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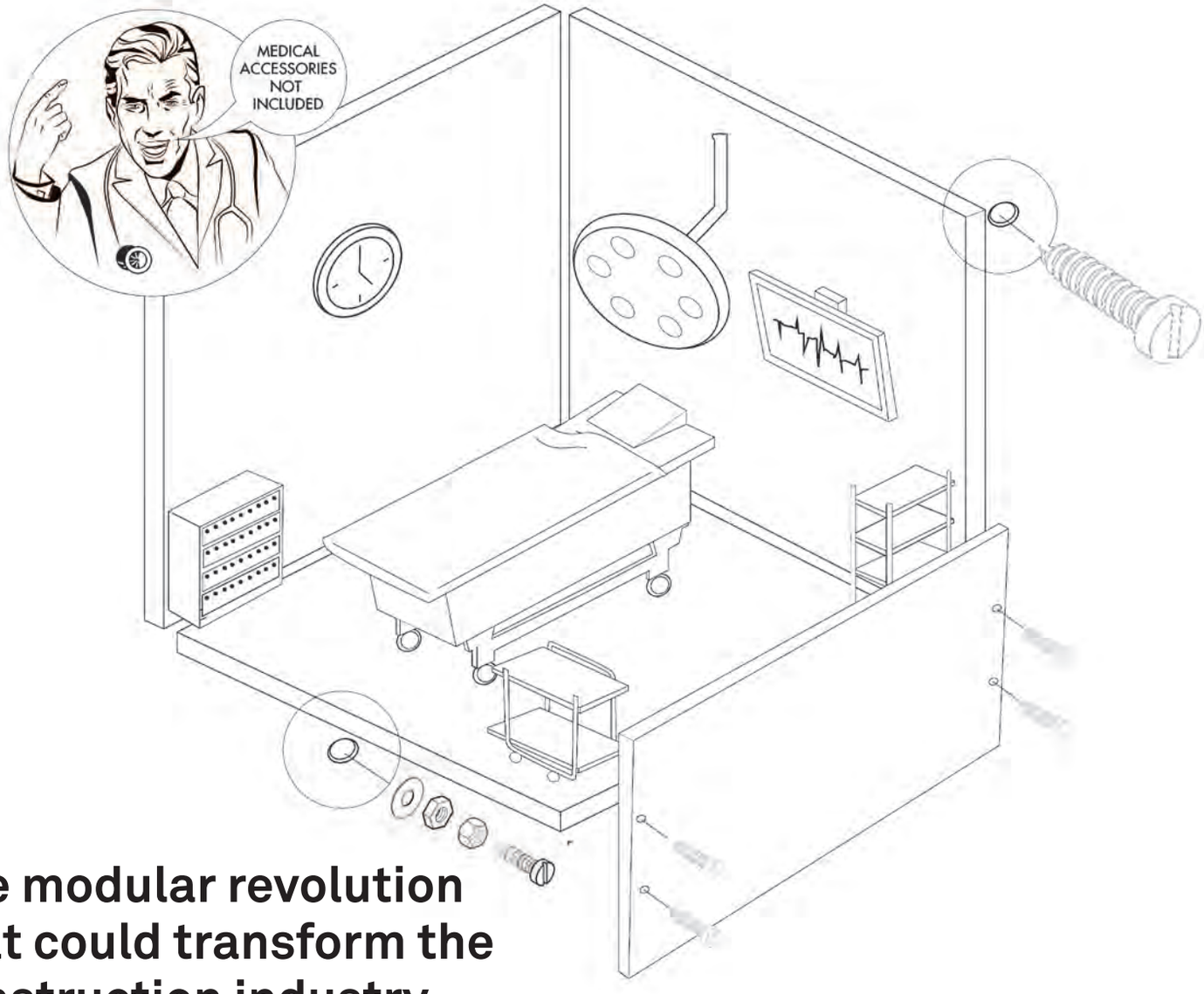

The modular revolution that could transform the construction industry

(instructions inside)

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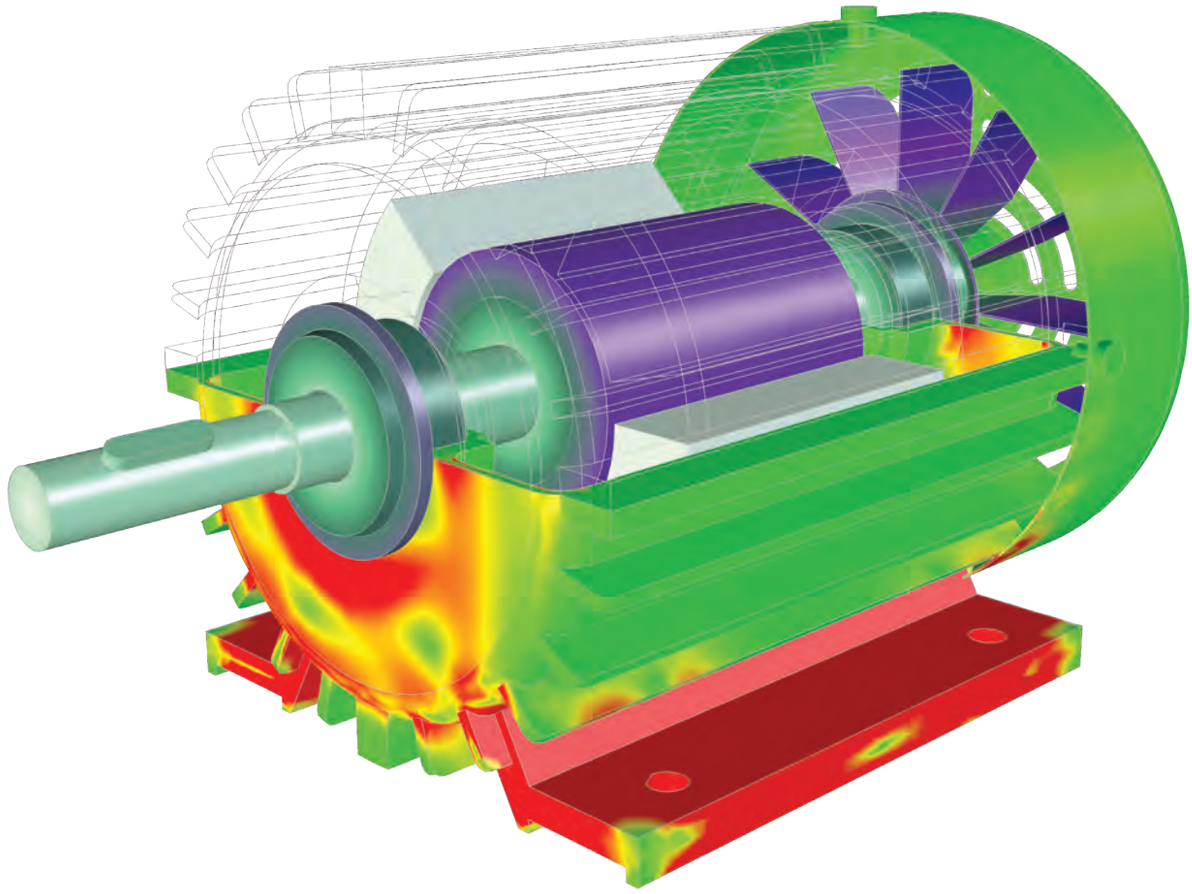

Visualisation of the von Mises stress distribution in the housing of an induction motor by accounting for electromechanical effects.

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features

our**opinion**

Brexit uncertainty

Industry's political backdrop changes so rapidly these days that it's a bit risky using a print column to comment on Brexit. But amidst the daily twists and turns of the UK's confused and tormented efforts to leave the EU, one thing that we can be reasonably certain of is that – barring a miracle – uncertainty will still be the name of the game by the time this issue lands.

And, as two of the UK's biggest sectors loudly reminded the government in recent weeks: if there's one thing industry can't stand, it's uncertainty.

Airbus's claim that it's considering the prospect of moving production from the UK, closely followed by warnings from the car industry that government red lines on Brexit will hit jobs and derail growth, shouldn't be any surprise. Both sectors have been lobbying the government – with growing levels of exasperation – on precisely these issues for the past two years. Faced with the growing fear of a no-deal Brexit and the very real prospect of the government removing the trading conditions that have helped drive their success in the UK over the past two decades, it would be a surprise if they weren't now turning up the volume.

> "Whichever side you sit on, industry's concerns should not be taken lightly"

Unsurprisingly, such comments have been polarising. Whilst many Remain voters despairingly discern the first depressing signs of an engineering "Brexodus", the hard Brexit brigade talk dismissively of politically motivated fear-mongering. The truth probably lies somewhere between these two extremes, but whichever side of the divide you sit on, industry's concerns should not be taken lightly. The fact that it feels the need to make such strong statements – statements that, in the short term, damage confidence and affect the morale and productivity of staff, statements that it would obviously rather not be making – is surely all the proof anyone needs that it's not simply playing politics.

In its industrial strategy (published in November 2017) the government outlined its plans to put Britain at the heart of the global industrial economy: a hollow pledge, indeed, if its most enduring contribution to the UK industrial landscape is to make it inhospitable to some of the world's most innovative and exciting businesses. With the countdown to Brexit well and truly under way, a governing party traditionally seen as a safe pair of hands for business must now do more than pay lip-service to the concerns of its engineering wealth-makers, and bring about an end to the uncertainty that's choking off UK industry's growth. Perhaps by the time this issue lands, we'll know whether or not pragmatism has triumphed over ideology. ■

Jon Excell Editor
jon.excell@centaurmedia.com

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the ENGINEER **Centaur Media Plc, 79 Wells Street, London, W1T 3QN**

Direct dial 020 7970 followed by extension listed Advertising fax 020 7970 4190 **Editor** Jon Excell (4437) jon.excell@centaurmedia.com **Features editor** Stuart Nathan (4125) stuart.nathan@centaurmedia.com **Senior reporter** Andrew Wade (4893) andrew.wade@centaurmedia.com **News editor** Jason Ford (4442) jason.ford@centaurmedia.com **Commercial director** Justyn Gidley (4942) justyn.gidley@centaurmedia.com **Recruitment advertisement manager** Michael Maunsell (020 7970 4679) michael.maunsell@centaurmedia.com **Business development manager** Paul Tilston (4487) **Account Manager** Lindsay Smith (4811) **Production** Wendy Goodbun (4807) te.production@centaurmedia.com, Gillian Maher, Mark Westwood, Press Association **Publisher** Simon Lodge (4849) simon.lodge@centaurmedia.com **Subscriptions & Customer Services** tecirc@centaurmedia.com

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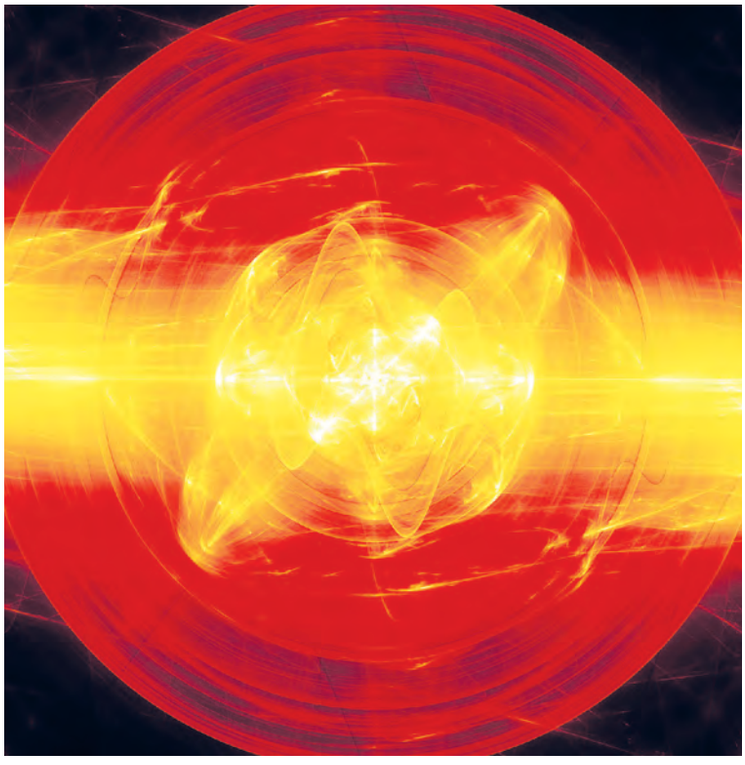
CENTAUR MEDIA

ENERGY

Fusion project to tackle turbulence

Researchers investigating ways to increase reactor output HELEN KNIGHT REPORTS



Fusion, the process that powers the sun, has long been seen as a potential means of generating abundant, clean energy.

However, despite years of research into the process, challenges remain about how to create and maintain the extremely high temperatures and pressures needed for sustained fusion.

One important factor is turbulence, which can decrease the temperature and pressure of the plasma inside the reactor, reducing the amount of fusion power that can be generated.

Now, researchers at the University of York are investigating ways to suppress this turbulence, in the hope of increasing the amount of fusion power that can be produced by reactors such as the ITER Tokamak project in southern France. The EPSRC-funded project, which also includes the UK Atomic Energy Authority as well as researchers from the Universities of Oxford, Strathclyde and Warwick, is also aiming to investigate ways in which the same amount of fusion power can be generated from smaller reactors, which would be cheaper and quicker to build and commercialise.

To generate thermonuclear fusion, a plasma of deuterium and tritium contained within a magnetic field must be heated to 100 million Kelvin – ten times the temperature at the centre of the sun. This causes the nuclei to fuse together to form a heavier nucleus, helium, releasing large amounts of energy in the process.

As the plasma is heated, the pressure at the centre increases towards fusion conditions, while that at the edges remains low, to be compatible with the material surfaces of the vessel, according to Professor Howard Wilson at the University of York, who is leading the project.

"The steeper you can make your pressure gradient, the higher you can make your central pressure, and the more fusion power you'll get out," said Wilson.

However, as the pressure gradient increases, it causes the plasma to begin churning, generating turbulence. This turbulence then pushes heat and charged particles out from the centre of the plasma to the edges, reducing the pressure gradient and the amount of fusion power that can be produced.

"If this churning didn't happen, then you wouldn't get this loss of heat and particles across the magnetic field lines," said Wilson. "In this way you could support a very big plasma pressure gradient, and achieve a high pressure in the centre and lots of fusion power."

Alternatively, you could achieve the same amount of fusion power, but from a smaller reactor, he said. To investigate ways of suppressing this turbulence, the researchers plan to use advanced simulation, alongside experiments at the newly upgraded MAST-U reactor at the Culham Centre for Fusion Energy in Oxfordshire.

The researchers are developing models for how the plasma behaves, and how the turbulence is generated, but the process is an extremely complex one to simulate, said Wilson.

"Turbulence in a fluid like water usually only depends on what we call the fluid variables, parameters like pressure and flow," he said.

"But in a plasma, there are a whole range of new waves that don't exist in neutral fluids like water or gas, as well as certain characteristic drifts of the particles that can resonate with those waves, amplify them, and cause them to crash and churn up the plasma, driving the turbulence."

So the researchers are aiming to develop models that simplify this process while keeping as much of the plasma physics as possible. They will then compare their predictions with data from real tokamak reactors, such as MAST-U. ■

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SALARY SURVEY 2018

Gender pay gap is getting wider

Women trailing by £13,000 a year JON EXCELL REPORTS

At a time when the gender pay gap is under increasing levels of scrutiny, *The Engineer*'s 2018 Salary Survey points to a widening gap between the salaries of male and female engineers.

Produced in partnership with technical recruitment consultancy CBSbutler, the survey – now in its fourth year – attracted responses from 2,864 engineers across the UK.

Female engineers, who accounted for just 7.2 per cent of respondents, are paid on average £35,800. This compares to an average of £48,720 for their male colleagues and marks a widening of the £10,000 pay gap identified by our 2017 salary survey.

This gap can be partly explained by the difference in seniority among male and female respondents. For instance, just 2.4 per cent and 11.3 per cent of male respondents describe themselves as graduates and junior engineers respectively, compared with 10.2 per cent and 20.3 per cent of female respondents.

However, the findings do suggest that male engineers at all levels of seniority are paid more than their female counterparts. Female graduates and junior engineers earn an average of £27,552, for example, compared with £31,051 for male engineers, a gap of around £3,500. This gap jumps to around £10,000 for senior engineers and managers, and widens even further at director level and above, where women earn £46,053, and men £73,595, a huge difference of £27,542.

More generally, this year's survey tells a story of stagnation, with many key measures showing little, if any, change from last year's results.

And although there are significant regional, sectoral and seniority-based variations, the mean average salary for engineers taking part in this year's survey is £47,896, a slight decrease on last year's average of £48,197. Our 2017 survey showed a year-on-year average salary increase of six per cent.

With industry facing a period of uncertainty, this stagnation is perhaps not surprising. And Brexit is clearly looming large in the thoughts of many UK engineers. Some 61 per cent of those surveyed are concerned about the impact of Brexit on industry, whilst 37 per cent say they are worried about the impact leaving the EU would have on job security.

Despite such concerns, though, UK engineers appear to be a fairly settled bunch, and although just 32.7 per cent of the total response group are content with their pay, more than half say that they are happy in their roles, and more than 80 per cent expect to stay in the industry for at least the next five years. ■

ENERGY

Storelectric going Dutch

UK start-up steps up challenge HELEN KNIGHT REPORTS

Storelectric is to build a large-scale compressed air energy storage (CAES) site in the Netherlands, after winning an international competition.

The UK start-up, which proposes storing energy via compressed air in underground salt caverns, was recently crowned the winner of the NAM70 Challenge, run by Dutch energy company NAM. As well as a €50,000 (£44,000) prize, Storelectric will partner with NAM, which is jointly owned by Shell and Exxon, to investigate the idea of repurposing oil and gas infrastructure. They aim to build underground storage sites in the Netherlands, and potentially the North Sea, to store energy from offshore wind farms and onshore solar power plants.

At CAES plants, excess electricity – for example from intermittent sources - can be used to compress and store ambient air under pressure in an underground cavern. Then, when electricity is needed, the pressurised air can be heated and expanded in a turbine to generate electricity.

However, as the air is being compressed, it heats up, and this heat must be removed before it can be safely stored, according to Jeff Draper, director of Storelectric.

"You can't put hot compressed air into a salt cavern at 500˚C; it would melt the salt cavern, so it has to go in at ambient temperature," said Draper. "The way the existing plants have done this is to release the heat from the compressed air to atmosphere on input, which is a waste of energy."

Such plants then use natural gas to reheat the air as it is expanded, reducing the overall efficiency of the process. Instead, Storelectric stores the heat removed from the air during the compression stage, and uses it to reheat the air again during the expansion stage, a process called adiabatic CAES. ■

Newsinbrief

BAE wins US marines deal

BAE Systems has won a $198m (£150m) contract from the US Marine Corps to deliver an initial 30 Amphibious Combat Vehicles (ACV), with options for a total of 204 vehicles which could be worth up to $1.2bn (£900m). The new vehicle is an advanced 8x8 open ocean-capable vehicle equipped with a new six-cylinder, 700HP engine. Work on the program will be carried out at BAE facilities across the US.

Rise of the robots

Global sales of industrial robots increased 29 per cent to 380,550 units in 2017, according to the World Robotics Report 2018. In Asia, China installed around 138,000 industrial robots, whilst Germany led the way in Europe with sales of approximately 22,000 units. Demand for industrial robots remained strong in the automotive sector, with approximately 125,000 sales, whilst the metal industry posted 54 per cent growth.

