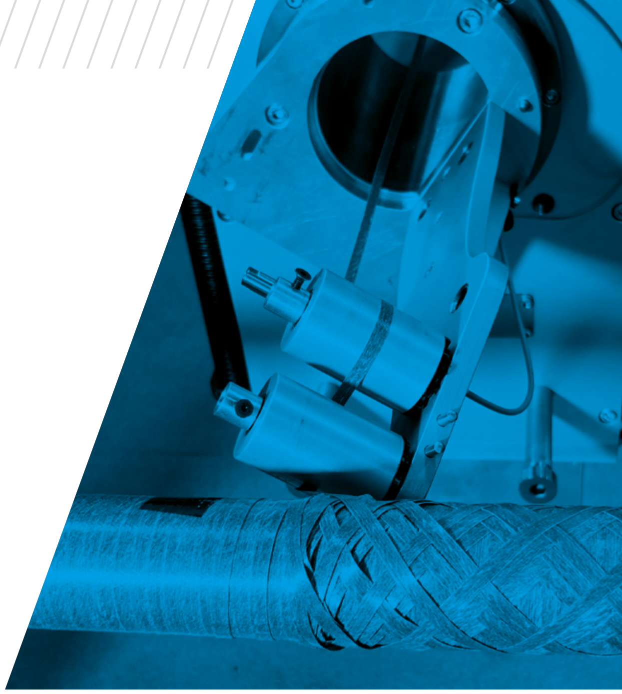
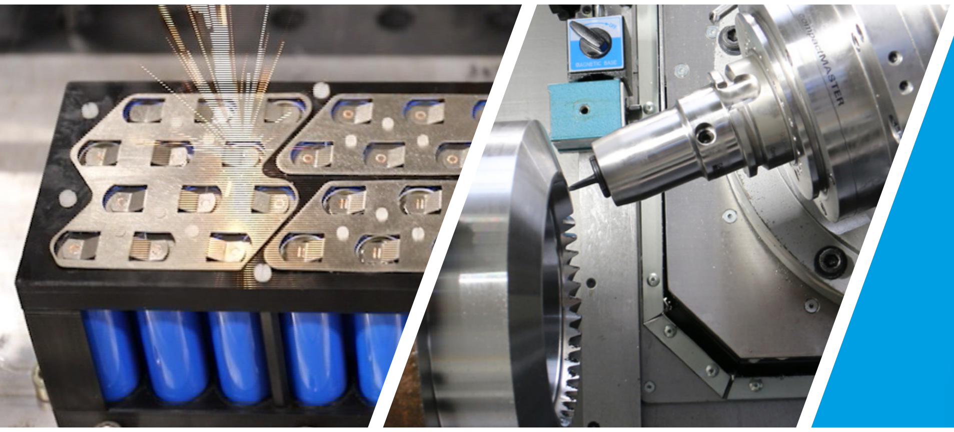
The University Of Sheffield.

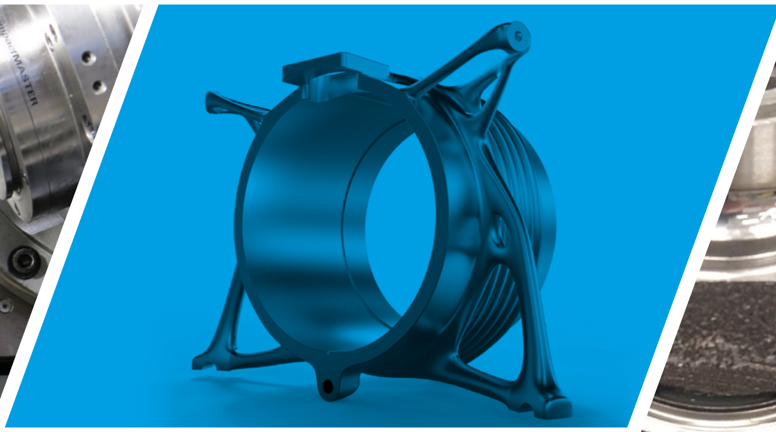
AMRC Advanced Manufacturing Research Centre

