan's Okinawa Yanbaru Seawater Pumped Storage Power Station. Built in 1999, it featured a striking octagonal upper reservoir set into the lush coastal vegetation. Instead of steel, the penstock was made of fibre-reinforced plastic to avoid corrosion and barnacle fouling, and the pump turbine included stainless steel to improve seawater resistance. Although widely hailed as an engineering success, the plant was shut down in 2016 as it no longer fitted local power demands.

Despite just one pilot project, seawater pumped storage is being explored in several countries, including the UK. South Australia's proposed Cullana plant could generate 225MW of electricity with eight hours' storage. The region already supports renewables, but arid conditions make traditional pumped hydro tricky. Combining existing solar and wind generation with coastal storage plants promises to be an innovative solution.

Elsewhere in Australia the planned Snowy Hydro 2.0 project will look to add pumped storage to the long-established hydro generation already in place. If completed, it will add generation capacity of 2,000MW and a massive 350GWh of storage. This year, a government-backed study by the Australian National University (ANU) into other viable locations identified 22,000 sites, the bulk of which are on the more densely populated east coast. Combined, these could provide around 67,000GWh of storage.

"We need to build only about one or two dozen to support a 100 per cent renewable electricity grid," Andrew Blakers, a professor of engineering at ANU and one of the report's authors, said recently.

"Pumped hydro, high-voltage DC interconnectors between the states, wind, batteries and demand management can do the whole job. Not just for electricity, but the whole job for energy: electrifying land transport, electrifying heating and cooling. You can have 75 per cent cuts in Australia's greenhouse gas emissions by electrifying nearly everything, and I think this is what's going to happen over the next 15 to 20 years."

The UK's topography may not be as rich as Australia's in terms of potential sites but there are ample resources to exploit. If tidal lagoons finally get the green light, they could also include a pumped hydro element, as well as help balance the grid via their natural geographic dispersion. And, with wind and solar costs still tumbling, there's no reason why the UK couldn't fully decarbonise over the next two decades. The fact that the Aussies are already in the race can only bring added incentive. ■

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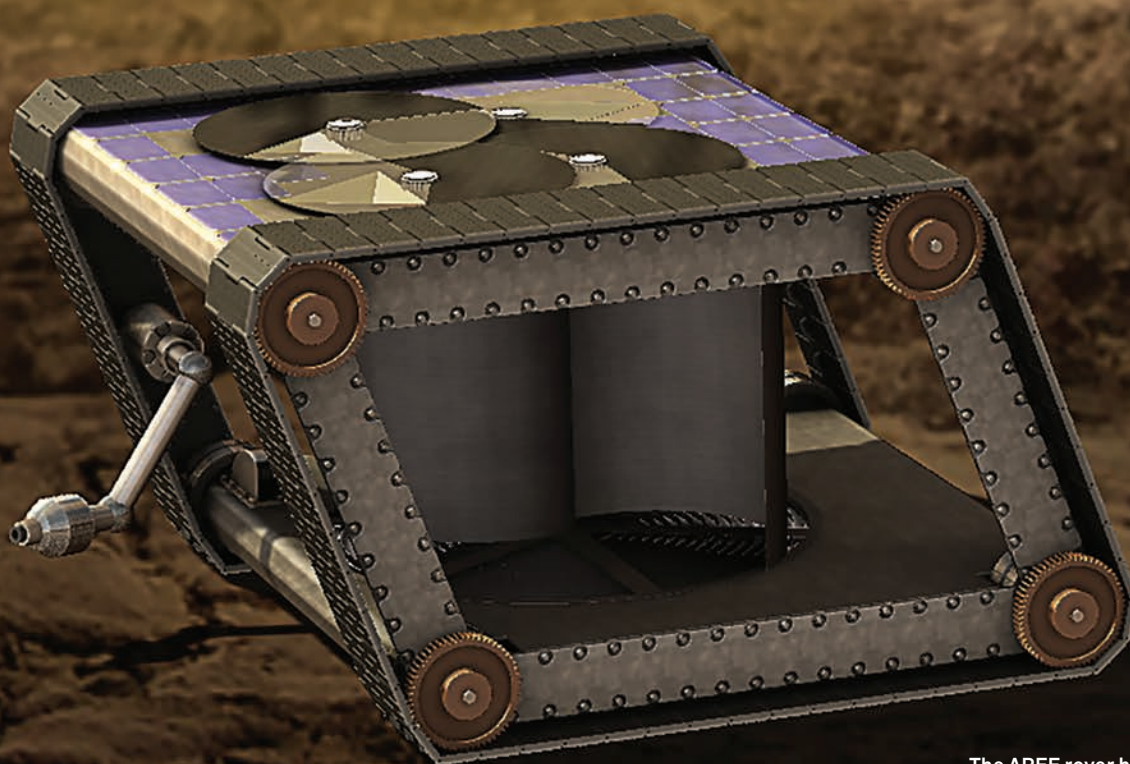
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Clockwork rover

Our nearest planetary neighbour could help us find life elsewhere in the universe, but to get there we'll need to go back to basics.

Stuart Nathan reports



The AREE rover has a horizontally symmetrical tracked design so it can move even if flipped over

Such is our fascination with Mars that it's easy to assume it's our closest neighbour. The subject of songs, books and films, the Red Planet has been intensely studied by orbiting probes, landers and rovers. It's currently the only known body in the universe that's entirely populated by robots; and it's the target for projected crewed missions in future decades.

But Mars is not our nearest neighbour. That distinction goes to Venus, which, at its closest (once about every 584 days), is around 25 million miles (40 million km) from Earth, compared to Mars' closest approach of 34 million miles. But we know comparatively little about Venus, having not investigated it nearly as closely as Mars nor sent as many missions.

This is because Venus is very difficult to study. The planet's surface is shrouded in a thick layer of opaque clouds, preventing it from being visible from Earth. Conditions there are frequently described as hellish. The surface temperature reaches around 475°C, above the melting point of lead, and the atmospheric pressure is more than 90 times that on Earth, enough to crush the hull of a nuclear submarine.

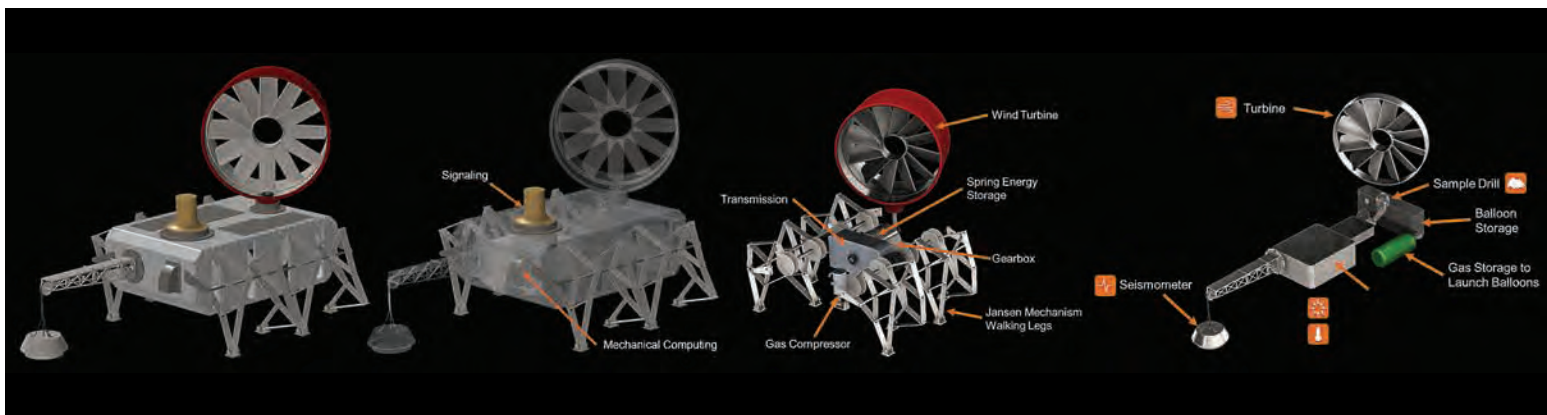
Only 10 landers have reached the planet's surface, the most recent in 1985.

Thanks to the temperature and the corrosive properties of the high-pressure CO₂ atmosphere, the longest any probe has remained functional is two hours and seven minutes, achieved by the Soviet Venera 13 lander in 1982. No rovers have ever been sent there.

But interest in Venus is increasing as we discover more planets in orbit around other stars. "We're looking for an Earth 2.0 elsewhere in the universe, and we'd like to know if they can support life, for two reasons: they're good candidates to have evolved their own life, and we might want to try to send humans there one day," said Jonathan Sauder, a mechatronics engineer at NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California, which designs the agency's exploration machines.

"But we have an Earth 2.0 in our own solar system. Earth and Venus have amazing similarities: about the same size; similar composition and gravity; Venus is slightly closer to the Sun but it's still in the theoretically habitable zone. So the question is: why is Venus Earth's evil twin sister?"

Venus shows us that just being in what's sometimes called the Goldilocks Zone – distance from the star means that conditions should be 'just right' for liquid water on the surface and therefore for the processes that started life



on Earth to exist – is no guarantee that those conditions actually exist.

“It’s so similar to Earth but it’s gone entirely south and is entirely caustic towards life. Understanding Venus can be incredibly important for finding out how planets became the way they are,” Sauder said. “We want to understand which planets would be good candidates for life and which would be poor.”

To learn why Venus is the way it is, we need to go back there, and preferably with a lander than can survive a long time. Rovers are more effective explorers than static landers, capable of moving up rocky slopes that allow the study of geological features that have evolved over time; sampling these would give clues as to how the atmosphere has changed. But such are the challenges to equipment that a radically different approach will be required from that which works on Mars. Conventional electronics won’t work on Venus, and the temperatures are a challenge even to anything electrical, so Sauder and his colleagues are investigating a new – or in fact old – approach: ditch electricity. Go mechanical. This is the concept behind a project called AREE (Automaton Rover for Extreme Environments), which could have additional applications millions of miles away from Venus and even here on Earth.

“I was working on another design study with a group of mechanical engineers and, in a coffee break, we were tossing around ideas about mechanical computers,” said Sauder.

Such systems can be quite complex, such as the Antikythera Mechanism, an arrangement of bronze gears and dials made in Greece around 200BC that could calculate the position of the Moon, five planets and several stars.

The coffee break also featured discussion of a more modern mechanical wonder: the Strandbeest kinetic sculptures by Dutch engineer-artist Theo Jansen, which can walk along beaches on many legs powered by the wind.

“We were thinking about if it would be possible to make a purely mechanical spacecraft and how it would be a fun engineering challenge,” Sauder said. “We thought Venus made a lot of practical sense for a spacecraft like that because we could design mechanisms to operate at those very high temperatures as long as we accounted for the materials’ coefficients of thermal expansion.” Such a robot could potentially operate for Earth years, the team thought.

Sauder and his colleagues worked up their idea into a concept and presented it to NASA’s Advanced Concepts team, who – to their surprise – liked it enough to commit some funding to turn it into a project. So the team turned their minds to what the rover’s mechanisms would have to do. An obvious starting point was locomotion. Inspired by Jansen, the first iteration of AREE had sides lined with many legs with a complex Strandbeest-like series of joints and linkages, powered by a small horizontal-axis wind turbine on top of the rover. However, by coincidence Jansen himself attended an event at JPL and cautioned the team against taking such a literal lead from his designs.

“He told us his leg systems worked on the smooth, firm beaches in the Netherlands but even patches of soft sand would make them unstable,” Sauder said. “We wanted to traverse a landscape that was rocky and hilly, so we needed something more robust. We ended up with a tracked design similar to a First World War tank, which is horizontally symmetrical so it can move even if it’s flipped over.”

This meant the wind turbine couldn’t be located on top of the rover. It was modified to a vertical-axis turbine called a Savonius rotor, which worked at low

“Earth and Venus have amazing similarities”

Jonathan Sauder

elevations and could be housed in the rover’s body.

“Nobody has developed a packageable, rechargeable battery that will work on Venus,” Sauder said, “so we’re working on storing the energy in a spring and driving the system directly.”

High temperatures increase electrical resistance so generators and motors would therefore have been inefficient.

The rover’s communication system was also mechanical. The design included a spot on the hull painted with a highly radar-reflective material and covered with shutters that could be opened and closed rapidly.

“An orbiter would beam down radio waves that would reflect back from the rover, and the shutters enabled us to signal in Morse code, like old ships that communicated with searchlights and shutters.”

This system sent information such as wind speed, temperature and even about surface samples. “We were going to do everything mechanically. But we’ve established over the past year that it makes sense to use some high-temperature electronic systems,” Sauder said. “There are silicon carbide and gallium carbide electronics that work at 450°C. They’re at a very low level of integration; the most complex circuits have about 100 transistors, equivalent to a 1970s calculator, but they can handle very basic sample analysis.”

Samples were collected by scraping loose material off the surface, or loosening it with a drill, and dropping it into simple chemical sensors. Such systems were solar-powered, Sauder said. “Off-the-shelf solar panels work at 450°C; they’re very inefficient but they will work for very small instruments. They die in about five minutes, so we have someone at JPL who’s working on photovoltaic substrates that can survive for longer – months at a time.”

Unlike a Mars rover, such a robot cannot be programmed with exploration routes. So Sauder plans to build in a very basic collision avoidance system. This will use a mechanical device to detect if the rover has bumped into an obstruction too tall to crawl over, then reverse the direction of travel, steer a small amount and try again. Several passes will take it past the obstacle.

“It would be an effective solution, if not a very efficient one,” he said.

Such rovers would be useful not only on Venus; Sauder noted that moons of Jupiter were subject to high radiation, so also unsuitable for electronic devices. “Mercury too, which has extreme temperature differences,” he said. “There are also terrestrial applications, like missions inside active volcanoes.”

The team is currently testing materials and mechanisms by building a clock that will work in Venusian surface conditions. It is also investigating lubrication; options include systems that require none and substances that acquire lubricant properties at high temperature and pressures.