Nuclear reactors plea

Foratom has called on the European Commission and other EU institutions to recognise and reward the long-term operation (LTO) of nuclear power reactors in their role to help Europe meet its climate targets. There are 126 operational reactors in 14 EU Member States, but the commission has warned that up to 50 reactors are at risk of early closure if their operators do not pursue LTO licences.

First US-made Volvos

Cars at Volvo's first US manufacturing plant will begin rolling off the production line this autumn. The plant in Charleston, South Carolina, will initially produce the new Volvo S60 premium mid-size sports saloon. From 2021, the factory will also build the next generation of the Volvo XC90 large premium SUV. Cars built at the plant are destined for the US market and international export.

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AEROSPACE

New Rolls-Royce engines launched for business jets

'Pioneering' Pearl series will propel Bombardier's Global aircraft

STUART NATHAN REPORTS

Rolls-Royce has launched Pearl, a new engine family for business aviation that will propel Bombardier Global series aircraft.

The Pearl 15 engine, the first in the new series, will deliver up to 15,125lb of thrust (67.3kN), nine per cent more than its predecessor, but will be 2dB quieter and will deliver a seven per cent improvement in specific fuel consumption, with best-in-class performance for NOx emissions, Rolls-Royce claims.

The new engine is descended from two ancestors: the BR700, Rolls-Royce's current class leader for business aviation, and the Advance2 technology demonstrator programme. These are twin-spool engines; that is, the high-pressure compressor and high-pressure turbine blades are mounted on a shaft that is concentric to, and rotates independently of, the shaft holding the low-pressure compressor and turbine blades.

In Trent engines, which power civil airliners and are triple-spool (with an intermediate stage of compressor and turbine, also mounted on a concentric, independent shaft), the intermediate stage compressor takes the majority of the load of forcing air into the combustion chamber. In Advance2, the high-pressure compressor takes on a greater proportion of the load.

The new series is designed specifically for long-range business jets, which will be capable of speeds of up to Mach 0.9.

David Coleal, president, Bombardier Business Aircraft, said: "The Global 5500 and Global 6500 aircraft have the longest range, the largest cabins and the smoothest ride in their class, and we are proud that they will be powered by the advanced and efficient Pearl engine."

Chris Cholerton, president of Rolls-Royce's civil aerospace division, added: "The Pearl engine is a pioneering product... The combination of outstanding performance, economy, and reliability levels make it the perfect fit for Bombardier's newest Global aircraft and, with the Pearl engine, we are extending our successful relationship with Bombardier, which started more than 20 years ago."

To date, Rolls-Royce has delivered some 1,700 engines to Bombardier.

The engine was designed at Rolls-Royce's centre of excellence for business aviation in Dahlewitz, Germany.

Other features include a new engine health monitoring system with advanced vibration detection, remote engine diagnostics, and equipment for bidirectional communication that will allow the engine monitoring features to be reconfigured from the ground. ■

The Pearl 15 is the first in the new series of engines

ENERGY

Tokamak reactor reaches 15 million-degree milestone

Plasma temperatures hotter than sun's core

Tokamak Energy has hit plasma temperatures hotter than the sun's core for the first time, reaching 15 million Kelvin.

The milestone was achieved using the ST40 device, the latest in a line of tokamaks the company has built in pursuit of commercial fusion. Using 'merging compression', the ST40 releases energy as rings of plasma that crash together and magnetic fields in the plasma reconfigure – a process known as magnetic reconnection. Merging compression involves high electric currents running through the internal coils of the ST40, requiring power supplies to deliver thousands of amps in seconds.

Though 15 million Kelvin may be an important landmark, it is a long way from the 100 million required for thermonuclear fusion on Earth.

The ST40 is the third machine in a five-stage plan that Tokamak Energy believes will lead to commercial fusion energy. **AW**

ENVIRONMENT

Mapping water contamination

Device helping to protect people in rural Colombia

ANDREW WADE REPORTS

An electrochemical device developed at Bath University is being used in rural Colombia to detect water contamination and help map problem areas.

The device measures four key physicochemical variables in water, namely pH levels, conductivity, temperature and dissolved oxygen. It also monitors the presence of heavy metals in water, including mercury. Developed in conjunction with Colombia's University of Los Andes, the system features a mobile app that uploads the readings to a web-based platform. This allows authorities and members of the public to see where contamination is at its worst.

"The novelty of this device lies mainly on the electrochemical detection and on the interactive process and display of the data," said Dr Mirella Di Lorenzo, project lead and senior lecturer at Bath University's department of chemical engineering.

"The device is an integrated sensor that includes probes for physicochemical analyses, together with electrochemical detection of heavy metals using screen-printed electrodes. The sensor communicates with a smartphone and the data is sent to an open-access interactive map."

According to the Bath team, Colombia is the third most mercury-contaminated country in the world, largely due to illegal metal mining. Rural indigenous communities have been particularly affected, with high rates of foetal malformations and brain disorders linked to the problem. ■


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ENERGY

Locking CO_2 in ground could help extract shale gas

Project explores use of carbon dioxide to enhance recovery of methane

HELEN KNIGHT REPORTS

Carbon dioxide could be captured and permanently stored, while simultaneously enhancing the recovery of natural gas from shale reservoirs.

Shale gas production has become an increasingly important source of energy in the US – and other countries, including Britain and China, hope to follow suit.

But despite around 20 years of commercial shale gas extraction in the US, very little is known about the flow of gas through the ultra-tight porous environment of shale formations, according to Dr Lei Wu at Strathclyde University.

Wu is leading an EPSRC-funded project to investigate this process, with the aim of using CO_2 to enhance the recovery of shale gas from geological reservoirs.

After around 10-20 years of shale extraction, when the tail production cannot cover the operational costs, the conventional procedure is to seal the wells forever.

However, in a recent field experiment in Tennessee, CO_2 was used in a shale reservoir to further increase the production of methane, said Wu.

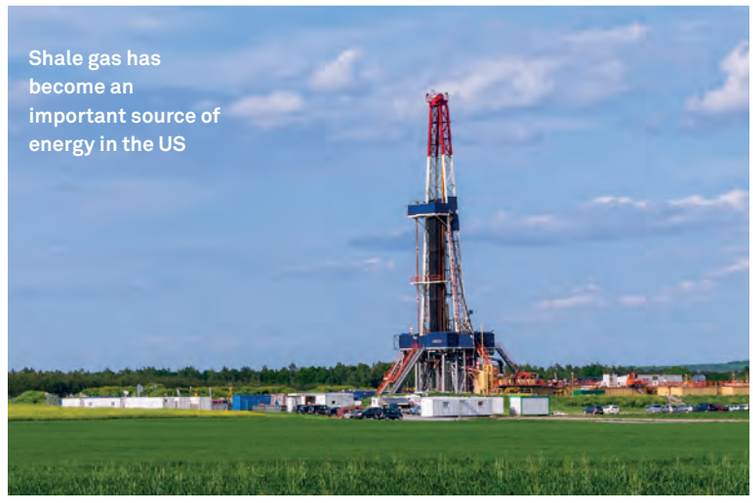
"They injected CO_2 into the depleted formation, and then closed the well for a few months, allowing CO_2 to diffuse into the shale matrix. They then reopened the well," he said.

The researchers found that not only did the CO_2 enhance the methane production, but some of the greenhouse gas had also been absorbed by the shale matrix, allowing it to be sealed and permanently captured, he said. "The shale formation prefers CO_2 to methane, so the CO_2 is absorbed and the methane is desorbed," he said.

To better understand this process, Wu and his colleagues will be developing gas kinetic theory, in which the dynamics of the gas is mimicked by a limited number of "particles" moving from site to site and colliding with each other, to investigate the flow of gas through the shale formation.

Unlike a conventional gas reservoir, pores within a shale matrix can be on the nanometre scale. At this scale, conventional fluid dynamics cannot be used, while full molecular dynamics simulations are too computationally demanding, said Wu.

"We need to know how much CO_2 is needed to replace the methane in the shale formation, how much more methane can be released, and how much CO_2 will be permanently absorbed by the shale matrix," he explained. ■



Shale gas has become an important source of energy in the US

AUTOMOTIVE

Consortium gets autonomous vehicle trials on the road

Testing environment will be largest in UK

A new consortium called Midlands Future Mobility will be testing and evaluating connected and autonomous vehicles and related technologies on 50 miles of roads around Birmingham and Coventry.

Led by WMG at Warwick University, the consortium includes Amey, AVL, Costain, Coventry University, HORIBA MIRA, Wireless Infrastructure Group, and Transport for West Midlands (TfWM). According to the group, it will use networked roads that cover a range of representative areas and will be the largest and most diverse testing environment in the UK. The project will see the deployment of new roadside infrastructure, including smart vehicle monitoring, data analytics and 5G-ready wireless infrastructure.

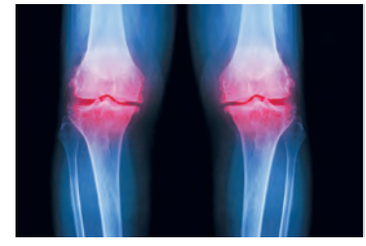
By using real-world environments, the consortium hopes to enable a variety of industries to test new vehicle technologies and services, with the aim of improving integration. **AW**

MEDICAL

CT scans to spot arthritis

New technique can detect small changes

STUART NATHAN REPORTS



A team from Cambridge University has used CT scanning to detect and monitor osteoarthritis.

Diagnosis of osteoarthritis depends on x-ray imaging to detect narrowing of space between the bones in the joint. But this effect can be gradual, subtle and difficult to spot, depending on the judgement and experience of the clinician. Lack of sensitivity of X-rays can also make it difficult to detect changes over time.

"Our ability to detect structural changes to identify disease early, monitor progression and predict treatment response is frustratingly limited by this," said Tom Turmezei, of Cambridge University's department of engineering.

Reporting in *Scientific Reports*, Turmezei and colleagues explain how they have turned to computerised tomography (CT) scanning to identify changes in the space between bones in the joints.

CT scanning is commonly used to look at internal organs, but not to monitor joints. However, with its ability to construct detailed three-dimensional images from "slices" through the body, Turmezei believes it could be helpful.

The Cambridge team has developed a technique called joint space mapping (JSM). The initial research was carried out on human hip joints from bodies donated to medical research. This revealed that the technique was more sensitive than the current "gold standard" for joint imaging with X-rays, proving at least twice as good at detecting small structural changes. ■

AUTOMOTIVE

Electric cars on track for improved inductive charging

Wireless spots placed in roads could make 'filling up' more convenient

HELEN KNIGHT REPORTS

Research led by Cambridge University aims to alleviate range anxiety for electric vehicle (EV) owners by developing wireless charging that is quicker and more convenient.

Residential charge points can take all night to recharge a battery and fast-charge stations are relatively scarce. Despite improvements in battery technology, the problem cannot be solved by improvements in battery chemistry alone, said Dr Teng Long at Cambridge, who is leading an EPSRC-funded project to improve wireless charging technology for EVs.

By using inductive power transfer, in which power is transferred from a ground-based transmitter coil to a receiver coil on the vehicle via time-varying magnetic fields, cars could be charged by small amounts, but more frequently, said Long.

"Currently, if you want to refuel your car with conventional fuels, you have to drive to a petrol station," said Long. "But if you decentralise that system it could become part of your daily drive, with wireless charging spots embedded in the road at traffic lights, for example, or parking slots."

The project, involving McLaren Group, Advanced Technology & Materials, and Dynex Semiconductor, will first develop more robust coils.

Existing coils are typically made of ceramic compounds, such as ferrites, which are quite brittle, said Long. "It's not a good idea to have such a fragile coil embedded in the road, where there will be wheels driving over it," he said.

So the researchers are aiming to develop coils using a nanocrystalline alloy, which they believe will prove to be much more robust than existing ceramic coils.

They also hope to improve the design of the power conversion system, reducing the number of individual components, in a bid to cut costs and increase robustness.

Finally, they hope to improve the technology's ability to tolerate misalignments between the car and the wireless charging spot, said Long.

In existing systems, even a slight misalignment of around 10 per cent can halve the system's efficiency, he said. "We all know that in real life you cannot park that precisely, some misalignment cannot be completely avoided, so we need to improve on that," Long explained.

By the end of the project, the research team plan to build and test a 7.7kW prototype system. ■

Fast-charge stations remain relatively scarce

MEDICAL

New method could be key to synthetic tooth enamel

Scientists develop mineralisation process to mimic body's hardest substance

Scientists at Queen Mary University of London have developed a method of growing minerals that mimics the structure of bone and enamel.

Enamel protects teeth from decay, even when faced with acidic foods and extreme temperatures. It is the hardest substance in the body, but unlike other tissues, it doesn't regenerate.

A synthetic replacement has long been sought, and could potentially help millions of people around the world with tooth pain. The team employed "a protein-mediated mineralisation process", where a protein triggers and guides the growth of apatite nanocrystals at multiple scales.

The mineralisation results in the nanocrystals organising into microscopic prisms that grow in clusters, similar to natural dental enamel development.

Indentation testing showed the synthetic hierarchical structures, though not quite matching the hardness of human enamel, outperformed bone and dentine.

The tunability of the mineralisation process means it will be possible to create materials that more closely mimic different hard tissues beyond enamel, including bone and dentine. **AW**

ENERGY

Ammonia goes carbon-free

Siemens' green energy storage demonstrator

HELEN KNIGHT REPORTS

Ammonia could be used to store renewable energy, and as a source of hydrogen for fuel cell-powered vehicles, thanks to a demonstrator developed by Siemens.

The Green Ammonia Energy Storage Demonstrator, developed by Siemens alongside the Science and Technology Facilities Council and the Oxford and Cardiff Universities, with funding from Innovate UK, shows the complete cycle of renewable power, storage as ammonia, and conversion back to electricity.

Powered by renewable energy, the device extracts nitrogen from the air and uses electrolysis to separate hydrogen from water, according to Ian Wilkinson, programme manager, Siemens Corporate Technologies.

The two elements are then combined using the Haber-Bosch process, in which hydrogen and nitrogen are reacted under high temperature and pressure in the presence of a catalyst, to produce ammonia.

"We know how to synthesise ammonia in big quantities, store it, and transport it; the infrastructure is already there," said Wilkinson.

However, existing techniques to produce ammonia typically rely on the use of natural gas or other fossil fuels, meaning they generate large amounts of carbon dioxide.

The new technique could be used as a means to store excess electricity produced by intermittent renewable energy sources, for use at times when the sun is not shining or the wind is not blowing.

Ammonia could then be burnt as a fuel in gas turbines, where it emits nitrogen and water, but no CO_2. ■

ENERGY

Nanowires offer high efficiency in thermoelectricity

Atomically thin materials display potential for use in sustainable energy

HELEN KNIGHT REPORTS

Nanowires as thin as one to two atoms can convert heat to electricity more efficiently than bulk materials, offering the potential for their use in sustainable energy, according to UK research.

Thermoelectric materials convert waste heat to electrical energy through a process known as the Seebeck effect. The materials are used in applications such as power plants and cars.

Researchers at Warwick University, in collaboration with the Universities of Cambridge and Birmingham, have discovered that shaping the materials into the thinnest possible nanowires means they conduct less heat and more electricity at the same time. This results in significantly greater efficiency than bulk versions of the materials.

The research investigated the crystallisation of tin telluride in extremely narrow carbon nanotubes, which they used as templates for the formation of the materials in their one-dimensional form, according to the paper's first author, Dr Andrij Vasylenko, from Warwick University's department of physics.

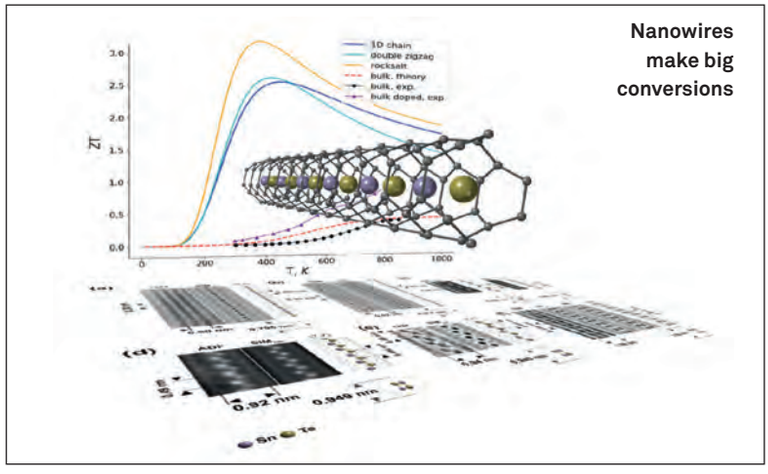
"By sublimation, we converted the material into its gaseous form, and the gas then filled the tube and crystallised," said Vasylenko.

They also carried out theoretical research, using quantum mechanical computations, to understand the formation of the tin telluride nanowires, and how their structure is affected by external conditions, such as pressure, temperature and the diameter of the carbon nanotubes.

The researchers, including Dr Andrew J Morris's group at Birmingham University, established a direct link between the size of the nanotube template and the resulting structure of the formed nanowire.

In the paper, published in *ACS Nano*, they demonstrated that the technique could be used to regulate the thermoelectric efficiency of tin telluride formed into nanowires just one to two atoms in diameter.

Dr Jeremy Sloan, of Warwick University, has now been awarded a five-year EPSRC Established Career Fellowship to further investigate the atomically thin nanowires. ■



Nanowires make big conversions

MEDICAL

Rosalind Franklin Institute aims to revolutionise drug discovery and biotech

First round of medical research projects announced at new £100m facility

The new Rosalind Franklin Institute (RFI) at the Harwell Campus in Oxfordshire has officially launched, with the first round of medical research projects announced.

Backed by £103m of government funding, the RFI will employ new technologies in pursuit of breakthroughs in biotechnology, medical diagnostics and drug discovery. Initial projects – funded to the tune of £6m – include an advanced camera system that uses light and sound to tackle cancer, a pioneering approach to molecular discovery for drug development, and a new testing facility that will harness AI to explore new drugs for clinical trials.

"The RFI will pioneer disruptive technologies and new ways of working to revolutionise our understanding of biology, leading to new diagnostics, new drugs, and new treatments for millions of patients worldwide," said Prof Ian Walmsey, pro-vice-chancellor of research and innovation at Oxford University and chair of the RFI's Interim Board.

"It will bring university researchers together with industry experts in one facility and embrace high-risk, adventurous research that will transform the way we develop new medicines." AW

MANUFACTURING

Sculpting with graphene foam

3D blocks created for use in batteries and sensors

STUART NATHAN REPORTS

Chemists at Rice University in Houston, Texas, have devised a method for making and sculpting three-dimensional blocks of graphene foam.

The soft, porous solids can be used as supports for components of batteries and super-capacitors and as a mould for materials to make flexible, conductive sensors.

The work was carried out in the laboratory of Prof James Tour, whose laboratory was the first to synthesise laser-induced graphene (LIG) by heating films of polyimide. This method creates a two-layered structure, with the polyimide remaining intact at the base but the upper layer transformed into interconnected flakes of graphene.

The team has now developed this technique further to make complete blocks of this graphene material. Initially, a single sheet of polyimide is treated as before. It is then coated with ethylene glycol and another layer of polyimide placed on top.

The top of this layer is again burned with a laser to transform it into LIG. The process is repeated with additional layers until the block is created. The block is then placed onto a hot plate to evaporate the ethylene glycol, then transferred to a furnace to burn off remaining polyimide, leaving behind a spongy block of interconnected graphene flakes with pores measuring 20 to 30nm in diameter.