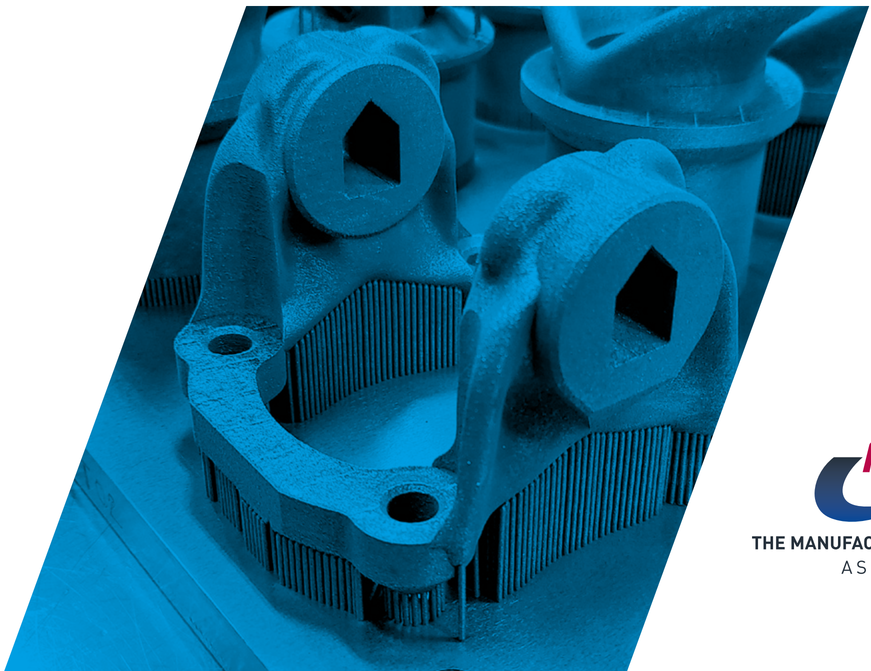
Project ELLI

Electrification and Lightweighting in Industry 4.0









CATAPULT High Value Manufacturing

MTA THE MANUFACTURING TECHNOLOGIES ASSOCIATION

Contents **quick links**

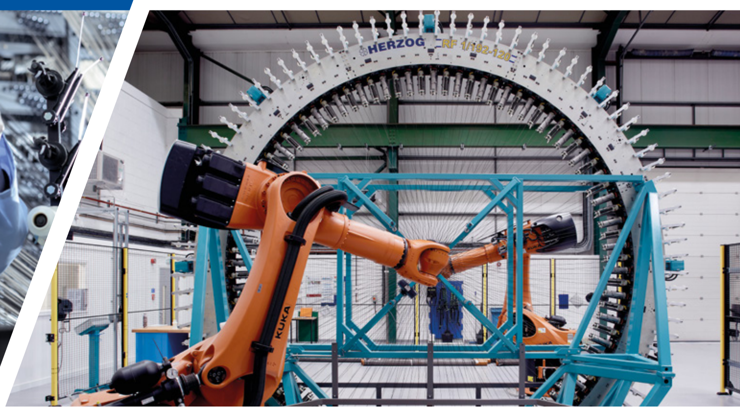
	Page
Future-proofing the manufacturing sector	3
The AMRC's MACH 2022 experience	4
Project **ELLI**	5
High-power electrical machines	
What are we innovating?	7
The challenge and what we did	8
Why it matters	9
Flexible manufacturing battery module	
What are we innovating?	10
The challenge and what we did	11
Why it matters	12
Lightweight vehicle architectures	
What are we innovating?	13
The challenge and what we did	14
Why it matters	15
Energy efficient manufacturing	
What are we innovating?	16
The challenge and what we did	17
Why it matters	18
Get in touch	19

Future-proofing the manufacturing sector

The University of Sheffield Advanced Manufacturing Research Centre (AMRC) is a world-class centre for research into advanced manufacturing technologies used in the aerospace, automotive, medical and other high-value manufacturing sectors. Our sites are in Rotherham and Sheffield in South Yorkshire, Preston in Lancashire, and Broughton in North Wales.

The AMRC has a global reputation for helping companies overcome manufacturing problems and is a model for collaborative research involving universities, academics and industry worldwide. Our engineers use the latest advanced technologies and sustainable manufacturing techniques to help manufacturers on their journey toward net zero.

The AMRC is a member of the High Value Manufacturing Catapult, a consortium of leading manufacturing and process research centres, backed by the UK's innovation agency, Innovate UK.



Return to contents

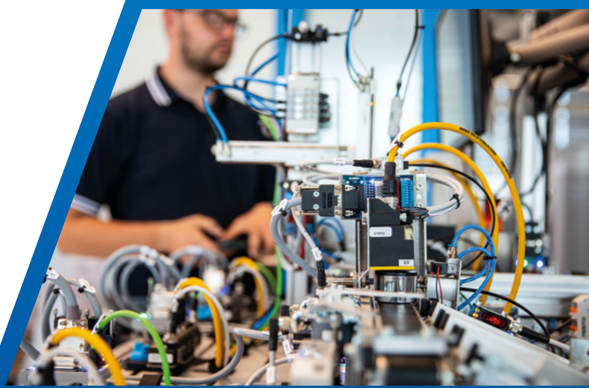
The AMRC's MACH 2022 experience

Professor Rab Scott, director of industrial digitalisation, University of Sheffield AMRC

To the casual passer-by it might appear that we have brought the same iconic Caterham 7 sports car we used to demonstrate Industry 4.0 technologies in 2018. But step onto the stand and look 'under the bonnet', and you will discover that the kit car has been transformed to now display how the AMRC is aiding manufacturers on their journey toward net zero.