AREE has funding for two more years, which will enable Sauder’s team to build a fully working scale prototype. If successful, they hope to apply for further funds from NASA’s Game-Changing Technology programme, which potentially could take them all the way to a mission proposal. ■



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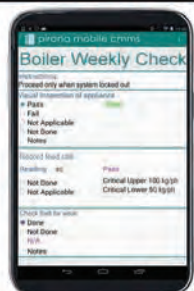
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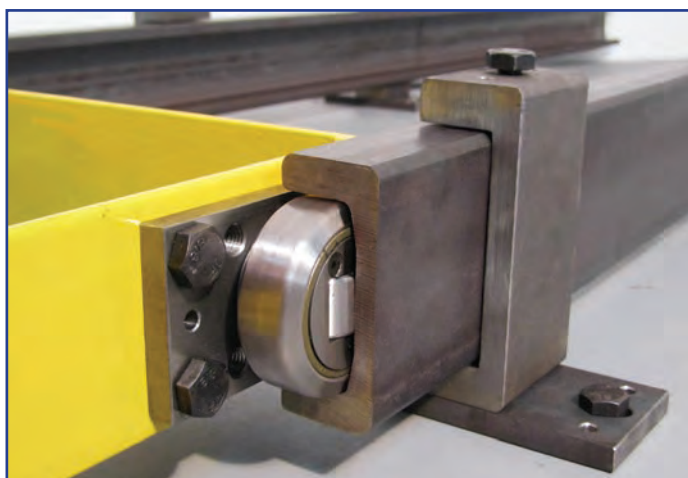
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Unstoppable momentum

GKN Driveline chief executive Phil Swash tells Jon Excell how electrification is driving a 'golden age' in automotive engineering

There are rarely many big surprises at car shows these days. While once upon a time manufacturers waited for the exhibition hall doors to open before performing the big reveal, today's events are typically robbed of their drama by months of pre-show hype.

Nevertheless, they provide a useful indication of the direction of travel. And, at this year's vast Frankfurt motor show, one word was on everyone's lips: electrification. In a relatively short time, this subject has moved from the fringes to the centre stage of the sector's strategy.

Unsurprisingly, the household names grabbed the show's headlines, with Audi, BMW, Mercedes and others all unveiling a mix of new models and thought-provoking concepts. From a technology point of view, however, it was the degree to which the industry's key suppliers were talking about electrification that was perhaps most striking – suppliers such as GKN Driveline, the automotive division of UK engineering multinational GKN.

Long renowned for its drive-shaft technology, and specifically the constant velocity (CV) joints that it pioneered for automotive use, GKN has evolved rapidly in recent years with a series of acquisitions expanding its expertise into almost every area of driveline technology, including, increasingly, electrification.

Talking to *The Engineer* shortly after unveiling its latest product in this area – an electric driveline concept dubbed eTwinstarX – the firm's CEO, Phil Swash, said that, while some had been surprised by the rise of electrification, GKN had had the trend in its sights for some time. "I could show you presentations and documents we presented to our board three years ago where we were saying 'This is going to be huge,'" he said.

Although some remain unconvinced, Swash thinks electrification's rise is now inevitable. "Whether it's trailblazers like Tesla, the diesel issues in Europe and America, or the Chinese market acceleration, all of these have come together at a time to really accelerate momentum, and I think that momentum is unstoppable."

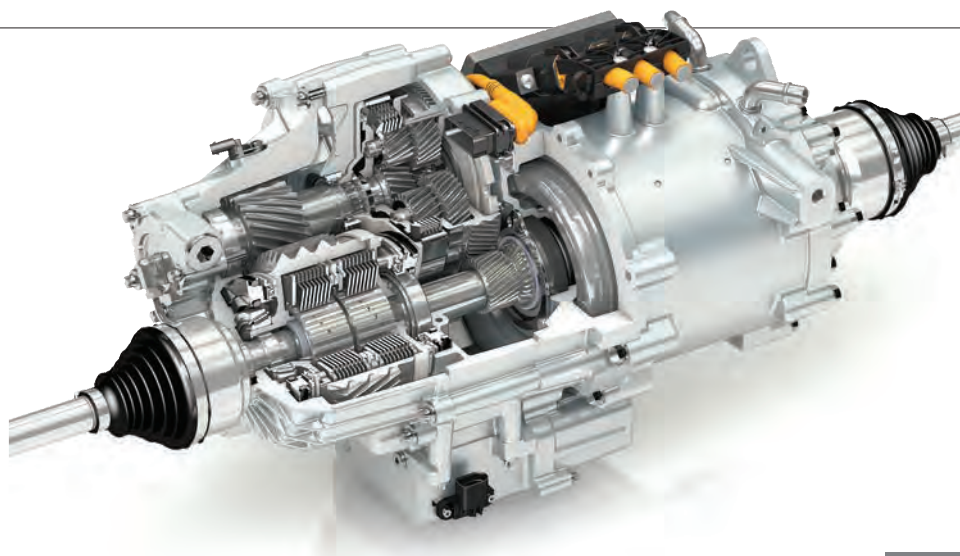
Indeed, adoption of the technology could ultimately outstrip even the boldest predictions, he claimed. "When you look at other new technology evolutions – laptops, phones, iPads – the hype is often too high initially and the volumes are never what the hype is. But, when they get to that inflection point, the proportion of sales they command is often far higher than anyone anticipated, and we think it will be the same for electric vehicles."



"To be an engineer in automotive today: oh my gosh, it's just fantastic"

The company's level of investment in the technology reflects this confidence. "The amount of investment we make in electrified drivetrain is very significant now: over a quarter of our engineering investment," said Swash. "When you think that less than 3 per cent of vehicle sales are electrified, it shows you how much we're investing ahead of that very, very rapid increase."

Clearly electrification isn't the only game in town, and GKN sees plenty of life left in conventionally powered vehicles. But, even here, R&D investment in existing areas



02



01

has clear benefits for the electrification market.

The group's traditional expertise in driveshafts is a good example. "Every battery electric vehicle/hybrid vehicle also needs really high-performance drive-shafts," said Swash. And, as concepts like bi-directional torque flow – to both deliver power and harvest regenerative power – get more established, GKN's expertise will become ever more important, he added.

Another established area of expertise with clear applications in the electric world is in all-wheel-drive

technology: "A lot of what we learn in AWD on the software control side reads directly across into e-drive, especially tuning the dynamics, torque vectoring, and so on."

Nevertheless, it was the firm's burgeoning electric credentials that took the limelight at Frankfurt, where, alongside the launch of the eTwinstarX, it announced a hook-up with the Panasonic Jaguar Racing Formula E team. The deal will see the entire GKN group provide design, manufacturing and consultancy services to the team, and Swash believes the firm has plenty to offer: from the light-weighting and composites expertise generated by GKN Aerospace to the drivetrain knowledge of its automotive division, and even the use of technology from the group's powder metallurgy business to help in the manufacture of cooling systems for the vehicles.

Beyond this, he hopes the relationship will help accelerate the development of electrification technology in general, and enable the firm to tap into motorsport's famed, fast-paced innovation culture. "We've done it to fast-track and demonstrate our latest technologies," he said. "It's a great proving ground and it drives you in a different way. The pace, demands and expectations are very different."

The differing expectations of other areas of industry are something Swash knows all about. Prior to joining GKN Driveline in 2015, he was CEO of GKN Aerospace Europe and, despite identifying many similarities between the two sectors – "they're both big global customers, with big complex programmes and massive investments" – he has, he said, been blown away by the rapid pace of innovation in the car sector.

"One of the great differences, and what's really great about automotive, is that the technologies we're developing today will be on a car in three years' time. That's so different from aerospace, where you can be working on a new process or product development for a decade and it still may not get on the next new aircraft."

It is, he added, a remarkable time to be working in the sector: "To be an engineer in automotive today: oh my gosh, it's just fantastic. What other industry would you want to work in at this time? We will look back and say these were the golden years, from an engineering perspective, from a product perspective. It's just fantastic."

Despite this, for the UK automotive sector in particular there are some large, Brexit-shaped clouds on the horizon. And, like most engineering firms with a big stake in the UK, GKN is, said Swash, concerned over the UK's future relationship with Europe. "We don't have any clarity yet on what the arrangement will be," he said. "For any business, barriers to the free movement of talent or import/export taxes generally aren't very good for trade. We're hopeful and engaged to try and ensure that the eventual arrangements don't create those barriers. But, until we have that certainty, we are concerned."

As a global company, despite being headquartered in the UK the home market accounts for less than 10 per cent of the automotive division's sales, so the firm will survive any Brexit-related slowdown. However, its continued presence in the UK will, said Swash, be largely dependent on a continued UK market for its products.

"We've been in the UK for a long time. We think it's important we're there; there's engineering heritage and we've invested heavily in our business. But, at the end of the day we're a global company and we'll go where our customers need us." ■

01 eTwinstar X, GKN's new electric driveline concept

02 The Panasonic Jaguar Racing I-Type 2 Formula E car

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Making tracks for tomorrow's drama

Novelist Jon Wallace considers the science fiction implications of engineering stories that have caught his eye. This month, the future possibilities of rail travel

For an invention getting on for 200 years old, rail transport has a remarkable durability as a badge of prestige among nations. China, France, Japan, Spain and Turkey are proud of their glimmering high-speed infrastructure, while nations such as India, Morocco and Saudi Arabia are all striving to join the bullet train club.

Even in the UK, where Dr Beeching and the demise of steam locomotion kicked much of the romance out of the railways, successive governments continue to view large rail infrastructure projects as almost sacred, a crucial marker by which national progress may be measured. Hence billions flow into the much-maligned yet seemingly unstoppable HS2 project.

The average British commuter, battered by strikes, rising fares, signal failures and overcrowding, is naturally wary of visions of gleaming wonder transport. Most would rather be promised punctual, clean, comfortable trains, hopefully with a seat.

So when *The Engineer* reports on Richard Branson's investment in Hyperloop One – a project to carry Britain's future commuters via vacuum tube and magnetic levitation – the average train drone, inhaling the armpit of a fellow traveller, will likely dismiss it as science fiction.

In fact, the genre's portrayal of trains extends far beyond speed. Certainly velocity plays a big enough part: a tin can packed with characters, hurtling across borders, is an excellent space for writers to create compact thrilling sequences; whether a Thermopylae-like bottleneck battle, as in the case of *Last Train to Busan*; as a missile in Iain Banks' novel *Consider Phlebas*; as a projectile through time in movies such as *Back to the Future, Part III*, and *Source Code*; or as a host for retold tales in the train robbery in Joss Whedon's *Firefly*.

The railway can be more than a tool for an action set piece. China Miéville's *Railsea* reimagines the railway, transforming it from disfigurement on the landscape to the landscape



itself: a tangled 'sea' of tracks, where a Moby Dick tale is played out with train substituted for ship, and giant mole for whale.

Further, as a means of travel where a class system is an inherent part of the package, the train is the perfect setting for writers interested in social commentary: see the revolution played out in the film *Snowpiercer*. Writers such as Stephen King even grant the train life, making suicidal monorail Blaine a character in his *Dark Tower* books.

In any case, the train provides intense, compressed drama. Sci-fi writers may well ask: will the hyper-efficient tube journey of the Hyperloop stoke the fires of rail fiction or be consigned to the history books?

We can look to the story of our own rail system for inspiration. As *The Engineer* readers point out, Brunel himself trialled vacuum-powered transport with his ill-fated atmospheric railway in 1847; the effort failed because of the unfortunate taste Devon's rats acquired for the seals between tube sections. Might nature intervene to doom the Hyperloop too?

Some engineers have raised fears about atmospheric pressure and thermal expansion

Hyperloop hopes to carry passengers at airline speed using magnetic levitation

warping and twisting the loop's tubes. This could well plague a Hyperloop with delays. We could tell the story of a Belgian detective travelling on a Hyperloop from Paris to Istanbul. Beset by delays and problems as tubes deform and fail, a journey that is supposed to last hours takes days — and the clueless conductor has no answers. In the morning the detective wakes to find the conductor murdered. His investigation concludes that all the passengers did it, each exacting a pleasing revenge for the age-old frustration of ruined travel plans.

We could craft a story based on the spiralling cost of rail travel: a world where the Hyperloop is the preserve of the rich, a conveyance rushing modern barons and princes between cities without the bother of glimpsing the land they govern. One brave trainspotter, desperate for rail travel to return to exposed tracks, begins blowing up stretches of Hyperloop running through the Midlands. He becomes a hero to the local poor, with whom he shares the spoils of wrecked Hyperloop pods. He's thought of as a modern Robin Hood, until the Hyperloop CEO, Guy Gisborne, offers him the chance to drive the Hyperloop pods himself — whereupon he betrays his outlaw ways for the thrill of an entirely ceremonial engine driver's hat.

Rail travel has a romantic place in writers' hearts, offering unique opportunities for strangers to meet and share brief encounters. It's also the place where many authors dream up their ideas: staring out the window as the world meanders by sparks a strange and creative brain chemistry.

It would be a shame indeed for trains to become too hyper, and for passengers to lose sight of the landscape. A great storytelling tradition, and a great many storytellers, could hit the buffers. ■

Jon Wallace is a science fiction writer. He is author of *Barricade*, published by Gollancz

Plugging the gap

Can Mini's first plug-in hybrid offer the best of both worlds or is it suited only to the school run?

Chris Pickering reports



It's fair to say the Mini brand has moved on somewhat from Alec Issigonis's iconic 1959 original. The Cooper SE Countryman All4 is a four-wheel-drive hybrid SUV. It has a plug-in capability and a useable electric-only range of up to 25 miles (40km). It also happens to sit on a longer wheelbase than an original Range Rover.

Not very 'Mini', you may argue. But, there again, broadening its repertoire has been the key to the brand's long-term success.

Under the skin, the second-generation Countryman uses the BMW Group's UKL2 platform, which is shared with half a dozen other models, including the BMW 2-Series Active Tourer, the BMW X1 and the Mini Clubman estate.

In the case of the Countryman, assembly takes place at the VDL Nedcar factory in the Netherlands. Prior to Mini's arrival, this was perhaps best known as the home of Dutch carmaker DAF and its somewhat eccentric range of CVT-equipped micro-cars. Today you'll find nothing as unorthodox. The Countryman's 1.5-litre 136bhp three-cylinder turbocharged petrol engine drives the front wheels via a reassuringly conventional six-speed torque converter automatic.