In *Advanced Materials*, Tour and his students explain how they modified a 3D printer with a custom-built fibre laser to mill the block into complex shapes.

They also carried out some application trials, using the LIG blocks as anode and cathodes in lithium ion capacitors.

The anode achieved a gravimetric capacity of 354 milliamp hours per gram, near to the theoretical limit of graphite, while the cathode's capacity exceeded the average capacity of other carbon materials, they said. ■

Bringing careers to life is key to inspiring female engineers

With women still making up only 11% of the sector, it is important that we show the next generation what we do and give them the information they need to make the best decisions about their future

STEM industries are at the heart of the UK's economic, intellectual and historical life. We have a proud history of industrial and engineering powerhouses across the country that carry world-leading industrial legacies that have helped power the UK's prosperity. By embracing new technology and Industry 4.0, the UK can maintain and enhance its reputation for innovation, skills and development.

In order to take advantage of this new technology revolution, the UK needs a strong STEM education and skills base to drive prosperity and productivity. And, with the need for continuous innovation in the face of unprecedented change, and with a large skills gap looming, it has never been more important to inspire and encourage people, especially women, to choose a career in engineering.

Sadly, we're falling short. As the Women's Engineering Society has highlighted, women currently make up just 11 per cent of the engineering sector in the UK.

We can, however, change this, and it is the responsibility of established organisations to celebrate female engineers, raise the profile of women in STEM careers and demonstrate a commitment to diversity in order to inspire future generations.

That's why last month, as last year, our respective organisations – Boeing and Cranfield University – supported International Women in Engineering Day (INWED) 2018. We sponsored INWED as it hosted 150 separate events across the country, plus 18 international events in locations such as Brazil and Uganda, aimed at inspiring young women to become engineers and encouraging institutions to 'raise the bar' in their hiring of women.

As industry professionals, we know that, in addition to this, industry and institutions must take the lead in inspiring young women by showing them what we do and providing them with the information they need to make the best decisions about their future careers.

Ahead of INWED 2018, we teamed up for the second year running to hold an event on the Cranfield campus for female students aged 11-16.

Professor Helen Atkinson

Sally Hoyle

"A diverse engineering sector is a moral imperative"

The event's itinerary was designed to demonstrate the practicalities of technical careers whilst showing the students the connection between the STEM subjects they take at school and the impressive careers they can lead to.

The students took part in fun, hands-on activities with cutting-edge equipment provided by Boeing, Cranfield and our partners, getting to grips with virtual reality headsets, drones, robotics and simulators and taking part in interactive engineering challenges.

They also met some of the leading figures and companies in the sector, and discussed one-on-one the trajectories to a successful career in engineering.

The event was designed to show the students possibilities for their careers that they had not thought of before, and hopefully inspired some of them to take the right steps towards an engineering degree or training.

Uncapping the huge talent pool represented by the female population will unlock potential and create a more creative culture, fertile for new ideas and innovation. Ultimately, this will keep the UK's technical sector competitive.

A diverse engineering sector is not just an economic imperative, it's a moral imperative, too. Supporting young women by utilising the resources and capabilities at our disposal is core to both Boeing's and Cranfield's values and should be central to the industry's approach to the challenges of the future. ■

Sally Hoyle is HR director for Boeing Europe & Israel and Professor Helen Atkinson CBE FREng is pro-vice-chancellor and head of the School of Aerospace, Transport Systems and Manufacturing at Cranfield University.

Prof Atkinson is also the chair of the reference group for the Royal Academy of Engineering's 'This is Engineering' campaign aimed at encouraging more young people to see how exciting careers in engineering are. Visit www.thisisengineering.org.uk to find out more.

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LEONARDO

Mailbox

Thehottopic

Airbus warning on no-deal Brexit

Aerospace giant's threat to move its production out of the UK has got readers talking

Not exactly surprising, since the government has singularly failed to provide any forward planning for post-2019, beyond promising instantaneous, wonderful trade deals with all and sundry. Any company is supposed to take a strategic view of the future and be prepared for as many scenarios as possible. I thought that was also a function of government! Instead of focusing on their individual best interests or narrow views, they are supposed to look at the big picture.
Nick Cole

Despite his 'I'm an engineer not a politician' claim, Tom Williams delivered a well-aimed and well-deserved kick up the UK government's posterior; if they and the EU can move beyond process and start negotiating details, maybe we can salvage something from the situation
Trevor

The main issue is the Brexit Committee's policy of not being at all helpful to manufacturing industry, the transport industry and everyone else by persistently stating that 'it will be all right on the night' without saying what they will actually do. Keeping it secret to avoid spoiling negotiations is nonsense; the EU 26 don't have a problem – we do, and lack of action by the government just feeds uncertainty and we will get more of these issues being raised the closer we get to the cliff edge.
Sandy

However we arrived at this point, I see the EU negotiators as deliberately making things more difficult than they need to, and to some extent they are showing up the very reason many felt they should make the split. Meanwhile, as one who does a lot of trade from the UK outside of the EU, I feel justified in saying that it really isn't THAT difficult.
Jonathan Douglas

The UK – or rather Theresa May – is deciding to leave the single market and customs union. That is going to make life a lot harder for many businesses, to the extent that the Government's own forecasts predict an eight per cent fall in GDP from this strategy (And given Brexit has already cost about two per cent of GDP, that eight per cent seems very optimistic).

As for working with Boeing, etc, do you think Boeing would set up an operation to make wings in the UK? Do you think that would please Trump with 'America first'? A lot of the expertise comes from the Continent, and many of the UK employees will relocate – probably to France.
Alex

The decades spent investing in science and engineering to make the UK a country of choice for intra-EU as well as global investment is all down the drain. Ditto for the City. If the UK ever gets back to leadership in many areas, I will be long gone. Tragic. I expect Churchill and Thatcher are revolving in their respective mausoleums.
John Logsdon

Airbus aside, it seems to me that the whole exit enterprise was flawed from day one. The exit from the EU was such an issue of complexity commercially, politically, etc, that is beyond the ability of almost the whole population, barring real experts (and I do not mean politicians of any persuasion!) to understand the multifaceted effects and counter effects in all areas. That, by the way, is not 'superior view' as I count myself firmly amongst the ill-equipped public.

Every pundit without fail has a different and equally convincing argument which in isolation could convince most people. No wonder industry is confused and concerned.
Stephen Rose

Inyouropinion

2018 salary survey

The fact of the matter is that smart people are not rare. Good engineers are not rare. We live in a labour market open to 500 million people, many of whom are better trained than us because they have better education (the French engineering schools are amazing). There is just too much supply of engineering talent for the demand, to warrant engineers being paid more than they are being paid now.
Mohammed Abdullah

The sales people always say they are the most important because without sales everybody would be out of a job. IT will say they are most important because without the systems we would not be able to operate. Accounts say they are most important because we have to adhere to law and control our cash. Logistics say they are most important because they deliver the goods to the customers. Engineers say nothing. They just get on with the business of producing goods. Without those goods there would be nothing to sell, no need for logistics, no cash to worry about, so no need for accountants.

So who is king; the engineer. However, we know that sales get paid more. Why? I suspect engineers are not just in it for the money but for the love of the job.
Mark Mason

Patents

Were the money necessarily spent up front on gaining access to intellectual property 'rights' spent by firms large and small developing their ideas so that there really was something to make and sell at the end, there would surely be a much greater cake –individual and for UK plc – to be shared.

Mike Blamey

The number of patent applications does not tell the whole story. The UK's lower numbers may well be linked to less innovation at the stage of commercialisation of technologies (a long-standing weakness of UK business).
Neil

Join the debate theengineer.co.uk

Thesecretengineer

Our 24-hour, connected, multi-platform world is supposed to make it easier to communicate with one another. So why, asks our anonymous blogger, is it often so much harder?

The ability to communicate around the world stands at a level that could only have been dreamed of even a mere 20 years ago. There's e-mails, Skyping, Facetiming and any number of other nouns that have been turned into verbs by the hip kids.

However, there is also a bit of a problem, in that some people do not actually reply to messages sent. I must admit that I'm a bit old fashioned with all this multi-platform communication malarkey and on the whole I just use e-mail and the telephone. I can hear some of you out there muttering, "Just send a read receipt request" with regard to the e-mail, but it has been my experience that these, too, have been ignored.

The telephone is barely any better. As often as not, the person you call isn't available and when you leave a message they never fail in not getting back to you. As far as I'm aware, the subjects I get in touch with people about are neither contentious nor trying and, of course, a lot of them are related to matters of benefit to the recipient, yet there does seem to be a growing trend for ignoring stuff.

I'm left wondering if this is a modern phenomenon and, if so then what's at the heart of it? With the expectations raised by immediate contact from virtually any part of the world, including trains and cars, is the normal sequence of such situations now seen as redundant? Could it be there is more opportunity to hide from stuff – the modern equivalent of the bottom of the in-tray? I may well be out of step with the new norm, but I think this laissez-faire attitude to be unprofessional and mentally mark down those who practise it.

I personally also have a problem with the questions of etiquette regarding all this. First, there is no way of knowing if the message has reached the intended recipient and been ignored or intentionally deferred, or merely that its been mislaid – either literally or metaphorically. A follow-up could be tried, but how many can you get away with before it potentially becomes irksome and you are undermining your own position?

If it is the case of a supplier for a commonly available item, then the solution is easy – you go and find another supplier. If it is more in the nature of establishing a collaborative relationship, or a single available source of supply, then things become a bit trickier. As the established rules of non-immediate (and occasionally sporadic) communication are eroded, the potential for doubt regarding intent, aligned with unnecessary conflict, increases.

The necessity of maintaining historic working practices in this way is, for me, reflected in the much vaunted idea of the paperless design office. Although we are not far off this, I still print out drawings and I think it is because of the way the human brain processes information. There is a reason that A0 was generally the largest sheet size for drawings and A4 the smallest. If you select the size correctly then you can look over the whole drawing and immediately understand the information in each view and how they inter-relate, as well as looking at details where required. Not so important for understanding overall geometry in the world of 3D CAD, but still significant when dimensioning complex objects. Relying on the screen results in much zooming in, zooming out and scrolling; making reconciliation of the macro and micro difficult. When A0 screens are common, then there will truly be no need for paper.

New technologies give new opportunities and we should explore how we use them without clinging onto historic methodologies. However, we should also understand how those methodologies are arrived at if we are not to lose old advantages whilst creating new ones.

The brain / eye interrelationship needs to always be central to the method of representing design information. Equally, clear and disciplined techniques need to be maintained in communication, no matter what the medium. ■

Engineering to mitigate climate change

Political leadership and the ingenuity of engineers must come together to deliver solutions to this complex global challenge

The striking of a global deal in 2016 to minimise the negative consequences of climate change was hailed by many as a resounding diplomatic success. Under the agreement, governments around the world agreed to limit global average temperature increase to less than 2°C above preindustrial levels, and to 'pursue efforts' to limit warming to 1.5°C. The Paris Agreement represented a powerful political response to a global grand challenge. However, recent news that global carbon emissions are on the rise, after three years of little or no growth, means the challenge of meeting the objectives becomes increasingly difficult.

Stopping climate change certainly requires a global solution, but the UK arguably has a responsibility to take a leadership role. Despite having less than one per cent of the global population, the UK is responsible for around 6 per cent of historical CO_2 emissions. Engineers will play a crucial role in delivering solutions to the challenge, whether through decarbonisation of power systems, transport systems and heating, advancements in renewable energy, or improvements in efficiency and demand reduction.

While efforts to date have focused mainly on reducing emissions from activities, some sectors, such as agriculture or aerospace, are very difficult to decarbonise, so mitigation efforts alone may not be enough. Recent analysis suggests the route to limiting warming to 1.5°C will require going a step further and employing methods to actively reduce the levels of greenhouse gases in the atmosphere – so called greenhouse gas removal (GGR).

After the publication of the government's Clean Growth Strategy, the Royal Academy of Engineering and the Royal Society were asked to provide advice to government on the potential role of GGR technologies in addressing both the global aspiration and the UK's stated ambition to reach net-zero greenhouse gas emissions at 'an appropriate point in the future'.

GGR covers a wide range of technologies and methods but, fundamentally, requires some means of extracting atmospheric greenhouse gases and fixing them in long-term storage. Removal can be via biological means, such as afforestation or restoration of wetland habitats, or it can utilise natural inorganic reactions, such as enhanced weathering of rocks – in essence, speeding up the planet's natural processes to sequester atmospheric CO_2. As these natural solutions are limited by the capacity or permanence of their storage, engineering solutions are also being developed. One such mechanism is bioenergy with carbon capture and storage, producing energy from burning biomass and storing the CO_2 produced in geological formations or the deep ocean. A further engineering solution is direct air capture, using chemical processing to extract CO_2 from the air, a process that is very much at the development stage. The report is expected to be published in the autumn, but the work to date has highlighted the complexity of this topic. Alongside the very significant direct engineering challenges entailed in delivering technologies that work safely and reliably at the scale required, decision-making around deployment will need to take into account many other factors.

For example, there may be significant environmental impacts associated with perturbation of ecosystems and risks to biodiversity. The economic viability also needs to be considered, the current carbon price being insufficient to support the necessary scale of investment in these technologies.

Issues of social justice and equity, as well as public perception, will need to be addressed since the use of such technologies may be controversial and local impacts will need to be tensioned against global benefit. However, the challenge we face is so great that deployment of GGR may nevertheless prove to be an essential part of our arsenal.

Engineers are also at the forefront of adaptation to climate change and to increasing our resilience to future climate-related risks. This was the theme of a 'Late Debate' I chaired at the start of June at the London Transport Museum, which asked how ready London is to cope with an increased frequency of extreme weather events, and what engineers can do to increase its preparedness.

In a lively debate (it concluded at nearly 10pm!), there was strong consensus that we need to adopt a more holistic approach to issues such as flood risk management, recognising that, in a complex and crowded city such as London, a systems approach is essential.

For example, one of the panellists spoke of his experience working on Crossrail – for which the design life is 120 years. Designing to deal with future flood risk depends on the performance of London's primary flood defences, as well as the security of the underground and surface railways to which Crossrail connects. One innovative approach has been to use excavated material from Crossrail on Wallasea Island to transform 670 hectares of farmland back into coastal marshland, providing a thriving wetland for tens of thousands of migratory birds and helping to combat future impacts of climate change on people and wildlife, including coastal flooding. This restoration of a habitat may even sequester some carbon.

This is a great example of political leadership and engineering ingenuity coming together to deliver an innovative solution that benefits communities and the environment. We will need many more of these partnerships, and all of our ingenuity, if we are to make progress at the rate required to both limit global temperature rise and increase our resilience to its harmful impacts. ■

Flat-pack to

Stuart Nathan **looks at the increasing use of modular techniques in construction and how this might represent a paradigm shift for this ancient form of engineering**

Construction is one of the most fundamental engineering sectors of all. Ever since humanity emerged from caves, we've been building shelters. And the way that we've done it is remarkably unchanged. The building materials – whether wood and straw, mud, bricks, stone, or steel and glass – are transported to the site where the building will stand and assembled by specialised professionals into a custom-designed form.

The next stage was established from the time we first had cities with a service infrastructure, so 4,000 to 5,000 years ago. Specialised tradespeople come onto the site and take over from the builders, connecting to services (in the case of plumbers and, more recently, electricians) and applying specialised finishes such as plastering and decoration. Times change, but a Roman builder or engineer would certainly recognise a building site in London today.

But that might be changing. The construction sector around the world, but particularly in Europe and most notably in the UK, is bedevilled by poor productivity and quality issues. One way to get around this, which is becoming

the future

01 Panels are produced with all services and finishes incorporated and can be built like a scaled-up IKEA flat-pack

02 Modular construction allows the different types of room needed for a hospital, such as this Oswestry orthopaedic operating theatre, to be standardised for manufacture in factories and installation on site. Image: ModuleCo

increasingly important in a variety of construction sectors, is a shift to modular construction.

In past times, this was known as prefabrication and did not have a spotless reputation. There is a cachet to the surviving post-war "prefabs" in Britain, but at the time, although welcome, they were not universally liked – the need to build quickly and on constrained sites meant they tended to be small, unattractive and poorly finished. They were only meant to last 10 years and that any have survived at all is a testament to conservationists. Some readers might also recall the partial collapse of the Ronan Point tower block in East London in 1968, which was caused by poor assembly techniques being applied to prefabricated wall panels.

But today's modular construction is different. It is marked by a desire to bring the advantages of modern industrialised manufacturing to the construction sector. Instead of building everything from small components on-site, whole rooms, fractions of complete buildings or highly finished panels are built in factories, with services incorporated into their structures, transported to site and assembled in place.

The ability to control the environment inside the factory, to use the most up-to-date digital design and manufacturing tools and to work under the strict quality control rules of the manufacturing industry, are key to the advantages of modular construction. Removing much of the work from open-air building sites – frequently wet and windy or too hot, often hazardous and always unpredictable environments – should make it quicker to construct a building, boosting productivity while also making it much safer and improving the final quality of the product.

"Digital is key to this," Peter Flint, chief executive of buildings and places at engineering infrastructure giant AECOM, told *The Engineer*. "It's the ability for us to design in a 3D environment and the ability to send a design straight to manufacturing, that allows us do this properly. The key thing you want to do is create fabulous homes to a higher quality than currently, in a safe factory environment, and digital design is the tool that will enable us to do that."

AECOM is active in the residential construction sector and favours a type of modular construction known as volumetric. Where much modular construction involves the manufacture of panels in a factory –whether these are wall, floor or ceiling – which are transported to the site as a flat pack and assembled accordingly, volumetric modular construction manufactures rooms – more like the portable classrooms that many of us who were educated in the 1980s will be familiar with – which are transported to site on the back of a trailer.

In AECOM's case, these modules would be large: Flint explained that its prototype two-bedroom apartment is assembled from two modules. "You're building a box, you're fitting out, and you're cladding it," he said. "The boxes are built in the factory, finished. Then they are wrapped up, protected, lifted into place, and you need to do a little bit of work connecting up and joining them together: sit them on the slab in the right location, plug into services, and where the boxes join there is a little bit of site work required just to seal it up and finish the junction." This level of off-site finishing allows as much of the building as possible to be made under high-quality, high-precision, controlled conditions, he explained. AECOM uses a lightweight, steel-framed structure to keep the weight of the finished modules low enough for them to be lifted and transported easily; weight having previously been a stumbling-block for the volumetric approach.

The innate drawback with the approach is that it depends on a very high level of standardisation between units. Variation is kept to a minimum, and this means that every unit is more or less identical. "It won't work in every case – you wouldn't use it for the Tate Modern extension, but I don't think the repetition necessarily means bad architecture," Flint said. Indeed, from the start of its ventures into modular residential construction, AECOM's design partner has been the Rogers Stirk Harbour Partnership, the architecture practice of Richard Rogers, probably the world's most famous and revered architect. "They'll be beautiful spaces," Flint commented.

London might be getting a taste of the Rogers-designed modular housing sooner rather than later. Until recently, AECOM was heavily involved in a project to redevelop the Silvertown area of Docklands, with 3,000 homes on 62 acres. The project was a partnership with developer First Base, with whom AECOM has a long relationship, but the site was sold and the product is now on hold. Flint hopes to be involved with whomever the new owner of the site turns out to be. A particular selling point might be that the company planned to build the factory to manufacture the modules on the site, thereby providing employment for this relatively deprived region of London.