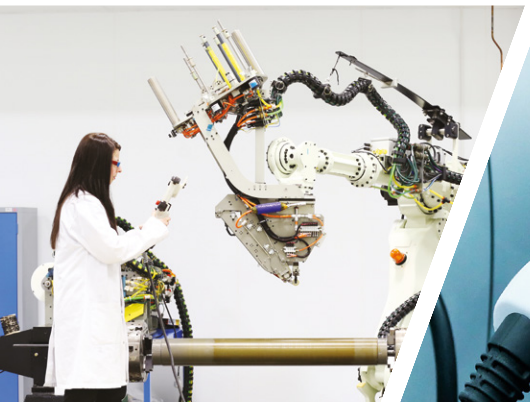
In many ways Project ELLI (Electrification and Lightweighting in Industry 4.0) epitomises all that is important to the AMRC and our partners as we increasingly consider sustainability on a par with productivity and profitability. It's a theme running through our stand from the materials we have used for our components, to freebies we hand out, and the marketing brochures we didn't print.

Through ELLI, we want visitors to learn how they can minimise material use, reduce energy requirements, improve in-service efficiency, and reduce the environmental impact of their manufacturing processes. More than anything though, ELLI demonstrates that cornerstone of success - collaboration.



Whether it's lightweighting with composite materials and optimal design principles, novel battery module assembly, additive manufacturing or advanced machining, we hope that there is something to grab your attention on this year's stand.

Project ELLI is the AMRC on four wheels, so come and have a look. Just mind the paintwork.



Return to contents

Project **ELLI**

Electrification and Lightweighting in Industry 4.0 is the focus of our MACH 2022 experience, centred around a Caterham 7 sports car.

Project ELLI is much more than a kit car. ELLI is a complex assembly demonstrator which displays the AMRC's world-class capabilities in mid-technology readiness level (TRL) research across multiple sectors and capabilities.

Project ELLI is the AMRC on four wheels, showcasing how manufacturers can make data-driven decisions on energy efficient products, using processes with a reduced environmental impact.

Continues...

Project **ELLI**

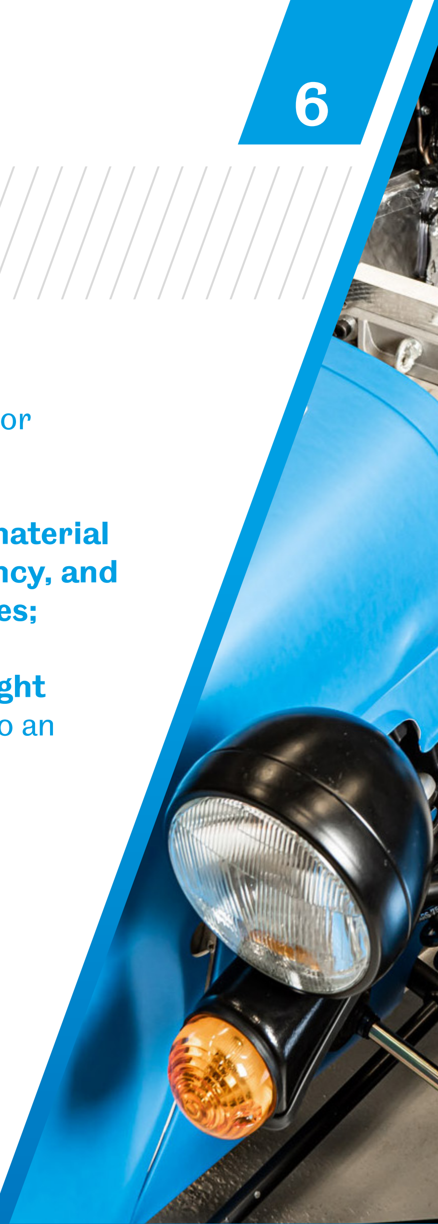
- **ELLI encompasses the skills of a number of different AMRC capabilities**, each having developed a manufacturing demonstrator for an automotive assembly operation;

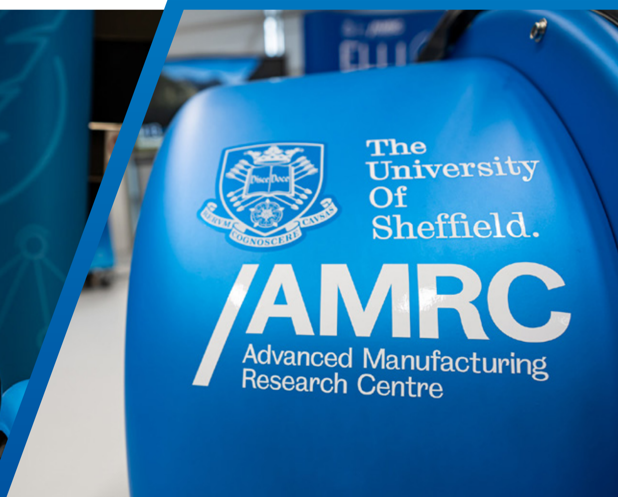
- ELLI is an example of how advanced technologies can **minimise material use, reduce energy requirements, improve in-service efficiency, and reduce the environmental impact of manufacturing processes;**

- The combination of these advanced technologies has led to a **weight reduction** on the Caterham kit car which has been converted into an electric vehicle;

- The Caterham 7 was also our showcase at MACH 2018 under the name Project RAID (Reconfigurable Assembly Integrated Demonstrator) which demonstrated how **Industry 4.0 technologies could assist in manufacturing assembly.**

Keep reading to understand more about Project ELLI's key components, developed using the AMRC's world-leading sustainable products and processes.