It's at the back where things get interesting. Stashed beneath the boot floor

The Cooper SE Countryman All4 has a longer wheelbase than an original Range Rover

is a 65kW (88bhp) synchronous motor, which drives the rear wheels via a two-stage single-speed transmission. This makes the Countryman a 'through the road' hybrid with no physical link between the two power sources. Combined, they produce up

to 224bhp and 385Nm of torque – comfortably more than the equivalent 2-litre petrol Countryman Cooper S.

The 7.6kWh lithium-ion battery pack sits under the rear seats. It has been accommodated by shrinking the fuel tank, which sits next to it, to 36 litres, from 51 litres in the regular petrol model. As a result there's no loss of cabin space; you can still comfortably seat one six-footer behind another. The motor and transmission do swallow up the underfloor storage in the boot but this makes a negligible difference overall. There's still 405 litres of luggage space, which puts it on a par with other premium crossovers, such as the Audi Q2.

You climb into a smart, funky cockpit that's quintessentially Mini, albeit appreciably higher up than those of its hatchback siblings. Prod the Start

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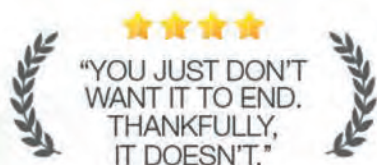
INSPIRED WORK



Mandy Camoran, Makers Monthly



Paul Strother, Door Handles Weekly



Sean Dundee, The Barn Door



Charlotte King, The Casual Reader

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01



02



03

button and you're greeted by... well, not a great deal. The Countryman defaults to Auto eDrive mode, which prioritises full-electric running at light loads, so we find ourselves trundling out onto the road in what is essentially a rear-wheel-drive electric Mini. Wonder what Issigonis would make of that.

Predictably, it's whisper quiet. There's a touch of wind noise as you start to go quicker but, overall, it has that trademark electric vehicle (EV) serenity. Squeeze the accelerator a little harder and the combustion engine spins seamlessly into life, making the Countryman a deceptively potent performer. It feels every bit as quick as the 6.8-second 0-to-62mph time implies, with a crisp throttle response and an appealing three-cylinder thrum.

There are two other drive modes: Save and Max eDrive. Save reduces the amount of motor assistance and increases the degree of energy harvesting to build up charge for future use. Meanwhile, Max eDrive, as the name implies, uses electric propulsion wherever possible – waking up the combustion engine only under kickdown or if the vehicle speed exceeds 78mph.

Driven in this mode, the Countryman delivers that classic EV trait of instant and formidable torque. The performance does bleed off after the initial surge, but it's enough to make good progress without troubling the combustion engine. (Incidentally, the battery always holds some capacity in reserve. This means that the car retains its four-wheel-drive capability and the full performance potential even when the electric-only range is exhausted.)

The electric drivetrain and its associated paraphernalia add around 190kg, compared to the mass of a Cooper Countryman All4 Auto with the same engine and a mechanical four-wheel-drive system. Drive the plug-in version in a manner wholly unsuited to its school-run remit and you start to sense that

01 The vehicle has three drive modes: Auto eDrive, Save and MaxeDrive

02 The car's 1.5-litre 136bhp petrol engine

03 The smart, funky cockpit is quintessentially 'Mini'

extra mass and perhaps a tad more body roll. It still feels nimble and alert by crossover standards, though, with the motor and battery actually helping to even out the front-engined Mini's weight distribution.

We didn't have an opportunity to test the full battery range but, according to the trip computer, we were on course to cover around 18

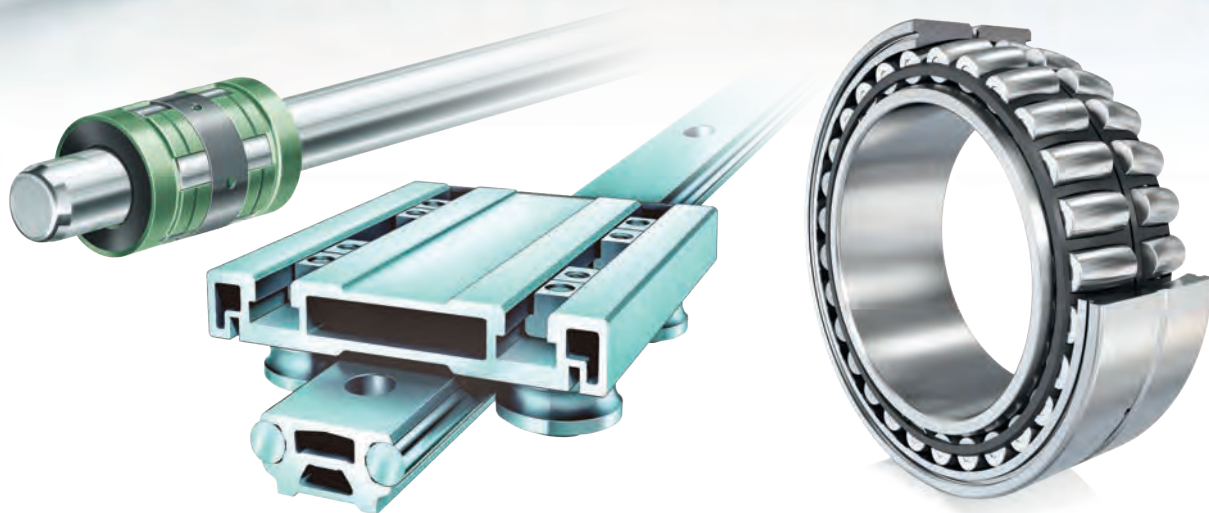
miles in real-world conditions. That may not sound a lot but it's more than enough for the average UK commute and you still have a petrol engine to banish any range anxiety. Expect around 50mpg in Auto mode (although official figures of 134.5mpg and 49g/km will go a long way with company-car drivers).

Once the battery is spent, it takes around two-and-a-quarter hours to recharge using a high-current wall box (or an hour or so longer on the mains). Save mode also seems to replenish the battery surprisingly quickly during normal driving, but it's those who intend to use the plug-in capability frequently who will benefit most from this concept.

Admittedly, if you are a driver who rarely leaves town, a pure EV like the forthcoming Mini Electric – slated to enter production in Oxford in 2019 – may be a better bet. Likewise, high-mileage motorway users will still be better off with a diesel.

But in between the two a lot of drivers could find themselves warming to the charms of a plug-in hybrid Mini. ■

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Moulding machine regains its bottle

Synchronous reluctance motor gets to work on plastic-bottle machine. Supplier: ABB

Northern Ireland manufacturer PrimePac has worked with ABB to breathe new life into an ageing plastic-bottle moulding machine.

The 23-year-old piece of equipment uses a hydraulic motor to run an extruder on a blow moulder. However, after running 24 hours a day for five days a week, its motor was operating inefficiently. Whereas previously it took 10 seconds to create a bottle, in recent years this had extended to 12 seconds. The extruder was also creating long tails of excess plastic that needed to be trimmed and recycled in a very energy intensive process.

PrimePac was quoted £30,000 to refurbish the machine, work that would have kept it running but still

using the same amount of energy. Seeking an alternative, it carried out

an energy assessment with Advantage Control, an ABB



authorised partner. A solution was found in the form of ABB's synchronous reluctance motor (SynRM) and an ACS880 drive that would not only reduce electricity use, improve speed holding and the quality and consistency of the finished product, but would also free electrical capacity that could be used to power a new injection-moulding machine.

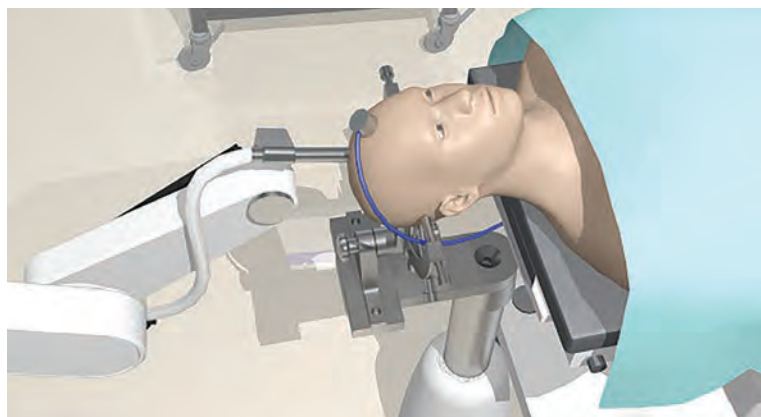
Data analysis following the installation revealed a 60 per cent energy saving and a 30 per cent improvement in output. Even taking the machine modifications into account, the £7,400 investment the 55kW SynRM package is expected to payback in under 12 months.

"We couldn't install a new electric machine because we didn't have the available power," said Clifford Craig, engineering manager at PrimePac.

"But with the 60 per cent energy saving we achieved on the old blow moulder we have been able to install another new all-electric injection moulding machine... We have managed to massively increase our production, just by installing one SynRM package from ABB." ■

Neurosurgery gets the needle

Programmable bevel-tip needle comprises four flexible interlocking plastic segments. Supplier: Elmo Motion Control



Researchers working on the EDEN2020 project at Imperial College London aim to improve neurosurgery by making it less invasive and reducing the risk of damaging healthy brain tissue.

This is achieved using a programmable bevel-tip needle (PBN), constructed of four flexible interlocking plastic segments. Each segment has a channel for drug delivery and a channel

containing a fibre cable used for shape sensing. Powered by a small ironless motor, each segment can move independently, allowing the PBN to change direction and be guided around brain structures to the right area.

This application required a motion controller capable of high synchronisation of the four axes, while achieving a positional accuracy down to 10µm.

Each segment motor is driven by an Elmo Gold-Twitter servo drive, while all controlled by an Elmo Platinum Maestro motion controller.

Platinum Maestro uses EtherCAT, an Ethernet protocol for motion control applications. The motion controller can command the axes at a 250µs EtherCAT cycle rate, allowing

it to quickly respond to or command the PBN to change direction to move around obstructions and avoid damage to brain structures.

Prof Ferdinando Rodriguez Y Baena, project coordinator for EDEN2020, said: "The system will be able to sense continuously deforming brain anatomy at unmatched accuracy, precision and update rates."

Gold-Twitter was chosen as its compact size allowed the robotic surgery station to be portable. The servo drive also produces a low level of electro-magnetic interference.

Reduced development time was a key factor in the project's selection of motion controller. The Platinum Maestro is an off-the-shelf motion controller offering tools and features that simplify and streamline the implementation of machine motion applications. Simple interconnection of the Platinum Maestro to all drives, and control over all drive parameters from the Platinum Maestro were other major benefits. ■



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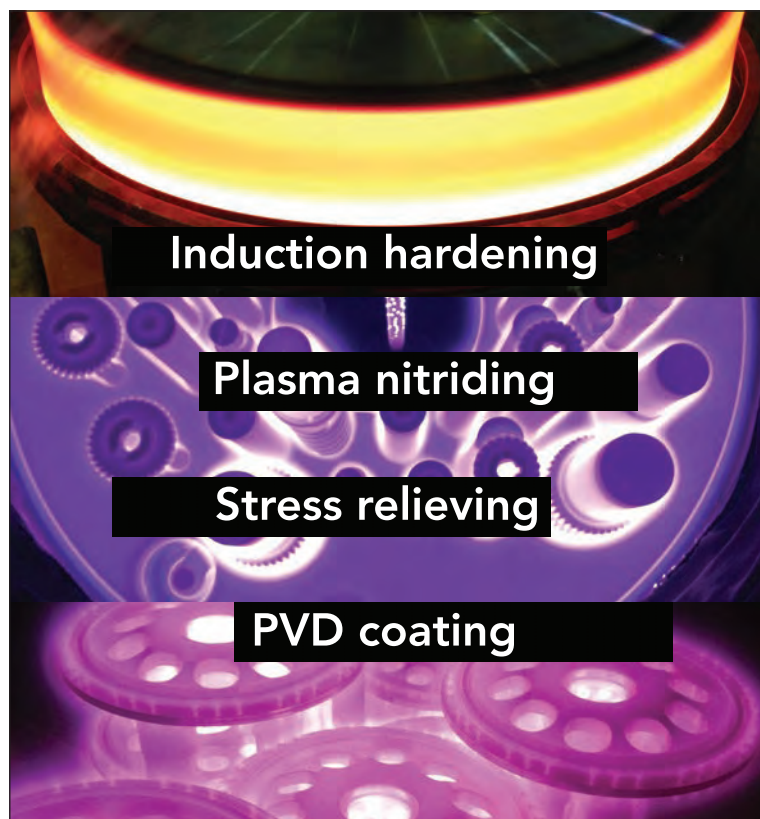
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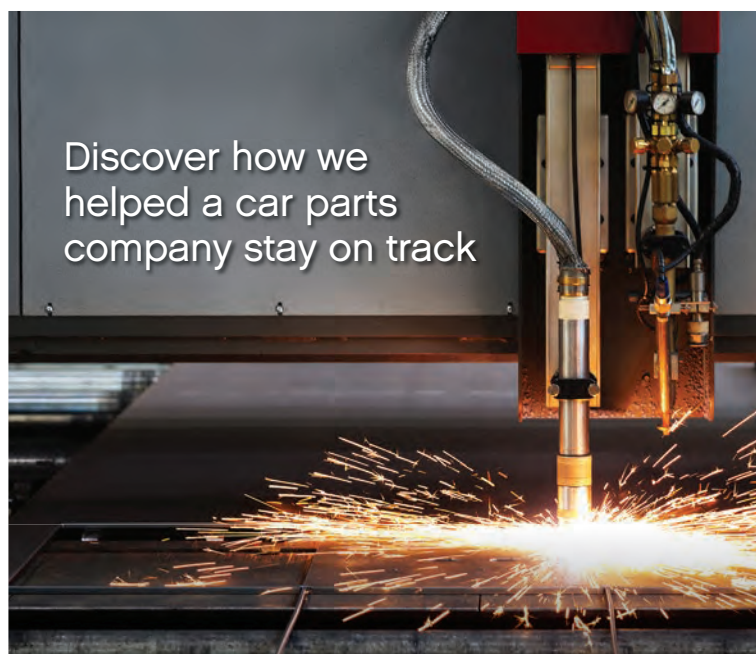
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Oil well gets a big lift from magnetic gears

High-tech replacement for the 'nodding donkey' exceeds 650 days in service. Supplier: Magnomatics

Magnetic gears, supplied by UK firm Magnomatics are providing a long-term solution to demanding applications in the gas and oil sector.