"The local authority was very interested because it provides not only fast, precision-built housing but also an opportunity for local employment," Flint said. "And that's a case for a lot of London boroughs, the housing requirement is quite clearly defined and if the solution is also providing local employment the local authorities get very excited."

AECOM is producing full-scale prototypes of its modular housing product in Newark, Nottinghamshire, where it will be fully tested, and is in discussions with several developers over putting its plans into practice. It is also partnering with the Advanced Manufacturing Research Centre (AMRC) in Sheffield on the engineering aspects of setting up manufacturing for its product.

With software such an important part of the modular construction paradigm, it's hardly surprising that software houses are a major part of the

story. Sarah Hodges, Autodesk's senior director for construction business strategy, explained that the company's role was almost as a nursemaid to guide companies in the construction sector into the world of manufacturing, which up to now has not been part of their make-up. Although they have bought items from manufacturers, such as fixtures and fittings, they have not been manufacturers themselves.

Autodesk is, of course, also not a manufacturer but, as *The Engineer* has reported, its business is now focused around helping its customers produce digital designs and working out how to give those designs physical form. "What we think about here is industrialised construction," Hodges said. "We think of that as having three main components. The first is design for manufacture. The second component is what happens in the factory in terms of prefabrication and modular construction, and the third is what happens on the construction site itself. So we seamlessly design directly for manufacture, we manufacture the component in the factory, and then we install it on site.

While AECOM is a client of Autodesk's, the software company is seeing a great deal of modular construction activity in a non-residential sector: namely, healthcare. For hospitals, the standardisation that is so key to modular construction is a positive advantage. "Bathrooms, for example, tend to be the same wherever they are in a hospital," Hodges explained. "They have the same dimensions, and the same fittings with the same layout. So they can be produced in bulk not only for each individual site, but for multiple sites."

For projects in healthcare, which according to Hodges was the biggest market for modular construction two years ago (residential was catching up fast and may now have overtaken it), five different standardised types of room can be specified for a hospital and designed in detail to be produced in factories and assembled on site. "We can specify in detail the components needed for those five types of room, fabricating them and delivering them just in time on site for assembly."

There are two main driving factors for the prevalence of modular in health care, Hodges explained. The first is that there are many ageing healthcare facilities in need of modernisation, and the second is the ageing population of "baby boomers" who are increasingly in need of hospital facilities. "Hospitals tend to look the same wherever they are anyway, and modularisation and standardisation are an advantage when you are looking after people in different places who have similar conditions and need similar sets of treatment."

While construction may, until now, not have had an image as a high-tech industry, the tools are now being applied to it are right at the cutting edge – up to and including artificial intelligence. "Today, we are spending a lot of time and research and development into how we more seamlessly design to the right level of detail and specification to directly manufacture, and this is taking on aspects of machine-learning intelligence to identify patterns that will help in architecture and get that model ready for fabrication," Hodges said.

Because Autodesk works with a variety of clients who embrace different concepts of modular construction technologies, it is not tied to the volumetric model that AECOM uses. Among its partners in the modular construction field are Boston-based Manufacton and San Francisco's Project Frog (Flexible Response to Ongoing Growth), both specialising in the manufacturability of modular designs and the latter being a specialist in panelisation to produce flat-packed designs for maximum transportability to site. "They think about prefabrication and flat-packing for just-in-time delivery and optimisation on site, so the components are very easily assembled, almost like pieces of IKEA furniture but on a much larger scale," Hodges said.

Architects are already converts to digital methods and often use a system known as BIM (building information management) to incorporate many details of the materials and products used in their designs into the working drawings. "We did a bit of research around using BIM-based systems to drive modular construction and these models estimate a 90 per cent reduction in overall waste on the project through the level of detail in design and driving straight to fabrication: they're stating a 30 per cent increase in productivity and reducing safety risks by a factor of four," Hodges said. "That's a tremendous impact on many of the factors that are critically important to the construction industry, primarily around the massive amount of waste that is produced in construction and keeping an eye to making sure we are keeping all our workers safe."

Hodges's role includes a great deal of international travel and she believes

03 Designing modular architecture to be flat-packed may reduce quality compared with volumetric, but improves transportability

04 A panel designed by Autodesk software being lifted into place on a construction site

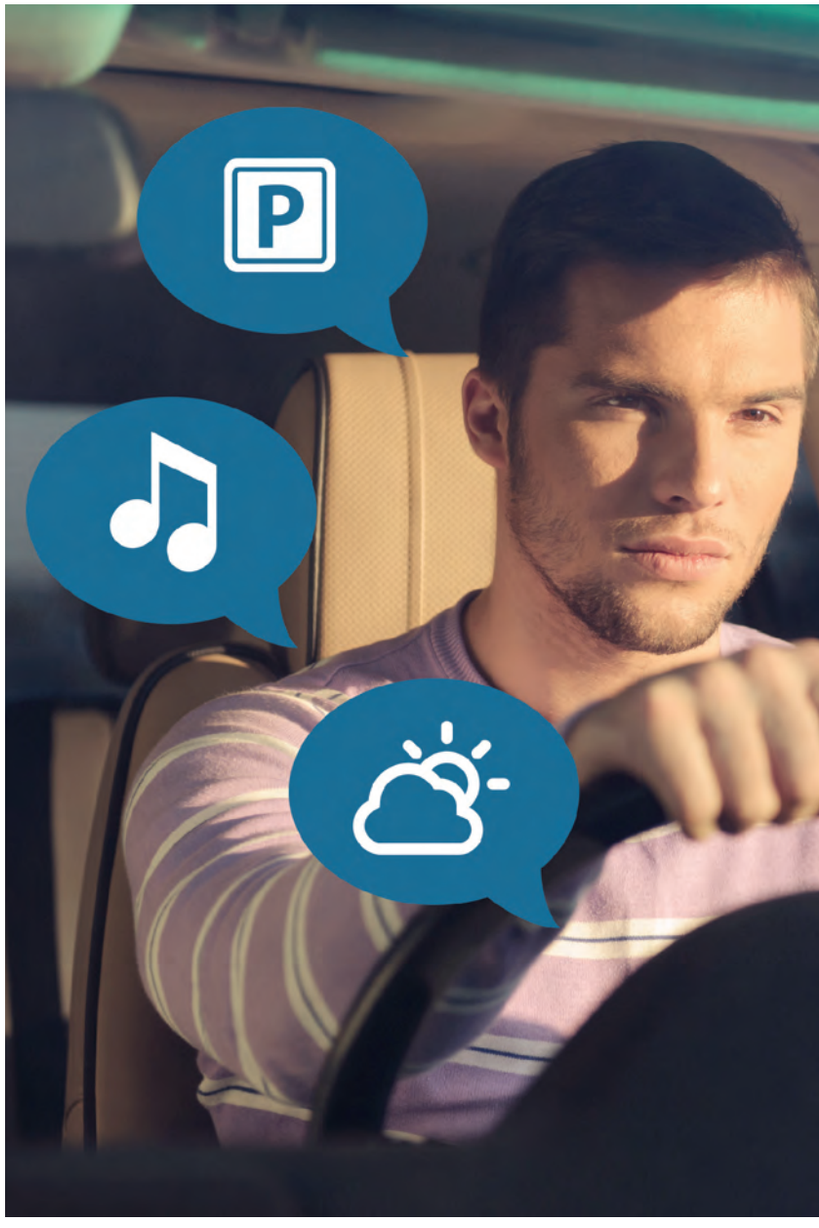
that the UK, the Netherlands and the Nordic countries are well ahead of the rest of the world in adopting modular construction approaches. Part of this is a huge demand for housing and infrastructure; in the UK's case, to update the ageing housing stock and the built environment, and elsewhere to add capacity in smaller cities. But for this region, she believes, the unpredictable weather and bad conditions on building sites are a definite contributing factor.

Another new development, Hodges suggested, may be the establishment of "flying factories" to manufacture the modules. Part of the reason for this is logistical factors in transporting modules to site are greatly reduced if the manufacturing is close by as possible. It may also reduce costs to be able to put up a temporary factory rather than relying on a permanent large facility, she said, adding that companies such as Skanska were looking into this possibility.

"Paradigm shift" is an overused term in the engineering world: everybody thinks that they are in the midst of a revolution even when they are not. But in the case of the construction industry, Hodges believes that modular techniques really might represent this much-maligned term, seeing a shift for this industry from its mud-clogged, risky millennia past to a future joining the automotive, aerospace and other manufacturing industries as a factory-based, well-lit, climate-controlled modern industry with little relation to what those Roman builders might have recognised. Some veterans will doubtless mourn the passing of scuttling around scaffolding beams and hoisting bricks around, but it's a changing world and many would be glad to see the back of it. ■

Siri hits the road

Voice-activated digital assistants are spreading from our homes to our cars. Stuart Nathan **looks at what it could mean for the future of driving**



This feature was brought to you by Nuance software. Not in any commercial sense, like the sponsorship clips at the beginning of soap operas, but very literally. After a mild stroke four years ago, I lost the ability to type with my left hand, and so I use Nuance's Dragon NaturallySpeaking system to dictate all my writing. The same disability has forced me to give up driving, as I can no longer reliably change gear or operate indicators in a timely fashion. So when Nuance invited me to see the voice-activated system it was developing for the automotive sector, my interest was piqued.

Voice-activated digital assistants are becoming familiar to many of us, with the technology arguably developed and certainly popularised by Google Assistant, Apple's Siri and the Amazon Alexa system. They are becoming increasingly common around the home, where they can be used for everything from controlling audiovisual systems ("Hey Alexa, play such-and-such a track by so-and-so" is, I suspect, a common refrain) to compiling shopping lists and accessing online information. Despite their possible security risks, digital assistants seem to be infiltrating so many homes that they may inevitably become as much a part of life as domestic staff once were.

The convenience of a digital assistant in the car is undeniable. If the driver can use their voice to operate all the ancillary systems – climate control, audio, sat nav and so on – then these are all things that they don't have to push a button to switch on and off, enter any information or otherwise take their attention away from what they are supposed to be doing: driving and concentrating on the road ahead and the surrounding situation. It's no surprise that, now Google, Apple and Amazon have let the genie out of the bottle, the automotive industry wants a slice of the action.

But there are a number of unique factors to take into consideration in developing such a system. One is privacy. A car's digital systems can contain information that many people would rather keep to themselves: if you use satellite navigation, for example, your car knows where you are and where you have been. If your car connects to your mobile phone, then it also knows who you've spoken to and might have access to any data you keep on there. If some overarching system has access to all of these, and its maker can make any claim to that data, then no driver in their right mind would use such a system.

Another issue is that people are increasingly using different digital assistants for different tasks. For some people, Siri is best suited to business or financial-related issues, and they wouldn't want to ask it how to get to their next meeting destination or weekend getaway.

Equally, if you're used to asking Alexa for your favourite playlist or to add laundry detergent to your shopping list when you're in your living room, you probably want to keep doing that from your driving seat.

> Google, Apple and Amazon have let the genie out of the bottle

Such considerations are at the heart of Dragon Drive, the system that Nuance has developed for the automotive sector and which is installed in the new models of Mercedes A-Class and Audi A8 cars. Designed using the same voice interface that Apple licensed to control Siri, the system is designed to allow drivers to speak conversationally and intuitively to their cars' systems, without having to learn and remember specific control words.

Moreover, the system is designed to work whether or not the car has an available connection to Wi-Fi networks, only connecting to the internet if necessary and therefore keeping as much data as possible on board. The

01 Voice-activated digital assistants in vehicles have many uses, but could come with privacy concerns

system does not send any information back to Nuance. The natural language system, named "Just Speak" by Nuance, allows the driver to issue commands without any sort of control-freak prefix (like "Hey, Alexa").

Just Speak is programmed to recognise context: so, for example, saying "I'm too hot" will switch on the air conditioning system localised to the seat where the system's microphone array detected the speaker. Similarly, in an appropriately equipped car, saying "I'm feeling tense" would activate the in-seat massage system, and "my hands are cold" would turn on the steering wheel heater.

The system is also linked to satellite navigation, and uses available add-ons. Asking it to navigate to a certain destination activates the system and provides turn-by-turn directions. Navigation by postcode is available, as is the system known as "what3words", which divides the surface of the world up into 3m squares and identifies each one by a unique combination of three words. This can lead to some odd-sounding phrases: should you want to visit *The Engineer*'s offices, you would say: "Navigate to what three words 'reform ashes flown'." (The Eiffel Tower is 'prices slippery traps'). The system also allows connection to weather services, once again providing contextual information, for example by saying "do I need an umbrella in Manchester?" Or "do I need sunglasses in Rome?"

Also built in is an 'intelligent arbitration' system which recognises the context of a question and arbitrates as to whether the in-car systems can answer a query or whether a different digital assistant system needs to be consulted. This would depend on the user's preferred settings. If, as in the previous example, the user prefers Siri to deal with financial information, asking the system "what's the latest on Airbus?" would tell it to connect to Siri to retrieve stock market information or the latest business headlines. Similarly, should you remember something to go on the shopping list while driving, mentioning that would activate Alexa.

And the system is already evolving. Although its first iteration is voice controlled only, Nuance is already testing a feature that adds gaze control, so that the driver can access certain functions merely by looking in the right place.

Gaze control unlocks a surprising array of functionality. The system Nuance is currently using is licensed from Tobii Technology, a Swedish start-up previously covered in *The Engineer*. Its technology exploits two evolutionary quirks unique to humans: one behavioural and one physical.

The behavioural quirk is pointing. Humans are the only apes that indicate to others where their attention is focused. Other primates can learn to do it, but only in captivity and never in nature: some dogs, of course, can also be trained; but humans innately start to point at things, typically at the age of 14 months.

The other may come as a surprise. Humans are the only mammal whose eyes have visible whites all the time when open. Evolutionary biologists believe that this trait developed so that other humans can easily determine where somebody else is looking; it is, therefore, a subset of pointing. All societies point at things, although customs differ: to some, pointing with the finger is rude; some African societies sometimes point with their lips; but everybody points. It is one of those things that defines what is to be human but hardly any of us realise or acknowledge it.

Tobii's system uses cameras and infrared light projection and mapping to detect the boundary between the white of the eye and the iris, both by looking for the change in colour and the bulge the iris makes at the front of the eye. Developed both to help disabled people use computers and for gaming, it is just one of many gaze-detection systems on the market. The detection device consists of a bar mounted on top of the dashboard facing the driver, and can also determine which way the driver's face is pointing even if their eyes are obscured by sunglasses.

The demonstration of the system was literally eye-opening. It is linked to cameras installed in the front of the car, so a glance at a building by the roadside and a query of "What's that building?" triggered a stream of information about the hotel the driver was looking at. "When is that place open?" while looking at a restaurant retrieved the opening hours; the system will also respond to a command of "book a table for two there at 8.30 tonight" by using online table reservation systems.

Other databases could also be used: for nature lovers, an enquiry of "What's that tree?" could be accommodated by connecting the cameras to a machine vision and AI system equipped to recognise local flora.

Such a system could also be of use to the insurance industry, were access granted to its data. If cars equipped with gaze detection were involved in an accident, it would be possible to determine where the drivers were looking at the precise moment the accident occurred, which could be invaluable in determining who was liable. This, of course, has legal implications, which Nuance is investigating.

Going back to the personal, Nuance's developers assured *The Engineer* that it would be possible for Just Speak to activate other electrical systems in the car. For example, "headlights on dipped", "full beam", "indicate left" and "indicate right" would all be workable commands if the user requested that these be programmed in. It would have to be a dealer or a manufacturer adjustment, but such functionality would allow me to once again drive safely and with confidence, despite my impaired movement. ■

Polishing the jewel in the crown

Rolls-Royce's chief technology officer talks about new horizons and latest developments in aerospace propulsion. Stuart Nathan reports

Rolls-Royce is sometimes called the jewel in the crown of British industry. A name with international recognition thanks to its heritage in the automotive sector (even though that is no longer part of the company), for many, it exemplifies the value of British know-how. Its jet engine products are highly visible everywhere in the world, and it represents a through-line for British inventiveness, from Frank Whittle's pioneering work in jet propulsion, to industrial exploitation and a tangible contribution to "UK plc". It is also a respected employer of engineers and a sponsor of much basic scientific research.

For a company so synonymous with technology – even in a world where, to some, technology means digital industries – the role of chief technology officer (CTO) must be a daunting one. But to Paul Stein it represents a logical progression of his career.

Trained as an electrical and electronic engineer, Stein ran Roke Manor Research for 10 years from the mid-1990s. "That gave me a grounding in what mobile telephony can do, what now we call the Internet of Things can do, what modern sensors can do and what modern software systems can do, so that was a pretty good background," he told *The Engineer*. From there, he took a sideways step into the civil service, spending three years as director-general for science and technology at the Ministry of Defence. "The role was about making sure that the UK was prioritising its defence research in the right areas," he said. "I felt very strongly that the MoD needed some help and I thought I could, in a small way, help what we need to do nationally. At the time, we had quite a pressing campaign in Afghanistan and wanted to make sure that the money was being spent appropriately to help our armed forces in theatre with technological superiority and at the same time preserve money for other threats and for future capability."

On reaching the end of his contract with the MoD, Stein decided that he wanted to return to industry. Initially, he wanted to go back to electronics, but "out of the blue" he was contacted by Rolls-Royce. "In a very famous phone call I had with Colin Smith, who was then the director of engineering and technology, I said 'but I don't know anything about gas turbines' and Colin told me I was perfectly qualified for the job because he had plenty of gas turbine experts, so I was offered and accepted the role of chief scientific officer."

It was a role specially created for Stein, tasking him with ensuring that Rolls-Royce was not blindsided by an emerging disruptive technology. "The role was to horizon-scan, attend conferences, look at what the competition is doing and what the start-up community is doing, and make judgements about whether any of that was going to have an impact on our business," he said. Stein spent six years in this role, followed by a single year as director of research and technology, before being promoted to CTO in April 2017. "My main role is to approve all technology investment across the company, making sure that it is spent effectively and efficiently, and that we have a technology plan that keeps our products and services competitive and that uses technology to maximise productivity and keeps business future optionality open for us as a company," he explained.

> "We have still got a long way to go in evolving the gas turbine; it still has a number of tricks up its sleeve"

Gas turbines still represent the core of the business, and as a propulsion system for larger aircraft – twin-aisle and longer-range single-aisle – Stein believes they will be unchallenged for the next 40 to 50 years. "We are still increasing our understanding of turbine machinery, despite the gas turbine being 70 years old," he said. "We have still got a long way to go in evolving the gas turbine; it still has a number of tricks up its sleeve."

The main thrust of development for gas turbines is always to make them more efficient, generating more thrust with less fuel, reducing noise and cutting harmful emissions. Carrying the flag for this technology is the latest generation of Rolls-Royce's Trent gas turbine line, the UltraFan, a development of the Trent XWB that powers Airbus's A350 airliner, the world's most efficient aerospace gas turbine. "To get the next step in efficiency, we have designed a new core to the engine, with a much larger fan

Rolls-Royce UltraFan blades take to the skies for the first time, on a 747 flying test bed in Tucson, Arizona

The test facility where the UltraFan was developed

at the front," Stein said. This may have knock-on effects for aircraft design, he admitted; it may become more difficult to sling engines with ever-wider diameters under the aircraft wing.

For smaller aircraft, however, Stein sees an increasing role for electrification of propulsion, although even electric aircraft may need an on-board gas turbine to generate electricity. Generating electricity may become increasingly important to Rolls-Royce in the future, he noted, as the nuclear sector becomes a larger part of the business. The company has been a nuclear player for many decades, building the reactors for the Royal Navy's submarine fleet, but it has not to date contributed to the civil nuclear sector. But that may be about to change, with the company's involvement in the UK's project to develop small modular reactors (SMRs). "Submarine reactors are there for a specific purpose – to propel submarines – and have not been designed as power stations," he said.