Return to contents

High-power **electrical machines**

What are we innovating?

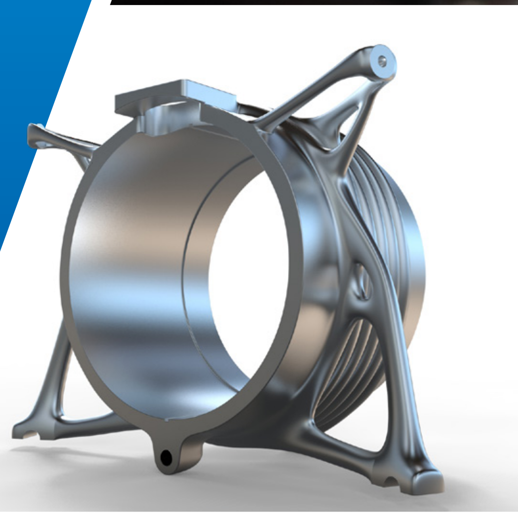
The Caterham's existing internal combustion engine has been replaced by an electric motor.

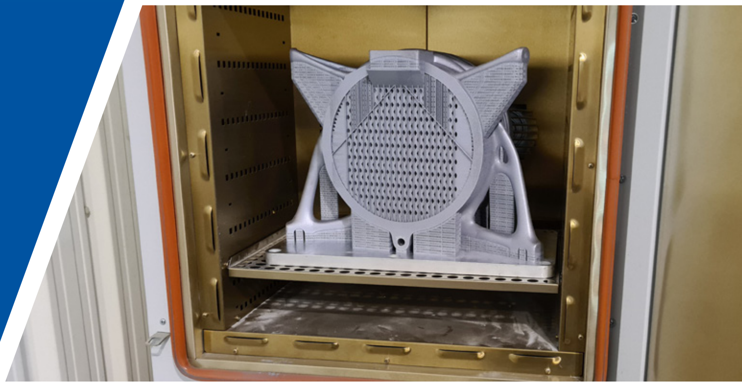
The motor uses an internal permanent magnet rotor; traditionally the rotor core with permanent magnets would be shrink-fitted to a central metallic shaft.

An electric motor's rotor and stator 'cores' are laminated to reduce electrical eddy current losses and improve efficiency; these are formed of several hundred thin sheets of electrical steel, cut to shape, stacked and fixed together.

In production, the cutting of electrical steel by mechanical stamping or laser cutting results in damage to the microstructure near the cut edge, which is detrimental to the overall efficiency of the resulting machine. An alternative option, electrical discharge machining, reduces microstructural damage but is too slow for all but prototyping.

The casing for the electric motor is traditionally manufactured through die casting and CNC machining - a process that consists of multiple parts, requires a large energy input, utilises material inefficiently and limits the freedom to design complex lightweight components.





Return to contents

High-power **electrical machines**

The challenge

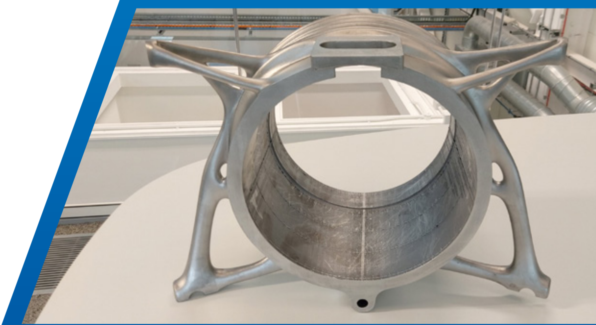
Lightweight the existing design for the rotor, creating a novel part that was also more sustainable than the conventional metallic component.

Develop a means of cutting electrical steel for the motor core that neither deteriorates the material properties, nor compromises production rates.

Optimise and lightweight the motor casing, incorporating the necessary mounting brackets and spiral cooling channels.

What we did

- Developed a novel way of producing a composite rotor component, designed for a pressing operation to emulate the high-volume manufacturing process of the automotive sector; a compression moulding process allowed for rapid processing times and production of multiple parts in one press;
- The novel composite rotor is half the mass of the metallic alternative and the environmental impact of composite components has been reduced by utilising a bio-based fire-retardant resin as the matrix material;
- Developed a remote laser cutting system for the processing of electrical steels. The high-speed galvo allows the laser to make multiple high-speed passes over the steel, progressively removing material through ablation, reducing heat build-up near the cut;
- The developed laser cutting system is anticipated to be faster than a conventional laser cutter and more gentle to the electrical steel, resulting in more efficient electrical machines;
- Used the original design space, loading conditions and applied material, to redesign the motor casing for additive manufacture (AM); the optimisation considered a system level design to enable part consolidation and multi-functional use. Support brackets were incorporated organically into the motor case as a single body and the final design used a liquid cooling circuit for greater thermal control;
- Collected digital datasets to compare the AM component with conventional processing methods.