ZiLift's TorqueDrive, which uses magnetic gears, recently reached the milestone of 650 days in service after it was used to replace the reciprocating pump, or 'nodding donkey', in a slim-bore well in California.

The artificial lift system comprises a progressive cavity pump, an electric motor and a torque converter, or magnetic gear, all within a 3ins (75mm) tube. As with all magnetic gears there is a point where the gear is overloaded and slips but without causing any damage. This feature is known as a torque fuse, or overload protection.

The whole assembly is lowered into the oil well, often around bends, or deviations, in the well that make life for the reciprocating shaft of a nodding donkey very difficult indeed.

Once in the well, TorqueDrive can

be operated very precisely. With integrated real-time performance data, embedded automation takes care of matching the pump performance to changing reservoir conditions. The continuous



pumping motion eliminates cyclic pressure pulses on the formation and reduces damage to the well bore that can lead to sand influx or reduced productivity.

The continuous pumping motion eliminates cyclic pressure pulses on the formation and reduces damage to the well bore that can lead to sand influx or reduced productivity. If the pump becomes clogged with sand and seizes, the inherent torque fuse of the magnetic gear prevents damage to the other drive train components. There follows some control intervention to cycle the pump, clear the blockage and continue operation.

The torque drive system installed in a highly deviated and slim-bore well in California recently passed 650 days operation. This is a significant milestone, given that the reciprocating rod pump it replaced was lasting less than 30 days.

The unit is operating deeper than 1,000ft underground, is exposed to hydrocarbons and other corrosive fluids in an ambient operating temperature in excess of 180°F. ■

Bearing on the Formula Student crown

Swedish manufacturer provides a range of bearings for winning student car. Supplier: SKF

SKF bearings have helped Cardiff University's Formula Student team power to the 2017 title, the first time a UK team has triumphed at the event.

Following four days of intense competition at Silverstone, Cardiff Racing emerged with a total score of 855.6, just edging out the University of Birmingham on 837.5 points. Sweden's Karlstad University completed the podium, some distance back on 732.9 points. In total, more than 2,000 students from 24 countries took part in the event, which is run by the Institution of Mechanical Engineers (IMechE).

SKF technology was at the heart of the Cardiff win, with the Swedish manufacturer supplying a range of bearings for the car, as well as technical assistance on bearings

selection and installation throughout the 2017 design programme.

According to the company, there are over 50 SKF bearings of various types used in the construction of Cardiff University's Formula Student 2017 car. The suspension alone features 44 SKF bearings, including 32 rod ends installed in the suspension wishbones. SKF left- or right-hand, female- or male-threaded rod ends consist of an eye-shaped head with integral shank, housing a spherical plain bearing. The suspension also includes four SKF needle roller bearings complete with inner ring at the rockers – a compact solution for this space-limited application.

Eight SKF GE10 C maintenance-free spherical plain bearings are used in the support of the wishbone



staging plates. These units are available in two formats: steel against PTFE or steel against sintered bronze, both of which are suitable for applications requiring

very low friction. Meanwhile, the hubs, drive train and steering mount assembly are equipped with more than 10 SKF-type 619/8-2RS1 sealed deep-groove ball bearings. ■

Opening a gateway for the revised painting processes

Digital technologies are being used to stabilise quality improvements. Supplier: Bosch Rexroth

Bosch's manufacturing facility in Pecinc, Serbia, manufactures automotive wiper systems and wiper blades, and has started to make use of digital technologies to stabilise its painting process. The facility is using IoT Gateway from Bosch Rexroth to provide the data basis for everything from running processes and quality improvements to predictive maintenance.

The Production Performance Manager (PPM) software from Bosch Software Innovations is used as an analysis tool. With the Starter Kit using both plug-and-play solutions, the production management team was able to stabilise the painting process for wiper arms quickly and easily. For this, the IoT Gateway

collects sensor and control data and sends it for targeted evaluation into the Bosch IoT cloud.

By implementing these technologies, the production management team was able



to avoid downtime and improve the productivity of the paint shop, which consists of 10 individual stations.

The data basis needed for this is provided by retroactively installed sensors and five different controller types, from which information is read. The Rexroth IoT Gateway collects all this information, including PLC blocks, inputs, markers and fault messages, without intervening in the automation logic.

For the evaluation of process-critical information, including moisture and reduced paint consumption, the IoT Gateway streams the collected data to a server hosted in Germany, where it is analysed and compared with defined limit values using the PPM software.

The technicians responsible in Pecinci continually optimise the equipment availability using these insights. To ensure improvement in the product quality, a track-and-trace function is also planned.

For the purpose of data analysis, the IoT Gateway from Bosch Rexroth generally includes high connectivity. This applies to software installed on site and cloud platforms. ■

Collaborate for more flexibility

Collaborative robot helps to cut lead times. Supplier: Universal Robots

MVI Maskinfabrik is a Danish fabricator that originally specialised in small-batch production with short lead times but wanted to increase manufacturing flexibility to introduce new products.

The company was also starting to receive larger orders so it invested in a collaborative robot from Universal Robots (UR), which provided the increased capacity and flexibility the company needed. It also cut welding times in half.

The UR5 was integrated into the production line to replace a welding robot that was four times the size of the UR5. The UR5 was also much cheaper than buying a new, dedicated welding robot.

A welding torch was mounted to the UR5 and, apart from a few hours of assistance from Universal Robots, factory manager Jens Christian Lægsgaard taught himself how to operate the robot arm.

Within days, the UR5 was MIG welding fittings in batches of 50 to several hundred.

"It takes about 15-20 minutes to programme the robot arm for simple welding jobs, more advanced jobs take a little longer," said Lægsgaard.

He added that a batch of 100 with 14 welds per fitting took 1.5 hours to programme and the robot completed each fitting in 1.5 minute. Manually it would probably have taken four minutes per part."



Lægsgaard said: "The robot... operates during the manual control and reworking of each item. If I had to do the work manually, I wouldn't be able to weld the new item and remove the high spots from the previous item at the same time. Thanks to the UR robot I can save

between 30 per cent and 50 per cent on working time per part by comparison with manual welding."

The ability of the UR5 to increase productivity with the addition of consistent accuracy has allowed the company to produce quality-assured new products. ■

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Review looks forward to a future of UK industrial digitalisation

Made Smarter Review answers calls from government on how the UK could boost productivity in the manufacturing sector by harnessing digital technologies

Industrial digitalisation could be worth as much as £455bn to Britain's manufacturers over the next decade, according to the findings of a newly published report.

The Made Smarter Review – previously known as the Industrial Digitalisation review – answers calls from government on how the UK could boost productivity in the manufacturing sector by harnessing industrial digital technologies (IDTs), including robotics, 3D printing, augmented and virtual reality, as well as artificial intelligence.

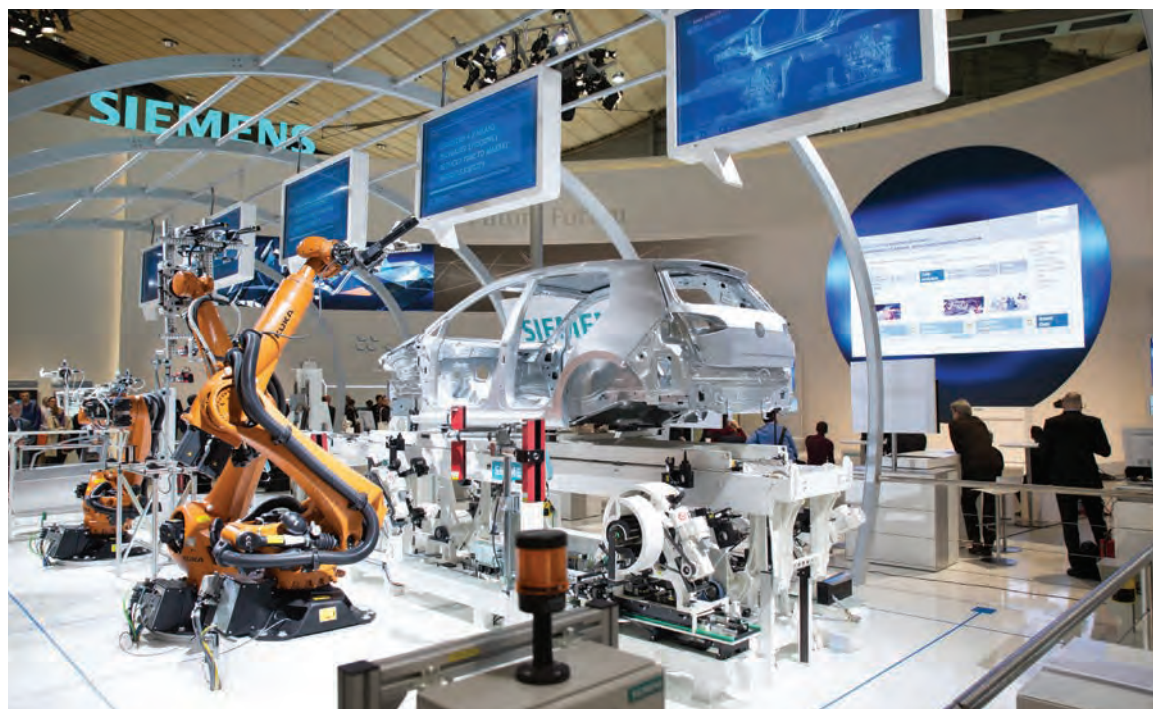
A report that accompanies the review sets out industry-led recommendations that should be implemented to help make the UK a world leader in the so-called Fourth Industrial Revolution by 2030.

By implementing these, the UK manufacturing sector could grow at up to 3 per cent per year, create 175,000 jobs, and reduce CO₂ emissions by 4.5 per cent.

In his foreword to the report, review chair and Siemens UK CEO Juergen Maier said: "Our proposals don't seek to answer every question about how we drive and embrace digitalisation. Rather, they seek to establish the institutional framework and ecosystems that will spur the next generation of domestic technological innovation."

The Industrial Digitalisation Review considers three key themes – adoption, innovation and leadership.

Adoption: Building a national digital ecosystem. Government and industry should create a significantly more visible and effective ecosystem that will accelerate the innovation and diffusion of industrial digital technologies. This includes a National Adoption Programme piloted in the North West, focused on increasing capacity of existing growth hubs and providing more targeted support. According to the report, the pilot would increase GVA



by 15 per cent over three years. It would also allow 20 start-ups to work with industry on new projects.

The review also recommends re-skilling or up-skilling one million industrial workers over the next five years to enable digital technologies to be deployed and successfully exploited through a Single Industrial Digitalisation Skills Strategy.

Innovation: Re-focus existing landscape by increasing capacity and capability through creating 12 'Digital Innovation Hubs', eight large-scale demonstrators and five digital research centres focused on developing new technologies as part of a new National Innovation Programme.

Leadership: Establish a national body, Made Smarter UK (MSUK) Commission, comprising industry, government, academia, further education and leading research and innovation organisations, responsible for developing the UK as a leader in industrial digitalisation technologies and skills.

The recommendations will be considered by the government and used to inform work towards a sector deal between government and industry.

"The business community has pulled together to shape these recommendations that will speed up technology adoption and bring new energy to the manufacturing sector," said CBI director general Carolyn Fairbairn. "The UK must compete with China, the US and much of Europe, where there are already advanced plans to embrace the fourth industrial revolution. I urge the government to consider these plans carefully, as they are focused on increasing productivity and wages, especially in smaller businesses."

Commenting on the report, Chris Richards, head of business environment policy at EEF, said: "The digitisation of manufacturing is real and is happening at pace, but this speed could create major winners and losers unless all of industry moves together.

"The opportunities are significant and the review highlights the barriers to adoption of new digital technologies that could stop us moving up the ranks, particularly the need for better leadership and a culture shift on innovation to boost adoption – particularly among SMEs."

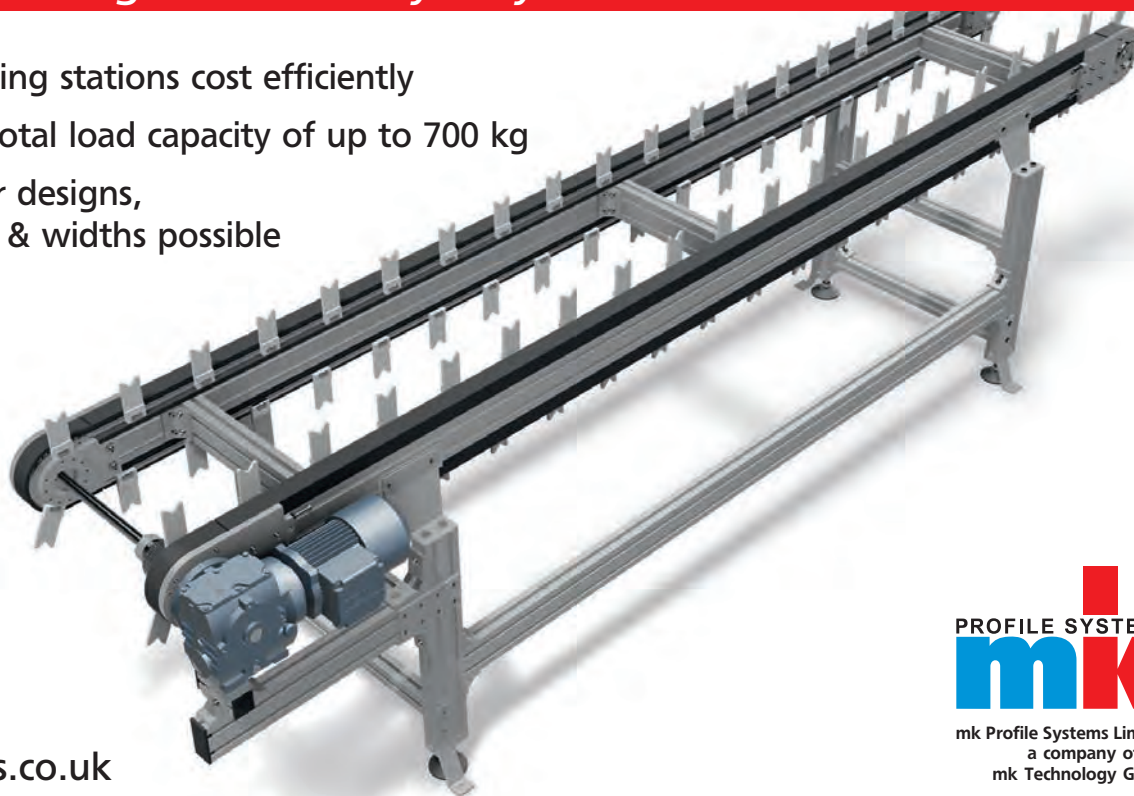
The government's Industrial Strategy Green Paper, launched in January, identified industrial digitalisation as one of five potential early-sector deals and the review began work with stakeholders to identify opportunities for how government and industry can work together.