The Rolls-Royce SMR design is specifically aimed at civil applications and was designed with a target electricity price of £60 per megawatt hour in mind – competitive with the current cost of wind power, Stein explained. Like the aviation sector, nuclear is a necessarily conservative industry because safety is so critical, and therefore the design of the reactor and steam raising equipment is in line with current nuclear reactor technology.

"The physics is completely conservative technology that we know, fuel systems that we know, operating regimes that we know. The revolution is in the manufacturing technology. Rather than being the result of an enormous on-site civil engineering project, with custom-made technology of huge scale, SMRs are prefabricated in a controlled environment using modern robotic assembly techniques, inspection techniques, and industry 4.0 devices," Stein said. The company is working with civil contractors and electrical specialists such as AMEC and Siemens, along with others, so that it can offer a complete turnkey solution to building and commissioning a full nuclear power station based around its compact prefab reactor. "A lot of virtual reality technology is going into designing the factory we will build if we get the product off the ground," he added.

Rolls-Royce is working closely with the UK government to advance the SMR project. "We are calling it the UK SMR solution," he said. "It's UK IP, UK manufacturing, UK jobs, UK research universities and work for the younger UK generation." The goal is for the UK to pioneer this technology, he said, but, if successful, Rolls-Royce would look to enter into an international corporation to exploit export markets.

Back with propulsion technologies, Rolls-Royce recently announced that it was among a group of investors taking a stake in Reaction Engines, the Oxfordshire-based company developing an air-breathing hybrid engine that can act like a jet in atmosphere and a rocket in space. This is an example of technology going full circle, Stein said, as the technology originated with thermodynamicist Alan Bond as part of a project called HOTOL some 30 years ago. The company is working with Reaction Engines on developing "quite a large number of technologies," Stein said.

Other innovations are taking place in the way Rolls-Royce maintains its engines. This has been revolutionary for the industry, Stein explained. The company pioneered a system of customers buying "power by the hour", essentially paying for flying time with the cost including maintenance. Because this service depended heavily on the company being able to monitor its engines in service and determine when they might need repairs or checks, this was, in effect, an early use of the Internet of Things, he added. The engines were equipped with sensors that transmitted data back to the company. It is now adding digital manufacturing to its list of digital technologies, in particular looking at using robotic techniques to allow engineers to probe the interior workings of engines while they are still on the wing and even to carry out repairs, such as rebuilding turbine blades using a combination of additive and subtractive technologies.

The interior of the engine will also be undergoing changes. For some time, the turbine fans in the hottest part of the engine core have been made from nickel superalloys grown as a single crystal. "We are always looking for materials that can survive hotter environments, that can be more reliable, that can be cheaper or lighter or any combination of the above," Stein said. The next stage from the current technology is likely to be ceramic matrix composites, which are strands of silicon carbide baked into a matrix of the same material (sometimes known as SiC-SiC for this reason). "We are at the start of the journey with those, and that's going to take quite a while, because nickel has been with us for some time and we are very used to its properties, but we are at the start of the journey to start using ceramics, initially for small parts of the hot end and then more and more with time as the technology matures and we understand the properties better." Although reluctant to give many details, Stein revealed that Rolls-Royce is now gaining experience of these materials in real gas turbine environments. ■

Mini gets personal

British marque is using the latest manufacturing methods to bring true personalisation to the mainstream car market, writes Chris Pickering

The 'new' Mini kick-started something of a revolution when the first example rolled off the Plant Oxford production line in 2001. But this time around it wasn't the car's clever monocoque construction, its space-efficient front-wheel drive layout or even the fact it was sensational to drive that set a new trend. Instead, it was about giving buyers the opportunity to stamp their own personal identity on the car.

Of course, companies such as Rolls-Royce have always been happy to sew hand-cut diamonds into the roof lining of your latest purchase or craft a matching luggage set out of ostrich skin from your own personal herd. But Mini brought a taste of this lifestyle to the high street and, since then, customisation has become big business for small hatchbacks. The average Mini now leaves the factory with options worth upwards of £3,500, while the rise of online car configurators has given buyers endless possibilities to tweak and tinker with their ideal specification.

Now, Mini has taken things a step further. Coinciding with the launch of its revamped three- and five-door hatchback models, the brand has introduced a new customisation service, Mini Yours Customised, which uses digital manufacturing techniques to create unique parts to the customer's own personal specification. Want the door light to project a chequered flag onto the pavement when you get out or want your signature etched into the sill plates? Mini can arrange it. Why you'd want to do that is perhaps a harder question to answer, but take it from us, there are plenty who will.

The first technique relies on the 3D printing of interchangeable interior and exterior parts. This allows you to add text, icons and patterns to both the dashboard fascia panel and the side indicator surrounds.

"Personalisation has always been a big thing for Minis, going right back to the bonnet stripes on the original Coopers," explained Thomas Schmitz, product manager for Mini's customisation service. "We needed cost-effective tools to create one-off designs."

Customers can create the designs themselves using an intuitive online app, from where the CAD data is sent direct to BMW's 3D printing facility in Germany. There, the parts are produced using a special process co-developed with Hewlett Packard. The finished items have a pleasingly glossy finish, while the designs are clear and the text is easy to read. What's more they're all designed to be shipped straight to the customer and fitted at home (so

> "It has always been a big thing for Minis, going right back to the bonnet stripes on the original Coopers"

Shining a light

The facelifted Mini hatchback is the first B-segment car to be offered with LED matrix headlights. As well as being some 2.5 times more luminous than conventional halogen bulbs, their matrix configuration allows the beam to be directed onto specific areas to avoid dazzling oncoming traffic.

A camera mounted on the windscreen detects the presence of oncoming vehicles and switches off parts of the matrix to reduce the intensity in certain areas of the beam. The idea is that this selective 'dipping' retains as much illumination as possible elsewhere. It also means that the system can operate automatically, theoretically eliminating the risk of dazzling oncoming traffic.

Plant Oxford

Mini's Oxford plant already produces the brand's five-door hatchback models, along with the Countryman estate version and selected three-door models.

The site has been used for car production since 1914. Final assembly now takes place in what was once the Morris bodyshop, built in 1926. Inside, it's a thoroughly modern affair, with a ground-level production line comprising 200 stations, including eight fitted with vision systems, where the car is optically examined for any anomalies or defects. Away from the line, a fleet of autonomous guided vehicles (AGVs) shuttles parts and assemblies around the factory, while a total of 4,600 people work on site.

The chassis are built in a £750m facility across the road – said to be the most up to date in Europe and home to 230 state-of-the-art robots. The petrol engines come from the Hams Hall plant near Birmingham, while the bare body panels are pressed in Swindon.

The factory received a further boost last year when it was confirmed that Mini's forthcoming electric model would be built on site from 2019.

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01 The average Mini customer will spend more than £3,500 on options

02 A side scuttle customised with the driver's name

03 Customers create the designs themselves using an intuitive app

you could swap designs as the mood takes you or put the car back to standard).

For the LED-backlit sill plates, a laser-etching process is used. Not only can this handle a similar range of text, icons and patterns, but it also allows customers to draw their own designs using a mouse or a touchscreen. You can even submit a different design for each of the four main doors.

Finally, the door light system uses miniature projectors, with interchangeable slides. These can be substituted for the regular courtesy lights to cast a message or pattern onto the pavement, a bit like the Bat symbol illuminating the clouds above Gotham City.

It's easy to dismiss this as superficial, but there is a huge demand for personalised products. What's more, it could just be the tip of the iceberg. BMW already uses 3D printing to manufacture functional parts for its i8 Roadster and the brand has hinted this is an area it's looking to expand.

It also points towards an increasingly digitised production process; one where consumers could potentially order a car straight from the factory to their own unique spec. And when that trend arrives, its impact could be every bit as wide-reaching as the design innovations pioneered by the original Mini.

Smarter simulation

Integrated solutions bring design, analytics and modelling tools together for a range of test needs

Maplesoft

Maplesoft has released MapleSim, an advanced system-level modelling tool that has been developed to help organisations reduce development risk, lower costs, and stimulate innovation. The latest release provides new tools for developing digital twins, in addition to greater connectivity with other modelling tools, and expanded modelling scope.

MapleSim is used across a number of applications and industries, including the creation of physics-based digital twins for virtual commissioning. Identifying the optimal motor size required to drive a mechanism is one of the most important goals of simulation with digital twins, and MapleSim 2018 provides tools that make this task easier.

The new 1D Motion Generation app lets engineers create motion profiles that adhere to defined velocity and acceleration constraints. They can define the desired motion of the joints, then run the simulation to discover the torques and forces required to create that motion. This information can then be used to correctly size the motors, ensuring optimum performance at minimal cost.

MapleSim has been designed to let engineers try out more ideas in less time, identify and prevent unexpected interactions between different domains, and generate computationally efficient models. New features in MapleSim 2018 further enable this work with more connectivity options and increased modelling scope.

The release also provides greater toolchain connectivity, with the ability to import models from even more software tools. With the expanded FMI support, engineers can import models defined using FMI 2.0 fixed-step co-simulation, plus FMI model exchange.

Other improvements include enhanced Modelica support for easy access to more third-party component libraries inside MapleSim. Similarly, the MapleSim Heat Transfer Library from CYBERNET offers improved tools for studying heat transfer effects and preventing overheating, while the MapleSim Hydraulics Library from Modelon and MapleSim Pneumatics Library from Modelon add-ons can both now take into account temperature effects during simulations. ■

MapleSim is available in English, Japanese and French.

Siemens

The latest release of Siemens' Simcenter Testlab software has been designed to offer test teams a complete set of capabilities to help create smart products under tight schedules.

Simcenter Testlab Neo extends its test-based engineering capabilities with end-to-end durability testing, combining data collection and data analytics, and introduces a new intuitive sound quality engineering solution.

It also strengthens integration throughout the Simcenter portfolio by introducing model-based system testing, embedding virtual simulation within physical testing for system validation at any development stage.

The portfolio includes full end-to-end durability testing, combining data collection and analytics into one environment. It covers every step of a typical test campaign, from channel setup and measurements, to validation, consolidation, analysis and reporting.

For interactive troubleshooting of noise issues and faster benchmarking of design variants, the new Simcenter Testlab sound quality solution includes a calibrated audio replay with interactive filtering, built-in guidance for occasional users, standard off-the-shelf procedures, and flexible combination of noise, vibration and harshness (NVH) and sound quality metrics.

Model-based system testing enables attribute-specific evaluation throughout the development cycle, using virtual models, combined virtual-physical models and physical prototypes.

Furthermore, Simcenter Testlab closes the loop with simulation by enabling the integration of models from Simcenter Amesim software for co-simulation, on-the-fly creation of model-based virtual channels using measured inputs.

With enhanced capabilities for NVH and acoustic design of electric vehicles (EVs), this latest release also specifically addresses the current challenges of digitalisation and electrification. In EVs, as the noise of an internal combustion engine is lower (or absent), secondary sources such as the wind, the road, or electric motors in components, are no longer masked and become more apparent.

This requires additional engineering effort and testing using techniques such as aeroacoustic testing, road noise transfer path analysis, and vehicle interior acoustics analysis, now available within Simcenter Testlab. ■

PTC and Ansys

Engineering software companies PTC and Ansys have joined forces to integrate the former's Creo 3D CAD solution with the latter's real-time simulation product, Discovery Live.

Announced at PTC's annual LiveWorx event in Boston, the partnership will enable users to visually assess the impact of design changes as they are made.

CAD and simulation are generally discrete processes that happen in isolation. By bringing them together, the companies say design engineers will be able to create better products, as well as reduce development time and costs.

"With the combined solution, engineers will be able to see the real-time results of simulation during the modelling process, enabling them to understand design changes in their models," said Jim Heppelman, president and CEO, PTC.

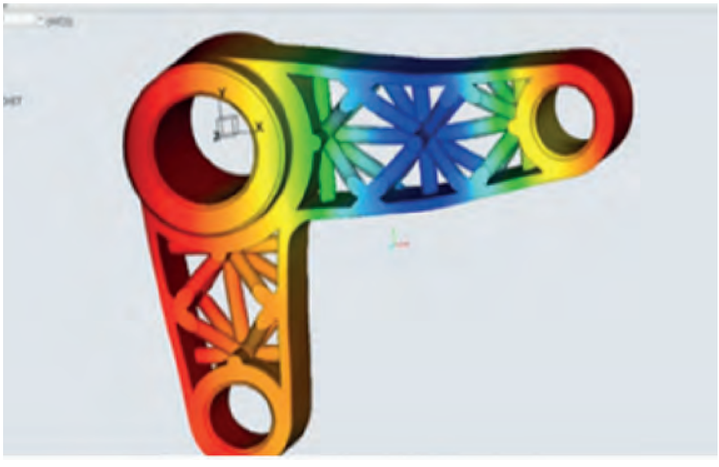
"This capability has the potential to dramatically improve engineering productivity and quality and the combined solution can be a differentiator in the market."

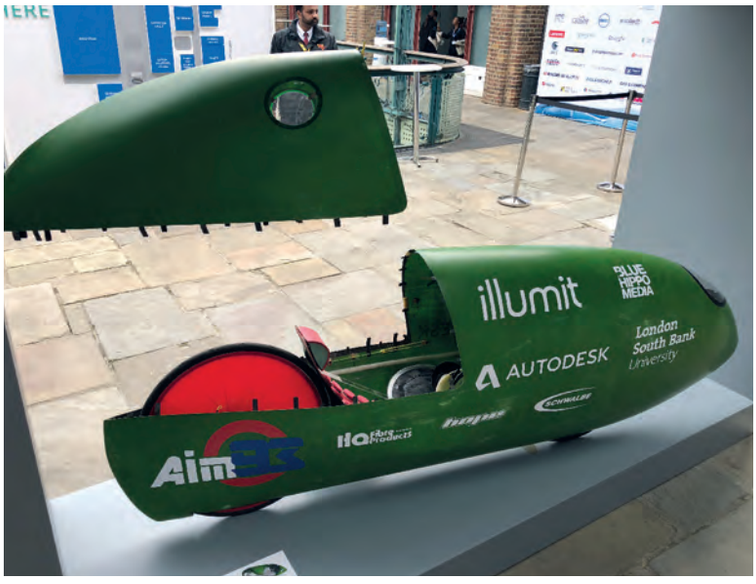
Although still in development, the solution was demonstrated during Heppelman's keynote address at LiveWorx. The first commercial product will combine Creo with Ansys Discovery Live, facilitating static structural, thermal, and modal simulation in real time.

PTC says that additional functionality will be added over time, with the goal of embedding increasingly advanced simulation capabilities into Creo. For Ansys, the partnership will mean its software reaches a much wider user base.

"By embedding Ansys Discovery Live into Creo, we will expand our audience to include design engineers – who will be able to design at the speed of thought," said Ajei Gopal, president and CEO, ANSYS.

"The power of simulation will now readily be provided to engineers as they make thousands of decisions and model explorations, providing them with unprecedented insight into their design choices." ■





Autodesk

A group of UK engineers have turned to simulation tools from Autodesk to help design what they hope will be the world's fastest recumbent bicycle.

Led by Glen Thompson, a London South Bank University design engineer, and renowned bike designer Mike Burrows, the so-called Aim93 team hopes that its newly designed human-powered vehicle (HPV) will break the current world record of 89.6mph when it heads to Nevada in September.

To make the Aim93 frame, Burrows used his normal approach: the design started on a large drafting board in the gantry office above his workshop; it then progressed through various lash-up prototypes to a track-ready frame design built by hand by wrapping carbon fibre around foam cores.

Thompson, meanwhile, got busy on the faring, using a much more digital approach: he took the published data for the record holder at the time, Varna, and ran Computational Fluid Dynamics (CFD) simulations on it, then started making iterative changes to achieve aerodynamic improvements.

"Aerodynamics of HPVs is a unique field because they have the lowest extreme of drag forces for any human-based vehicle," said Thompson. "Setting up a CFD model needs highly detailed settings to arrive at reliable data. The software tends to underestimate forces, and for many HPV teams in the past, the move from CFD to road-test data has led to disappointing results. Autodesk CFD Motion, and their expert Heath Houghton, enabled us to verify our results and build confidence in the predictions."

Meanwhile, in 2016, the team brought on Barney Townsend to improve on Burrows's hand-crafted frame using Autodesk's generative design technology, which is now part of Autodesk Fusion 360 Ultimate, a cloud-based product development platform.

Generative design uses machine learning and the power of the cloud to generate design solutions that a human would never consider. The designer then works with the software, choosing trade-offs to achieve the goals they establish for size, weight, material, manufacturing method, and more.

"Basically, once the software knows the spatial and load conditions it must work within, it fills this with material and then nibbles away at it, continuously analysing the internal stresses to remove as much mass as possible without going below the specified safety factor for the structure to do its job," said Townsend. "It then presents the designer with a series of outcomes from which to make a decision."

So far, the 90mph mark has proved elusive for HPVs, but the Aim93 team thinks it can beat that significantly. "All our simulations show that we should be able to hit 93," Townsend added. ■

products
pumps and valves

Launch the Nautilus

A low-noise air compressor, and the toolmaker supporting a world land speed record attempt

Atlas Copco

The Bloodhound SSC project is one of the most ambitious in the UK, aiming to construct a car capable of travelling at 1,000mph to put the world land speed record in British hands for a generation. Toolmaker Atlas Copco is a key contributor to the effort, supplying equipment such as wrenches, grinders, pneumatic drills, compressors, air receivers, filtration and pipework.

"We have supported the project by providing their workshop in Bristol with a full range of assembly tools, as well as compressed air equipment," says Jamie Buckling, marketing and communications coordinator, Atlas Copco UK. "Our top-of-the-line equipment gives their engineers the accuracy and control needed for this kind of extreme technology. For instance, our smart tools ensure that you get the right torque values every time. One of the compressors is used to 'dry' actuate the car's jet engine."

According to Chris Dee, lead assembly and build engineer, the company's contribution has been crucial for some four years, helping the team apply precision loads to the car's components that will allow it to travel at its extreme target speed. "This has extended not only to the headline items like the wheels, but also in the systems area to torque printed circuit boards that will see heavy vibrations. We have also used Atlas Copco compressors and air tools to allow us to precision-fit the panels of the car, some of which will see exceptional loads." ■

Vert

Edinburgh-based compressor manufacturer Vert Rotors is launching an easily transportable unit aimed at metrology applications in automotive and aerospace, which it claims will operate quietly enough to prevent damage to users' hearing.

The Nautilus compressor can be wheeled to the point of use and connected directly with no need for installing airlines to transport pressurised air.

Olly Dmitriev, chief executive, said: "The introduction of such small, mobile compressors and these industrial environments has never been successfully achieved before now.

"We are on the cusp of an industry-wide revolution in how we deliver compressed air."

Typically, compressors capable of delivering 300 psi pressure – the claimed performance of the Nautilus – operated noise levels of around 100 decibels (dB), about the same as a motorcycle.

However, Dmitriev claims that the Nautilus produces noise levels of 65 dB, about the same as an air conditioner.

The cost savings of using a portable compressor in precision manufacturing environments is crucial, according to Vert. High output is vital to secure income, and ensuring cost of production remains within budget is a key factor for such companies, it says. ■

Brunel unveils £15m advanced metals centre

AMPC offers access to new processing and casting techniques JASON FORD REPORTS

The AMPC at Brunel University

Britain's automotive and aerospace manufacturers now have access to new metal processing and casting techniques at the Advanced Metal Processing Centre (AMPC) based at Brunel University.