The novel composite rotor is

50%

the mass of the metallic alternative

Return to contents

High-power **electrical machines**

Why it matters

"If the UK is to truly make electric flight a reality in the next 15 years, manufacturers will need to find a way to vastly improve the continuous power density of electrical machines. These innovations - a lighter and more sustainable rotor, a flexible and energy efficient steel cutting process, and an optimised motor casing - will allow more efficient and power-dense electrical machines to be manufactured."

Dr Lloyd Tinkler, technical fellow - electrical machines, University of Sheffield AMRC.

Can we help you overcome your manufacturing challenges using the capabilities we demonstrated on the Caterham's electric motor?

Get in touch with our team at enquiries@amrc.co.uk

Return to contents

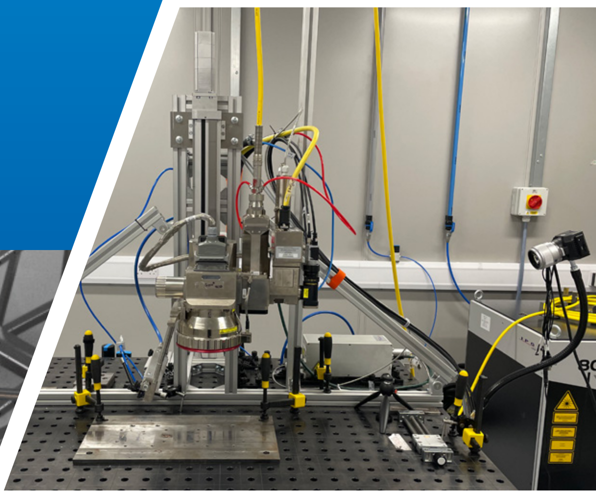
Flexible manufacturing **battery module**

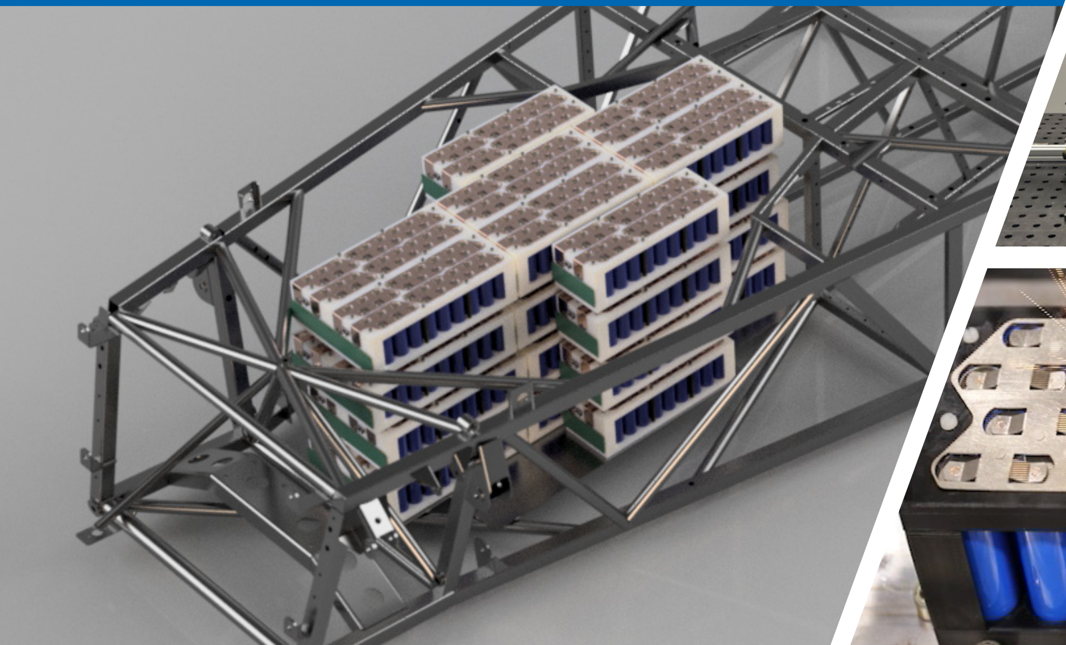
What are we innovating?

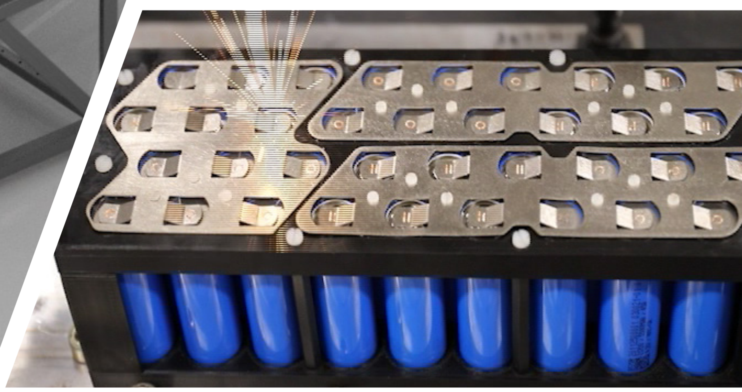
Battery technology continuously moves forward with new chemistries, novel cooling systems and a variety of applications across industry sectors. This research and development activity requires small numbers of prototype packs for validation testing, however a single battery pack for an electric vehicle (EV), for example, contains thousands of components, making the manufacture of bespoke, small batches challenging.