The review brought together input and recommendations from more than 200 stakeholders, including Rolls-Royce, GKN, IBM, and Accenture. The review also received input from SMEs such as Yamazaki Mazak; Vertizan; Cambridge and Newcastle universities; and the Digital Catapult and High Value Manufacturing Catapult. ■

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Advanced Manufacturing



Broken machines and faulty parts are hampering productivity

Counting the cost of UK downtime

The impact of machine downtime is costing Britain's manufacturers over £180bn every year, a study has found.

Research conducted by Oneserve, an Exeter-based field service management company, in partnership with British manufacturers, found that broken machines and faulty parts are hampering productivity.

Consequently, three per cent of all working days are lost annually in manufacturing due to faulty

machinery, equating to 49 hours of work and £31,000 per company.

Three quarters of the senior business leaders surveyed outsource their machine maintenance, at a cost of £120,000 annually, but nearly all (83 per cent) said they replace machines at least once a year.

Chris Proctor, CEO of Oneserve, said: "One of the most common technical faults is the overheating of particular parts, especially where there is metal on metal, as these can short electrical circuits and cause machines to stop running.

"Vibrations, usually the first sign a machine is breaking, are another major cause of internal technical fault – they cause a cascading effect that can have a devastating impact on the machine. General wear and tear, as well as

operator misuse, can also be the cause of technical fault."

The situation can be reversed with predictive models that use machine-learning algorithms and data collected from machine sensors to monitor performance 24/7.

"At a simple level, the software can analyse the timings of certain actions against the PLC to monitor whether the machine is slower or quicker than usual; this can also be done in relation to heat and vibrations," said Proctor. "Alternatively, a video camera can be installed inside the machine, which, along with sophisticated neural networks, can analyse to the nth degree the machine's performance – notifying supervisors in advance when performance strays from the norm." **JF**

BAE moves to axe jobs after workload fall

BAE Systems is to shed 1,735 positions in its aerospace and maritime divisions as the company aligns its workforce with a declining workload.

Corporate restructuring will see a further 150 roles made redundant in BAE's applied intelligence cyber security business. In total, 1,915 positions are at risk.

Uncertainty surrounding a proposed 24 Typhoon aircraft deal with Qatar and a drop-off in orders for the Hawk trainer jet means that production rates will be reduced for both aircraft. Similarly, the withdrawal of the RAF's Tornado fleet will see support and sustainment activities at RAF Marham in Norfolk and RAF Leeming in Yorkshire wound down and ending in 2019.

As a result of these changes, there is a total proposed reduction of up to 1,400 roles within BAE Systems' Military Air business across five sites over the next three years. The company proposes a further reduction of around 375 roles across its Maritime Services division to "closely align capacity with workload". **JF**

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ADDITIVE MANUFACTURING

Supersonic technology aids 3D-printed enhancements

Rocket nozzles can accelerate air up to three times the speed of sound to deliver high-density parts JASON FORD REPORTS



The Speed3D technology has been able to print a flywheel in 11 minutes and 38 seconds

Australia's Speed3D has developed the world's first metal printer that uses supersonic deposition technology in order to deliver

manufacturing-grade 3D-printed parts at production speeds.

Rather than using heat to melt metal powders, Speed3D's patented technology uses supersonic deposition in which a rocket nozzle accelerates air up to three times the speed of sound to deliver

manufacturing-grade metal and high-density parts.

In doing so, the technology has shown that it can print a flywheel in 11 minutes and 38 seconds compared to the 20 hours it would take with traditional manufacturing. Similarly, results from Speed3D have

shown that a car part can be printed in 20 minutes for \$30 instead of taking upwards of 100 hours for \$3,000.

Byron Kennedy, CEO and co-founder Speed3D told The Engineer that the underlying technology has been used for many years in the repair world, where metals such as titanium, inconel, steel, stainless steel, copper, and tantalum are used. He added that large casting markets are showing interest in the system and the company will initially focus on aluminium cast parts.

"Copper is also a material that is very easy for the technology to print at very high speeds, which opens up thermal and electrical conductivity opportunities," he said via email. "More materials will follow with a particular focus on steel."

Speed3D's process has the advantage of not melting metal particles, so oxidation is less of an issue compared to laser printing. The system also has a deposition efficiency of over 90 per cent and any undeposited powder is collected external to the printer, said Kennedy.

To build a part, Speed3D's software takes a standard .STL file for printing that can be generated with any CAD program.

"Of particular interest is our ability to simulate the part prior to printing," said Kennedy. "This enables you to see if there are any components that will fail to print and adjust accordingly. Once the simulation is satisfactory a print file is generated that is sent to the printer." ■

INSPECTION

Clean bill of health for production

Technique scans for tiny spots of dirt and grease

STUART NATHAN REPORTS

Tiny specks of dirt or grease left on components during manufacturing can have disproportionately serious effects, such as ruining the

effectiveness of seals between components. Despite advances in quality control and inspection, it has not been possible to find a way to inspect every component on an assembly line for every trace of contaminant. An advance from Fraunhofer's Institute for Physical Measurement Techniques (IPM) in Freiburg promises to change that.

The technique uses an inline ultraviolet laser, which scans across the surface of components 200 times per second, in a point-by-point grid pattern. Any contaminants caught in that grid – whether specks of grease, residues of organic cleaning fluids or

stray fibres – reflect light in the visible fluorescence spectrum.

The system incorporates a detector that responds only to the specific fluorescence wavelengths, ignoring all other reflections; this not only identifies the presence of contaminants, but because of the scanning grid pattern, reports precisely where they are.

"The outstanding spatial resolution of this system enables us to identify even the slightest deposits or films of less than 10mg per square metre" said Andreas Hofmann, business development manager at IPM. The system can examine every

metallic component in-line without adding any time to the production process, he added.

The system can also detect fragments of metal that may have stuck to components in previous machining steps. "The preprocessed components are cleaned using water or compressed air. Any remaining chips are contaminated with oil or other fluorescent substances," added Hofmann.

The team is undertaking further studies to adapt the techniques for non-metallic components. It presented the system in October 2017 at the Parts2Clean exhibition. ■

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4IR: Finding the low-hanging fruit

You don't have to be a big spender to take advantage of Industry 4.0, writes Kieron Salter

The Fourth Industrial Revolution, also known as 4IR or Industry 4.0, is often regarded as the total digitisation of a manufacturing process, using vast amounts of real-time data to manufacture production quantities of 'one-off' items without incurring the cost of new tooling. UK manufacturers tend to perceive risk when the topic is mentioned.

However, another interpretation of 4IR may seem much more appealing to many engineers and manufacturers and enables them to take advantage of some 'low-hanging fruit'.

This interpretation involves using digital control systems to improve the performance of a specific stage within a larger manufacturing process. Typically, this may involve the more accurate deposition of industrial adhesives to a complex component, which is made of several parts.

In this example, digitisation has improved accuracy, reduced failure rates and significantly cut down on material use. Employing digital controls here has also improved productivity.

This becomes even more of an opportunity when you consider recent figures from the Engineering Employers' Federation (EEF) that show that just 11 per cent of manufacturers think UK industry is ready to take advantage of 4IR. Furthermore, statistics from accountants PwC show that UK companies are planning to invest on average seven times less than their German counterparts in 4IR over the next five years.

The lack of investment could see UK manufacturers seriously miss a trick and lose work to their European peers, especially as it does not take a huge amount of effort to embrace 4IR and digitisation.

Another example of where digital control could be quickly utilised is screen printing — a process typically employed to apply adhesives to laminated bonded parts. This is seen in the manufacture of automotive windscreens and kitchen worktops.

Replacing this with a digital process enables one to print only where the adhesive is needed. It therefore cuts down on material use and provides endless opportunities for personalised products and flexible manufacturing processes.

Digitisation can also have a positive impact on accuracy, cutting waste and cost from a component that suffers from inherent material waste and quality issues. The component consists of several materials, each having undergone their own unique manufacturing process. Once complete, these are bonded in a relatively uncontrolled way, resulting in a fair amount of wastage. This can prove inefficient in terms of time to manufacture.

One solution would be to manufacture the entire component digitally, perhaps via 3D printing. However, this is still some years away from being a cost-effective and viable option for many manufacturers.

Nevertheless, there are other quick wins that

digitisation can bring to this problem. For example, we've automated the adhesive deposition required to bond the parts together in a precise and controlled way, resulting in a reduction in material wastage and ensuring an accurate bond every time.

This is one of the best examples of adopting 4IR in a way that does not involve huge set-up costs, while still reaping the benefits that digitisation can offer engineers and manufacturers.

These are just a few instances of the low-hanging fruit available to companies operating in the 4IR sphere. My main point is that 4IR is nothing to baulk at and dismiss because of a perception that it involves huge set-up costs. 4IR offers massive opportunities

"It's not about totally digitised processes. You can adopt part-digitisation to use 4IR technology when you need it"
Kieron Salter

for manufacturers, so it is important to remember that it's not about totally digitised processes. You can adopt part-digitisation through software to use 4IR technology when you need it. ■

Kieron Salter is MD of high performance engineering firm KWSP

Elements of digitalisation offer advantages for engineering firms of all sizes
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Good turn-out

Developments in turning technology embrace automation, integration with associated processes, multitasking, better swarf management and new cutting grades. Mike Excell reports

Horn has introduced a modular thread whirling system and turbo whirling options with three roughing inserts and six finishing inserts per tool cassette



Automation and easy integration continue to influence production equipment development. For example, DMG Mori has introduced a mobile robotic cell, Robo2Go, to automate turning. The unit loads raw billets from a tray and unloads machined components automatically, and can be relocated easily by pallet truck to serve four

lathes sequentially. Operation, says DMG, requires no specialist knowledge of robots, as graphics-based programming is via a Powertool app running directly in the Celos machine tool control interface; the operator merely enters the workpiece dimensions, selects chuck and gripper, chooses one of the pre-defined workpiece tray arrangements and starts the automatic process.

"This intuitive way of programming a robot is especially

suitable for SMEs that want to exploit the competitive advantage of flexible, unattended production," observed Silvio Krüger, CEO of DMG Mori Systems. "Reluctance to automate has been noticeable in this customer segment, partly because of a lack of programming knowledge and also due to uncertainty that the robot would be fully utilised. It caused some to regard such an investment as risky, but the simplicity of Robo2Go has overcome this." The equipment allows free

access to the working area of the lathe for setting up; a laser scanner system slows or stops any robot movement if operators encroach on the defined safety area.

EMO 2017 in September reflected the attraction of automation. Presentations included the Nakamura-Tome WY-150, a twin spindle twin turret machine configured with what is said to be the world's fastest high-speed gantry; and Mazak's UK-manufactured Quick Turn 250MY + TA-12/200, a turning

centre linked to a Fanuc robot for loading. This integrated machine loading solution addresses applications requiring prolonged unmanned running. Both the machine tool and the robot are controlled from the Mazak SmoothG CNC, providing a seamless operator interface and enabling fast set-up.

The TA-12/200 is equipped with separate grippers for loading and unloading; a workpiece stacking principle uses interchangeable workpiece support pillars, with layout and set-up guided by a GUI integrated into the SmoothG CNC. Alongside this set-up at EMO were a QT-PRIMOS 150 SG 2-axis machine; and a MULTIPLEX W-300Y + GL-200, a twin-spindle, two-turret machine – each equipped with gantry loaders.

Turn-mill developments

The Nakamura and Mazak displays also illustrated the continuing significance of multitasking machines. Latest developments include DMG Mori's move to combine the speed of multi-spindle automatic turn-milling with the versatility of sliding-headstock technology. Two new machines – the Multisprint 25 and Multisprint 36 – can make components from bar of up to 25mm and 3mm diameter respectively. The larger machine can also turn chuck parts up to 50mm diameter – a process that can be automated by one or two robots in the working area. The machines are currently being tested for 12 months by five selected customers under production conditions, with commercial release due in early 2018.

Turn-mill sliding head machines are of course well established in the field, with Citizen Machinery, one of the leading protagonists, providing many illustrations of the value of this continually developing technology. One example can be found at HPC Services, based near Derby, which has ordered the latest Cincom L20-VIII LFV turn-mill centre from the company. LFV stands for low frequency vibration, and by including this feature in the machine specification, HPC managing director Paul Cobb believes production using high performance materials such as 321 corrosion resistant and 416 chromium steel can be significantly improved, enabling it to competitively quote on new work, which would

previously have been declined.

The patented LFV process enables selected operational sequences to be programmed, in terms of chip size, at the machine control. It is now being used to transform production over a wide range of material types and is said to eliminate problems such as 'bird-nesting'; improve depth-of-cut and surface finish; delay the onset of built-up edge on tooling; and dramatically aid the management of swarf. It can be applied to turning, profiling, facing, taper and interrupted cutting sequences plus drilling and even thread cutting.