The new centre will allow manufacturers to work with Brunel on large-scale research and development projects and investigate ideas such as novel structures for lightweight car parts to a commercial level.

The AMPC was opened at the Brunel Centre for Advanced Solidification Technology (BCAST) on 13 June and is funded by £15m from the government.

It is the second phase of BCAST's scale-up facility, following on from 2016's launch of the Advanced Metal Casting Centre (AMCC). According to director and founder Prof Zhongyun Fan, BCAST's long-term aim is to reduce the amount of new metal mined from the ground.

"It is essential that we continue to be able to find even better ways of creating high-quality components and systems from metals that have already been used at least once," said Fan.

The industrial and pilot-scale metal processing equipment will enable the processing and fabrication of extruded metals, such as novel bending processes, machining and advanced joining techniques; casting processes, including gravity die and sand casting, adding to those available in the AMCC.

The facilities will similarly enhance the characterisation of supporting materials and include two X-ray computed tomography systems for 3D inspection: a 450 kV system for inspection of large-sized components, capable of imaging defects of 100µm; and a 150 kV system with micron-scale resolution in small samples.

Optical 3D scanning facilities will enable the precise measurement of components by stereo-camera optical 3D scanning with triple-scan functionality, additional photogrammetry, touch probes for out-of-sight measurement, and inspection turntable.

A key feature of the AMPC and the AMCC is that BCAST's researchers and seconded engineers from its partners will work side by side.

CPI ahead of the pack

The Centre for Process Innovation (CPI) is to jointly develop raw materials and formulations to enhance the performance of metal packaging.

Crown Packaging Manufacturing is leading the collaboration, alongside speciality chemicals supplier Thomas Swan & Co Ltd and AkzoNobel.

Typically, consumer product packaging is protected with an organic coating on the internal side, which protects against contamination of the product by the metal, and prevents the product from degrading the metal packaging.

Additionally, the external surface is often printed for decorative purposes.

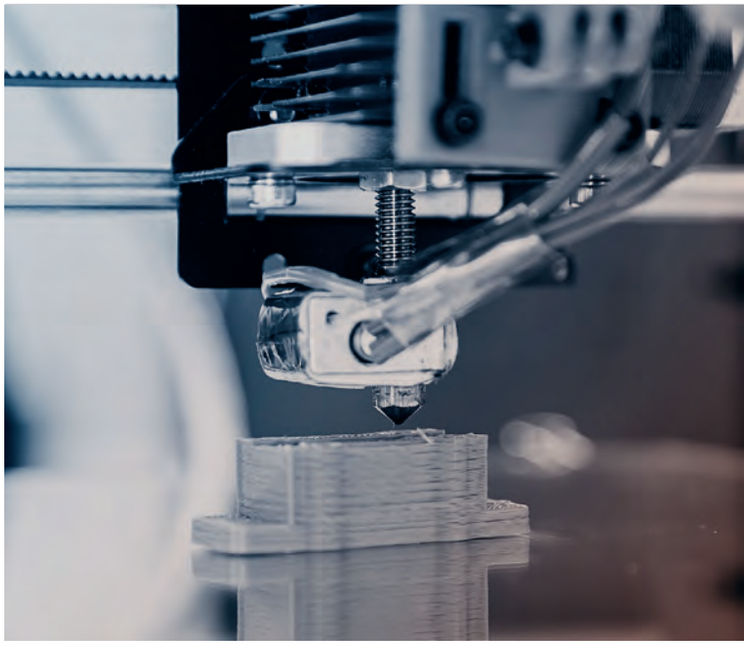
Epoxy-based coatings – the most commonly used protective technology for metal packaging – are preferred because of their favourable chemical resistance to food products and chemicals. They also adhere well to a number of substrates.

This project will seek to formulate a new set of thin film coatings with improved barrier properties, therefore lowering manufacturing costs and increasing productivity.

David James, development manager, AkzoNobel Packaging Coatings, said the collaboration would enhance his company's future generation of BPA-free products for food and beverage coatings. **JF**

3D printing takes a quantum leap

Researchers demonstrate how process can work at molecular scale STUART NATHAN REPORTS



UK researchers have devised a method for 3D printing at molecular scale to fabricate electronic components that have quantum technology potential.

Until now, 3D printing or additive manufacturing, has only been able to manipulate matter in powder form. However, research from Nottingham University has shown that it can also work on the molecular scale, opening up possibilities for making electronic components that could have applications in quantum computing.

A team led by Dr Victor Sans Sangorrin, of the faculty of engineering, and Graham Newton, of the school of chemistry, used photochromic molecules, which change colour when exposed to light, combined with a custom-made polymer. Sans and Newton used a nanostructured tungsten-containing polyoxometalate that changed colour from colourless to blue when illuminated, and returned to colourless when exposed to oxygen in the air. This was printed as a composite with a polyoxymethylene polymer, a class of materials used as engineering thermoplastics because of their stiffness and low friction.

In a paper in the journal *Advanced Materials*, Sans and Newton explain that this new material can store information reversibly.

"We can now take any molecules that change properties upon exposure to light and print them into composites with almost any shape or size," said Newton. "In theory, it would be possible to reversibly encode something quite complex like a QR code or a barcode, and wipe the material clean, almost like cleaning a whiteboard with an eraser." He added that, although this initial research used photochromic materials, any material that reversibly changes properties in response to an external stimulus could be used. "This approach could be used to develop materials for energy storage and electronics," he said.

"This bottom-up approach to device fabrication will push the boundaries of additive manufacturing like never before," Sans added. ■

Steel deal opens up new range of products for carmakers

Carmakers will have access to a new generation of steel products following an agreement between Tata Steel Europe and POSCO.

Tata Steel's cross-licensing agreement with South Korean steelmaker POSCO will allow the company to increase the range of advanced products to markets such as the construction sector.

The deal will allow Tata Steel to access physical vapour deposition (PVD) technology, a process that gives steels anti-corrosion coatings without the current requirement to heat them during the hot-dip galvanising process. This has the potential to allow for an increase in the number of steel products on which specific anti-corrosion coatings can be used.

Serica low-waviness coating

The new PVD technology developed and patented by POSCO is already adopted in the electronics industry but needs further development for automotive and construction applications. The technology will help Tata Steel meet the emerging need for sustainable steel products for next-generation cars and buildings.

Hot-dip galvanising takes place in molten zinc at temperatures of around 460°C, which can negatively effect the microstructures and mechanical properties of steel, especially high-strength steel. Electro-galvanising overcomes this as it takes place at room temperature but incurs high-costs associated with energy consumption and is limited in the range of coating that can be applied.

Sander Heinhuis, head of marketing, Tata Steel Automotive, told *The Engineer* that PVD involves condensing a vapour of the desired coating on to the strip surface in a vacuum. PVD can be carried out at low temperatures, which allows a new range of microstructures and strength levels to be developed.

"These are of particular interest to automotive OEMs [original equipment manufacturers] due to the weight-saving advantages they offer and because PVD overcomes the hydrogen delayed fracture risk," he said. "Exceptional surface quality can be achieved, which leads to superior paint-appearance also highly sought after by automotive OEMs. In addition, PVD can be used to apply differential coating types and thickness to each surface of the strip and can be used to build up multi-layer coatings."

According to Heinhuis, automotive OEMs see advantages in PVD treated steel in relation to press performance and surface appearance. **SN**

Contents

How local manufacturing is redefining humanitarian aid

Advancements in technology and design mean that, now more than ever, supplies made in the field can make all the difference when it comes to disaster recovery and helping war and weather-torn areas. Field Ready's Eric James **explains how**

In regions where something as simple as an umbilical cord clamp or a plastic u-bend can help save lives, local manufacturing can have a hugely positive impact. Hard-to-reach areas stricken by disaster, conflict and poverty can be slow to receive emergency aid, and broken or non-existent supply chains often mean that people don't have the equipment they need when or where they need it.

Access to the right technology can circumvent supply chain problems and mean the difference between waiting weeks and sometimes months for medical equipment, power or clean water, and having systems up and running in a day or less. But local manufacturing isn't just about the technology. It's about putting the people – the communities – first, focusing on the support they need on the ground. We can then apply design thinking and other methods to map the technology best suited to their needs and alleviating their suffering as quickly as possible – not the other way around.

While 3D printing parts in these remote areas can often be a good fit for cutting out supply chains and speeding up access to much-needed equipment, we understand that is not a panacea – especially when it comes to creating high volumes of equipment or parts quickly. We've seen success in local manufacturing using technologies that make the most of available materials.

In March last year we worked with local Syrians in the immediate aftermath of bombing raids to create airbags designed to lift heavy debris from collapsed buildings to rescue trapped civilians. By manufacturing the bags on the ground with local materials (such as wood, metal and recycled/upcycled plastic), we were able to respond more quickly – saving time, money (the locally produced airbags were 90 per cent of the cost of commercial equipment) and, most importantly, lives.

Hurricane relief

After category five hurricanes Maria and Irma hit the US Virgin Islands in December, the island's energy systems were devastated, leaving residents waiting for days and weeks for their power to be restored and for aid to arrive. Our team worked with locals on the ground in St Thomas to round up solar panels that looked damaged beyond repair. After testing them, we found that many were still functional – they just needed to be charged.

Rather than waiting weeks for new parts or panels to arrive, we used CAD software and a 3D printer – powered by industrial batteries – to create a prototype part to attach a power lead from a solar panel to a large battery on site. The battery would give the solar panels enough of a boost to start charging. Within a day, we'd perfected the design and soon the panels were back up and running with the charge they needed to get to work powering lights, mobile phones, laptops and even some Wi-Fi stations throughout the island.

3D printing parts in Nepal after the 2015 earthquakes

Restoring some local power meant opening up communication channels, helping to restore hope and taking those first steps toward an easier everyday life for those hit hardest.

Supporting innovation

Necessity truly does breed invention and we see this time and again with local manufacturing. Since the 2015 earthquakes in Nepal, we've worked alongside local communities using manufacturing technologies to address health needs and support projects aimed at improving livelihoods, preserving their environment and increasing safety measures so that future natural disasters take less of a toll.

To improve the efficiency and safety of wood-burning cookstoves used throughout Nepal, local innovator Madhukar KC had spent 10 years perfecting his design to get more oxygen to the wood so it burns more efficiently.

By translating his wood-carved burner design into a CAD model and printing it, KC was able to take his mould to a local sand-casting foundry, where it was cast in aluminium and cast iron, creating a safer and more efficient burner. His design uses fewer wood resources, burns more cleanly and cooks faster. KC has since been awarded a contract by the Nepalese government to make 210,000 cookstoves – providing him with not only a sustainable income, but also a growing and successful business.

Leaving behind knowledge

Local manufacturing will benefit as applications such as 3D printing evolve and improve – but that does not mean it is limited by technology. As we've seen, the success of local manufacturing is often driven by extreme circumstances – it is not until traditional supply chains are interrupted or broken down that local communities across the globe are forced to become more self-reliant.

Empowering local communities and working alongside people to combine creative problem solving and technology can make all the difference in those hours following a crisis – saving lives and improving livelihoods. We start by alleviating immediate suffering and progress to implementing longer-term solutions, so when we leave a region it's not just technology we're leaving behind, but shared knowledge and expertise. ■

Eric James, PhD – co-founder and executive director, Field Ready, a not-for-profit organisation

Would you like to learn more about local manufacturing and humanitarian aid? Check out Field Ready's good works and join them from 10-12 July at this year's Additive International (formerly the International Conference on Additive Manufacturing & 3D Printing): www.additiveinternational.com

Machine tools on the right track

Global developments continue to meet a wide range of challenges from end users in both high-end technology and traditional markets. Mike Excell **reports**

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Notwithstanding the vagaries of global consumption, machine tool builders (MTBs) continue to invest in new production capacity to meet demand from increasingly sophisticated users. Mazak exemplifies this, announcing the completion of the first construction phase and the start of assembly operations at its new Inabe plant – its sixth in Japan. The plant will manufacture large, five-face machining centres and five-axis machine tools, mainly for the aerospace, construction machinery and energy industries; and raise production capacity in Japan by 20 per cent.

Meanwhile, more than £2m has been spent upgrading Heller Machine Tools' manufacturing plant in Redditch, Worcestershire, providing a 30 per cent boost to output of horizontal machining centres.

Commenting on the underlying production strategy, David Evans, UK operations manager, said: "As part of our expansion, we installed an 11-station Strothmann flow line and new logistics system for complete manufacture of horizontal machining centres – originally, our machine assembly was purely a mechanical process on an adjacent flow line and the machine had to be lifted off to be finished in a separate part of the factory. When we first moved from block assembly of machines in one location to the old flow line, there was an immediate 20 per cent increase in productivity. The new Strothmann system has resulted in a further reduction of at least 20 per cent in overall assembly time and we intend to improve on that by making the process even leaner."

Mill-turning developments

Modern machine tools tend to be multifunctional, and whilst the Mazak and Heller initiatives focus on what can be clearly identified as machining centres, developments in mill turning continue apace, and include a new compact machine from DMG MORI for turning and milling large diameter components. The NTX 3000 2nd Generation multitasking centre is capable of simultaneous five-axis CNC machining of complex workpieces within a footprint of only 16.5m^2. Experience gained from installing more than 1,000 of the smallest, 65mm bar NTX 2000 model, drove design of the new machine. It has a robust machine bed with roller guideways and offers high process stability and flexibility. Comprehensive water cooling of the spindles, ball screws and ball nuts ensures thermal stability in continuous operation. Magnetic scale feedback of linear position to a resolution of 0.01 micron is a further option, as is a range of automated workpiece handling systems.

The value of multi-axis machine tools is being demonstrated throughout the manufacturing supply chain, encouraging forward-looking SMEs and subcontractors to sustain investment levels and exploit the latest technology. Worthing-based Roscomac invested around £3m-£4m with Citizen Machinery UK in the first six months of 2017, and is now enjoying the benefits. The investment programme started with a Miyano BNE-51MSY multi-axis turn-mill centre and two Cincom sliding head turn-mill centres, M16-V, and L20-VIII LFV. Such was the impact, in terms of productivity and problem-solving, of using low-frequency vibration (LFV) technology on the L20, that managing director Joe Martello ordered another L20 and a smaller-capacity L12-VII.

Game changer

Sean Keet, cell leader, said: "We had been experiencing problems with swarf when machining certain difficult components made from high-grade alloy and some stainless steels, plus copper, plastics and some difficult-specification aluminiums. Despite constant monitoring, we often faced significant levels of scrap or reworking, in particular due to swarf marks on critical features."

Production of these parts has been transformed, with LFV described as "a game changer." LFV is based on initiating selectable sequences programmed at the machine control through 'G-codes' to impart the size of chip to be produced. This introduces oscillation of the cutting tool through the servo axes of the drive system in the direction of feed in phases of tens of microns, which are precisely synchronised to the rotation of the spindle. The resulting controlled 'air-cutting' breaks the swarf into a designated chip size, which prevents 'bird-nesting' and can be applied to turning, drilling and even threading cycles. LFV can be switched in or out of the programmed cycle as required and helps reduce the onset of built-up edge on the tool tip, extending its in-cut life. It also allows increased depths-of-cut and enhances the achievement of improved surface quality.

Disruptive technology

The multifunctional trend enters disruptive technology territory with VIPER grinding. VIPER was the fruit of collaboration, back in 2001, between Rolls-


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Royce and Makino. Now, NCMT, which supplies Makino machines to the UK and Ireland, has won the Queen's Award for Enterprise in International Trade 2018 for export success. Since 2005, NCMT has been licensed to sell VIPER across Europe; it has supplied more than 160 cells so far, many of them automated, into aerospace supply chains in the UK, continental Europe and as far afield as Thailand and Mexico. The process uses small aluminium oxide grinding wheels exchanged from the tool magazine on Makino machining centre platforms, allowing manufacture of nickel alloy components, such as turbine blades, much more efficiently than previously. Metal removal rates are five times greater than on traditional, higher capital cost, creep-feed grinders. Benefits include reductions in capital investment, set-up times, production costs, lead times and consumable costs – and very high accuracy.

01 Restoration of 'Sir Nigel Gresley' prompted investment in a new turning centre from XYZ

02 CoroMill Plura HFS targets high-feed side milling of titanium components

03 B-axis spindle, optional lower turret and counter spindle of DMG MORI's NTX 3000 2nd Generation.

Train time

Of course, less sophisticated solutions are appropriate for many machine tool users. The workshops of the Llangollen Railway provide maintenance for its own rolling stock, as well as supporting other heritage railways. A new project, to restore the iconic streamlined A4 Class locomotive 'Sir Nigel Gresley', prompted investment in an XYZ SLX 425 ProTURN lathe.

Built in 1937, the locomotive holds the post-war steam speed record of 112mph. The latest overhaul required sending the boiler to Llangollen for refurbishment and recertification. This included replacing the boiler stays – threaded shafts that support and brace the metal walls of the firebox against the pressure. As there are 296 of these stays in various lengths, with threaded ends, an upgrade from manual turning was deemed wise. The ProTURN lathe enables each boiler stay to be machined complete in half the time taken on a manual lathe. "The ProtoTRAK control makes life very easy as it guides you through everything, the TRAKing feature is very handy and the Do-One canned cycle feature in the control is extremely useful for machining features such as radii and chamfers," said Llangollen machinist Michael O'Toole. "In addition to the easy conversational programming, we always use the Verify graphical system for added reassurance."

O'Toole's comments underline the fact that even the 'simple' manufacturing solutions encompass a level of technology we've come to take for granted. The key to investment is always about selecting the right machine for the job, and the view from the shop floor is a critical factor in making the right decision. ■

CUTTING TOOL DEVELOPMENTS

Milling titanium
Addressing the challenges of machining titanium parts for aircraft, Sandvik Coromant has introduced the CoroMill Plura HFS solid-carbide end mill. It exploits milling strategies such as high-feed side milling (characterised by low radial engagement, constant chip thickness, and high feed rate and speed). Sharp edges combine with a new coating that features a TiAlN inner layer and a silicon-containing outer layer. The outer layer reacts with titanium alloys and forms a sub-micron protective layer. During cutting, chips glide on top of the protective layer, preventing fast deterioration of the original coating and prolonging tool life.

Tangentially mounted inserts
WNT's System SOGX series of turning inserts and toolholders combine to provide users with four useable cutting edges. In addition to maximising the number of cutting edges, by tangentially mounting the inserts, a stable process is ensured, even under extreme cutting conditions. This is further enhanced by the availability of a coolant supply that can be precisely directed and fed from either the rear or side of the toolholder.

Internal cooling
Horn Cutting Tools offers Boehlerit's new turning toolholders with connections for internal coolant supply. They are available from stock with toggle clamp (ISO-P) and screw clamp (ISO-S) systems, allowing manufacturers to benefit from the productivity advantages of cooling directly at the cutting edge.

Wave mill expanded
Sumitomo Electric Hardmetal has extended its WFX-Type Wave Mill screw-locking shoulder milling cutter range using the proven economic advantageous series of four corner inserts into the WFXH, a high feed rate multi-purpose roughing, and WFXC chamfering-type bodies. By maintaining the use of existing inserts in the WFX Series, tool management and stock holding of inserts becomes more economic, extending their use to a wider range of applications.