A key challenge is the joining of cylindrical cells to busbars. Traditionally, prototypes are made by hand using resistance welding techniques that are laborious and slow. Laser welding offers a flexible, high-speed solution but comes with challenges when applied to the materials and assembly variations found in battery packs.

AMRC North West is supporting industry with flexible, high-quality, cost-effective battery pack assembly research.







Return to contents

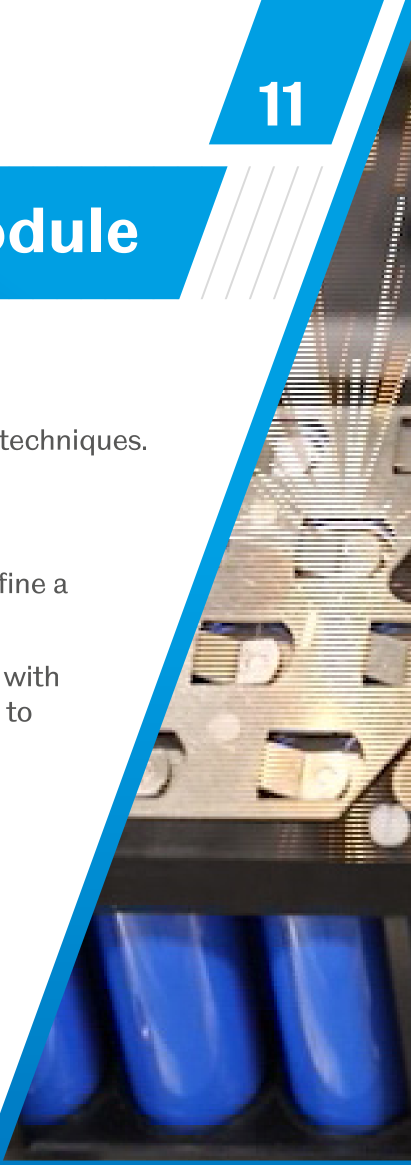
Flexible manufacturing **battery module**

The challenge

Design and assemble a bespoke battery module, utilising novel laser welding techniques.

What we did

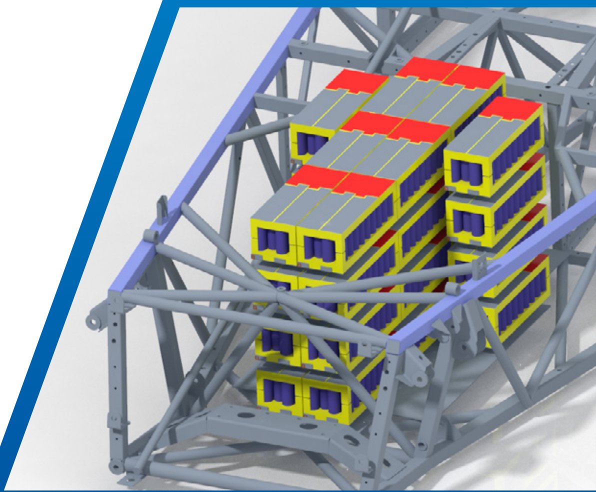
- Used a combination of high-level analysis and detailed module design to define a battery pack configuration that met the concept requirements;
- Developed the laser welding capability to suit the busbar and cell materials with an emphasis on in-process monitoring, high-speed cameras and metrology to analyse the factors affecting the weld;
- The laser welding process proved to be fast and effective with various options for in-process monitoring to drive quality towards a zero defect process;
- A battery module with 25 cells in a 100x100mm area was laser welded with a scanner head in 1.5 seconds, compared with 25 seconds using a conventional resistance spot welding technique.



A battery module was laser welded

17x faster

when using a scanner head, compared with conventional resistance spot welding



Return to contents

Flexible manufacturing **battery module**

Why it matters

“This capability is the stepping stone for further developments that would see a zero defect joining process for battery modules. This can be delivered alongside reductions in cycle time in a flexible manner suitable for high-value, low-volume production.

By supporting manufacturing research in this area, AMRC North West is aiding novel battery system development, bringing the next generation of battery systems closer to market.”

Richard Heggie, technical fellow - batteries, University of Sheffield AMRC North West.

Can we help you overcome your manufacturing challenges using the capabilities we demonstrated on the Caterham’s battery module?

Get in touch with our team at enquiries@amrc.co.uk

Return to contents

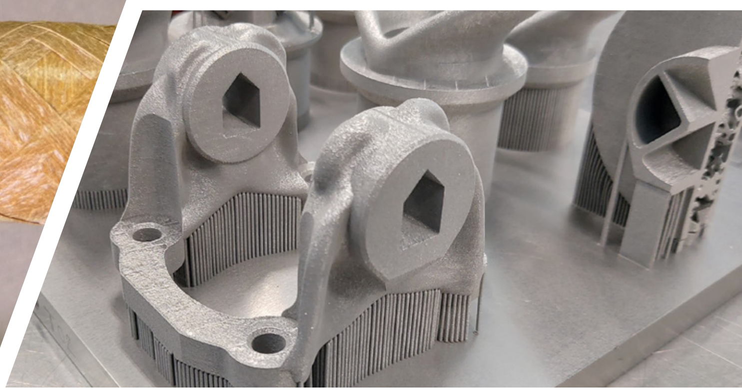
Lightweight vehicle architectures

What are we innovating?