Keeping it simple

Sophistication and automation are not appropriate in every circumstance, and many small niche manufacturing companies are still taking their first steps into CNC. PGS Precision Engineering specialises in bespoke gunsmithing. A move from one-offs to higher volumes, prompted investment in an XYZ SLX 355 Protturn lathe from XYZ Machine Tools. Attractions include ease of use of the Prototrak control system; the tracking facility allows the operator to manually run through the program using the handwheels before pressing cycle start. The SLX 355 can also be operated as a manual machine; while 95 per cent of the work is programmed the bespoke nature of the products calls for manual intervention to achieve 'final fit'.

Cutting tool developments keeping pace

Modular thread whirling with turbo options

Horn has introduced tools for thread whirling, having six or nine inserts, providing an efficient, cost-effective way to produce single- and multi-start external threads and profiles. Very short cycle times are achievable when used on sliding-head lathes and the process offers other significant advantages over single-point thread cutting.

1 DMG Mori has introduced a mobile robotic cell, Robo2Go, to automate its CNC turning centres

2 Mazak's QT-Primos 150 SG was exhibited at EMO with the GL3 integrated gantry load/unload system.

3 Millturning capability of DMG Mori CLX 450 at Bristol-based Mil-Tu-Fit Engineering enables one-hit machining

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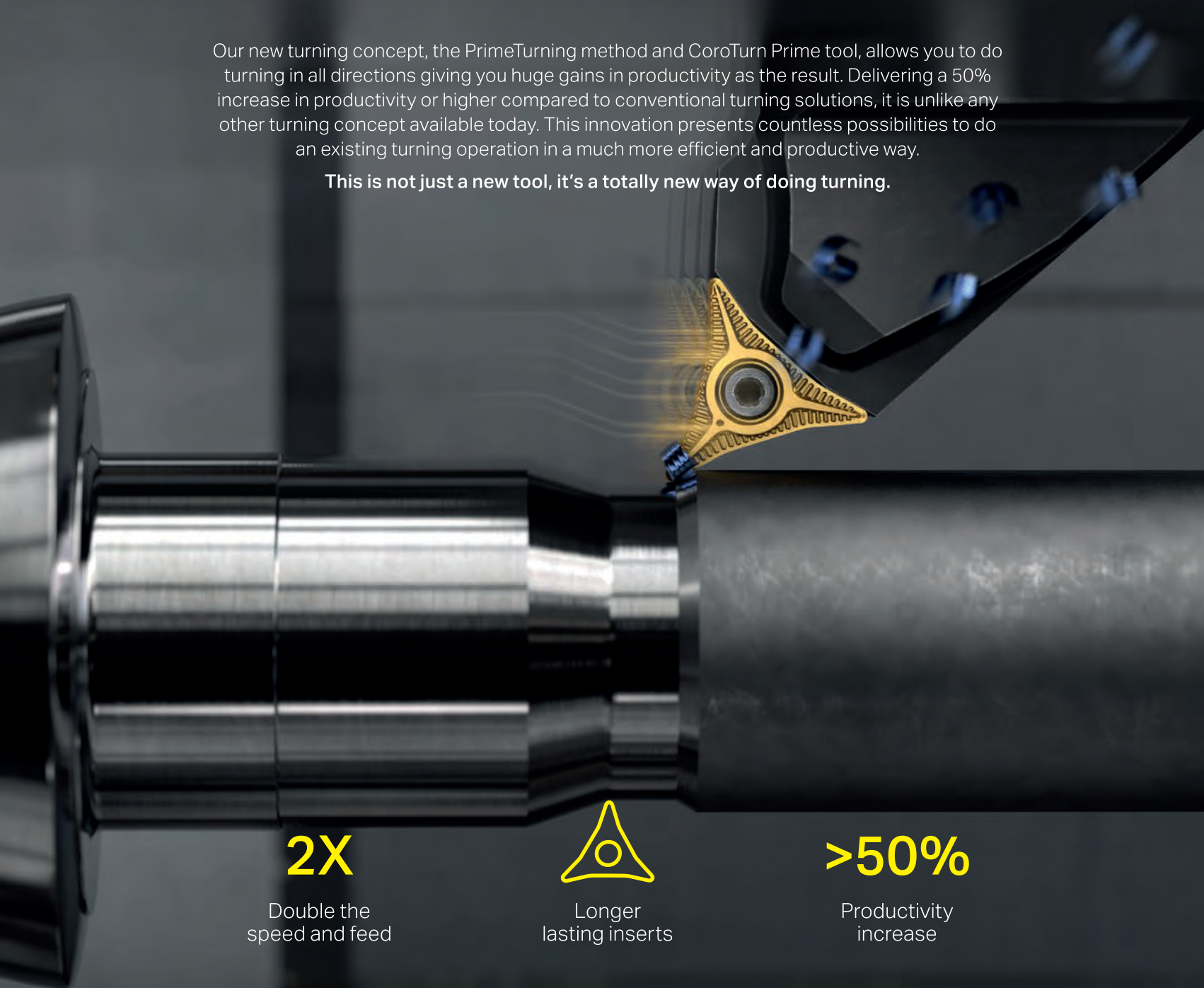
03

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With its base carriers and ring cassettes, the new type M271 modular tool system offers a multitude of combinations tailored to the various Swiss-type lathes and drive units on the market. The S271 high-precision system allows customers to choose between conventional whirling with six or nine indexable inserts per ring cassette; or the new Horn turbo whirling method, which uses nine precision-ground, double-edged indexable inserts. Three are for roughing, the remainder being finishing inserts, and all are tailored to the thread profile and material to be machined. Each cutting edge is subject to equal load, an additional factor in extending tool life. Inserts are held accurately in place by a Torx screw, achieving maximum rigidity and precise indexing. Thus handling is optimised during insert replacement in the new modular whirling heads or conventionally in Mono block tools.

Dedicated to stainless steel

Sandvik Coromant is introducing a dedicated turning insert GC2220 in response to challenges associated with stainless steel workpieces. The insert is designed to offer higher resistance to plastic deformation and provide greater edge line security. (Plastic deformation takes place when the tool material becomes soft, typically as a result of elevated cutting temperatures.)

GC2220 is a CVD-coated gradient sintered carbide designed specifically for semi-finishing to rough turning under stable conditions where higher wear resistance is required. Inveio coating from Sandvik Coromant is deployed to provide unidirectional crystal orientation in the alumina coating layer, delivering higher levels of wear resistance and tool life. This advanced and proprietary technology is supported by a columnar MT-TiCN inner coating that is hard and resistant against abrasive wear. It's claimed that longer tool life will enable machine shops to reduce their cutting tool inventory. Beneficiaries are said to be customers tasked with external and/or internal turning operations in austenitic and duplex stainless steel components such as pump housings, axles, shafts, seals,

5 These prismatic aluminium medical parts are now produced in one hit on a Biglia 6-axis lathe at Kent-based AES Precision Engineering, instead of on two 3-axis machining centres

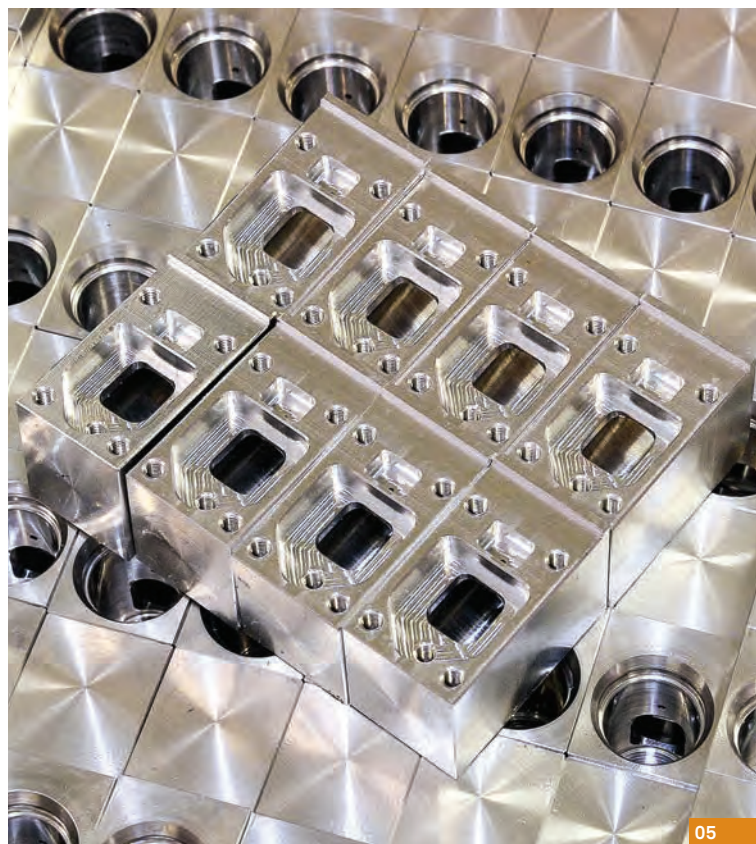
6 PGS Precision's directors with rifle barrels machined on their XYZ SLX 355

valves and flanges. Further materials where the attributes of GC2220 will prove advantageous include martensitic stainless steels and low carbon steels.

Smaller workpiece machining

AC1030U is the latest turning insert development from Sumitomo Electric Hardmetal targeted at high precision small workpiece machining, it covers a wide range of material types where improved levels of surface finish are required. This is achieved by embracing a special high precision grind to the cutting edge and the incorporation of Sumitomo's Absotech Bronze multi-layer coating, which not only helps resist micro-chipping problems but contributes to extended levels of consistent production.

The grade combines Absotech Bronze PVD coating and Sumitomo's latest precision ground FYS, a narrow breaker width G-class chipbreaker development to aid chip control and help to ensure a stable operational strategy. AC1030U inserts can be used for both turning and grooving of smaller inner diameter bores on workpieces produced from alloy, stainless and heat-resistant steels, pure iron, mild steels as well as non-ferrous materials where chip control is difficult to manage. Absotech Bronze technology comprises five alternate layers of TiAlSiN and AlTiSiN coatings that are applied to a special tough carbide substrate that has double the fracture resistance of more conventional substrates. The coating has excellent heat and oxidation resistance with high orders of adhesion strength and resistance to peeling-off as it has improved boundary control between the coating and the carbide substrate. ■



05



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Power moves

A £13m project is considering effective assembly procedures for ensuring appropriate quality and reliability for the electric vehicle battery packs of the future. Mike Farish reports

If electric vehicles are to assume a central role in personal and public transport in the coming decades then several things need to happen to make that a practical reality not least the development of new more energy-intensive battery technologies and comprehensive recharging infrastructures.

But there will also have to be something else – effective assembly procedures using state-of-the-art techniques for ensuring appropriate quality and reliability for the battery packs that will provide the vehicles with their power source. Moreover they will also have to be procedures that can be scaled up with no compromise to those essential preconditions from initially low to much higher production rates as market demand increases.

Now, thanks to a two-year, £13m project that has just reached its conclusion, a prototype manufacturing facility that aims both to prove out the necessary procedures and to provide relevant companies with practical experience of them has come into existence in the traditional heartland of the UK's automotive manufacturing industry.

The project, called AMPLiFiI (Automated Module-to-Pack Pilot Production Line for Industrial Innovation), has involved a consortium of vehicle manufacturers, equipment suppliers and academic institutions with the first of those categories including Jaguar Land Rover, JCB and Alexander Dennis. The new facility itself is operated by

project leader Warwick Manufacturing Group (WMG) at its base in the University of Warwick.

At first sight the compact facility looks modern but unexceptional, just a circuit of assembly stations – some open and manual, some enclosed and automated – linked by a conveyor system. But, as Prof Robert Harrison explained, the facility does not just embody current state-of-the-art manufacturing good practice it also exploits innovative product design to facilitate optimised production processes.

Indeed the “integration of product and process” is, he states, an absolutely fundamental element of the whole initiative.

Right at the start, therefore, the project had to make a decision about the most fundamental element of the battery packs that would be developed for manufacture on the line – the size and shape of the individual lithium-ion cells that provide the basic power source. Prof Harrison said that the decision went in favour of cylindrical cells 18mm in diameter by 65mm in height simply because cells of that type are the most “widely commercially available”. As such counterparts with a square cross-section or even in flat ‘pouch’ form were discounted as candidates.

In the product configuration that the project has developed those basic units now form the starting point for a three-layer hierarchy. These are respectively: cell; module (a tightly packed collection of cells in its own framework with an integral busbar system to provide



01/02 The WMG-led AMPLiFiI project hopes to supercharge the UK's battery manufacturing sector



“Every cell is tested for polarity, voltage and resistance”

Prof Robert Harrison

Harrison said that this format effectively allows for as few as just seven cells to form the most basic sub-division of a module and as many as a couple of hundred to be configured together to form a complete module. Moreover it also very cleverly allows groups of cells be placed either way up within that framework to allow for the creation of either serial or parallel configurations within a single module. In turn this ability to vary cell orientation supports the hugely important operational principle that complete packs can be either ‘high-power’ or ‘high-energy’, making them equally suitable for applications such as powering, say, respectively a piece of construction equipment moving very heavy loads short distances or a passenger vehicle transporting relatively light loads over extended ranges.

There are also, he added, other ways in which the configurability of the cell-module-pack sequence supports flexibility of use. One is in the choice of cooling technique between either the use of end-plates covering the top and bottom of each pack or flexible tubing carrying a water-glycol mixture running through the body of each module. Another is that the modules can be just as easily stacked on top of each other or placed side-by-side to exploit most effectively the physical space available within a vehicle.

The prototype manufacturing installation developed at Warwick to turn this product concept into a reality is, Harrison observed, a mix of current “good practice” and genuine “innovation”. Two sets of procedures on the line are, he says, “particularly critical”.

The first of these is the testing of each individual cell right at the start of the process, which is carried out fully automatically on batches of cells that have been loaded into a specially designed holder. “Every

individual cell is tested for polarity, voltage and internal resistance,” he confirmed, after which it is accorded an individual identity that it retains throughout every successive operation. Cells usually carry an appropriate unique identification mark from their own manufacturer that can be utilised to support this capability. “The birth history of the system is recorded and from then on there is a no-faults-forward policy,” he observed, the point being to make “quality and traceability” fundamental elements of the whole set-up.