Closing the circle

AMRC's Advanced Structural Testing Centre supports local innovators with global potential. Mike Excell reports

Design it, make it – and prove that it's right. It's a philosophy that underpins any successful manufacturing project, so when Sheffield-based steel fabricator A K Orme and Sons landed a China-bound contract to supply strengthening rings for large grinding discs, the integrity of the product had to be ensured. The rings are made by cutting steel rods to length, bending the lengths into a circle and welding the ends together, which means that the weld strength is critical. The challenge of testing these parts was presented to the Advanced Structural Testing Centre (ASTC) at the University of Sheffield Advanced Manufacturing Research Centre with Boeing (AMRC).

Effective testing required cutting both welded and unwelded sections, out of the ring, and machining the sections so that the tensile strength could be measured perpendicular to the weld. Delivering tensile test pieces to meet this criterion – straight pieces, correctly orientated, cut from a curved rod – required the use of accurate polymer jigs, which were designed and produced by the AMRC's design and prototyping centre's additive manufacturing facility. The test pieces were machined on a two-axis lathe, and tested within the ASTC.

Integrated approach

The ASTC houses several basic machine tools for creating test pieces, and alongside the sophisticated technology that proliferates throughout the AMRC, it's interesting to observe traditional skills being exploited in this way to create one-offs. The Orme project, directly supporting a local business, nevertheless highlights the integrated approach which characterises the AMRC – and the ASTC in particular, which is now projecting its remit across a wide range of manufacturing industry challenges.

The ASTC has developed its capacity over the past decade as a resource for effectively 'closing the loop' on the total manufacturing process. Facilities are mainly dedicated to applying loads and pressure to parts and assemblies – as well as test 'coupons' – to determine fatigue life and compressive or tensile strength, and predicting how they will perform in demanding service environments. Most types of material can be tested, including composites, ceramics, rapid-prototype filled lattices, aluminium, steels and high-performance alloys.

The equipment ranges from laboratory-scale impact and tensile testing machines to 2MN actuators. A 10m^2 'strong floor', with 1m pitch equipment locating points, allows rigs to be built to accommodate virtually any testing requirement.

A combination of actuators and bespoke fabrications from the AMRC or local suppliers enables the ASTC

01 The GB1 GameBird attached to the whiffletree for testing

02 The Advanced Structural Testing Centre team (Phil Spiers far left) after getting the GameBird into position

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to carry out tests for all industries, including the civil engineering, rail and marine sectors – and, on occasion, the aeronautics sector.

Sky high

The ASTC is headed up by Phil Spiers, who is also on the council of the Royal Aeronautical Society, having worked in the aerospace sector, with Messier-Dowty and Martin Baker, for many years. He was approached by a company developing a small aircraft, the GB1 GameBird, to quote for airworthiness testing. "It's a two-seat aerobatic aeroplane," he explained, "similar to the type used in the Red Bull air races."

GameBird was developed by Lincolnshire-based Game Composites. The challenge for the ASTC was to build a test rig large enough to accommodate the complete aircraft; the strong floor and the space around it were key enablers.

> "We had to flip the whole plane over so that it sat upside down"
>
> Phil Spiers

"The wingspan was 8m – and it just fitted," said Spiers. "We designed the whiffletree for it, and we had to flip the whole plane over so that it sat upside down."

A whiffletree is used to distribute force when applying loading to test aeroplane wings and fuselages, simulating what happens in flight. Typically, load is applied from one direction at the centre, and from the other direction to the tips and other critical points. The whiffletree for the project was built by AMRC apprentices, and welding experts from the Nuclear AMRC.

In this case, the process meant twisting the fuselage and the wings and monitoring 11 reaction points. The European Aviation Safety Agency was involved in observing the tests, which required the GameBird to withstand 36,000 cycles for certification; and included a load test equivalent to 10G, at 73C (the maximum operating temperature likely to be encountered – in desert regions, for example). "A complex test," said Spiers, "and you get to know what the product should feel like and sound like as loads are applied." Early incidents prompted some redesign of the airframe, but eventually the aircraft passed the series of tests and as such became the first fixed-wing light aircraft to be designed, built and subjected to a full airworthiness test in the UK for more than 30 years.

Up on the roof

Few of the projects undertaken by the ASTC are as spectacular as GameBird, but many have arguably more widespread and practical significance in consumer markets. For example, Leeds-based KEAH makes specialised products for the construction sector; its roof batten joint is designed to speed

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03 The GB1 GameBird in flight

04 The aircraft in position

05 Controlled tests on runflat assemblies

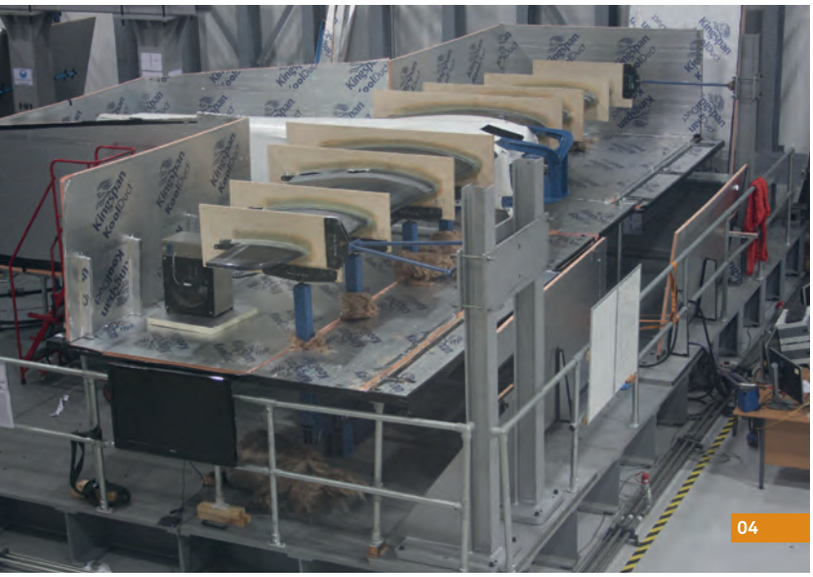
(Images supplied by Steve Caborn)

up a time-consuming manual job routinely carried out as a part of house-building. Horizontal roof battens normally must be trimmed to size and nailed to roofing trusses; the process is slow and wasteful, and also prone to generate weak points as a consequence of trimming, nailing, patching, splitting of batten ends and joint failure.

The roof batten joint is a plastic, injection-moulded, push-fit connection, which is designed to join battens at any point along the roof structure, not just at the trusses. The task presented to the ASTC was to confirm that the joint did not in itself create a weak point. "Other test houses had quoted and were cheaper," said Spiers. "But the team at ASTC were able to offer ideas and develop a test specification which was realistic for the application. KEAH constructed a roofing model that fits perfectly into our 'tall rig' ".

In all, 28 configurations of the joints were tested to destruction at various angles, corresponding to standard roofing practice. The results showed that the joints were stronger than traditional fixtures – and in fact could withstand the same loads as the plain continuous batten – effectively coping with "a 20st roofer standing at the worst point."

In fact, the joints are able to support double this load. "It's a commercial success for all parties" said Spiers. KEAH is now working with national roofing and construction companies to develop the market for this "simple but powerful concept."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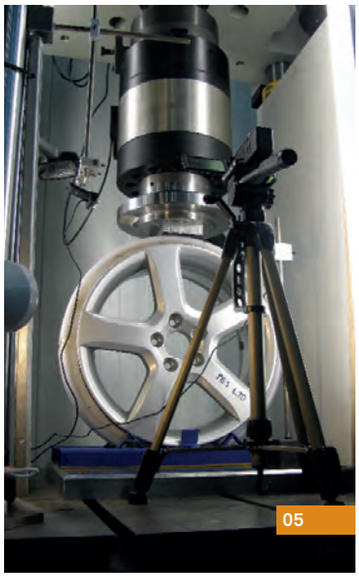
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Supporting local innovators

In terms of industries served, these two examples demonstrate the scope of the ASTC. Many of the projects undertaken support local enterprises – but this shouldn't be surprising, since many of the UK's most innovative companies are located in Sheffield, some in the Advanced Manufacturing Park (AMP).

Runflat Systems is based a few hundred yards away; the company has developed a tyre insert that will allow vehicles with punctured and completely depressurised tyres to continue to operate effectively. The design process has been supported by Performance Engineering Solutions and additive manufacturing specialist Materialise – both of which are based at the AMP. "Runflat will do 350 miles at 55mph with all four tyres deflated," said Spiers. The ASTC has assisted product development by carrying out controlled tests on components and assemblies that would not be possible on the test track.

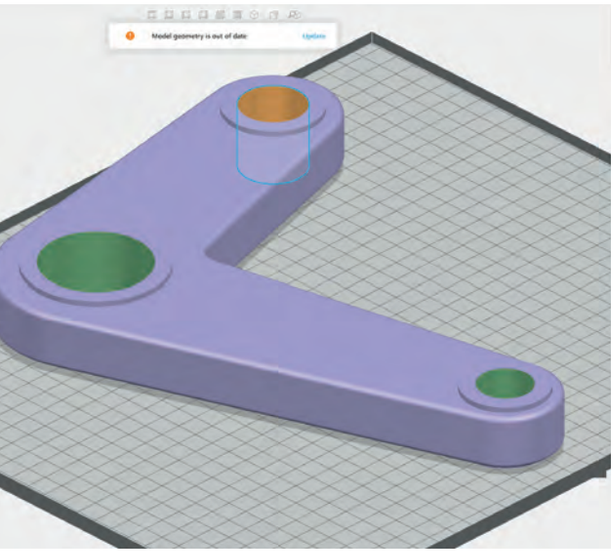
"We have tested the whole unit, individual pins and joints, the 'gearbox' (which tightens the unit), cables and the full subassembly," said Spiers. So far, target markets are essentially military and police vehicles, but the product may ultimately find its way into road cars.

A creative and flexible approach to testing is possible because not only is the ASTC accredited by UKAS, it is the only structural test facility within a UK university structural test laboratory to hold ISO 17025 'in-house methods' accreditation. This gives it the licence to develop test procedures in collaboration with clients to prove out components under real-world conditions.

The core philosophy, as with the AMRC in general, focuses on partnership and teamwork, and this brings knock-on benefits. For example, the 5m-high 'tall rig' used to test the roof batten joint was developed in collaboration with Gripple (another Sheffield company). Gripple manufactures wire joining and tensioning systems, and the rig was in fact initially designed for conducting longer and more accurate tests on longer (4m) struts produced for its seismic bracing systems.

Testing projects undertaken by the ASTC range from the prosaic to the exotic; from access ('manhole') covers – which must withstand huge loads – in aluminium, to actuator rods for commercial aircraft assemblies, made from titanium reinforced with silicon carbide monofilaments – plus new fibre/resin combinations from the AMRC Composite Centre.

What's common to all, said Spiers, is that "pretty much everything is safety-critical; you have to know that when the product goes out there it's not endangering life, limb or health." ■



Stratasys

Additive giant Stratasys is seeking beta customers for software designed specifically to improve the firm's solution for the production of jigs, fixtures and other manufacturing tooling.

This new software component – called Jigs and Fixtures for GrabCAD Print – simplifies and automates print preparation for rapid tooling applications.

Stratasys fused deposition modelling (FDM) technology is used extensively for rapid tooling applications across industries.

Companies from the Team Penske motor racing team to consumer vacuum maker Oreck use FDM technology to accelerate the production of fit-for-purpose jigs and fixtures to reduce cost and repetitive stress injury, while improving cycle time and production flexibility.

The firm claims that the new software will help industry streamline operations and improve efficiency for jig and fixture creation.

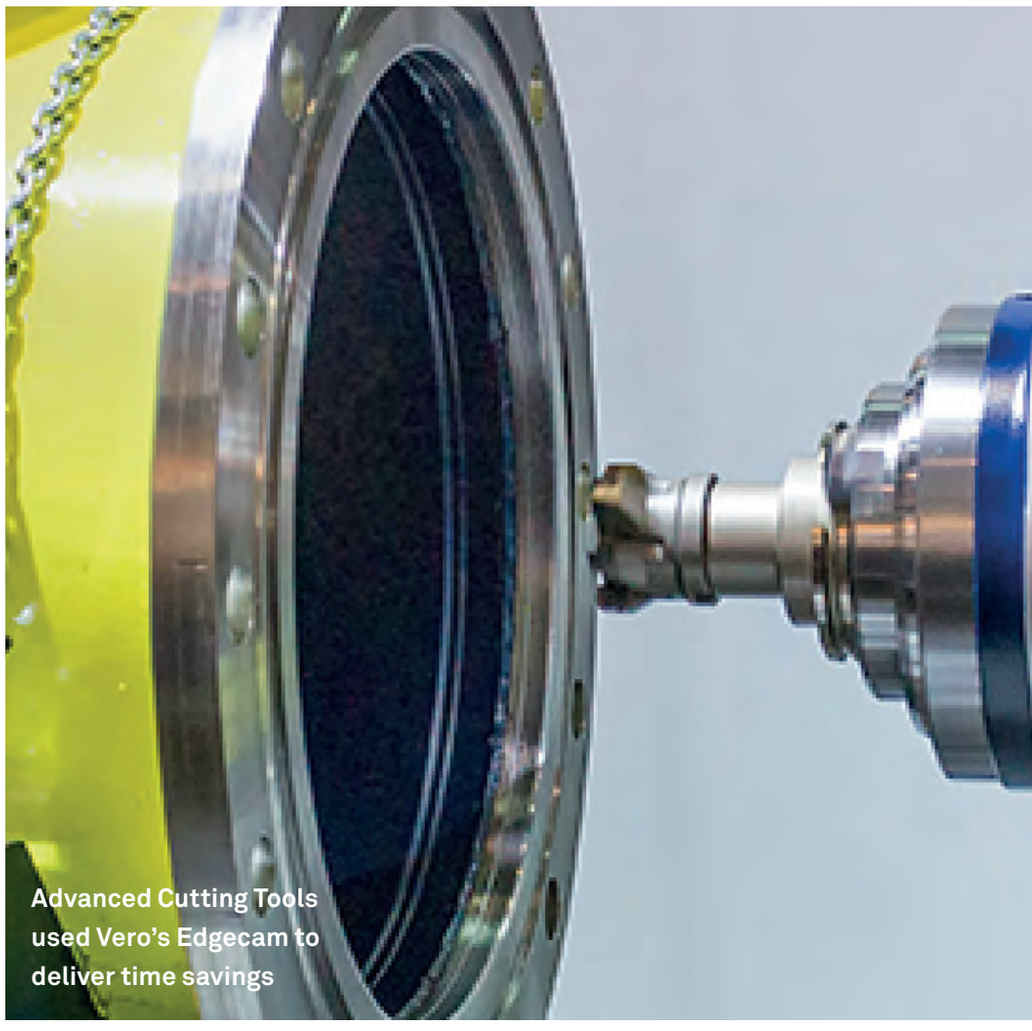
Offered through GrabCAD Print, the software embeds application expertise, automates several complicated and time-consuming processing steps, and eliminates the need for multiple programs within the workflow.

It expands upon the capabilities offered in Stratasys Insight to streamline the toolpath planning process; increasing ease of use and reducing time and costs to create jig and fixture parts.

What's more, by accepting native CAD designs, the part's original design intent is maintained. This eliminates the need for users to convert their CAD design to an STL file, which can result in key information being lost during translation.

Stratasys added that, as well as opening up jig and fixture CAD design to more users, the software saves time and eliminates unnecessary iteration during the design and processing phase.

The Jigs and Fixtures for GrabCAD Print software is targeted to manufacturing engineers, tooling designers, and production managers, as well as service bureau programmers, executives, and owners. ■



Advanced Cutting Tools used Vero's Edgecam to deliver time savings

Cutting-edg

The latest developments in software are helping firms improve efficiency and reduce costs

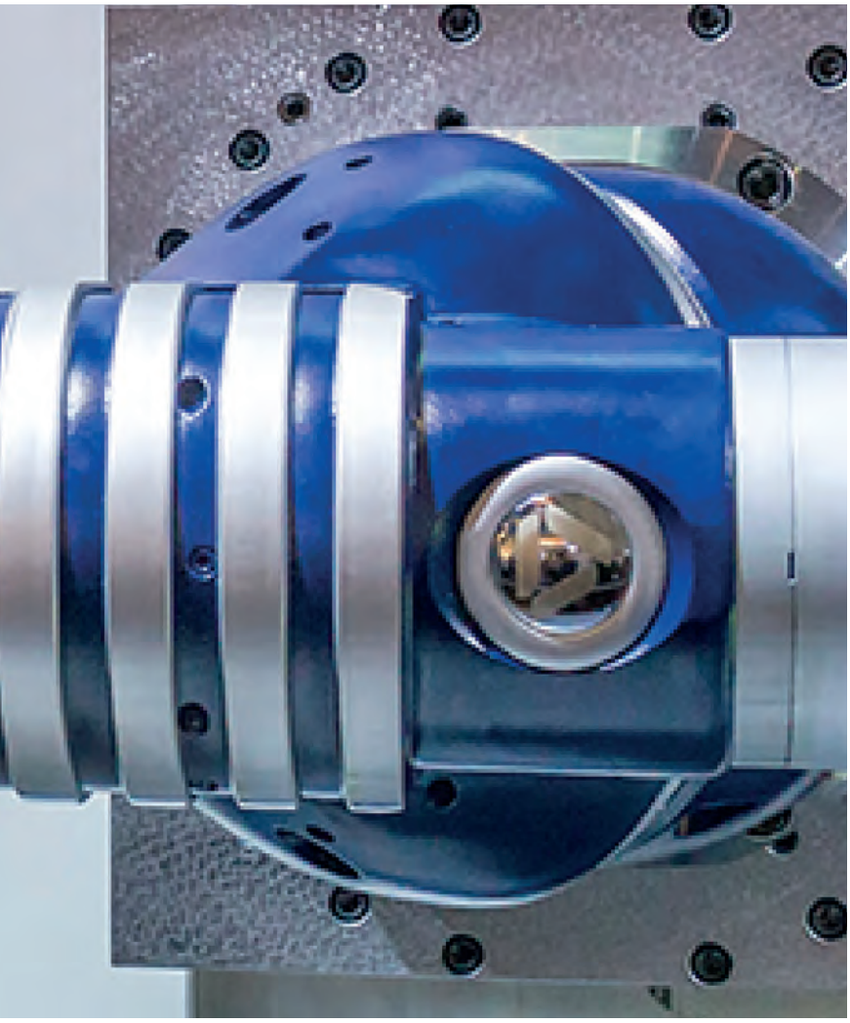
Open Mind

Version 2018.2 of Open Mind's hyperMILL CAD/CAM suite contains a number of improvements, including to its drill hole and pocket recognition and 3D-optimised roughing capabilities.

According to the firm, the most important additions are to be found in the CAD section: hyperCAD-S. This CAD software, which is specifically designed for CAM programming, provides working solutions to many familiar challenges posed by meshes, faces and volumes, enabling the creation of highly precise components and tools. The data is prepared for subsequent NC programming independently of the original CAD system.

Another improved feature is the electrode module, which automatically derives electrodes from the faces to be die-sunk within the component geometry. With the 'Virtual Electrode' function, copies of an electrode that has already been created can now be generated in various different positions.

These are checked for collisions and can be assigned the technology values of the master electrode or new technology values. During electrode milling, these values are processed accordingly. The reference system and



e of CAM

eroding position for each copy are included in the report. Two new functions have now been added to the 3D Z-level Shape Finishing strategy to reduce programming times and improve milling results. The Automatic Face Extension function can be applied during programming to extend the selected milling surfaces.