The driveshaft sits between the Caterham's differential and wheel hubs, and is used to continuously transmit torque from the engine to the wheels, while allowing for the motion of the suspension. It does this by being spring-loaded between two constant velocity (CV) joints.

Traditionally, driveshafts are steel, cast and machined, made from multiple pieces and assembled. This results in the component being heavy and over-engineered.

The CV joints are usually machined, requiring unnecessarily high energy input across a series of processing steps, inefficient material utilisation and limitations in the freedom to design complex lightweight components.



Return to contents

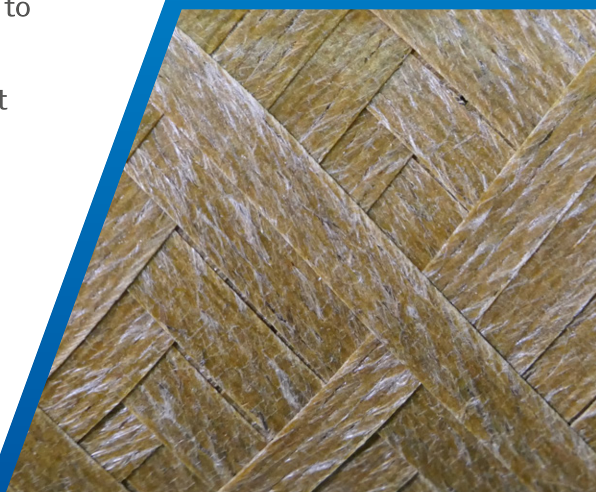
Lightweight vehicle architectures

The challenge

To develop an alternative manufacturing option for the driveshaft that would be lighter than the original steel component and more sustainable.

What we did:

- Used advanced filament winding technology to create an optimised composite tube with lightweight 3D printed metallic end fittings bonded to the end, to form a hybrid driveshaft;
- Selected a winding tape for the tube comprising biodegradable flax and re-formable thermoplastic polypropylene (PP) to form a flax/PP composite. The tape has a lower level of embodied CO_2 compared to conventional epoxy-based carbon fibre reinforced polymer (CFRP) composite components, and superior impact and damping properties - this makes the driveshaft more sustainable, smoother and quieter;
- The driveshaft's constant velocity (CV) joints were redesigned for additive manufacture (AM) through topology optimisation to remove material from non-critical regions of the geometry that would not affect performance requirements;
- The optimised CV joints were 3D printed in titanium with various end fitting geometries; these were tested and downselected to find the optimum fixation and alignment;
- The changes made to the driveshaft resulted in a 60 per cent mass reduction through a combination of lightweighting and part consolidation; this was done without compromising performance.



60%
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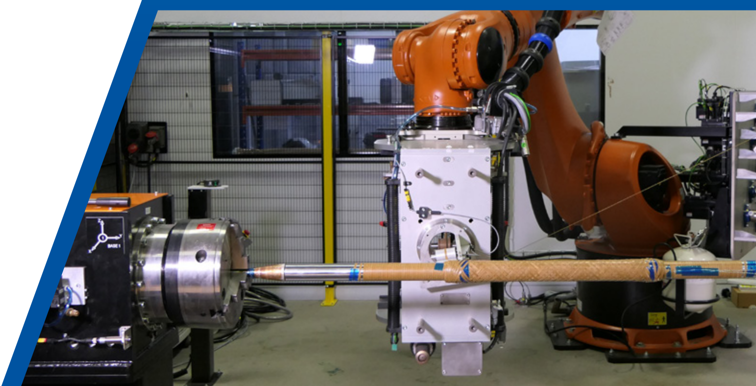


Return to contents

Lightweight vehicle architectures

Why it matters

"This hybrid driveshaft proves that manufacturers can explore alternative, more sustainable methods of manufacture for metallic components. The novel flax composites and the optimised metal AM CV joints together have produced a component that has a reduced environmental impact and generates less unnecessary waste."

Matt Smith, technical lead - composites, University of Sheffield AMRC.

Can we help you overcome your manufacturing challenges using the capabilities we demonstrated on the Caterham's driveshaft?