The second is the welding of the busbars to the cells. Again this is an automated procedure and once more product and process have been designed together. The novel physical feature in this case is the design of the tabs that are welded to each end of an individual cell to make the required electrical connections. But as with the initial inspection the underlying principle of the manufacturing process is that of ensuring quality and traceability to which end, Prof Harrison confirmed, “each weld is logged.”

Very obviously, therefore, the supporting IT infrastructure for the installation is crucial to its effectiveness. Prof Harrison explained that infrastructure is not something that has been invented for the project but is instead an implementation of the Industry4.0 concept. The whole installation is, he said, “configured around a Profinet network with a gateway to Cloud analytics”. In turn, an important consequence of that is that the whole set-up can be easily reconfigured to meet new demands. “We can map new workstations into the system very easily,” he said, adding that this is aided by the fact that the whole set-up is highly modular with the control systems for each workstation co-located with them at the lineside and not installed ‘remotely’ elsewhere.

The first stage of the project formally concluded at the end of October and Harrison is confident that it has already got some real achievements to its credit.

Benchmarking of the product concept has shown it can achieve as much as a 30 per cent increase in the density of active material in complete battery packs over some systems on the market now. ■

electrical connection between them); and pack (the number of interconnected modules that make up the complete power source for a vehicle arranged in a manner that suits the particular vehicle involved and with a single overarching ‘battery management’ system).

But, as Harrison further explained, the project has devised a form of physical packaging for the electrical components that supports comprehensive “flexibility and configurability” at each of those three levels.

The cells are held in a plastic framework comprising a latticework above and below to allow for busbar connections that is held together with solid sidewalls and end-strips. Those two elements can each be varied in size but are joined in different ways – adjacent sections of latticework being clipped together while ultrasonic welding is used elsewhere. The busbars themselves, by the way, which have pulsed arc welded connections to each end of each cell provide further structural integrity for the module assembly.

01

A measure of success

The EPSRC Future Metrology Hub is expanding the possibilities of the discipline. Will Stirling reports



Measurement and validation is a cornerstone of manufacturing engineering, arguably the most important pillar, and overlooked in terms of 'manufacturing strategy' and by the media, in comparison to more visible fields such as additive manufacturing and robotics. That could change, as a new heavily invested UK research centre for advanced metrology gathers steam.

For decades, a manufacturer of components that require a high degree of accuracy would machine and form their parts using machine tools, and measure a regularly but randomly selected part on a coordinate measurement machine, or CMM. This process validates the parts, in batches, for an industry where such verification is a regulatory requirement, such as aerospace. Such a CMM measurement is typically done in a quality room by a dedicated team, though not always.

This final stage or 'tailgate measurement' is an additional process, and therefore a cost for a company. Depending how frequently each part is validated, it either adds greatly to the total manufacturing time or, for less frequent measurements, risks potentially scrapping a whole batch of parts that were made before the offending component failed the CMM stage. With Industry 4.0 and smart factories being the à la mode terminology, this area is receiving huge attention and is a main focus of the EPSRC Future Metrology Hub headquartered at the University of Huddersfield.

Embedded metrology – built into or alongside machines and measuring in-process – have several advantages over the traditional, separate CMM verification stage. First, speed, as the operator avoids having to remove and measure the part. Second, the advantage of measuring every part being made

provides 100 per cent verification, rather than a sample rate. Finally, said Christian Young, hub manager: "For high-value parts you can reduce or even eliminate the rework stage. For parts with features machined to the micron scale, not only must you remove it and measure it you then have to bring it back and reposition it before you can begin to re-machine. Validating it on the machine removes this intermediate stage and has the potential to dramatically reduce the time taken for corrective machining."

So how can smart measurement work? Metrology technology has been drifting towards non-contact, optical or laser systems, combined with or instead of touch probes, for several years. But – for some applications – these tend to be much slower, requiring manual and accurate positioning during manufacture. The strobe angle of the optic can be affected by reflections – known as optical diffraction – and there are other practical challenges.

The hub's work is focused on this. One project is to increase the capability for high dynamic range measurement, the ability to move measurement equipment away from the work piece and measure from distance. "We are looking at methods to move the equipment further away, potentially up to



01

several metres, while still maintaining the capability for micron level accuracy," said Young.

New equipment is being developed to progress metrology for the smart factory, where less human interference and higher accuracy is desirable. Measurement heads on robotic arms can deliver in-process measurement today. Renishaw has an in-process metrology system with SAI, a wheel manufacturer in Taiwan. It reduced rework by 80 per cent, and reduced scrap from 2 per cent, to 3 per cent to 0 per cent, where previously some wheels had to be processed twice to achieve the necessary precision.

But typically a factory would still move the measurement station in, measure the part, then move the tool away, remaining a secondary process and causing delay.

The hub is now looking to develop measurement equipment on the machine, which is still independent of the manufacturing process, but doesn't have to be manoeuvred into place. Optical interferometers, where electromagnetic waves are superimposed causing interference and therefore map a position, allow such measurement and can be mounted for measuring



02

“For high-value parts you can even eliminate the rework stage”

Christian Young

01 The new hub is based at the University of Huddersfield

02 In-process metrology is a key area of research

at some distance, carrying out the measurement stage more quickly especially for high-volume applications such as automotive. Lower volume, but much larger components such as aircraft wings that need to be measured very accurately, are also not well suited for a small mobile metrology station to measure in stages. “If you can move that station further back, you can take in the whole part and measure it.” Scanning devices, such as Faro’s Cobalt Array Imager, can be used for this but such light-based systems have accuracy limitations. Optical interferometry is a technique being researched by the hub that could plug the accuracy gap.

Appropriately for metrology, the Future Manufacturing Hubs, which are funded with £10m by EPSRC, are measured on their impact on industry. The team at Huddersfield has already delivered tangible results as part of previous projects. “Working with Rolls-Royce, we reduced manufacturing downtime for calibration by a factor of 10 from days to just hours,” said hub director Prof Dame Jane Jiang. “The challenge to the hub is to now achieve a similar level of improvement, reducing downtime from hours to minutes.”

Smart metrology such as these optical interferometers is essential to the ‘future factory’ where more point-of-manufacture quality and process control is applied to improve manufacturing productivity, and enable highly automated production with minimal skilled labour. “This will naturally reduce dependence on traditional ‘tailgate measurement’ and dedicated quality rooms,” said Paul Maxted, director of industrial metrology applications at Renishaw.

As there will still be some industries where final validation is a regulatory requirement (for example aerospace and medical) there will still be a need for some end of line CMM verification under Industry 4.0. However the confidence of parts conforming at that point will be much higher due to the measurements and controls applied during production, said Maxted.

“We also see a requirement for increased levels of measurement during production to allow more visibility and responsiveness to address sources of variation and prevent quality issues – infrequent measurement leads to ‘blind spots’ where there will be an amount of work-in-progress that will need to be quarantined and validated when issues arise – this is particularly relevant to high-volume, lean manufacturing industries where part flow is tuned to downstream machining and assembly operations,” Maxted added.

Embedded metrology for manufacturing is just one field of research in an exciting area of British engineering, which also includes forensic metrology, such as ballistics identification, and metrology for medical engineering.

The Metrology Hub operates a spoke model with the universities of Bath, Sheffield and Loughborough University, which have expertise in fields such as large volume metrology which supplement Huddersfield’s background in surface metrology, optical instrumentation and machine tool metrology. ■



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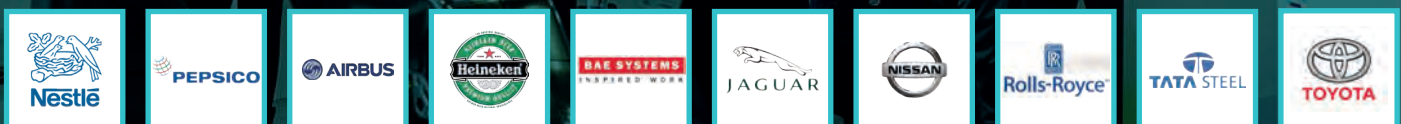
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Getting a sense of the bridge

World's first 3D-printed bridge to be equipped with sensor network. Supplier: MX3D

Britain's national institute for data science, the Alan Turing Institute (ATI), is to turn the world's first entirely additively manufactured bridge, a stainless-steel structure that is scheduled to be installed across a canal in central Amsterdam in late 2018, into a 'living laboratory' with a sensor network that will both help to understand how such structures behave in use and allow the bridge to be modified if that proves necessary for user safety.

The project will be carried out with MX3D, an Amsterdam-based robotic manufacturing specialist that is making the bridge; Autodesk; the Amsterdam Institute for Advanced Manufacturing Solutions; and Imperial College London.

The bridge is to be a 12m-long stainless-steel structure that has been designed by Joris Laarman Lab, a design practice in Amsterdam that specialises in digitally optimised structures. MX3D is building it as part of a project involving Arup as lead structural engineer, metallurgy

input from AcelorMittal and robots from ABB. When completed, it will be not only the first 3D-printed bridge, but also the world's largest 3D-printed structure of any type. The ATI project will see a network of sensors installed on the bridge to measure both structural data,

such as strain, displacement and vibration as it is used by pedestrians and cyclists, and environmental factors, including air quality and temperature.

The data from the sensors will be mapped onto a 'digital twin' of the bridge, which is being developed by the steel structures research group of Imperial's department of civil and environmental engineering. This model will change over time, imitating the real bridge more and more closely as more data comes in.

"The Alan Turing Institute's digital twin of the bridge will help with the creation of a new design language," said Gijs van der Velden, chief operating officer of MX3D.

"This data-centric, multidisciplinary approach to capturing the bridge's data will also mark a step-change in the way bridges are designed, constructed, and managed, generating valuable insights for the next generation of bridges and other major public structures," said Prof Mark Girolami, director of the Turing-Lloyd's Register Foundation Programme for Data-Centric Engineering. ■



All eyes are on the new frames

New Veroflex material has been optimised for glasses frame prototyping. Supplier: Stratasys



A large company might produce some 150 new glass frame designs every week, with every one taking about 18 months to develop using traditional techniques. Additive manufacturing specialist Stratasys claims it can reduce that time down to about eight weeks, using a new material optimised for glasses frame prototyping called Veroflex.

Designed to work with Stratasys's J750 multicolor multimaterial 3D printer, Veroflex is available in six mixable colours (CMYK, white and clear) and can simulate the textures of wood, bone, stitched leather and carbon fibre, Stratasys says. It can withstand all tests needed for prototyping, including drop tests, lens

mounting and stress and wearability tests. "The eyewear market continues to expand, driven by new technologies, demand for customisation and growing addressable markets," says Mike Vasquez, founder and CEO at the digital manufacturing consultancy, 3Degrees. "As the industry seeks to maximise its opportunity, Stratasys' prototyping solutions for frames and eyewear accessories, which can cut time to market by upwards of 80 percent, will be an attractive solution that is able to deliver immediate value for users looking to make parts with a high degree of mechanical function and appearance." ■

Get your teeth into an update of ancient processes

Laser-driven additive manufacturing replaces Bronze Age dentistry. Supplier: Renishaw

Swift Dental Group, which manufactures one-of-a-kind implants, orthodontics, bridgework and crowns from measurements of individual patients made by dentists, has updated its manufacturing techniques from methods – essentially unchanged since the Bronze Age – on the newest 21st century machinery. The company, the UK's largest dental laboratory, has acquired laser-driven additive manufacturing technology through a partnership with Renishaw.

Previously, Swift had used lost-wax casting – a technique known to the sculptors of Ancient Greece – to make the metal frameworks of their products. Wanting to update to digital

manufacturing, Swift initially worked with a German company to develop an entirely new technology, but instead decided to opt for a metallic powder-bed 3D-printing process.

Renishaw supplied its AM250

system, which uses a ytterbium fibre laser to melt fine cobalt-chrome powder in 40-micron-thick layers to build up the final article, coupled with a DS30 blue-light scanner, which converts a dental impression



or model into a 3D digital file. Up to 300 frameworks can be printed within eight to 12 hours. Within a fortnight of starting production at Swift, Renishaw mirrored its production line at its site in Gloucestershire, ensuring that if any glitches occurred, it could take over production. "The fact that Renishaw offered us the mirrored production line during set-up gave us the assurance that there would be no loss of production or downtime during the initial changeover," said Swift's business development manager, Paul Perkins.

The new process has helped Swift increase right-first-time production, Perkins said. "Previously, around two products in every 10 would need a rework after the end-customer's first fitting. The AM250 has helped reduce this drastically. This reduction is a benefit for dentists as it helps reduce the amount of appointments needed for each customer, which has a significant effect on the revenue of the practice." The company plans to buy another additive system to manufacture chrome removal partial dentures. ■

Putting additive on a bigger stage

Optical system is a critical component in the new RenAM 500Q. Supplier: Renishaw



Renishaw has introduced a new additive manufacturing (AM) machine that it claims will bring the benefits of AM to a wider range of components, applications and markets.

The firm's new RenAM 500Q four-laser additive manufacturing (AM) system, launched at this month's Formnext exhibition in

Germany, significantly improves productivity in the most commonly used machine platform size.

By positioning the machine competitively, Renishaw will bring the key benefits of a substantial reduction in cost per part while maintaining the quality and precision offered by standard single laser systems. By speeding up the process by up to four times Renishaw expects the RenAM 500Q to broaden the market appeal of metal additive manufacturing into applications that are presently uneconomic and potentially into new industries that have yet to fully embrace AM in production applications.

At the heart of the RenAM 500Q is

the optical system and control software, which has been designed, developed and manufactured in house. Just like the rest of the machine, this represents a significant investment in technology development and infrastructure. The optical system is a critical component within the AM system. The laser beams are delivered into the optical system via four separate channels. Each laser is dynamically focused before being directed into a single thermally controlled galvanometer (galvo) mounting that houses four pairs of digitally controlled guiding mirrors.