This CAD-for-CAM feature eliminates the need to modify the milling surfaces in the CAD system beforehand. The New Tool Types feature allows barrel cutters to be applied to the 3D Z-level Shape Finishing strategy as a standard tool. Furthermore, this new addition supports tangential and conical barrel tools.

One of the new functions in hyperCAD-S makes it possible to measure the distances between two shapes. This function can be applied to face models, solids, meshes or stock and allows a face created using the 'Global Fitting' function to be compared with the original face. Moreover, casting allowances can be reviewed very quickly. The frequently used 'unwrap' command has now had a 'radial' mode added. This allows radially aligned curves or texts on rotational solids to be unwrapped with a constant radial length, which is very useful for engraving and tire labeling.

Meanwhile, for easy changes to milling boundaries and turning contours, the software offers a 'V sketch' command. This is used to assign geometric constraints to 2D contours. When individual contours are changed, the sketch is automatically updated using their dependencies. ■

Vero

Machine tool distributor Advanced Cutting Tools (ACT) has used Vero's Edgecam software to deliver a 65 per cent time saving on a customer's aerospace component.

According to Michael Richardson, ACT's owner and managing director, providing the right equipment for customers is not enough. More importantly, the company offers tailored machining strategies and Edgecam CAM programming for specific parts, delivered through its Technical Solutions service.

"Our philosophy is that the cutting tool you buy from us isn't important, but what you do with it is," said Richardson. "So we look at the components our customers want to produce with the tools, and what they're looking to achieve with them. That may include increased productivity, greater efficiency, and faster machining cycles. In many cases, we'll suggest changes to the strategies, and give them an Edgecam program for optimum machining of the part."

Richardson uses Edgecam to program parts on site and says customers can instantly see the benefits. One recent job helped deliver what the ACT boss describes as "phenomenal" savings for a manufacturer in the aerospace industry.

"The customer was working on a complex part that took four hours and 20 minutes to machine, in four operations," Richardson explained. "They were two years into a five-year contract with it, and during that time they'd succeeded in getting better prices from suppliers, but the part had never been in profit.

"We carried out a complete overhaul, reprogramming it with Edgecam, which also involved changing the setups and workholding. It became a three-operation process, and the production time was reduced to 93 minutes." ■

CNC Software

Connecticut-based CNC Software has released details of its Mastercam 2019 product ahead of its official release later this year.

Mastercam is a Windows-based CAD/CAM software solution for two- to five-axis routing, milling and turning, two- and four-axis wire EDM, 2D and 3D design, surface and solid modelling.

According to CNC, the latest edition will increase machining productivity and reduce overall production costs with new 2D through multi-axis milling automation features, CAD and model preparation improvements, expanded 3D tooling, accelerated finishing and powerful turning and mill-turn enhancements.

Re-engineered chamfering and holemaking strategies, plus the new multi-axis deburring, will provide increased time-saving automation and simplicity. New milling toolpath strategies, like the high-speed Equal Scallop toolpath, will offer both machining performance and surface finish improvements. Mastercam 2019 also includes additional support for the Sandvik Coromant PrimeTurning method, enhanced grooving, bar feed, and other features for turning and mill-turn applications, plus new lathe and Swiss-style machine support.

With improvements to toolpath and machine simulation, toolpath graphics, and other verification and analysis tools, the new release will deliver greater programming assurance and allow for more informed decisions before a job is run. Improvements include support for block drilling multiple holes simultaneously and better axis control in simulation, allowing the user to easily check machine limits or collision checking.

Mastercam 2019 will make its public debut this September at the International Manufacturing Technology Show in Chicago. The event, which is held every two years, attracts an audience of more than 100,000 from across the US and around the world. ■

Your chance to be

Maintec promises exciting new content and features for November as it helps reliability, maintenance and asset management employees prepare for challenges to come

Maintec, the longest-standing exhibition dedicated to the maintenance, plant and asset management industry, has announced some important developments to the event's format when it returns to the NEC, Birmingham on 6 and 7 November 2018.

Throughout its 44-year history, Maintec has remained at the heart of the maintenance engineering community, and changes to the event come in response to feedback from both the exhibitor and visitor audiences.

Not only has Maintec moved to a new date in November to become a better fit with industry sourcing and buying cycles, but it will also feature a host of the UK's leading engineering suppliers and manufacturers, as well as a strong programme of professional, technical seminar content.

Unique insights into advanced activities

In light of the political and technological changes seen within the UK's engineering sector in recent years, careful consideration has been taken to put together a programme of CPD-accredited professional education that provides valuable professional development for the maintenance managers, reliability engineers and the engineering teams who attend from across the UK.

The show will feature two theatres; Maintec Insights and Reliability Dialogue. The Maintec Insights theatre will include a combination of case studies, technical insights and state-of-the-nation presentations from key high-level experts from the world of maintenance engineering.

Kicking off the Maintec Insights programme will be an opening keynote session from Dr Jenifer Baxter, head of engineering, Institution of Mechanical Engineers, who is responsible for engaging with government, industry and academia to ensure that the engineering perspective is included in policy making, innovation, and research and development. Baxter's session will set the scene for the conference, discussing the importance of effective maintenance and future tech trends from the engineering sector.

The day's programme will then move towards end-user applications of advanced maintenance activities, with each session providing unique insights and best practices being adopted by maintenance teams that work at some of the UK's leading sites.

The Reliability Dialogue theatre, new for 2018 and sponsored by Bosch Rexroth, will address the changing face of reliability and automation and the impact this has on the future of maintenance engineering. Over a mix of presentations and panel discussions, leading experts will discuss and debate key topics facing end users in the industry, with an opportunity for the audience to join in the discussion and ask questions of the panel.

Top suppliers and manufacturers under one roof

Bosch Rexroth, one of the world's leading suppliers of drive and control technologies, will be exhibiting at the event for the first time and joins many other

part of the future

01

03

maintenance technology, asset management and plant equipment manufacturers and suppliers who have confirmed they will be returning to the show this year, including: RMS, Megger, Fluke, Cordex, Shire Systems, Radwell, Pruftechnik and UE Systems.

Tim Else, director, Western Business Exhibitions (WBE), said: "It is our principle aim to ensure Maintec remains pertinent to the UK's maintenance and reliability engineers.

> "We want to make sure it remains at the forefront of industry"
>
> Tim Else

"For 2018, we have made sizeable changes to the event and its seminar programme to make sure it remains at the forefront of industry and delivers value for the engineers who attend the event."

"We are delighted to be hosting some of the leading brands in engineering, who bring a wealth of knowledge and expertise to the show floor. The powerful combination of professional content and leading suppliers makes Maintec 2018 a must-attend event for anyone who has responsibility for maintenance and reliability for their organisation."

This is the second edition of Maintec since its acquisition by WBE, which also organises the Health & Safety Event series. In 2017, WBE delivered the most successful Maintec in the show's recent history, delivering a 62 per cent increase in visitor numbers and attendance of engineering teams from 15 of the UK's top 20 manufacturing sites.

The show attracts engineering visitors from across multiple industries, including energy, manufacturing, automotive, hazardous environments, aerospace, utilities, oil and gas, food and drink, rail, and ports and marine – for all of which Maintec has become a must-attend event in their professional calendar. ■

Registration for the event is free, including entry to both conference theatres, and is now open. For more information, visit www.maintec.co.uk.

01 Maintec returns to the NEC, Birmingham on 6 and 7 November 2018

02 The show provides networking opportunities for those working in a variety of engineering sectors

03 The show will feature two theatres – Maintec Insights and Reliability Dialogue

Canterbury Christ Church University

Head of School of Engineering, Technology and Design

Excellent Salary and Benefits SAS0967

Canterbury Christ Church University is creating a new School of Engineering, Technology and Design, and applications are invited for the founding Head of the School. The successful candidate's principal responsibility will be to nurture, manage and deliver an excellent student experience, internationally excellent research and knowledge exchange and an outstanding inclusive work environment for staff. The successful candidate will be expected to create an inclusive, flexible and supportive work environment, which will embrace innovation and work closely with engineering/technology companies.

Closing Date: 22nd July 2018

Senior Lecturer Engineering Industrial Engagement Lead

£32,548 - £47,722 p/a SAS0961

The Faculty wishes to appoint an inspirational engineer to be the key point of contact between our new School of Engineering, Technology and Design and engineering companies.

Closing Date: 8th July 2018

Various Lecturer/Senior Lecturer in Engineering Posts

£32,548 - £47,722 p/a SAS0963/SAS0962/SAS0964/SAS0966

The Faculty wishes to appoint a number of inspirational engineers; Product Design, Chemical Engineering, Mechanical Engineering, and Software Engineering to help shape our new engineering provision.

Closing Date: 8th July 2018

All positions provide the opportunity to join the team at the start of this journey of creating a new engineering school, and contribute to the development of a problem-based/CDIO curriculum which will produce work-ready engineering graduates and to work with a wide range of partners to transform engineering education in the region. The project has received significant capital investment and will be formally established in August 2019 and new building planned to open summer of 2020.

We welcome applications from a diverse range of engineering backgrounds. We will support your personal development in engineering education practice. We are keen to attract staff who will embrace the benefits of working/researching with engineering companies as well as offering a supportive and flexible working environment, also support STEM candidates who are seeking to return to engineering after a career break.

Informal enquiries to the Dean of the Faculty of Social and Applied Sciences, Professor Callum Firth, on 01227 922208 or callum.firth@canterbury.ac.uk

To gain further details about this post please visit our Vacancies page: **www.canterbury.ac.uk**

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July 1955 The winds of change

Orkney was home to the UK's first grid-connected turbine

There are currently 7,063 onshore wind turbines operating in 1,529 projects around Britain, with a combined operational capacity of 12GW. These figures come from RenewableUK, which estimates current offshore capacity at 7.1GW, a figure that will grow if new seabed rights are made available to offshore wind developers.

The wind turbines that define this form of renewable energy are getting bigger, too. In March, GE Renewable Energy unleashed the 12MW Haliade-X, a 260m-tall offshore turbine capable of generating enough energy for 16,000 European homes, rising to one million households in a 750MW configuration wind farm. Back onshore, the same company announced a 4.8MW wind turbine in September 2017 that is equipped with a 158m rotor and a range of tip heights up to 240m.

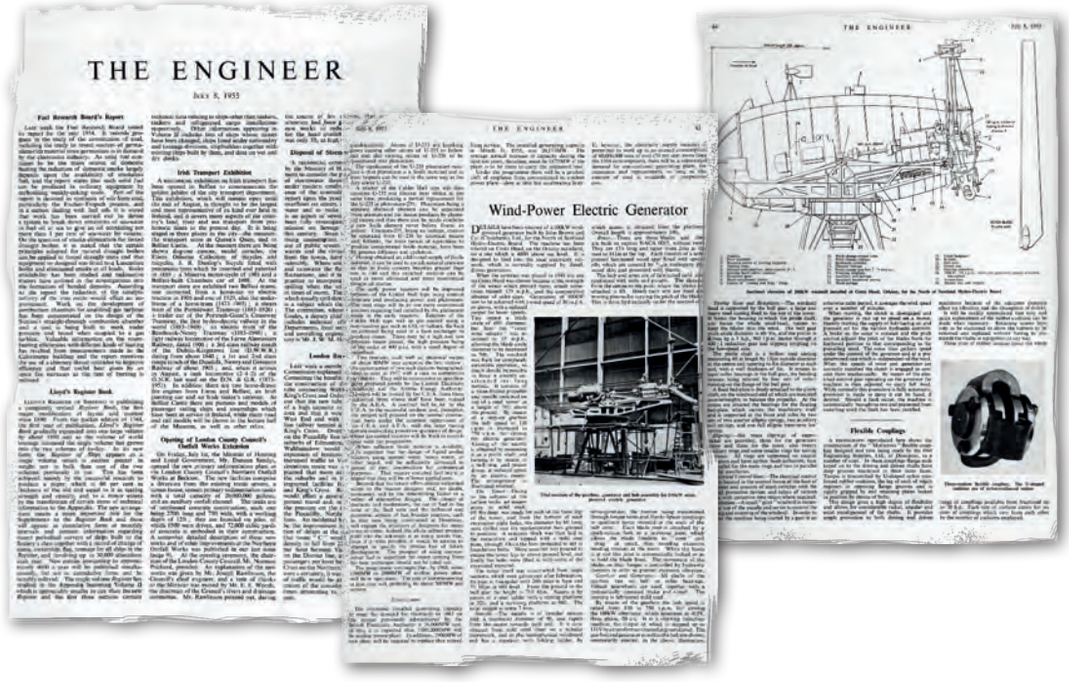
Electricity-generating wind turbines can be traced back to 1887 and James Blyth's battery-charging machine, which was installed at the electrical engineer's holiday home in Marykirk, Scotland. Nearly seven decades later, *The Engineer* received word from Costa Head, on the Orkney Mainland, about a 100kW wind-powered generator built by John Brown and Co (Clydebank) for the North of Scotland Hydro-Electric Board.

This wasn't *The Engineer*'s first encounter with the machine. In 1950 the journal received notice that an order had been placed for the windmill and by 1955 full details had been disclosed.

Critics of wind power often ask where the electricity is going to come from when the wind stops blowing – an issue deemed almost irrelevant at Costa Head, on account of winds in excess of 125mph and 'the comparative absence of calm days'. The generation target of 100kW was to be achieved with a wind speed of 30mph or above.

"This meant a blade circle of 60ft diameter, but later the 'rated wind velocity' was increased to 35mph, allowing the blade circle diameter to be decreased to 50ft," wrote *The Engineer*.

In common with the machines that followed, the Costa Head windmill was built for completely automatic operation, 'so that it should be possible to leave it entirely unattended for long periods'. It consisted of a three-bladed propeller and nacelle mounted on top of a seven-ton steel tower 78ft above the ground. By means of a step-up gearbox, the hub speed of 130rpm could be increased to 750rpm for driving the electric generator. Yawing of the nacelle was obtained by mounting it on a pintle shaft and turning it with a bull ring and pinion driven at reduced speed by an electric motor.


THE ENGINEER

July 8, 1955

Wind-Power Electric Generator

Critics ask where the electricity is going to come from when the wind stops blowing - an issue almost irrelevant at Costa Head

Unlike today's glass and carbon fibre composite blades, the three blades for Costa Head consisted of a compressed laminated wood spar fitted with spruce ribs, which were covered by 3/32in mahogany plywood skin and protected with plastic.

"Inside each arm are fixed and moving pistons for varying the pitch of the blades," *The Engineer* reported. "This is done hydraulically under the control of a servo-governor, the motion being transmitted through torque tubes and Hardy-Spicer couplings to quadrant boxes situated at the ends of the hub arms."

Our correspondent added that each blade root was attached by a quick-release fork to a universal joint, allowing the blade to 'cone' and 'drag' at speed, which helped avoid excessive bending stresses at the roots.

"When the blade is at rest, this joint is automatically locked so as to hold the blade fixed." *The Engineer* wrote. "The movement of the blades on their hinges is controlled by hydraulic dampers in order to prevent excessive vibration."

A small 'pilot' windmill mounted on top of the nacelle controlled the starting and stopping of the windmill. To prevent the turbine being started by a sudden gust of wind, the pilot windmill averaged the wind speed over a number of minutes. **JF**

Word of the issue

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

After our earliest ancestors had mastered working with stone tools, it took many thousands of years before the dawn of the Bronze Age heralded man's first experiences with metal.

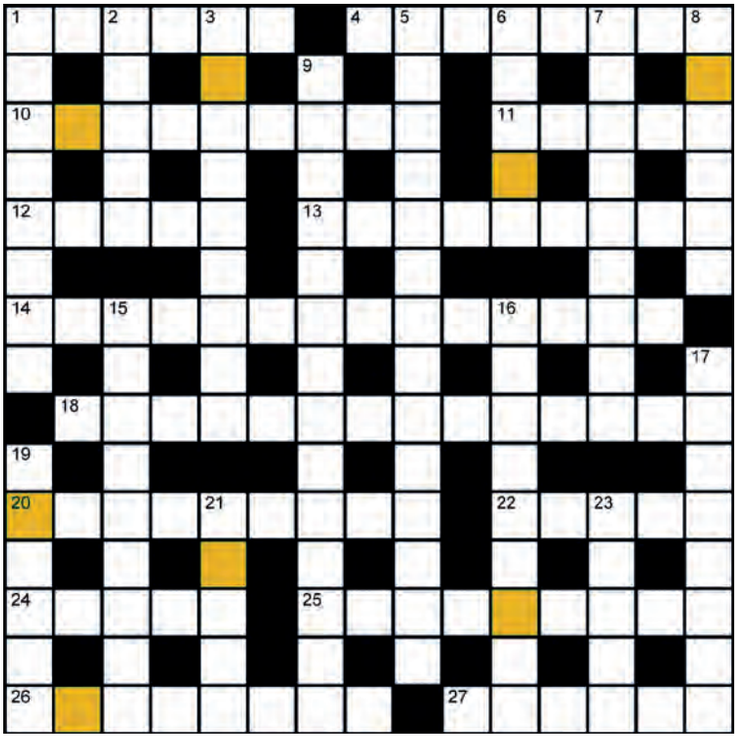
With etymology, we would expect any references to metals at this time to be most simplistic, for this is true of all words with a long history. Modern English has a wealth of words, all of which were once new and based on words and terms in existing terminology.

'Metal' came from Old French, meaning not only 'metal' but also 'material' and 'substance' and evidence of the more basic origins of the word. This is seen in Latin '*metallum*', ('metal' but also 'mine', 'quarry', 'mineral') and in turn from Greek '*metallon*' ('metal', 'ore' and earlier as 'mine', 'quarry', 'pit'). Related words are '*metalleutes*' 'a miner' and '*metalleia*' ('a search for metals', 'mining').

All these are traceable to '*metallan*' meaning 'to seek'. Hence the earliest references to metal were not as a noun but in the act of seeking the ore

Bigpicture

Spencer Fowers, senior member of technical staff for Microsoft's special projects research group, prepares Project Natick's Northern Isles data centre for deployment off the coast of the Orkney Islands in Scotland. The data centre is secured to a ballast-filled triangular base that rests on the sea floor, with seawater helping to cool its servers.



Prizecrossword

When completed rearrange the highlighted squares to spell out a bridge in London. The first correct answer received will win a £20 Amazon voucher. Email your answer to **jon.excell@centaur.co.uk**

Across

1 Cause to become separated (6)
4 A hypothetical perfect fluid (5,3)
10 Explosive mixture (9)
11 Slippery mud or filth (5)
12 How one is taken when startled (5)
13 Process of becoming larger (9)
14 Severe period of financial difficulty (8,6)
18 Skilled aerospace worker (6,8)
20 Coarse natural fabric used for upholstery (9)
22 To burst forth like volcano (5)
24 Observable (5)
25 Immediately (9)
26 Principal pipe supplying a household (3,5)
27 Get excited or stimulated (4,2)

Down

1 Reduced the level of land (8)
2 Kingdom in SW Pacific (5)
3 Mechanism of gears that is driven by a coiled spring (9)
5 The dissimilarity of things that are compared (6,8)
6 Passage between seats (5)
7 A detailed plan to determine a course of action (9)
8 Gracefully slim (6)
9 Method of tending to the affairs of a group of people (14)
15 Having no smell (9)
16 Detailed plan of journey (9)
17 Use special care in dressing (6,2)
19 Press tightly together or cram (6)
21 Person employed as one in crowd in film (5)
23 Cause to become loose (5)

June's highlighted solution was Tenement. Winner: **Edward Kingham**

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