Get in touch with our team at enquiries@amrc.co.uk

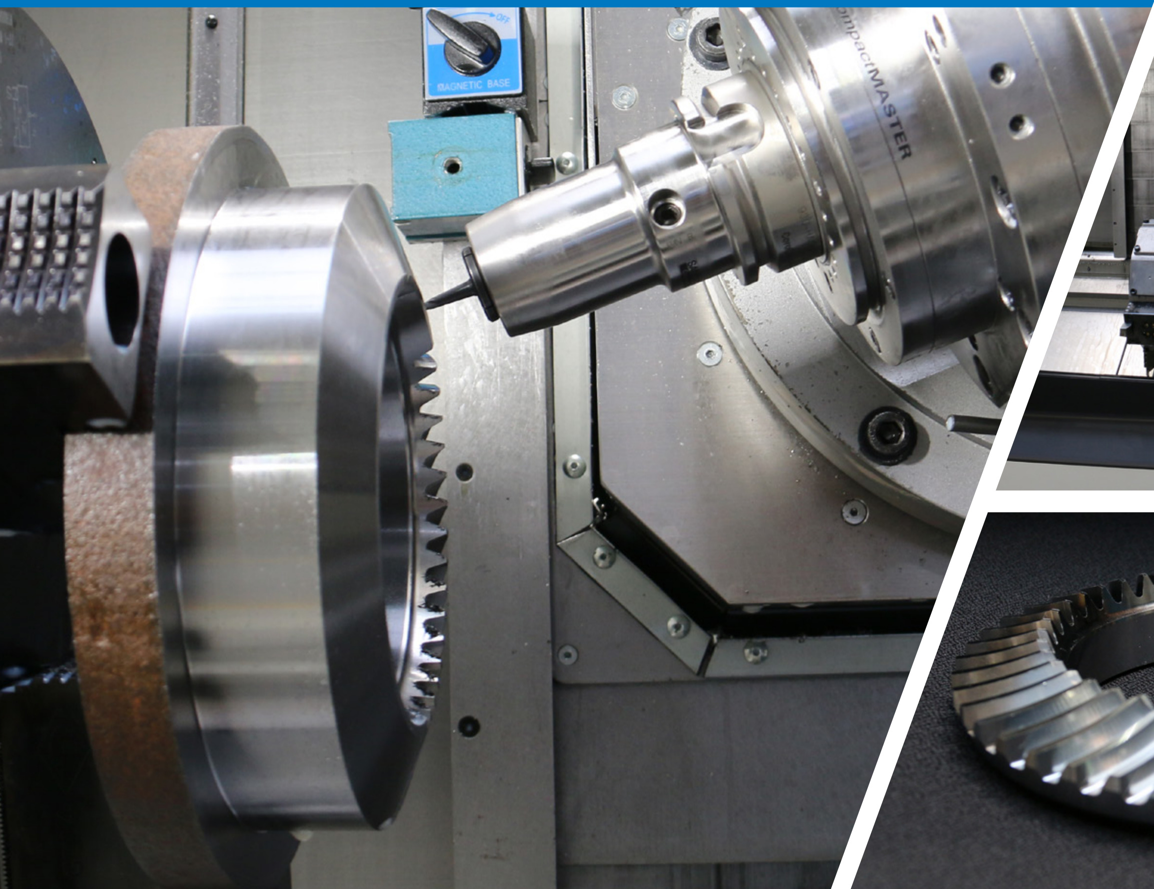
Return to contents

Energy efficient manufacturing

What are we innovating?

Manufacture of the Caterham's gear differential - consisting of output and input shafts, bevel gear and differential gear cage - is traditionally a bought out assembly with the shafts and cage cast, machined with dedicated machine tools, heat treated and finished.

When assessing these processes and potential alternatives, manufacturers can easily understand cost and time impact, but less so energy usage and wider environmental impact.



Return to contents

Energy efficient manufacturing

The challenge

Assess the opportunities for improved sustainability in production of the Caterham's gear differential using data-informed manufacturing techniques.

What we did

- Developed a 'CO2 calculator' and established a data capture mechanism to be able to make changes to method of manufacture based on the amount of CO_2 generated or energy required to produce the components;
- Established a standard by assessing the energy usage of the traditional method of manufacture process;
- Compared current production methods with alternative technologies available at the AMRC including: multifunctional machine tools, novel gear forming, power skiving and broaching;
- Identified opportunities to reduce energy expenditure based on manufacturing experience and advice from tooling providers;
- Targeted high-energy usage areas for the differential components, the rough and finish turning, and looked for opportunities to produce the features faster and more efficiently;
- Virtual machining simulations tested the solutions and proved them to be achievable;
- Established methods of data capture for energy consumption and spindle load, and investigated how the AMRC's suppliers were approaching the challenge of sustainability;
- Additively manufactured an optimised lightweight bracket for mounting the gear differential.

Intelligent tool selection and strategy can remove up to

2.2x more

material per minute

than conventional turning and use

25% less

energy, with no discernible reduction in quality

Return to contents

Energy efficient manufacturing

Why it matters

"The key element is less about the components than about the mindset and data capture techniques that can be deployed across projects to assess the energy usage in manufacture; using the data, we can expand our knowledge of high-energy usage processes and seek to find ways of reducing them in the future.

A wide database of operations, processes and alternatives gives our partners a more thorough understanding of energy usage in production and allows the AMRC to offer alternative, more sustainable production methods which do not impact the cost or time of manufacture."

Jack Greaves, technical lead - machining, University of Sheffield AMRC.

Can we help you overcome your manufacturing challenges using the capabilities we demonstrated on the Caterham's gear differential?

Get in touch with our team at enquiries@amrc.co.uk

Return to contents

Get in touch to see if we can help you overcome your manufacturing challenges by using our world-class capabilities.

Email us at
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Return to contents