Each pair of mirrors can guide every laser to cover the entire

working area of the powder bed. This is achieved by positioning the guiding mirrors as close to the centre of the working area as possible and provides significant productivity and quality benefits when building parts. Using additive manufacturing to produce the galvo mounting has proven to be a key enabling technology, allowing tighter packaging of the mirrors and conformal cooling channels to maintain precise thermal stability.

With the significant improvement in throughput comes the additional challenge of managing process emissions. Creating and maintaining a stable processing environment is an area where Renishaw is already an innovator and leader, in using vacuum purging and efficient management of process shielding gas that helps deliver the lowest cost of ownership in class. Ensuring that the additional process emissions caused by three additional laser channels are efficiently removed is achieved by higher gas throughput. ■



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Crossing over into new terrain

Rapid development of automated and connected vehicles is creating new skills requirements in the automotive industry. David Fowler reports

01 A Bosch connected vehicle concept

02 The automated connected vehicle is also at the heart of Jaguar Land Rover's future plans

Automation, connectivity and the parallel development of electric vehicles are at the heart of car makers' strategies. According to Joerg Schlinkheider, Jaguar Land Rover chief engineer for automated driving, the company uses the abbreviation ACES, for automated-connected-electrified-shared.

"ACES is in our DNA now for the future," he said, adding that "automated vehicles will be connected to the cloud, to the customer and to all kinds of service".

At the same time, major markets, from Europe and the US to China, are demanding electric vehicles.

"The skills we require are getting much more specific," said Schlinkheider. Such skills include those in artificial intelligence, which is "a technique that helps detect and classify objects around [the vehicle] much better than in the past"; and in human-machine interfaces, which have become a growing area of focus since the first smartphones appeared.

The techniques involved in creating the user experience for the iPhone are feeding into systems in cars.

"Is the radio or navigation system seamless to use as a device?" asked Schlinkheider. Information to aid the driver also needs to be displayed. Is it in automated or manual mode? What is the distance to the car in front?

"That is a very important field. You need to understand the psychology behind it, and to orchestrate the information using graphics and colours so that the customer can understand it better."

For electric vehicles, materials scientists are needed. "It's clear we have to understand the chemicals in the battery to develop better batteries and extend the range of the vehicle," he said.

The need for connectivity is creating requirements for a range of software specialists, including app developers for infotainment systems, experts in localisation services and cyber-security specialists. In addition, because "an automated vehicle is a kind of robot", robotics specialists are needed too.

With the advent of the internet of things, the vehicle will be connected to everything, said Schlinkheider. "Right now, the vehicle is one of the white spots — not being connected that much. So cyber security is a very important topic."

Changes are affecting the supply chain as much as the car makers themselves. Arun Srinivasan, executive vice-president and head of mobility solutions at Bosch UK and Ireland, said the development of autonomous, connected and electrified vehicles was "the next threshold in the evolution of the automobile". Bosch has over 2,000 engineers developing the technology.

With the UK automotive industry in a resurgent period, said



01



02

Srinivasan, “the need for good, qualified engineers with skills that bridge the traditional and digital worlds has never been greater. Increasingly the analytical mind of an engineer needs to be paired with a creative ‘thinking outside the box’ approach”.

These skills are not replacing those of traditional engineers but “represent a continuing evolution in the skills of our workforce”, he added. “We are increasingly looking for people who can work differently in more agile ways across domains.”

This includes people “with systems engineering competences from the automotive and allied engineering fields; and, more importantly, people who are keen to broaden their outlook and experience”.

Tim Carling, director of engineering technology at specialist engineering recruitment consultant Matchtech, whose division focuses on electronics and software systems, said: “We’re seeing a change in demand. Traditionally, we’ve supplied software and hardware engineers for body electronics, powertrain and infotainment. In the past two or three years there’s been a significant move to application software and AI skills, and an increase in demand for radar, lidar and communications specialists.”

For Carling, the industry buzzword is ADAS: advanced driver assistance systems. In addition, the shift to

hybrid and electric powertrains is fuelling demand for power electronics specialists. He said: “OEMs are focused on strategy as much as developing the technology. The majority of demands are fed through to the supply chain.”

This is fuelling mergers and acquisitions as companies seek to acquire the right skills. For example, in August Intel bought Israeli sensor and computer vision specialist Mobileye in a \$15bn (£11.4bn) deal to boost its presence and credibility in the automotive sector.

Carling said: “Three years ago, you didn’t see automotive companies looking for network security and AI specialists.” A race is under way, “with every tier in the supply chain looking for the next-generation technology”.

At the same time, the rise of the euro against sterling following the Brexit vote is making German salaries very attractive, so the German automotive market “is pulling on an already depleted UK talent pool”.

Developments are moving fast. Jaguar Land Rover will launch its first full battery electric vehicle, the I-PACE sports saloon, in the second half of next year. Its first automated capability will appear in the next three years with the expected introduction of a ‘traffic jam pilot’: a system to take over from the driver when on a motorway or other highway with no pedestrians and in difficult or congested conditions at up to 40mph. The speed will be raised incrementally and the capability to drive on urban and inner-city roads brought in over the next 10-15 years.

For anyone seeking to work in this rapidly expanding area who wants to improve their marketability, Schlinkheider noted that automated driving technology was not part of current traditional university courses. However, online university Udacity offers a Self-Driving Car Engineer ‘nanodegree’, which can be completed in nine months, as well as in AI, robotics and other related subjects. Jaguar Land Rover is a hiring partner of Udacity.

Schlinkheider said: “We’re working with such organisations to define the skills required and to find candidates for the future.”

“The need for engineers with skills that bridge traditional and digital worlds has never been greater”

Arun Srinivasan, Bosch UK and Ireland

For Bosch, Srinivasan said: “In the UK, our Graduate Specialist Programme in particular is an outstanding opportunity to advance personally and professionally in a chosen discipline.”

Graduate specialists work alongside more experienced staff on real projects, quickly taking on responsibility and demonstrating leadership. The scheme incorporates placements at various Bosch sites, including internationally, and over two years participants receive advice and supervision from a mentor.

Srinivasan added: “Aside from classic engineering subjects, there is a huge opportunity for software expertise in the automotive domain, particularly for engineers looking at future vehicle electrical and electronic architectures, and systems engineering.”

Carling said there was good news for those with the right skills. “For anyone with skills in electronics, embedded and application software, or an AI background, the view is that the industry is skills short in the UK.”

“Two years ago, clients were more selective about having automotive experience. But now there are opportunities for those who’ve worked outside the sector. People are coming in from communications, and other safety-critical areas such as rail and aerospace. There’s a lot of crossover. It’s a bright outlook: a vacancy-heavy, skills-short market.” ■

November
1945

Magnetic offensive

Britain's foray into magnetic mines reaped significant rewards at sea during the Second World War

Unexploded sea mines remain a hazard in the waters around Britain but in November 1945 they were being hailed as a key weapon in the defeat of Hitler.

What set the sea mines of the Second World War apart from their predecessors was the fact that they could be used offensively, and the magnetic mine played its part in taking the fight to enemy targets.

The UK's first foray into magnetic mines came with the M Sinker during the First World War. As noted by our correspondent, work on the magnetic mine and torpedoes was hastened greatly by the realisation in 1935 that Britain had to rearm.

"Hand in hand with these developments went the investigations into the magnetic properties of ships which formed the groundwork for the system of conferring a high degree of immunity upon ships by 'degaussing' them," the author said. "As a result of all the work upon development, we produced a very satisfactory and robust form of magnetic mine. In the development of our magnetic mine we had worked on the principle of using the horizontal component of a ship's magnetism to actuate the firing mechanism. This component had been selected because it is the stronger of the two except immediately under and close to the bottom of a ship, and because it is, for the practical purposes of mine design, unaffected by the earth's magnetic field."

The use of the horizontal component presented other advantages. According to the author, the sensitive element in British magnetic mines consisted of a CR (coiled rod).

"This rod had to lie horizontal and, since our mines were long and torpedo shaped – because they were designed to be dropped from torpedo-carrying aircraft of the Fleet Air Arm – we were able to use a CR rod running through the charge and thus nearly as long as the mine itself," said the author. "This was a great advantage, for the sensitivity of the mine depends upon the length of the CR rod. The fact that these mines were robust



Royal Navy minesweepers are still dealing with Second World War mines

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was of great importance, for comparatively little was then known about shock and the absorption of shock, particularly as applied to the delicate instruments of the modern mine when it is dropped into the sea from an aircraft."

In tests, it was found that that the mine could be dropped with a parachute measuring 5ft in diameter. The early lack of precise knowledge in dealing with the shock of dropping the mine had an incidental, but very important, effect upon the future development of Britain's mines.

"In designing the mine considerable space was left in the chamber housing the actuating mechanism in case additional shock-absorbing packing should be found necessary. That refinement was not needed, and the extra space allowed us to fit developments to our existing mine without having the casing redesigned. Our magnetic mine was cylindrical in shape. The parachute was attached at one end and the other end was chamfered in order to turn the mine to the

horizontal in the water so that it would not stick nose down in the seabed."

The *Engineer's* naval correspondent added that Germany's use of the mine was tactically flawed.

"That is not to say that it did not cause us casualties and much food for thought. It did. But the necessary reticence regarding our own mining campaign and technical developments in this field of sea warfare has tended to give the impression that the Germans called the tune, and that we followed panting and occasionally, by lucky chance, producing a timely antidote to German ingenuity.

"Nothing could be further from the truth. We used secrecy to our great advantage, and, taking the mine warfare of the past six years as a whole, we were ahead of the Germans both in the production of mines fitted with 'circuits' calculated to provide work and headaches for the German technicians, and in the rapid production of effective sweeping arrangements and antidotes to the new forms of mine produced by the enemy." **JF**

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Word of the issue

Anthony Poulton-Smith explores origins of the word 'casting'

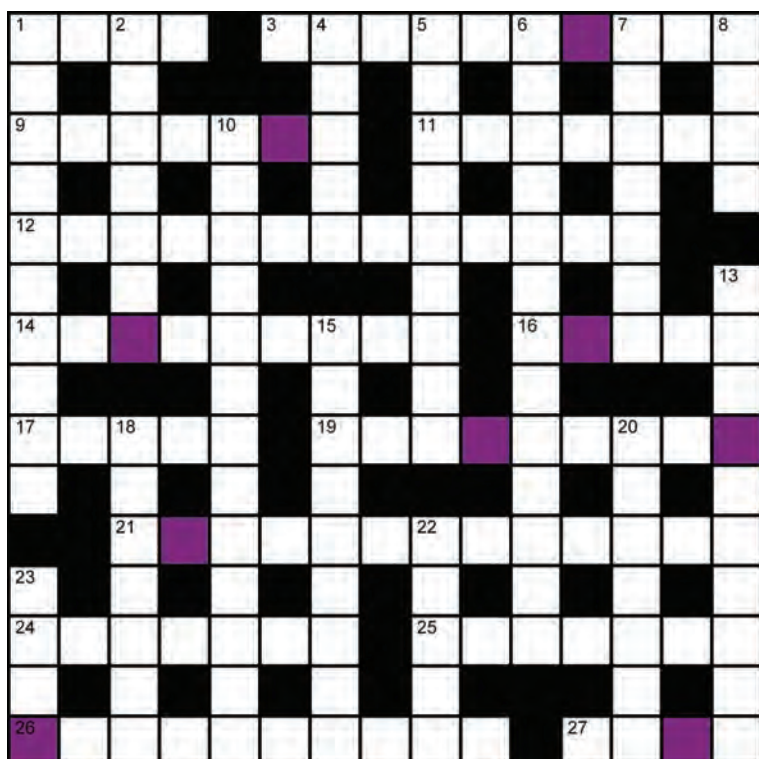
We still use 'cast' in the sense of 'throw', in contexts such as fishing. We should also look at the synonyms of these other contexts, particularly the most obvious example 'throw'. While no angler would ever consider 'throwing their line', a potter will 'throw' a pot. By examining the history of both we find 'throw' to be an Old English word *throwan* used to mean 'twist, turn, writhe' – Saxons used *weorpan* or 'warp' instead of 'throw' as we would in the modern sense.

By contrast 'cast' arrived with the Scandinavians, albeit not in general use until the 12th century. With a root shared with Old Norse *kasta*, Swedish *kasta*, Danish *kaste*, and Frisian *kastin*, there is still an expression, although little used today, where warped timber is referred to as 'cast'. Here is the link. Where timber was 'warped' or 'cast', later the use of 'throw' instead of 'warp' resulted in 'cast' also falling out of favour.

Bigpicture



Bloodhound SSC, the supersonic British car designed for speeds of 1,000mph, has moved a step closer to its ultimate goal following the completion of a series of 200mph test runs at Cornwall's Newquay airport.



Prizecrossword

When completed rearrange the highlighted squares to spell out a railway pulled by a moving cable. The first correct answer received will win a £20 Amazon voucher. Email your answer to jon.excell@centaur.co.uk

Across

- 1 Make over (4)
- 3 Promotion by means of an argument and demonstration (5,5)
- 9 Clap one's hands to show approval (7)
- 11 Government trade prohibition (7)
- 12 Cable for long-distance communication (9,4)
- 14 Small water course (9)
- 16 Being on the exterior (5)
- 17 Kind of heather plant (5)
- 19 Relating to the motion of objects under gravity (9)
- 21 From or between other countries (13)
- 24 Element used in transistors (7)
- 25 Regular income from a capital investment (7)
- 26 Household in which an orphaned child is placed (6,4)
- 27 To be dressed in (4)

Down

- 1 Trialled in realistic working conditions (4-6)
- 2 Effect involving the apparent change of sound wave frequency (7)
- 4 Indicating hearing or sound (5)
- 5 Relating to severe atmospheric conditions (9)
- 6 View of the people (6,7)
- 7 A violently fast stream of water (7)
- 8 A catch for locking a door (4)
- 10 Nucleus of the helium atom (5,8)
- 13 Craftsman skilled in building with blocks (10)
- 15 Maze of underground tunnels (9)
- 18 Frozen spikes of water (7)
- 20 Capable of being shaped or bent (7)
- 22 Device that signals the occurrence of an undesirable event (5)
- 23 Expression of incredulity (2,2)

August's highlighted solution was Pinion. Winner: **Gavin McCarthy**

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